THEME 2

Forestry in an Expanding Economy

Forests in an Expanding Economy

K. D. Singh *

1. INTRODUCTION

India is fortunate to have almost 150 years of uninterrupted forest management history. In this long period, the country has undergone different phases of economic growth, which permit drawing of useful inferences about the future state of forests shaped by economic and social forces and required institutional adaptations. The economic growth of the country can be divided into four phases: 1) Static growth (1901-1950); 2) Slow growth (1950-1980); 3) Take off phase (1980-2000); and 4) Expanding economy (2000-2020). The paper presents developments in the field of forests and agriculture, which had competing claims on the use of land.

1.1 Forests in the period of static economy (1901-1950)

This period is characterized by static agriculture economy (in fact, a small decline!) and stagnant per capita income (Table 1). To estimate the size of the land transfer from forest to agriculture, a model study was made by FAO / UN Forest Resources 1990 Assessment Project, which indicated the deforestation to be of the order of 14 million ha during 1901-1950 (Figure 1).

Table 1: **Agricultural stagnation in India during 1900-1950 at 1948-49 prices. Source: K. Mukherji (1962)**

Year	Population (Million)	National Income (Rs Crores)		
		Total	Agriculture	Per Caput income
		Crores	Crores	Rs
1900-01	232	5109	3976	220
1910-11	247	6241	4433	253
1920-21	251	6469	3807	259
1930-31	276	7684	4598	278
1940-41	315	8646	4534	275
1950-51	359	8850	4405	246

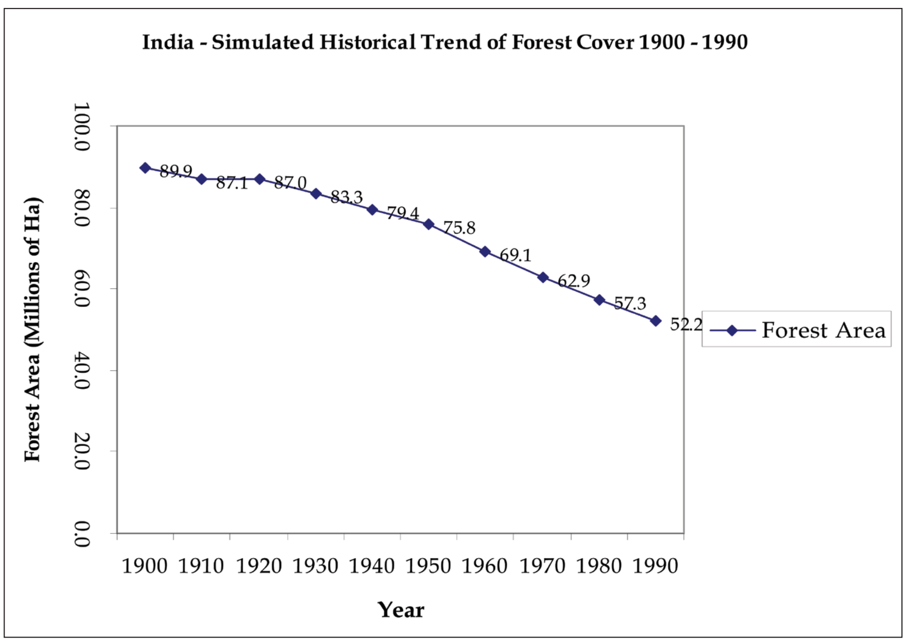

Figure 1: **Simulation of natural forest loss during 1901-1990, FAO (1993).**

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1.2 The period of slow economic growth (1950-1980)

Figure 2 gives a visual impression of the historic changes in gross domestic products after independence (1950-2000). Below the exponential curve two trend lines are shown. The upper line indicates the trend assuming a continuation of past economic growth; whereas the lower broken line is intended to suggest likely growth in the forest fringe regions during the same period. The growth is very slow, because the area lacks infrastructure, amenities and human resource capabilities. Most of the people in the regions live much below the poverty line.

According to statistics in Table 2, the GDP per capita during 1950-1980 grew by 1.5%, but the area under agriculture expanded by 22 million ha *to meet the demand for additional land under agriculture*. There was also expansion of area under shifting agriculture in the north-east and some central states of India. The land area under agriculture became stable only after 1970 with the arrival of green revolution. FAO Forest Resources Assessment 1990 made a model study, which estimated that (natural) forests of the country declined from 75.8 million to 57.3 million ha during 1950 to 1980. This does not include the area under shifting cultivation (about 7 million ha). By adding this area to FAO model figures, one would get FSI equivalent of forest area of approx. 64.3 million ha in 1980.

Table 2: **The GDP during 1950-1980, agriculture area expansion and deforestation.**

Year	Population (millions)	Economic Trends		Agricultural Land Use		
		Real GDP Growth (%)	GDP / Caput (%)	Net area sown (million ha)	Area irrigated (%)	Yield of Food Grain (kg/ha
1950-51	361			118.75	18.1	536
1960-61	439	3.7	1.5	133.20	19.1	710
1971-72	548			140.27	24.1	872
1981-82	683			140.00	29.7	1023

Source: GOI 2000 (National Agricultural Statistical Handbook)

1.3 The Take-off period (1980-2000)

During 1980-2000, economy took off exponentially that helped agricultural productivity to rise from 1023 to 1626 kg per ha (Table 3). The net area sown, after deducting areas sown more than once, was between 140-142 million ha. This met national requirements of food and provided some surplus for export. As a result, the transfer of forest land to agriculture decreased and virtually stopped. Though the area under agriculture remained stable during 1980-2000, the demand of land for non-agricultural purposes rose to 4.55 million ha, a trend, which is expected to continue later also. The transfer of forest land for non-forest purposes has been a major source of on-going inter-ministerial squabbles. Such land transfers are normal in an expanding economy, as land is needed for urban / industrial developments, but it is equally important to include environmental costs in the calculations and take adequate measures for greening.

Table 3: **India's economic development during 1980-2000**

Year	Population	*Economic Trends*		*Agricultural Land Use*		
		Real GDP Growth (%)	GDP Per Caput (%)	Net area sown (million ha)	Area irrigated (%)	Yield of Food Grain (kg/ha)
1981-82	683	3.7	1.5	140.00	29.7	1023
1990-91	843	5.9	3.8	143.00	35.1	1380
2000-01	1027	6.2	4.4	141.63	43.4	1626

Source: National Census 1999 and GOI 2005 (Ministry of Agriculture Statistics)

In the post-1980 period, there was a definitive shift in the national preference towards the environmental functions of forests over economic functions, as evident from a number of reinforcing developments, which includes:

- The Forest (Conservation) Act 1980 to control indiscriminate diversion of forestland by States for non-forestry purposes. The Act made it compulsory for States to obtain the approval of the Central Government before making any transfer of

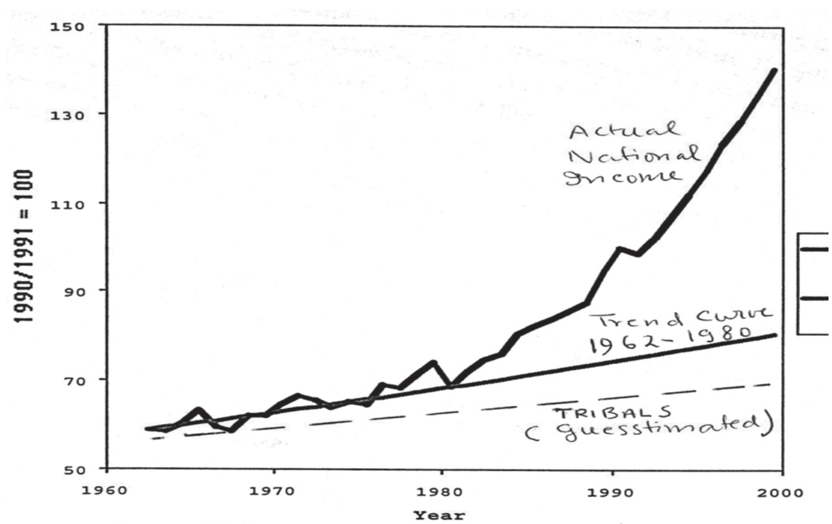

Figure 2: **Growth of real GDP per capita during 1960-2000**

(Sources: IMF)

forestlands to non-forestry uses, and made it mandatory to undertake compensatory plantations equal to double the size of the area deforested.

- Ban on "Green Felling" over 1000 m in hills.
- The Supreme Court judgment in 1996, which redefined the scope of the Forest Conservation Act 1980, suspended tree felling across the country unless prescribed in a government approved working plans and sought to radically re-orient the licensing and functioning of the forest-based industries in the forest rich north east.

The National forest Policy 1988 in Article 2.2 categorically states: "The Principal aim of Forest Policy must be to ensure environmental stability and maintenance of ecological balance including atmospheric equilibrium, which is vital for sustenance of all life forms, human, animal and plant. The derivation of direct economic benefit must be subordinated to this principal aim. The policy further advocated creation of "a massive people's movement with the involvement of women, for achieving these objectives and to minimize pressure on existing forests". The policy gave rise to popularly called 'Joint Forest Management (JFM). It is interesting to look back and evaluate the impact of government policy and laws on the rate of forest loss during the period. FAO Forest Resources Assessment 1990 and 2000, using high resolution satellite images of 1980, 1990 and 2000 made a sample study on the subject and provides the following figures on the decadal developments during the period:

- The closed forest area lost was 1% during 1980-90, but stable during 1990-2000;
- The trends towards forest degradation had been reversed; and area under long and short fallows and shrubs decreased;
- Forest fragmentation increased (bad for wildlife!);
- Agriculture land area was stable; and
- Plantation area increased.

It may be noted that FAO forest definition does not include shifting cultivation, which forms a part of agriculture. Except for fragmented forests category, all other forest classes show amelioration (reduction / trend reversal) indicating that the ecological objectives of policy by securing a stable forest area had been more or less achieved. However, we have to examine the impact of the policy on social and economic contributions of forests and on the quality of forest itself, which is an essential requirement to produce goods and services on a sustainable basis. This may include variables such as forest quality in terms of stocking and increment, impact on sustainable community income, increase in biological diversity; impact on the watershed quality and carbon storage, etc. These are questions included in ITTO 2000-Sustainable Forest Management objectives.

2. FORESTS IN AN EXPANDING ECONOMY (2000-2020)

A vision of the national economy (2000-2020) including parameters such as demography, urbanization, GDP during the period 2000-2020, is presented in Table 4. The per capita GDP, which tripled during 1980-2000, is expected to almost quadruple during 2000-20. The urban population is expected to grow from 28% in 2000 to 38% in 2022.

Table 4: **Socio-economic trends during 2000-2020**

Year	Population		Urbanization Trends	GDP / Capita (All)	GDP / Capita Lowest (10%)
	Billions	No/ha	(%)	US$	US$
2000	1.01	307	28	429	159
2010	1.16	357	32	762	282
2020	1.30	405	38	1538	569

Sources: GOI (2006); Kalam et al. (1998)

The income of the poor (lowest 10%) is expected to improve; but the relative divide between rich and poor is likely to remain almost the same (Table 5).

Table 5: **The changing priorities in the forestry sector production in India**

S.N.	Forest Functions	Changing Importance of Forest Production	
		1980	2010
A.	**Production of Goods**		
	Industrial forestry	High	High
	Agro-forestry	Limited	Very High
	Non Timber Forest Products	Medium	Very High
	Fuel wood	Very High	Very High
	Fodder and Grazing	Very High	Very High
B.	**Production of Services**		
	Climate change	Almost Unknown	Very High
	Watershed services	Medium	Very high
	Protected Areas	Medium	High
	Biological Diversity	Limited	Very High
	Eco-tourism	Limited	Medium

Source: India-IIASA (2008)

By 2020, about 40% of the country population will be urban live in urban areas and enjoy a high level of income. However, the economic lot of forest fringe communities would not improve to that extent. They most likely will still use the forests as the source of subsistence and income, unless drastic development measures are taken, which seem urgent to arrest forest degradation. As the forest fringe dwellers essentially depend on subsistence economy, the risk of forest loss for subsistence is real, unless their economic lot is improved! A joint study carried out by TIFAC and IIASA in

2008 clearly brings the rapid and fundamental changes taking place in the forest systems of India towards a more comprehensive and multiple use of forestry (see Table 5). A very obvious fact is increasing societal preference for environmental functions of the forests. Followings are the brief itemized comments on future societal needs:

2.1 Industrial Forestry / Agro-forestry

The total industrial demand of wood in terms of Round Wood Equivalent (RWE) in the year 2000 was estimated at 58 million m^3 with a deficit of the order of 29 million m^3. The projected demand is expected to reach 153 million m^3 in the year 2020. The import of wood, particularly pulp and paper products, registered a four-fold increase during the last decade. It is worthwhile to investigate that the growing demand of raw material by forest industries can be used as an opportunity to accelerate economic development in the remote regions and the north-east in particular.

By the end of the millennium, agro-forestry was producing more industrial and non-industrial wood than forestry proper. It was also improving the productivity of the farm environment and providing additional income and employment in the rural areas. The achievement of the minimum forest cover targets, enshrined in the Eleventh Five Year Plan document, to a great extent depends on the success of agro-forestry. A key requirement to enhance farmers' income is to make trees grow as a part of the value chain. This calls for advance planning of future use, when trees will mature, their prices and use. The ideal would be for a tie-in between industrial location and tree growing in terms of quality and quantity. This would also help in getting R&D investment and even buy-back arrangements. The National Agriculture Policy 2000 states: "Agriculture has become a relatively unrewarding profession due to generally unfavourable price regime and low value addition, causing abandoning of farming and increasing migration from rural areas. Farmers will be encouraged to take up farm/agro-forestry for higher income generation by evolving technology, extension and credit support packages and removing constraints to development of agro-forestry". The following case study of Yamuna Nagar, Haryana, conducted in 2006 can be taken as an example:

- Annual wood supply: 2.3 million cubic metre
- Price of unprocessed wood: 3 500 million Indian rupees
- Price of processed product: 17 000 million Indian rupees
- Employment generated: 1 50 000 man days

2.2 Non-Timber–Forest-Produce

Figure 3 provides an estimate of Timber and Non-timber Forest Products contribution to national GDP. Timber revenues rose from less than Rs. 5 Billion in 1980 to over 20 billion Rs. by end 2000. The NTFP contribution followed that of timber very closely and exceeded timber towards the end of 2000. The NTFP export has been growing between 5–15% annually (average 11%); the state revenue from non-timber resources has crossed levels to that fetched by timber. However, not even a fraction of this boom in NTFP trade trickles down to poor forest fringe dwellers. A way to improve the situation could be by infrastructure development (micro credit and transport facility), training and value addition of NTFP. Cultivation of medicinal plants is another promising area for investment in view of the steadily growing international demand, which exceeded US$ 12.5 billion in 1994 and US$ 30 billion in 2000, with annual growth rates averaging 5% to 15%, depending on the region (Singh 2008).

The Girijan Cooperative Cooperation (GCC) in Andhra Pradesh was established as an autonomous corporation in 1980 to get rid of the middlemen and thereby increase the share of benefits to the tribal people and provide them sufficient employment. The GCC was able to eliminate middlemen, provide essential commodities including food and medicine even in the interior area and extend credit facilities for agricultural activities listed below:

- Forest area: 3.2 hectares
- Number of forests districts: 25 (on an average 1 30 000 hectare per district)
- Beneficiaries: 2.5 million tribal people
- Number of depots: 817
- Processing units: 8
- Annual turnover: US$ 25 million

Though most of marketed NTFP originated from Government Forests, only a small fraction of the market value trickled down

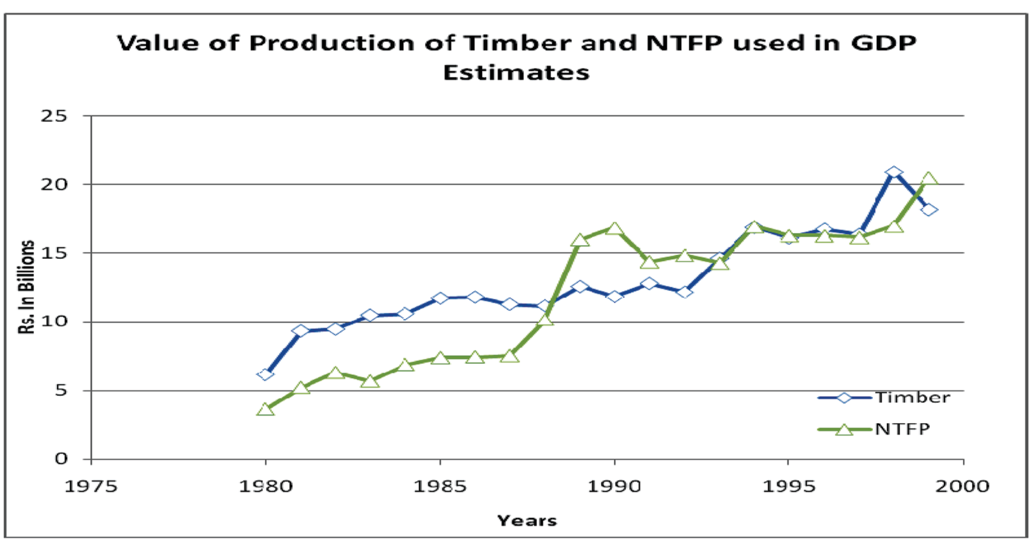

Figure 3: **NTFP & timber in GDP estimates**

(Source: Chauhan et al., 2008).

to poor forest fringe dwellers. NTFP removal has very important relation with biodiversity conservation. A way to improve the situation could be infrastructure development (information on prices, micro-credit and transport facility), training and value addition of NTFP. The forest dwellers are among the poorest of the poor and depend significantly on forests for their livelihood. Their sustainable development is a major challenge to the sector and the nation

2.3 Fuel wood, Fodder and Grazing

Nearly 173000 villages (about 28% of the total) are located along the forest fringe (FSI 1999). Forests support grazing of nearly 60% of the livestock (270 million out of about 450 million) and firewood to most of near by villages for auto-consumption and sale. National Afforestation Programme, popularly called Joint Forest Management (JFM), has been a major ongoing Forest Department activity in all the States of the country since 1993. Out of the total 173000 villages at the forest fringe, JFM had been implemented in 125000 villages and JFM Committees formed in 99868 villages (Singh 2008c). States have started innovative mechanism of decentralization of power not only for forest protection but also in forest development or expansion of forest cover through the mechanism of Forests Development Agencies created at the forests division level. There are around 800 forest divisions in the country and the States have already covered around 500 of them in the last 2 years. All money for plantation activities, under FDA, is passed on to communities or JFM Committees directly. To reduce the demand on wood, one of the steps taken is the supply of cooking gas to the forests and forest fringe dwellers free of cost in the beginning. However, a lasting solution seems a development programme owned and implemented by rural communities through an integrated effort of all sectors and not only by forest sector alone.

2.4 Climate Change

There is a lot of talk about benefit to the forest sector and eventually to the local community resulting from international agreements like Reducing Emission from Deforestation and Degradation (REDD) and Compensated Conservation proposed by India at the recent Conference of Parties to the UN Framework Convention on Climate Change (UNFCCC). These statements seem to be still an expression of intent. Much needs to be done to negotiate a proper mechanism for monitoring and implementation and with binding commitments. The potential role of forests in the context of climate change as well as soil and water conservation is widely accepted. Hopefully, world leaders will put in place a proper mechanism at the next conference.

2.5 Integrated Watershed Management

Most of forest region is hilly and mountainous. Therefore, a strategy based on watershed development with emphasis on water conservation, appropriate combination of annual and perennial crops is most likely to provide a reliable source of income and livelihood security. A balanced approach to land use will be more profitable and ecologically more sustainable. Land use choices need to be made after proper land evaluation taking into account land capability, farmer needs and market demands (and micro-financing) in order to give the highest economic return to the farmer. Economic gains estimated high (6%) as there will a possibility of value addition from combining crops, forestry and cattle rearing. There are many success stories on the subject, which provide a sound basis for planning such projects. The main development goal will be to make the community self-reliant in respect of basic needs and consist of:

- Improved agriculture practices through soil and water conservation, minor/micro irrigation, technology upgrading and extension with greater emphasis on high value crops including medicinal and aromatic plants;
- Livestock improvement including poultry etc;
- Access to safe drinking water;
- Other income generating activities; and
- Improving access to markets, market information and rural roads/marketing infrastructure.

The above issues are important in most forestry regions of the country. Other important considerations are: participation of all stakeholders including the private sector's involvement, building sustainability into the design of programmes at the start-up stage itself, promoting use of social capital, cost sharing among stakeholders and use of sustainable models/ practices. Forests located in the upper river catchments play a critical role in conserving soil and ensuring ground water supply downstream. An integrated land use planning, taking into account land capability, farmer needs and market demands (and micro-financing), is expected to result in prosperity of farmers in the entire river basin.

2.6 Protected Areas Management and Biodiversity Conservation

An internationally accepted definition of Biological Diversity, owing to UNCED, is the following: "biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species (viz. genes), between species and of ecosystems" (CBD 1992). The aim should be to cover all levels of biological diversity concerns from gene to ecosystem and limit not only to species and taxa. The genetic impoverishment of species is a prelude to their extinction. The aim should be to arrest the forest fragmentation in an early stage by ensuring that the number of individuals per species (i.e. number of stems) does not fall below a critical limit in all forest types, where the species occurs. (Prevention is better than cure). There is an urgent need for a good analysis of FSI continuous inventory of our forests and wild animals. Therefore, it is important to see “conservation” (of nature) overall in terms of “species and stock enrichment” and not limit only to “forest cover”. Accordingly, the first goal should be to enhance the overall biological diversity in all forest types by treatments ranging from strict protection to sustainable management of forests and even planting of indigenous species to provide perching place to birds and insects. All parts of our country should be made more “natural” by planting trees of appropriate species. The track record of forest protection, particularly tigers has been poor. There is a strong emerging consensus that, if forest conservation is to succeed, conservation efforts need to go beyond protected areas and cover all forests. Even the most ambitious exponents of biodiversity protection only hope to achieve around 10% of the geographic area of the country under parks and reserves. It is presently (4.75%) of the land area. Obviously, the fate of most of biodiversity will depend upon what happens to rest of forests under sustainable forest management.

2.7 Eco-tourism

It is obvious that forest eco-tourism should be seen in the larger context of tourism in general and motivations for travel to and in India. The *data and statistics* are very weak on the current volume and characteristics of the tourism and hardly anything of scientific value exists on forest eco-tourism. This makes it difficult to execute any demand *analysis* of eco-tourism in India. But there is also a supply side issue of forest eco-tourism. There is hardly any information available on interesting areas/places for forest eco-tourism. In *order to develop the forest related eco-tourism there is a need to map out (inventory) interesting and potential areas for forest eco-tourism*. This mapping should not only target so-called trophy tourism but to areas fulfilling the basic principles of eco-tourism. After the mapping and inventorying this information has to be analyzed with respect to how these areas can fit into an overall efficient tourism concept.

3. TRANSFORMING 2020 VISION INTO ACTION

According to physiographic zone degraded land availability can be classified into two landscape types, viz. forested and non-forested (mainly agricultural). These constitute potential land areas in million ha for 2020 Action (Table 6).

Table 6: **The current land use and forestry (2008) and recommended (2020) targets.**

Regions	The Land Use and Forest classes by Physiographic Zone	Forest / land use (million ha)	Targets (million ha)
I.	**Forest Regions ~ 164 million ha**		
1.	Near Natural Forested areas	49)	NTFP Management/ Conservation (**64**)
2	National Parks / Protected Areas	15)	
3.	Settled / Shifting Agriculture Areas	15)	Integrated Watershed Management **(20)**
4.	Deforested lands in Hill / Mountains	30)	
5.	Non-Tree Regions (Glaciers, deserts)	55	Conservation
II.	**Cultural Region ~ 165 million ha**		
6	Irrigated agricultural areas	50)	Socio-economic/ Carbon/ Industrial Forestry **(15)**
7	Rain-fed with favourable weather	20)	
8	Rain-fed low lying flood plains	20)	
9	Lands in the arid and semi-arid zone	50	Socio-economic / Abiotic / Carbon (**10**)
10	Ravines, gullied lands /River Banks	25	
Total	**All Lands**	**329**	**All Sources (109)**

Note 1: The tree cover has been converted in forest cover terms using FSI factor.

Sources: FSI, 2005; MA, 2005; CSO, 2006; Singh, 2009

3.1 Institutional adaptation

An important point to note is that all challenges of 2020 are characterized by extreme social and environmental complexity. The Forest system has to strengthen its Science, Information, Technology and Extension arm to effectively cope with new challenges. Some ideas for this purpose are graphically shown in Chart I and Chart II. The greater dynamism of Indian Agriculture in the post independence era has been clearly the result of larger, more intensive and coordinated research programmes linked with a countrywide network of extension services to farmers. The Forest System has to follow emulate the success story of agriculture.

3.2 Priority Areas

Forest system in the country has to give major emphasis to inclusive growth and environmental conservation, both of which form an important part of the national development Agenda and millennium development Goal (MDG). Within forested regions, there is a group of lands classified as protected areas **(**i.e., 15 million ha**),** and near natural forest (i.e., 49 million ha) closely connected with livelihood of local communities (indigenous people, local communities and public at large). Here local communities could play a lead role in effective protection and management and also due share of benefit from NTFP sale as enshrined in Article 8(j) of Biological Diversity Convention. In the agricultural regions, suitable agro-forestry practices need to be researched upon for them. Gullied and ravine lands (i.e., 25 million ha) may be put under block plantation.

3.3 Capital requirements

The rising demand for forest goods has positive implications for capital investment to new ventures to enhance sector contribution to the national economic growth, employment and poverty alleviation, in particular, the latter through development of NTFP and trees outside forest, which are of direct concern to estimated 300 million tribal and rural poor. The supply gap of nearly 95 million m^3 of industrial wood by 2020 could be met from the forest plantations in non-forest areas through private and public partnership, which would also create substantial new employment opportunities to the rural poor and add value through processing by a ratio of 1:3. The greening of the country will also have a positive impact on climate change, perhaps, one of the most important global concerns and likely to be funded

4. CONCLUSIONS AND RECOMMENDATIONS

Among the multiple development opportunities mentioned earlier, few trends can be identified with respect to the Indian forest ecosystem, which should serve as pillars/platforms for new initiative in the sector:

- Over the years the natural forests have suffered degradation/ depletion due to an ever-increasing and unorganized demand on forests for firewood, fodder and free grazing. This depletion is not a technical forestry problem but rather a social problem linked to population growth and poverty among tribal and rural people living in or on the fringes of the forests. This trend can be reversed by improved governance, local people involvement to protect, manage, utilize and market forest/ tree produce. The government role should switch over to provision of science, information, technology, extension and financial support and let communities (farmers, forest fringe dwellers) assume the lead role in forest protection and sustainable management and marketing.
- The Non Timber Forest Products have assumed a higher value/ contribution to the Indian economy compared to timber from the Indian forests. This trend is likely to grow over time. An important challenge is to develop an institutional basis for forest protection and management, harvesting and marketing of NTFP (all integrated), which gives back to communities a sense of forest ownership and the due share of benefits.
- Some 80% of timber production for the forest industry stems from trees outside forests. There is a huge potential to increase the timber and bamboo production from agro-forestry (outside forests) with more income to farmers. This potential is seriously underutilized and its growth constrained by administrative, institutional and governance problems.

It has been the experience all over the world that economic development is accompanied with enhanced recognition of social, economic and environmental functions of forests,. India will be no exception to that. The challenge to the forest system is to rise to the occasion, make required institutional adaptations and contribute to the national development, in particular, to inclusive growth, conservation of biodiversity and climate change and land amelioration.

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Valuing the Forests for Sustainable Development

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FOREST ECOSYSTEM SERVICES AND HUMAN WELL-BEING

The current year, 2011, has been declared by the United Nations General Assembly as the International Year of Forests to raise awareness on sustainable management, conservation and sustainable development of all types of forests and to further highlight the important role of forests for people. Also the recently accomplished international study in the International year of Biodiversity (2010), on "The Economics of Ecosystem and Biodiversity" popularly known as TEEB, has been an attempt to demonstrate the economic value of biodiversity, ecosystem and their services and their integration into everyday decision making. It flags the importance of measuring the ecosystems which we tend to manage and estimates ecosystem services as percentage of GDP of the poor. Thus there is a perceptible shift the way forests and its contribution to the economy is perceived. There is an urgent need to recognize the important role of diverse ecosystem services from forest in the expanding economy and need for increased investment for conservation of this important resource base. For a large population, particularly in developing countries forests are more than a mere gift of nature- it is a source of their sustenance.

Forest is one of the most important components of the terrestrial environmental system and provides a complete resource base. They are important to all human populations as they play a vital role in the economic development of a country by providing a vast array of environmental, social and economic benefits and help in maintaining its ecological balance life by providing wide range of ecosystem services like carbon storage, regulation of climate, purification of water and mitigation of natural hazards such as floods and droughts

The Millennium Ecosystem Assessment (MA, 2005), an international synthesis analyzed the health of the Earth's ecosystems and provided summaries and guidelines for decision-makers. It concluded that human activity has significant and escalating impact on the biodiversity of world ecosystems and reduced both their resilience and biocapacity. The report referred to natural systems as humanity's "life-support system", providing essential "ecosystem services. The assessment classifies these ecosystem services as provisioning (products obtained from ecosystems), regulating (benefits from regulation of ecosystem processes), cultural (non-monetary benefits that enrich the quality of life) and supporting (services needed to produce all other services) services (MA 2005). It placed human well-being as the central focus for assessment, while recognizing that biodiversity and ecosystems also have intrinsic value. Such linkages are very influential in forestry sector in India as the forest ecosystem services and the human well-being through livelihood benefits, have very high correlation.

STATUS OF FORESTS RESOURCES IN INDIA

India is one of the seventeen mega-bio-diverse countries (Conservation International 1998). It also ranks 10^{th} in the list of most forested nations of the world (FAO 2005). As per the latest estimate of the India State of Forest Report (India-SFR 2009), the forests constitute 21.02% of total geographical area of the country. The area under tree cover outside forests is reported to be 2.82%. Thus the total of forest and tree cover becomes 23.84% (78.37 million ha) of the geographical area of the country (328.73 million ha). The decadal change in the forest cover (1997-2007 assessment) as per India-SFR 2009 has been 31,349 km^2 (4.75%).

Over a period of time, the methodology to assess the forest cover of the country has been refined. The dense forest have been further classified into moderately dense and very dense based on canopy density, and mangrove forests have been included in the forest cover estimation. With this classification the India-SFR, 2009 indicates 728 km^2 increase in the forest cover in the country between 2005 and 2007 assessment. Forest cover is shown in three density classes viz., very dense forest (VDF) with more than 70% canopy density, moderately dense forest (MDF) with canopy density between 40% and 70% and open forest (OF) with canopy density between 10% and 40%. Scrub and water bodies are also delineated. Area under VDF, MDF and OF also includes mangrove cover of the corresponding density class. The total forest cover of the country as per 2007 assessment is 690,899km^2 (excluding scrub forest) and this constitutes 21.02% of the geographic area of the country. Of this, 83,510km^2 (2.54%) is very dense forest, 319,012km^2 (9.71%) is moderately dense forest while 288,377km^2 (8.77%) is open forest cover. The non-forest cover includes scrub and is estimated to cover an area of 41,525km^2.

Despite having large area under command the forestry sector is competing with agriculture sector due to relentless pressure of an ever increasing population, which has grown from 361 million in 1951 to 1,210 million in 2011 with decadal growth rate of 17.4% over 2001(Provisional Census data 2011). The per capita availability forests has, thus, declined considerably from 0.08 ha in 2001 to a minimal figure of 0.06 ha in 2011, which is one of the lowest in the world.

ECONOMIC DEVELOPMENT OF INDIA AND GDP CONTRIBUTION OF FORESTS

Economic development of any country is mainly based on its resources and entrepreneurial skills. Forests despite constituting 23.84% of total geographical area of the country, therefore creating 'natural capital base' seemed to have made very small contribution as per the current system of national accounts; the reason being non recording and non recognition of its ecological

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services in the current accounting system which considers only marketed goods.

The value of forest reflected in the System of National Accounts (SNA) represents less than 10% of the real value. In 2005-06, forests contributed Rs. 24104 crores to India's GDP at factor cost at the current prices, which was 0.7% of the GDP. As matter of fact there has been a steep decline in the contribution of forestry sector to the GDP over the years. The share which was 2.6% in 1950-51, reduced to 1.9% in 1960-61, 1.8% in 1970-71, increased marginally to 2.2% in 1980-81, declined again to 1.6% in 1990-91 and to 1.0% in 2000-01 and finally to 0.7% by 2005-06 as shown in Table 4 and 5.

FOREST AS NATURAL CAPITAL

The term capital is defined as something which earns its return through market mechanism and thus we invest in such capitals such as physical capital, human capital, social capital and financial capital. Traditionally, most of the natural resources are taken as "free gifts of nature", hence not been treated as capital. The basis for estimating economic value of a resource or an environmental amenity is its probable effect on human welfare. There is lack of understanding of the true role of forests in the well-being of the people, forest lands have become degraded on account of overuse and mismanagement, the investment in the sector has not kept pace with the removals and the few resources available to the forestry sector are often put to non-productive uses.

One of the reasons for degradation of forests is low investment in the forestry sector. The investment in the Environment and the Forestry sector as per Eleventh five year plan is only 0.8% of the total outlay which is even less than the percentage for Tenth plan at 1.15% (Eleventh Five Year Plan). Whereas the investment in the manmade capital and financial capital is on rise, the forestry sector on account of lack of appreciation of its true and total value has always been less appreciated and thus has received less budgetary allocation and investment. Low investment in the sector is clearly manifested by low annual growth of the sector as compared to other sectors of the economy. Forests if treated as a natural 'capital' asset and their true contribution is assessed through economic value of not only timber, non timber goods but also through their ecological services like carbon sequestration, watershed, eco-tourism, biodiversity, etc., their contribution to the economic system would be very high and this would attract investment in 'natural-forest capital'. TEEB (2008) also emphasized that, in spite of the crucial ecological, cultural and economic importance of these services, the biodiversity of ecosystems is still declining worldwide. One major reason for the continued loss and degradation of ecosystems is that the value (importance) of ecosystems to human welfare is still underestimated in most economic development decisions because the benefits of their services are not, or only partly, captured in conventional market economics. Furthermore, the costs of externalities of economic development (e.g. pollution, deforestation) are usually not accounted for and inappropriate tax and subsidy systems stimulate over-exploitation of resources and other ecosystem services. There is, therefore, a need for developing a system to have reasonable estimates of contribution made by forests to Gross National Product (GNP) and a comprehensive system of resource accounting to incorporate costs of environmental degradation in the use of natural resources for developmental purposes (Lal, 2005).

There is also a lack of data: most decisions in which trade-offs in ecosystem services are involved are based on incomplete information, leading to non-sustainable developments. Often the economic and social costs of non-sustainable ecosystem use are only realized when values are lost that can often only be restored at high costs, if at all.

Due to high dependence of people on forests and use of most of its ecosystem services free of charge, people have become accustomed of using such services directly. They are aware of their uses but not their value, resources have not only been used but overused, misused and finally abused (Verma, 2008). This fact was highlighted in the very first attempt to calculate a global value for natural resources, when a team of researchers from the United States, Argentina, and the Netherlands led by Robert Costanza, put an average price tag of US$33 trillion a year on these fundamental services from various ecosystems (Costanza, 1997). The neoclassical economists introduced the term "natural capital" alongside "man-made capital" and, in assessing the value of resources, recognized the changes in natural capital such as depletion, degradation or regeneration that occurs as a result of human interference. Whereas man-made capital has established markets and thus the values generated by them enter into the accounting system of the country, most of the goods and services provided by forests do not have markets and thus do not find a place there. In the current scenario the tangible values are under-estimated and the intangibles are completely ignored by the prevalent accounting system. Therefore it becomes necessary to reflect the true contribution of forests in a country's accounting system by incorporating its total economic value such that the sector receives due credit in the planning and decision-making process and an appropriate budgetary allocation is established for its sustainable management. Valuation of Forests provides an important tool for decision makers on weighing the cost and benefit of development projects.

The recent National Environment Policy 2006[1] also recommended the use of economic principles in environmental decision-making. It states that "it is necessary that the costs associated with the degradation and depletion of natural resources be incorporated into the decisions of economic actors at various levels, to reverse the tendency to treat these resources as "free goods" and to pass the costs of degradation to other sections of society, or to future generations of the country'. Specifically it recommended (i) to strengthen, including through capacity building, the initiatives, taken by the Central Statistical Organisation in the area of natural resource accounting, with a view to its adoption in the system of national income accounts. Further strengthen in all respects, the system of collection, collation and analysis of all significant and relevant environmental monitoring data, (ii) develop and promote the use of standardized environmental accounting practices and norms in preparation of statutory financial statements for large industrial enterprises, in order to encourage greater environmental responsibility in

[1] SPSS Inc. Headquarters, 233S, Wacker drive, 11th floor, Chicago, Illinois, 60606, USA

investment decision-making, management practices, and public scrutiny, (iii) facilitate the integration of environmental values into cost-benefit analysis, to encourage more efficient allocation of resources while making public investment decisions. It further emphasized on developing mechanisms for payments for various ecological services from ecosystems.

FORESTS RESOURCE AND POVERTY ALLEVIATION

India's forests, about one fifth of India's land mass, are the single largest land based resource that has the potential of reducing poverty of the people of this country and, indeed, they have supported the poor to meet their basic requirements over the long history of this country. But in the preceding few decades the capacity of the forests to cater to the poor has eroded. If managed properly, forests can play a very important role in addressing the Millennium Development Goals (MDGs). The first MDG of eradication of extreme poverty and hunger and the seventh goal of ensuring environmental sustainability are very strongly linked where in the context of India looking to the high dependence of people on forest resources; forest if managed properly in true understanding of its immense value, can play a very vital role in ensuring eradication of poverty.

SUSTAINABLE FOREST MANAGEMENT

Doctrines related to forest management have changed considerably overtime from earning maximum revenue from the forests to sustained yield, sustenance to ecosystem approach in forest management to Sustainable Forest Management (SFM). Sustainable Forest Management encompasses both key elements: economics and ecology. The sustainable development envisages both economic growth and ecological stability. The definition of sustainable forest management given in the Helsinki's Conference of European Ministers in 1993 as "*use of forests and forest land in a way and at a rate that maintains their biodiversity, productivity, regeneration capacity and their ecological, economic and social functions while not causing damage to their ecosystems*" indicate that in addition of ecological and economic aspects, social aspect is equally important.

Sustainable Development

Sustainable development not only encompasses the environmental consideration but further aims to improve the human well-being. "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (Our Common Future, 1987)

Why there is so much talk of Sustainable Forest Management?

Over a period of time the benefits derived from forest are no more limited to timber, fuelwood and fodder for domestic consumption but include services such as watershed management, recreation, clean environment, etc. Now there are many stakeholders including forest based industries, environmentalists, pharmaceutical companies, etc. As a sequel, demands on forests have also increased. We know much more now about the forest ecosystem- increased knowledge about goods and services that forests provide. Socio, cultural and spiritual values of forest, though was known but not truly appreciated. The economics of ecosystem and biodiversity are now better understood, there are few tools available for forest valuation.

Economic Valuation of Forests

Several attempts have been made in India recently through case study approach to estimate economic value of intangible benefits of forests like eco-tourism, recreation, water supply, watershed value, carbon store and biodiversity purposes. In this regard it will be useful to mention structure developed in the study on Forest Resource Valuation and Accounting for the State of Himachal Pradesh done by Verma (2000)[1], which was an attempt to estimate the total economic value of forests of Himachal Pradesh based upon which an economic instrument CLEV (Compensation for the loss of ecosystem) was introduced in Himachal Pradesh in 2002.

For integration the valuation approaches, Honb'le Supreme Court in its Judgment dated 26th September 2005, in T. N. Godavaraman Thirumulpad vs. Union of India directed to set up an expert group to suggest suitable NPV. The following issues were examined by the expert group. (i) To identify the definite parameters (scientific, bio-metric and social) on the basis of which categories of values of forest should be estimated; (ii) To formulate a practical methodology applicable to different biographical zones of India for estimation of value in monetary terms in respect of each of the above categories of forest values ;(iii) To illustratively apply this methodology to obtain actual numerical value for different forest types for each biographical zone of the country; (iv) To determine on the basis of established principles of finance , who should pay the cost of restoration and / or compensation with respect to which category of values of forest and (v) which project deserves to be to exempted from Payment of NPV. The committee setup by Supreme court gave its recommendation with respect to charge of NPV for forest diversion but the mechanism is yet to be standardize a for estimating the value of conservation of forest.

Means of Recognizing Increasing Role of Forest in Expanding Economy

With the changing and evolving forestry sector, the increase in forest cover puts forward a strong case for the important ecosystem service i.e. carbon sequestration, as a mitigative strategy for climate change. Thus the evolving strategy of Reducing Emissions from Degradation and forest Degradation with increase in the carbon stock (REDD+) is a global PES mechanism for forest conservation and enhancement with emphasizes on the community benefits and biodiversity conservation.

WAY FORWARD AND CONCLUSION

For understanding the ecosystem services and the role of forests for human well-being, it is essential to develop a standardized framework for valuation of forest ecosystem services. Having estimated the values both in terms of cost of provisioning and the price of services, the next step would be to develop markets for ecosystem services from forests. This would help in getting returns on forest investment and to incentivize communities engaged in forest resource conservation. Further, these markets can also increase the economic value of forest ecosystems. Market based approaches are increasingly applied to achieve conservation objectives all over the world. Compared to previous approaches followed in India for forest conservation which were mostly command and control type, market based mechanisms would play a dual role by means of performance based payments which would lead to livelihood opportunities and forest conservation.

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Table 1: **Forest Ecosystem Services Classification as per MA (2005).**

Provisioning	Regulating	Cultural
Firewood, pulpwood, fodder, timber, non-edible oils, medicines, fibres and flosses, resins, lac, tendu and other leaves, bamboos and canes, raw materials for clothing etc. raw materials for manufacturing, etc. and construction, biochemicals, water habitat (indigenous people and wildlife), recreation	Soil conservation, protection and regulation of water supplies, amelioration of climate, sediment control, shelter from hot and cold winds, absorption of dust and noise, maintenance of genetic pool, maintenance of visual quality of the environment, maintenance of carbon dioxide balance in the atmosphere.	Aesthetic, artistic, spiritual, historic, scientific, educational, inspirational, symbolic
Supporting nutrient cycling, soil formation, primary production		

Source: MA, 2005

Table 2: **Forest Cover in India 2007[1].**

Class	Area (km²)	% of Geographical Area
Forest Cover		
Very Dense Forest	83,510	2.54
Moderately Dense Forest	319,012	9.71
Open Forest	288,377	8.77
Total Forest Cover*	690,899	21.02
Non-Forest		
Scrub	41,525	1.26
Non-forest**	2,55,839	77.72
Total Geographical Area	3,287,263	100.00

Source: India-SFR, 2009

**Includes 4,369 km² under mangroves*

*** Excludes scrubs and includes water bodies*

Table 3: **Class-wise Change in Forest Cover between 2005 and 2007 (km²).**

Class	Assessment 2005	Assessment 2007	Change 2005-07
Very Dense Forest	83,472	83,510	38
Moderately Dense Forest	319,948	319,012	-936
Open Forest	286,751	288,377	1,626
Total Forest Cover	690,171	690,899	728

Source: India-SFR, 2009

[1] e-mail: sarangi.tapas@gmail.com

Table 4: **Share of Forestry Sector in the GDP in different time periods (%).**

Years	Share of Forestry in Total GDP	Growth rate in GDP-Forestry Sector	Growth rate in overall GDP	Growth in Implicit Price Deflator	
				Forestry Sector	Total Economy
1950-1960	2.0	0.2	3.6	1.4	1.6
1960-1970	1.8	2.7	4.0	7.3	6.3
1970-1980	1.9	-0.1	2.9	13.8	7.7
1980-1990	2.0	0.4	5.6	11.9	8.8
1990-2000	1.2	0.9	5.7	8.0	8.8
2000-06	0.9	1.4	6.5	3.7	3.8
Average 1950-06	1.7	0.9	4.6	8.1	6.4

Source: CSO, 2007

Table 5: **Contribution of Forestry and Logging to Gross Domestic Products (GDP) at Current Prices and 1999-2000 Prices in India (Rs. Crores).**

Year	GDP at Factor Cost at Current prices			GDP at Factor Cost at 1999-2000 prices	
	Forestry	All sectors	% Share of Forestry	Forestry	Growth rate
1950-51	250	9719	2.6	12542	-
1955-56	212	10518	2.0	12372	4.0
1960-61	311	16512	1.9	12876	1.1
1965-66	477	26047	1.8	15820	13.4
1970-71	780	42981	1.8	17355	4.9
1975-76	1451	77071	1.9	19500	2.8
1980-81	2921	132520	2.2	15796	-1.5
1985-86	4808	254427	1.9	15571	0.6
1990-91	8244	515032	1.6	16280	-1.3
1995-96	12190	1083289	1.1	16307	-0.4
1999-00	17916	1786526	1.0	17916	4.4
2000-01	19298	1925416	1.0	18399	2.7
2001-02	20913	2100187	1.0	18964	3.1
2002-03	21048	2265304	0.9	19090	0.7
2003-04	22374	2549418	0.9	18872	-1.1
2004-05	22855	2855933	0.8	19169	1.6
2005-06	24104	3250932	0.7	19482	1.6

Source: CSO, 2007

Some Thoughts on Managing Forests: Old and New Paradigm

Tasneem Ahmad *

INTRODUCTION

The importance of maintaining growing forests cannot be better realized than in present day scenario when as a result of increasing use of fossil fuels to meet the energy needs of the country, elevated emissions of the green house gases into the atmosphere are escalating the ill effects of global warming. One of the efforts to reduce global warming involves sequestration of carbon, which constitute a major component of greenhouse gases from atmosphere responsible for over half the enhancement of the greenhouse effect. When it comes to sequestering carbon dioxide, there is nothing on the planet earth except a growing plant that can do it. Physical manifestation of carbon sequestration from atmosphere is in the form of increase in volume and weight of the plant. It is a matter of fact that no tree grows indefinitely. Initially rate of growth increases, then after some time the rate of growth slows down, and ultimately after a certain age, which is specific to the species and varies from 50 years in case of *Babul* to 80 years in case of Teak and 150 years in case of *Sal*, it virtually stops. So, such a fully grown tree which is not growing in terms of volume may remain green and may be good for shade, but does no good to the environment as the sum total of carbon dioxide taken in and given out (in the process of respiration) almost balances each other, and is sometimes negative as well. At this age the tree is mature, and this is the time when the tree must be removed and used as timber, and in the space vacated by it, new trees of long rotation be allowed to come up either naturally or by means of artificial reproduction so as to continue the process of carbon sequestration unabated at optimum levels which the trees are capable of doing at different ages of their life. The same logic is applicable to forests as well. The forests, during their annual growing season, sequester carbon to produce wood (measured in cubic volume) which gets deposited in the trees of the forests in proportion and at a rate specific to the species and the age of the trees. This annual production of wood per ha in terms of cubic volume (Current Annual Increment or CAI) is smaller in a forest which is too dense or is too thin in terms of volume in cubic meter per ha. Therefore, to get maximum sequestration of carbon from the atmosphere, the growing stock in a forest in terms of cubic volume per ha has to be maintained at such levels which would produce maximum CAI.

It need not be emphasized that like any other living being, continued existence of forests can be ensured, only if sustained reproduction of trees in appropriate number and their proper growth is ensured. Therefore, any forest management strategy that does not adequately address the reproduction needs of the forest on sustained basis and to the desired extent deserves to be modified forthwith. Similarly, any forest management strategy that fails to create conditions favourable for the optimum growth in terms of volume also deserves to be discontinued.

In view of these general principles, it is essential that the forests are maintained in a healthy state and favourable conditions are created for them to put up optimum annual growth together with adequate reproduction such that all direct and indirect benefits which they are capable of providing may continue to accrue to the society for all times to come. Besides socio-political reasons and increasing biotic factors, failure on the part of professional foresters in skilfully managing these forests is bound to inflict incurable injury on these forests and deny them opportunity to efficiently sequester carbon from the atmosphere in the form of wood. If a farmer makes a mistake in his methods of farming, he can correct it immediately by the expenditure of additional money and labour. A forester can correct his mistakes, if he discovers them at all, only after a long lapse of time. It must be kept in mind that the consequences of the injury caused to the forests in terms of observable units is so slow that often it is too late to take remedial measures by the time ill effects actually start getting realized by the society. Although socio-political support is a prerequisite and an integral part of any efficient forest management strategy, the scope of this paper has been kept limited to the analysis of the role of the silvicultural aspect of forest management and its impact on growth of forests with an object to invite attention of the fellow foresters in the country towards the present state of our forests and measures required for their improvement.

OLD AND NEW PARADIGM IN MANAGING THE FORESTS

The fundamental requirement with regard to the management of forests in the past was to have *organized forest*, that is to say, a forest which is demarcated, surveyed, settled, and its working prescribed in a Plan. The Plan called "Forest Working Plan" *inter alia* used to set forth the purpose with which the forest was to be

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managed, so as to meet the wishes of the owner, and prescribed treatment by which the purpose could be accomplished keeping in view the clearly defined object of management. Keeping in view that the forest is a renewable resource; the objects of management usually were as follows:

(i) To improve of the quantity and quality of growing stock,
(ii) To ensure sustained yield of big size timber and that of fuel wood to meet demands of the society,
(iii) To meet legitimate demand of local population, right and privilege holders, as regards timber, fire-wood, brushwood and grazing, etc.
(iv) To maintain forest cover on hills and steep hill slopes to conserve and improve the locality factors, and to ensure water supply, and
(v) Consistent with the above objects, to obtain the maximum sustained annual revenue compatible with the principles of silviculture and forest conservancy.

The chief purpose of a working-plan was, generally, to secure the condition of crop that is necessary in order that the forest may yield perpetually a regular supply of produce in highest quantity. Besides protection of site and maintenance of forests on physical grounds, the produce aimed at was mainly wood in the form of timber of valuable trees which normally have long rotation. The growing stock (of wood) in the forest which produced wood annually during growing season was treated as "capital", and the annual production (of wood) was harvested keeping the "capital" intact by carefully constituting a series of crops which would meet the requirements of regular supply of wood (timber) perpetually. While harvesting, need to have equal or sustained supply of wood from period (year) to period (year) from an organized forest in perpetuity gave rise to the concept of *Normal Forest* which, in addition to being constituted of a complete series of trees of all ages from seedling to exploitable tree, has each age class occupying equal areas, is completely stocked and the growth is proportional to the fertility of soil. A forest in which quantity of material in the capital, as represented by the growing stock, is insufficient or superabundant or a complete scale of age classes does not exist was considered as abnormal. Though perfectly normal forest is a purely ideal creation, the working-plans prescribed set of cultural rules and methods of execution of certain treatments so as to create forests as near to normal forests as possible. In short, the management of forest was primarily aimed at maximizing annual production of wood (in form of timber) which the site was capable of producing without adversely affecting the total growing stock together with desired control in terms of composition and structure of the forest. The general principle adopted was that the forests having mature crop (mostly old and mature trees), dead and diseased trees which have lost vigour must be removed and replaced with long rotation vigorously growing young trees in adequate number, either naturally or by artificial reproduction, and tended in such a way that the young regenerated crop produced maximum wood per year throughout its life until it matured again. It is important to mention here that besides providing gainful employment to the local inhabitants specially the tribals living in the forest on works related to the silvicultural operations year to year on sustained basis as per prescriptions contained in the working-plans, the timely supply of various forest produce specially small timber, bamboo and fuel-wood (obtained as a result of the working of these organised forest) to them to meet their legitimate livelihood needs was a very important socio-economic aspect of this kind policy adopted in managing government forests at that time. This automatically prevented these local inhabitants from entering into forest and cutting down trees at will or indulging in encroachment for cultivation or any other purpose.

Briefly speaking, in the present day scenario, the concept of "organized forest"- a pre-requisite for an efficient forest management strategy- is not insisted upon. The forests are being treated as a non-renewable resource; and accordingly, the object of management has shifted from taking steps to create conditions favourable for sustained reproduction of desired tree species and their appropriate growth in the forest, to the their preservation as such. In some parts of the country, a blanket ban has been imposed on the practice of silviculture (ban on felling of green trees). The proponents of this policy argue that by banning green felling, they have maintained and conserved large tracts of forests and green cover for national and global benefit at the cost of the socio-economic interests of the State.

PRESENT STATUS WITH REGARD TO DISTRIBUTION OF STEMS AND GROWING STOCK IN IRREGULAR FORESTS

Before proceeding further, it would be essential to have a look at the present condition of our forests. Chart I in respect of forests in Betul district of Madhya Pradesh, and Chart II in respect of forests of East Melghat Forest Division in Amravati district of Maharashtra contain typical examples to demonstrate general status of forests in terms of distribution of stems in various girth classes and total stocking in carefully selected representative sample plots on the sites having different productivity as compared with the desired distribution of stems and corresponding normal Growing Stock for a balanced uneven aged stand on the site of same productivity. For the sake of simplicity, the species have been classed in two groups. First group contains seed origin live stems of Teak (*Tectona grandis*) and its main shade intolerant associates, namely Bija (*Pterocarpus marsupium*), Kalam (*Mitragyna parviflora*), Ain (*Teminalia tomentosa*) and Haldu (*Adina cardifolia*). The other group contains live stems of all other tree species found in the sample plot including their coppices, if any, and those of teak and its associates included in first group. As, generally, girth is closely related to age, simple perusal of these charts reveal that the forest in these two plots is **unbalanced uneven-aged** as it does not contain stems of all the age classes in appropriate number necessary to ensure that the trees arrive at rotation age at short intervals indefinitely. As regards Growing Stock (GS), it would be observed that in the forest shown in the Chart I (Betul), the GS is 89 cu.mts. per ha as against desired normal GS of 77 cu.mts. per ha. (for cut off girth of 150 cms in respect of All India Teak Site Quality III/IV sites) on which optimum CAI per ha is expected to accrue. Similarly, the forest in Chart II (East Melghat) has the GS of 112 cu.mts. per ha. as against desired normal GS of 103 cu.mts. (for cut off girth of 180 cms in respect of All India Teak Site Quality II sites) on which optimum CAI per ha is expected to accrue in the crop. Thus both the forests are over stocked as compared to the desired normal stocking, and as a consequence of this, annual growth in terms of cubic volume (CAI) will continue to decrease and would virtually stop as the crop becomes denser with passage of time. This is the stage when the forest loses its environmental significance as a result of its failure to efficiently sequester carbon to produce wood. To avoid occurrence of such situation in the forests of the country, the professional foresters are expected to realize this fact, and must not hesitate in removing excess volume of the GS from the forest through suitable silvicultural interventions at appropriate time in order to maintain the same at such levels on which maximum CAI would accrue on the given site.

As regards status of reproduction, it can be seen that in both these forests, reproduction of teak and its associates (which are intolerant to shade) is practically absent while the reproduction of other species (which are mainly tolerant to shade) including their coppices is noticed to some extent. Overall population of plants in lower girth classes irrespective of species is much less than desired. If the situation is allowed to continue as such, intolerants as well as many less tolerant tree species would disappear from the forest converting it into useless jungle. This process would definitely be hastened, if the forest happens to be prone to grazing and fire. As the chief reason for the failure of reproduction in such forests is over stocking, the same will have to be reduced through a carefully chosen silvicultural system to create space for new reproduction of desired species to come up and grow. This becomes all the more necessary in view of the fact that most of our forests are prone to excessive grazing, especially during rainy season when the process of reproduction starts, and thereafter fire

PRESENT POLICY AND ITS CONSEQUENCES

Present policy of the Government with regard to management of forests does not adequately take into account silvicultural needs; a pre-requisite of which is to have organised forests. It is a matter of fact that any forest in respect of which no settlement of right of users has been done to extinguish rights injurious to the due maintenance of forest, cannot be expected to perform direct and indirect services to the society in perpetuity. Existence of Protected Forests in many States is an example of this.

As regards ban on green felling, it is wrong to say that correct silvicultural working of any forests reduces green cover. The general policy in many states imposing blanket ban on felling of green trees, irrespective of age and species, completely ignores the basic principles of forest management with regard to the importance of sustained establishment and growth of new reproduction, and maintenance of the Growing Stock at optimum levels in a forest. Such policy decisions appear to be probably based on the misplaced notion that felling of green trees in a forest is against the principles of forest conservation. This general prohibition on felling of green trees does not take into account the fact that under a well conceived silvicultural system, cutting of mature trees (though green) and crops is always done with a definite purpose. The purpose is to break forest canopy to create enough space in the air to ensure admission of adequate sun light on the forest floor required for the new reproduction to come up in adequate number and grow, and at the same time not to allow the crop to become so dense that it fails to produce desired annual growth per unit area. It must be borne in mind that in any forest not under silvicultural treatment, diseased, injured, crooked and defective trees are apt to accumulate. They not only continue to obstruct (mainly due to shade of their crown) establishment of new reproduction as long as they remain there, but also cause retardation in the development of better individuals around them. In such unmanaged or mismanaged stands severe losses are commonly caused by such damaging agencies like fire, insects, fungi and wind. Experience tells us that inferior species (which are mostly tolerant) flourish at the expense of valuable species (which are mostly intolerant) and therefore, reasonable silvicultural efforts must necessarily be made to keep them under check by carrying out cuttings in a regulated manner to ensure maintenance of desired composition of species in the forest. In fact forest is a renewable resource and must be managed as such for the betterment of people and the country. The imposition of blanket ban on the practice of silviculture (green felling), or the neglect of correct scientific working of these forests either as a result of mismanagement or no management has paralysed the process of reproduction leading to disturbance in composition and structure of the forest. This may even lead to their extinction (particularly intolerant species) from the face of the earth only in short period of time especially in the presence of ever increasing pressure of adverse external influences like fire, uncontrolled grazing, and encroachment for cultivation or for other purposes, thefts or felling of trees with no definite plan for assured reproduction.

While carrying out cuttings as a part of any silvicultural intervention in a forest to regulate the Growing Stock, it is ensured that only mature trees/crops are removed at proper time so that the productivity of the site does not degrade. In fact, immature cuttings impoverish the site, while delayed cuttings lead to decay, and becomes obstruction for the new reproduction to come up. Under correct scientific management, age and corresponding size is carefully determined as to when a tree is required to be removed. Even when timber production is not a criterion of management, the techniques employed for improving the habitat of wildlife in the forest are essentially silvicultural. Concentration of wild animals and birds is seen more often in worked forest than unmanaged or wild forest. Interception of precipitation by dense, untreated forest can cause appreciable reduction in the water yield. Similarly, forest fires and faulty management practices induce erosion or compaction of soil which in turn reduces the water retaining capacity of soil. Only carefully managed forests can take care of such situations.

When the forests were being tended/worked in the past in accordance with the policy adopted at that time to make them capable of producing maximum quantity of timber on sustained basis which the site was capable of (by having vigorously growing trees in the forests), they, besides efficiently discharging their function related to environment protection in the form of carbon sequestration, created favourable conditions for the local inhabitants including the tribal to live in total harmony with principles of forest conservancy. The entire socio-economic life of these people depended upon the wages earned by them on forestry works and the forest-produce obtained by working of coupes in these forests. The suspension or inadequacy of working in forests has deprived forest dwellers of productive employment opportunities together with denial of forest-produce, including small-timber and fire-wood to them from the worked coupes in a lawful manner. As a result, having left with no alternative many of these forest dwellers are now forced to indulge in encroachment for cultivation on forest lands, illicit felling and poaching of wild animals etc. to earn their humble livelihood which subject them to criminal proceedings according to law. This is the chief reason for the increasing dissatisfaction among them against the Government/Forest Department. Instead of diagnosing the problem correctly and taking remedial measures to re-introduce silvicultural working in these forests, the Government by voluntarily rendering themselves helpless to prevent the destruction of the forest property it actually desired to protect, decided to burden these forests with rights by enacting the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act-2006. The application of this Act, especially in respect of Reserve Forests does not seem to be the best approach to address the present day needs of the forest dwellers.

It is a matter of fact that suspension or inadequate working of most of the forests in the country according to the established silvicultural principles now a days in the name of environment protection has lead to their over stocking. This over stocking has retarded the growth of the forest in the form of reduced per hectare Current Annual Increment (volume of wood) year after year; thereby reduced rate of carbon sequestration by the forest from the atmosphere year after year. More the over stocking, less is the efficiency of the forest to sequester carbon; manifested in the shape of reduced annual wood production (CAI). In addition, such over stocking in the forest does not allow new reproduction of trees (specially those from seeds) to come up and grow

CONCLUSION AND RECOMMENDATIONS

In view of the above facts, we must frame policies to skilfully use established silvicultural principles for managing our forests with the dual object of producing timber to its maximum (which the site is capable of producing on sustained basis) to meet socio-economic needs of the country, and to mitigate and combat global warming by taking into account following points:

(i) We must maintain growing forests; that is to say that the volume of the growing stock per ha (timber volume in cubic meter) in the forest must be maintained at such levels on which maximum Current Annual Increment accrues on every given site.

(ii) We must maximize production of wood on sustained basis by applying appropriate silvicultural practices per our old policy and promote its use as timber (rather than substituting it with any other material) as it is the most meaningful way to arrest and block carbon dioxide.

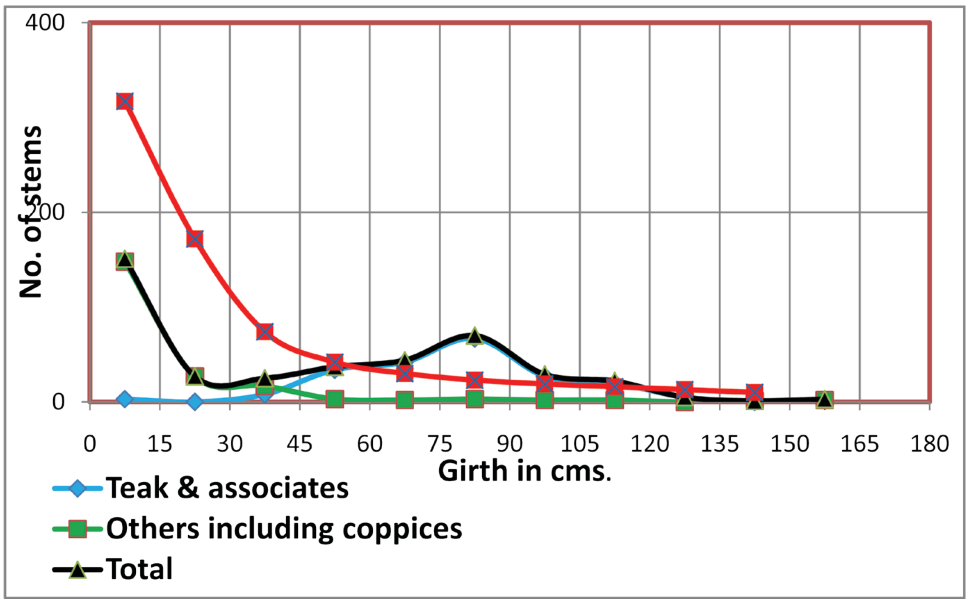
(iii) This implies that the forests having mature crop (mostly old and mature trees), dead and diseased trees which have lost vigour must be removed and replaced with long rotation vigorously growing young trees in adequate number, and thereafter tended in such a way that the young regenerated crop produces maximum wood per year throughout its life until it matures.

(iv) We should not be swayed by emotional cry of some ignorant people to promulgate “blanket ban on green felling”. Let us have logical and scientific approach to every problem. We should try to educate people that felling of mature trees (and using the same as timber and not fuel-wood) and replacing them with adequate number of new growing timber trees of long rotation (either naturally or artificially) is indeed the only option available for augmenting carbon sequestration needed to improve the environment of our mother earth for better quality of life for the future generations.

Plate 1: **Carbon sequestered in the leaves and branch wood together with heat arrested is being released back into the atmosphere in a forest fire. Had forest fire not taken place, carbon dioxide and heat in them would have remained blocked together with the formation of humus; making the soil more fertile with increased water holding capacity.**

Plate 2: **Carbon sequestered in the form of wood in a forest plantation. After this forest matures, it must be replaced by a new forest either by artificial or natural reproduction, and the wood obtained be used as timber such that the carbon sequestered and the heat absorbed during the life time of the this forest continue to remain blocked for long period of time.**

Chart 1: **NG Curve in forest of Betul district of Madhya Pradesh.**



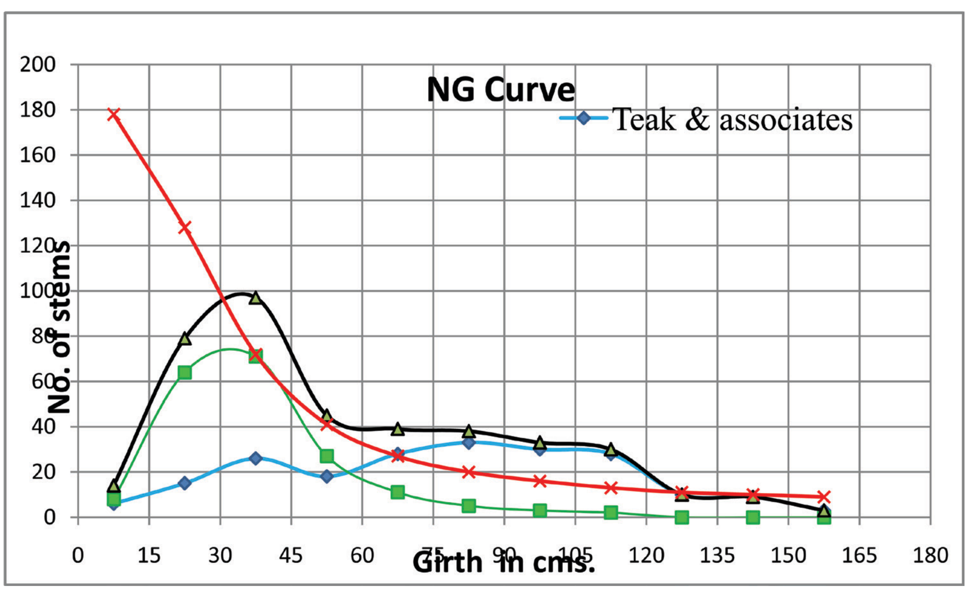


Chart 2: **NG Curve in forest of East Melghat in Amravati district of Maharashtra.**

Economic Valuation of Forest Ecosystem in Dudhwa National Park, Lakhimpur-Kheri

Dr. Jitendra Vir Sharma *

INTRODUCTION

Forests in India are treated primarily a social and environmental resource, only secondarily a commercial resource. The prime objective of National Forest Policy is to provide ecological security to the nation along with meeting the subsistence and livelihood requirements of the people living in and around forests (Anon. 2008). Forests are natural resources and considered as the wealth of nations or a natural capital. Traditionally, these resources are taken as "free gift of nature". The neoclassical economists introduced "natural capital" with "man-made capital" and recognized the changes in natural capital such as depletion, degradation or regeneration as a result of human interference in assessing the value of the resource. Unlike man-made capital, natural capital is strongly linked with the habitat and ecology and provides multiple and interrelated benefaction to human well being (Anon. 2006). The nutrient cycling services of forests promotes the growth of forests itself. Man-made capital is typically unidirectional and also has established markets. However, most of the goods and services provided by forests do not have markets. As a result, the intangible services of forests such as recharging of ground water, regulation of stream flows, flood control, prevention of soil erosion, nutrient cycling, water purification, carbon storage and sequestration, pollution control, micro-climatic functions, biodiversity, evolutionary processes, human habitat, recreational, spiritual and aesthetic values are grossly underestimated or ignored during development planning. The situation has changed considerably post Rio Earth Summit due to increased awareness on the value of forests as a natural capital. Policy makers all over the world are increasingly realizing the need for valuing both the economic and ecological contributions of forests to society, so as to assess the true significance of forests and their contribution to the nation's well being. Millennium Ecosystem Assessment, which was carried out between 2001 and 2005, placed human well-being as the central focus for assessment, while recognizing that biodiversity and ecosystems also have intrinsic value. "Tools now exist for a far more complete computation of the different values people place on biodiversity and ecosystem services. However, some ecosystem services are more difficult to value, and therefore many decisions continue to be made in the absence of a detailed analysis of the full costs, risks, and benefits" (Anon. 2005).

The present system of national accounts (SNA) in India is primarily focused on growth rates of Gross Domestic Product (GDP) and it fails to capture several important elements of natural wealth – both qualitative and quantitative. Despite making significant contribution to India's economic and ecological systems, forests of the country do not get appropriate recognition in the national income (GNP) of the country. In 2002-03, forests contributed Rs. 27, 0130 million to India's GDP at the current prices, which was 1.2% of the GDP. The contribution of forests to India's GDP has varied from 1-1.5% during the nine-year period from 1993-94 to 2002-03. Similarly, the contribution of forestry and logging to Net Domestic Product [NDP] also varied from 1.3% to 1.6% during the same period. The CSO considers recorded timber, minor forest produce and fuel wood harvest from forests and does not consider unrecorded removal of forest produce and its ecological benefits to the society. It is time to consider true value of forests considering goods and ecological services provided by forest ecosystem. It has become mandatory to assign economic value to the goods and services provided by forest ecosystem which are ignored by CSO while calculating the contribution of this sector into GDP which is depriving the nation in achieving the objectives of National Forest Policy [NFP] due to allocation of inadequate financial resources to forestry sector. The forest and wildlife sector is suffering from inadequate financial resources, lack of capacity of human resource involved in the sustainable development of forests and also lack of political commitment. The financial allocation by Government of India to this sector has been below 1% except seventh plan when it touched 1% (Anon. 2004).

It is increasingly recognized that forests provide a range of goods and services, some of which have significant economic value. These include fertile soil and timber, of course, but also non-timber products, recreation, landscape value and a wide range of environmental benefits such as climate regulation, watershed protection and the conservation of biodiversity. This follows a typology introduced by Pearce et al. (1989), which recognizes three types of environmental value: Direct use value includes the benefit of using forest resources as input to production or as a consumption good. Indirect use value provide indirect support and protection to economic activity and property by natural forest functions, or forest "environmental" services. Non-use value includes all other benefits which cannot be characterized in terms

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of a current or future physical interaction between the forest and consumers.

The Total Economic Value (TEV) of a forest system refers to the sum of (compatible) values: i.e. direct and indirect use (and their associated option values), plus non-use values. Different forest land use options will be characterized by a different combination of direct, indirect and non-use values, and thus a different total economic value. Only part valuing forests of this value is reflected in market prices, however, creating a risk that forest planners and land users will ignore or underestimate certain important forest benefits (Adger, W. N., Brown K. 1995).

India has vast forestry resources with 16 forest types and 221 forest sub types spread over different agro-climatic zones throughout the length and breadth of the country. The valuation of goods and services of varied forest types is a huge task. A number of valuation studies are available, however, they neither represent all the forest types covered by statistically drawn samples, nor do they encompass all the relevant use and non-use values. This creates problems for proper aggregation and arriving at even near an approximate value. Ideally, broad based studies are required, taking the country as a universe and data collected from statistically drawn samples from all over spread of forestry resource in question. This is however a huge task, requiring a coordinated effort from a number of institutions and funds. The study presently available at country level is by Chopra et. al. 2002 which has taken into account five components on the output side viz., industrial wood, fuel-wood, NTFP, eco-tourism, carbon sequestration. Findings from the range of studies conducted at micro level in different parts of the country have been amalgamated by using econometric techniques to arrive at values of output for NTFP and eco-tourism. A new methodology has also been applied to estimate the flows of carbon sequestration benefits. The said study reported a range of 1.7% to 4.58% as the contribution of forest to the GDP, with an average value of 2.37%. This value however does not include a number of goods and services such as watershed benefits, ecosystem services and biodiversity values.

Forestry sector in India have inadequate financial resources for implementing sustainable forest management (SFM). National Forestry Action Plan was prepared to implement SFM and also assessed need of US$30 billion for 20 years. Only around 30% of the need is available at national level from all sources. The gap may be met if policy makers are convinced with the true value of ecosystem services provided by forests in India (Anon. 1999 and Anon. 2008).

The Dudhwa National Park (DNP) represents woodland, grassland and wetland ecosystem and provide variety of goods and services having use and non-use value such as timber, fodder, minor forest produce (MFP), carbon sequestration, soil and water conservation, gene pool preservation and biodiversity conservation. Dudhwa National Park spreads over 811km² near the border of India and Nepal encompassing Northern tropical semi evergreen forests, moist deciduous forests, moist Savannah forests and tropical, seasonal swamp forests. It has a variety of biodiversity including 296 plant species, 47 mammals, 449 avian fauna, 35 reptiles, 10 amphibians, and 27 fishes, 120 invertebrates (Singh and De, 2000). There are 127 villages having 180103 human population and 78241 livestock population in and around forests and have their dependence for fodder and energy requirement. Since, DNP represents varied ecological services; it was identified area for economic valuation of ecological services.

STATEMENT OF PROBLEM

The economic value of natural resource as natural capital or asset can be defined as the sum of the discounted present values of the flows of all goods and services from the resource. The economic concept of value is based on a premise of neo-classical welfare economics that the purpose of an economic activity is to increase the well being of individuals who constitute society and that each individual is the best judge of what is good or bad for him or her. The basis of estimating economic value of a resource or an environmental amenity is its probable effect on human welfare. However, the anthropocentric focus of economic valuation does not preclude a concern for the survival and well being of other species of the ecosystem. People do value other species not only because of their direct utility to them but also because of altruistic or ethical concerns. The estimation of economic values of natural resources, environmental amenities and ecological services is necessary, as there are no markets for most of them and as there are externalities in their use. Such values would help in determining the trade-off between economic development and quality of environment and in determining the extent of financial liability of firms and households, who degrade natural resources and pollute the environment. Further, it helps in preparing green national accounts, i.e., accounts that incorporate national income accounts, the benefits and costs of natural resources and environmental amenities and services. On account of absence of any framework for estimation of such values, the present system of income accounting in the forestry sector only takes note of contributions such as industrial wood, fuel wood and minor forest products. In India, forests meet nearly 40% of the energy needs of the country, of which more than 80% is utilized in rural areas. Forests also provide about 30% of the fodder needs of the cattle population. Forest products play a very important role in rural and tribal economy as many of the Non-Timber Forest Products (NTFP) provides sustenance to the rural poor. For landless families and marginal farmers forest related activities often provide the primary source of income. Number of goods and services provided by forest ecosystem has not been considered by CSO for the purpose of calculating contribution of these goods and services from forests into GDP (Anon. 2006).

For reflecting the true value of forests to the nation's national income, it is imperative to conduct natural resource accounting (NRA). NRA is a revaluation of the National Income Accounts of a country, adjusting for the values of natural resources used in various economic activities during the past "fiscal year". The changes in both "stock" and "flow" of forests need to be accounted for. Forests get degraded in quality and quantum due to economic and human activities. They also go through natural decay and regeneration (Anon. 2006). Forests may also have been enhanced due to plan interventions, forest conservation and management of Protected Areas. Forests in India differ from state to state and within state also. There is diversity of forest ecosystem in the country. There is need to valuate different goods and services derived from forests for estimating Total economic Value of the forest ecosystem. The Dudhwa National Park has been identified for the study of Total Economic value of the Forest Ecosystem. DNP represents woodland, grassland and wetland ecosystem and provide variety of goods and services having use and non-use value such as timber, fodder, minor forest produce (MFP), carbon sequestration, soil and water conservation, gene pool preservation and biodiversity conservation.

METHODOLOGY

The Total Economic Value of Dudhwa National Park has been calculated using different methods for each of the goods and services provided by the said forest ecosystem. Market price method has been used for assigning value for Fuel-wood, fodder and MFP. The questionnaire has been designed to generate primary data for calculating direct benefit to the society by way of consuming such forest product and collect for generating employment. Legally such forest products are not permitted from protected areas but people live in and around forests are getting benefit. The random sampling method has been used and 10% villages have been selected from each range of the DNP. The different income group families and people were interviewed for primary generating data. There are 127 villages in and around DNP in which more than 180163 people and 78241 livestock (Singh and De, 2000) depends for their energy requirement, fodder and, also the employment. The average members in the family is 4.5 including children as indicated by the survey report. Around 29.83% families use LPG for cooking food and 5% population collect fuel wood from DNP as a source of their employment. The villagers use around 50% of their energy requirement from agriculture waste. Around 70% families are consuming 10 kgs fuel wood per day. Five percent people go to DNP around 240 days in a year for collecting around 40 kgs fuel wood per day and sell in the market for earning their livelihood at the rate of Rs.1 per kg. The villagers do not go to the DNP during festivals and in rainy season also. The above mentioned facts have been derived from the survey done in the villages in and around DNP. The data was obtained through a questionnaire on the basis of random sampling of the villages. On the basis of primary data generated through survey and demographic data taken from secondary source (De and Singh 2000), the monetary value of fuel wood consumed by the villagers in and around DNP is Rs. 155.98 million which has been calculated by using Market Price Method.

There are 78241 cattle in 127 villages in and around DNP including 32385 cow, 37188 buffalo and 8668 goat and calf. The quantity of fodder requirement is necessary for calculating the monetary value of DNP through fodder and grazing. All cattle have to be converted into Adult Cattle Unit. Cow is the basic adult cattle unit and its weight is 350 kgs. The weight of buffalo is 400 kgs and goat is one fifth of cow. The requirement of cattle is 2.5% dry fodder of its body weight. The wet fodder or fresh grass from DNP is four times of dry fodder. The requirement of Adult cattle Unit is 35 kgs per day and fodder is required for cattle throughout the year (Anon. 1985). Around 50% requirement of fodder is met by the villagers through other sources such as fodder from agricultural fields. The 50% requirement is met through grazing of cattle in DNP and bringing fodder for stall feeding. The market Price Method has been adopted for calculating the monetary value of the fodder and grazing from DNP at the rate of two rupees per kilogram. The data was obtained through a questionnaire on the basis of random sampling of the villages. On the basis of primary data generated through survey and demographic data taken from secondary source (De and Singh 2000), the monetary value of fuel wood consumed by the villagers in and around DNP is Rs. 228.16 million which has been calculated by using Market Price Method.

As many as 41,103 families in 127 villages in and around DNP collect minor forest produce for their day to day consumption and also collect for their livelihood. The villagers collect medicinal herbs such as *Asparagus racemosus, Tinospora malabarica, Piper longum, Grewia hirsute, Mallotus philipinesis*, fruits of medicinal value such as *Terminalia belerica, T.chebula, Emblica officinalis, Casia fistula, Aegle marmelos*, honey, wax, thatch grass and narkul. The most important is thatch grass. All families consume minor forest produce from DNP(Singh and De, 2000) . Only 5% families collect MFP for their livelihood. During rainy season, edible fungus locally named as *katanua* has been collected and sold in the market. Thatch grass is another important MFP consumed by the villagers living in and around DNP. The families earn around 200 rupees per day by collected edible fungus. The season for collecting *katanua* is only for 25-30 days in a year. On the basis of survey, each family consumes thatch grass worth Rs 600 and other miscellaneous MFP worth Rs 500. The data was obtained through a questionnaire on the basis of random sampling of the villages. On the basis of primary data generated through survey and demographic data taken from secondary source (De and Singh ,2000), the monetary value of fuel wood consumed by the villagers in and around DNP is Rs. 52.4 million which has been calculated by using Market Price Method.

The area of DNP is 888378.8 hectare and 24.56% area represents wetlands, grasslands, compartment lines, fire lines, rivers and roads which have been excluded for the purpose of calculation of annual benefits of the carbon sequestration from DNP. The dominant tree species is *Shorea robusta* popularly known as Sal in India. Most of the compartments in the forests of Dudhwa National Park are of quality class II and III. The average annual increment in the forests of DNP is 6 cubic meter per hectare in tree crop (Smithies A.R. and Howard S.H. 1923). The forests of DNP maintain 56% carbon in the soil and 44% carbon in the wood form. The density of Sal is 0.8 and the annual increment of wood is 4.8 tonnes per years per hectare. The annual contribution of carbon is 5.45 tonnes per year per hectare in DNP. On the basis of annual yield prescribed in the Working Plans of North Kheri and South Kheri Forest Divisions, the than areas of Dudhwa National Park (Gupta Chandra, 1973), (Pant Suresh Chandra, 1990) and (Srivastava D.N. 2000), around 5.45 tonnes of carbon per hectare has been sequestered by the forests of DNP. The annual monetary value of DNP for carbon sequestration is Rs. 363.32 million.

The Travel Cost Method (TCM) has been used to assign the recreation value. A questionnaire was designed to generate primary data under Travel Cost Method (TCM) for estimating the willing to pay by tourists for the recreation (Sharma, M.L. 2006). The secondary data of the tourists for 2005-06, 2006-07 and 2007-08 have been obtained from the office of DNP. There are two kinds of tourists visiting DNP. Day tourists and other tourists who stay for the night also. The further categorization is high income group, middle income group, students and foreign tourists. DNP is remotely located and tourists come to DNP only for wildlife interest. There is no other purpose to visit DNP except wildlife interest of the tourists. The cost incurred by tourists on their travel to DNP from their home (distance cost), fee of the park, lodging and boarding, cost of the time spent by tourists and other miscellaneous costs have to be taken into consideration while estimating recreation value under TCM. The survey data has been analyzed along with secondary data, particularly demographic data. The average number of tourists for the last three years is 7635. The estimated annual recreation value of DNP is Rs. 49.9 million.

Forests provide ecological services to the society such as soil and water conservation, clean air and recharging the water level. The natural services that for millennia have purified the water and air supported the growth and reproduction of food plants, controlled pests, and even moderated the weather and its impacts are declining rapidly. Land clearing for agriculture, industry and mining, and development is affecting ecosystems worldwide. As habitats become fragmented, with only pockets left here and there, the services those natural systems provide become less effective. Twenty one percent of area in DNP is wetlands and grassland which are performing the function of recharging the ground water. The rest 79% area of DNP is dense forests with ground, middle and top storey of the forests which is largely sequestering carbon and purifying the air. The secondary data from Natural Resource Accounting of Forests Resources, Delhi Institute of Economic Growth (Chopra K. and Kakekodi G.,1997) been taken as Rs.624 per hectare. The monetary value of the ecological function of DNP has been calculated by multiplying the area of DNP which is Rs. 55.14 million.

The bequest value originated when people are willing to pay to conserve the benefits of protected area for the use of future generations. By doing so, these people do not have intention to use the benefits during their life span, but are bequesting those benefits for the future generations. The DNP is having 47 species of mammals, 449 species of birds, 35 species of reptiles, 10 species of amphibians, 79 species of fish, 120 species of invertebrates and 302 plant species. The Government is spending the public money on the conservation of biodiversity for future generations, and also sacrificing the timber harvest for the conservation of biodiversity. It is non-use value for the present generation. The monetary value of sacrificing timber harvest has been calculated on the basis of data collected from adjoining forest areas of South Kheri Forest division (Gupta Chandra, 1973), (Pant Suresh Chandra, 1990) and (Srivastava D.N. 2000). Most of the areas in DNP are of quality class II and III forests. The Government is not harvesting any timber from DNP since its inception in January, 1977. The working plans of North and South Kheri Forest Division before 1977 were also studied. The prescriptions made at that point of time are not applicable in present time. The data for timber harvest were taken from South Kheri Forest Division on the basis of prescriptions made in the existing working plan. Since, dominant species in DNP is *Shorea robusta*, the yield table prepared by E.A. Smithies and S.H. Howard (1923) was also studied. On the basis of average annual production of timber harvested by UP Forest Corporation in South Kheri Forest Division, the Government is sacrificing 5.95 cubic meters per hectare timber production in 66% woodland of 88873.90 hectare DNP area with the average royalty during last three years paid by UP Forest Corporation as Rs.8880. The Government is sacrificing the revenue Rs. 309918931 or 309.91 million each year. The Central and State Government are also spending Rs. 30 million for the conservation of biodiversity for future generations. Thus, the bequest value of DNP is Rs 339.91 million per year.

The role of DNP to enhance the agriculture productivity by providing better moisture regime has been estimated with the help of primary data generated from the villages 5, 10 and 15 kilometers from its vicinity. The DNP is situated in Terai region of Uttar Pradesh. There is enough moisture and high level of ground water available not only near DNP, but in other areas also. The agriculture production is 2.78% more in the fields which are adjoining to DNP. There is damage to crop also due to wild animals which is 2.69%. There is not much contribution of DNP for enhancing the agriculture productivity in the adjoining villages and net contribution is negligible or zero.

TOTAL ECONOMIC VALUE OF DNP

Dudhwa National Park has a multi-facet impact on carbon sequestration, tourism, soil and water conservation, livelihood and subsistence need of the people living in and around DNP, preservation of gene pool and conservation of biodiversity for future generations, besides large number of environmental benefits. On other hand, its negative side includes damage to crop, livestock and human being by wild animals. On the whole, it has net positive impact. On the basis of analysis of data generated largely through primary source and partially through secondary source, the important findings of the investigation and breakup of Total Economic Value of DNP are listed ahead.

DNP fulfils the fuel wood requirement of 127 villages in and around DNP, and also provide employment to the local people through collection and sale of fuel wood .The annual contribution of DNP with respect to extraction of fuel wood is Rs. 155.98 million which has been estimated through market price method of economic valuation. It is 12.53% of annual Total economic value of DNP.

DNP supports the fodder requirement of 78788 unit livestock in 127 villages located in and around of the park largely through grazing. The annual contribution of DNP with respect to fodder and grazing is Rs. 228.16 million. It is 18.33% of annual Total economic value of DNP.

DNP fulfils the need of MFP in 127 villages located in and around park, and also provide employment to the substantial number of people through collection and sale of MFP. The annual contribution of DNP with respect to MFP is Rs. 52.41 million. It is 4.21% of annual total economic value of DNP.

The forests of DNP sequester carbon from the atmosphere and also hold the soil carbon intact. The DNP has 66% of total area as woodland or tree crop dominated by *Shorea robusta* popularly known as Sal. The quantum of carbon sequestration annually has been calculated on the basis of annual increment of dominant woody mass in the forests of DNP with the help of yield table available for terai area of UP by Smithies and Howard(1923). The forests of DNP contribute through carbon sequestration to the

Goods/Services	Annual Monetary Cost (Rs.)	Percentage
Fuel wood extracted from Dudhwa National Park	155989920 or 155.91 million	12.53
Fodder and Grazing from Dudhwa National Park	228169028 or 228.16 million	18.33
Minor Forest Produce (MFP) extracted from Dudhwa National Park	52411633 or 52.41 million	4.21
Carbon Sequestration from Dudhwa National Park	363323160 or 363.32 million	29.18
Eco-tourism/Recreation from Dudhwa National Park	49981000 or 49.98 million	4.01
Ecological Functions from Dudhwa National Park	55145251 or 55.14 million	4.43
Bequest Value	339918931 or 339.91 million	27.31
Value of Enhancing Agricultural Productivity	0	0
Total Economic Value (TEV)	1244938923 or 1244.93 million	100

society equivalent to Rs. 363.32 million per annum. It is 29.18% of annual Total economic value of DNP.

The average annual tourists in DNP are 7635 and use the direct benefit of recreation by watching wildlife and forests. The Travel Cost Method has been adopted to calculate the annual recreation value of DNP. On the basis of primary data generated through questionnaire and secondary data available in the office of DNP, the approximate recreation value of DNP is Rs. 49.98 million per annum**.** It is 4.01% of annual Total economic value of DNP. There is enough space to enhance contribution of DNP towards its TEV through recreation with the help of management intervention and improvement in tourism policy.

Forests provide ecological services to the society such as soil and water conservation, clean air and recharging the water level. The natural services that for millennia have purified the water and air supported the growth and reproduction of food plants, controlled pests, and even moderated the weather and its impacts are declining rapidly. The secondary data from the study done by Kanchan Chopra and Kakekodi (Natural Resource Accounting of Forests Resources, Delhi Institute of Economic Growth) has been used for calculating the economic value of the ecological functions of DNP which comes around Rs. 55.14 million per annum. It is 4.43% of annual Total economic value of DNP. The low contribution of DNP towards soil and water conservation is low due to high sub-soil water level.

DNP supports a rich biodiversity comprising of 47 species of mammals, 449 species of birds, 35 species of reptiles, 10 species of amphibians, 79 species of fish, 120 species of invertebrates and 302 plant species. The Government in India is paying the non-use value of the DNP, and conserving it for future generations. The expenditure on DNP and sacrificing the cost of timber harvest has been taken into consideration while calculating its bequest value. The bequest value of DNP for supporting gene pool conservation is approximately Rs. 339.91 million/ per annum. It is 27.31% of annual Total economic value of DNP.

Generally agriculture crop adjoining to forest areas has better productivity than the areas away from the forests. The water level is much higher in such areas that impact the productivity of the agriculture crops. DNP is located in Terai area of Uttar Pradesh. The water level is higher in most part of the district. On the basis of primary data generated through questionnaire in this regard, there was not higher productivity in the areas adjoining to DNP. The loss to the crop is being compensated by the Government and insurance. There is no economic value to the agriculture producers adjoining to the DNP than those who are away from DNP. There is not much contribution of DNP for enhancing the agriculture productivity in the adjoining villages.

CONCLUSION

Total Economic Value (TEV) concept is widely used in the environmental economic. The efforts have been made to quantify the identified benefits. Both primary and secondary data have been collected, compiled and analyzed. Forests have variety of products and uses. The valuing this benefit is an important task for quantifying economy-environment inter-relationship. These benefits can be quantified and valued using various approached. The TEV concept is used to cover all direct and indirect values i.e. actual use value, option value and bequest value. On the basis of primary and secondary data generated through questionnaire and review of literature, and also with the use of various methods of economic valuation of Forest ecosystem, the Total Economic Value (TEV) of Dudhwa National Park (DNP) is estimated Rs. 1244.93 million per annum. The Contribution of DNP is around 39% for direct use value such as fuel wood, fodder, MFP and recreation, 31% for indirect use value such as ecological function and carbon sequestration, and 30% for non-use value or bequest value of preservation of biodiversity. The economic value of forest ecosystem may apply on areas having same kind of flora, fauna and geography. Mountain Ecosystem contributes 69% of TEV towards soil and water conservation (Verma Madhu 2000). Dry deciduous forests contributes 30% of TEV towards enhancing agriculture productivity in the adjoining fields (Pandya et al 2001) DNP does contribute very little towards the enhancement of agriculture productivity in its adjoining agriculture fields which is countermanded by the damage of crop by wild animals. The DNP is getting Rs. 30 million budgetary allocation per annum from all sources against the requirement of financial Rs. 100 million. The outcome of this investigation would also justify the need of financial and human resource requirement for the protection, conservation and preservation of forest ecosystem in DNP.

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Managing Degraded Arid Sandy Salt affected Soils with *Atriplex* SPP for Improved Productivity

Ranjana Arya *

INTRODUCTION

Atriplex shrubs have been recognized for their high productivity, tolerance to saline sodic soils and production of quality forage material. They tolerate high levels of salt in soil and water and resist low and high environmental temperatures and droughts (Pasternak et al, 1986; Uchiyama, 1987). With remarkable phytomass production and re-growth after browsing, and their relatively high crude-protein content and apparent high digestibility coefficients, these shrubs might be a valuable protein supplement to nutrient-deficient herbage on rangelands and in arid and saline zones. Halim et al., 1990 reported that *Atriplex lentiformis* has recorded the maximum survival out of the ten chenopods tries in salt affected lands of Iraq. Atriplex spp. have been planted on more than 1,000,000 ha in Middle East (Nefzoui, 1997). Shrubs of genus *Atriplex*, popularly known as saltbushes, are salt excluders; the leaves accumulate salt in the cell vacuoles and in bladder cells. *A.lentiformis* (Torr.) S. Watson - excretory halophyte, family Chenopodiaceae occurs from central California to Sonora, Mexico. Its value as livestock forage led to its introduction into Australia, Middle East and Asia. It is a perennial shrub with open, upright structure. It grows fast up to 2.5 m in height and width under favourable conditions. The leaves are silvery blue green in colour. It is dioecious in nature. *A. amnicola*, commonly known as river saltbush or swamp saltbush, native of western Australia, is salt tolerant and fairly drought tolerant species and once mature, tolerates waterlogging well (Runciaman and Malcolm, 1991). It is one of the most palatable shrub and in a study Riaz et al 2003 concluded that *A. amnicola* leaves could be used for partial substitution of conventional forages to support livestock population. *A. stocksii* Boiss, is a short much branched robust monoecious perennial shrub, 20-60 cm high found on mud flats along sea coast or in saline soils in Bharoach, Cambay Gujarat (Shah, 1978) and along Arabian sea coast in Pakistan (Agha et al, 2009).

Salt affected soils are wide spread in all climatic zones but these dominantly occur in arid and semiarid regions. Approximately 2.60 m ha area is affected with salt problem in states of Rajasthan (0.38 m ha) and Gujarat (2.22 m ha) out of 6.73 m ha reported for India (Sharma, 2004). However, establishment of plantations in these salt affected water-logged areas is very difficult. Mounding practices were reported to help establishment of plantations on saline waterlogged sites (Arya et al, 2006). Performance of *A. lentiformis* was studied earlier with different management practices in arid salty conditions of Rajasthan (Gupta and Arya, 1995, Arya et al 1998). The results of three experimental trials laid in August 1997 and 2000 with *A. lentiformis*, *A.amnicola* and *A. stocksii* with different treatments (gypsum and nitrogen doses) and mode of planting, control, double ridge mound (DRM), and circular dished mound (CDM) are presented here.

MATERIALS AND METHODS

Site Conditions

The experimental area is located in Jodhpur, Rajasthan characterized by sandy plain with compact substrata at shallow depth, which is impervious to roots and water. The soil was classified as lithic, calcid, coarse sandy to loamy sand, shallow (25 to 40 cm soil depth) with a thick hard pan of calcium carbonate underneath it. The soil pH ranged from 8.8 to 9.8 while EC_2 from 4.2 to 16 dSm^{-1} having salt encrustation (EC value up to 48 dSm^{-1}). The exchangeable sodium ranged from 30-60%. The soil gypsum requirement was found to be 6 tha^{-1}. Percent SOC ranged from 0.1 to 0.2%. The mean annual rainfall of the area is 350 mm, which is mainly confined to the monsoon period (from July to September). The total number of rainy days during the year varies between 8-17 days. The maximum and minimum temperature ranges from 48^0C in summer to 4^0C in winter. Average wind velocity in the summer months is recorded as 20 to 30 km h^{-1}. The annual rainfall during the study period was –1997 (Aug-Dec, 201 mm), 1998 (478.5 mm), 1999 (296.1 mm), 2000 (293.3 mm) 2001 (429.9 mm), 2002 (50.6 mm) and 2003 (419.4 mm).

Data and field procedure

Trial of *A. lentiformis* was laid in 1997 with three levels of gypsum: Control (no gypsum), Gypsum @ 100% soil GR, and Gypsum @ 150% soil GR and six nitrogen levels (0, 9, 18, 27, 36 and 45 g of N) in the form of urea. Pits of 50 x 50 x 50 cm were dug and 3 kg farmyard manure (FYM), 15 g single super phosphate (SSP) and gypsum (as per the treatments proposed) were mixed with pit soil at the time of planting. Crescent shaped drainage trenches were made around individual plant along the slope to facilitate the leaching of salts

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Second trial with *A. amnicola* was laid out in August 2000 with three planting treatments (double ridge mound S_1, single ridge mound S_2 and bund S_3) and two levels of gypsum, full gypsum requirement G_1 and control G_0, leading to a total of six treatment combinations. The trial was laid in a randomized block design with three replications at a spacing of 3m x 3 m . There were 12 plants in each treatment. Three kg FYM and, 15 g SSP and gypsum at 100% soil GR as per the treatment were mixed with pit soil at the time of planting.

Third trial with *A. stocksii* was laid in a RBD in August 2000. Four replications of 6 plants each, thus 24 plants per treatment, were planted at a spacing of 3 x 3 m. Three kg FYM, 15 g SSP and gypsum at 100% soil GR was mixed with pit soil at the time of planting. Soil drenching with 0.2% chloropyrophos was also carried out. For making double ridge mounds, bunds (0.50m broad and 0.45 m high) were constructed with the help of tractor. Ridges (20 cm high) were made manually. Distance between two ridges (planting space) was 1.2 m. Circular dished mounds were prepared by raising soil to a height of 20 cm in a circle of 2.0 m diameter manually. DRM was adopted from the studies carried out in Australia (Ritson and Pettit, 1992), while CDM was developed on our field experience. No rainfall was received after planting. Monthly irrigation of 30 lit/irrigation was given from September 2000 to May 2001. Then irrigation was provided in October, 2001 and March to May 02. Due to complete monsoon failure irrigation (25 lit/plant) was provided in Aug, Oct, Nov `02, Jan and March-May 03 to save the plantations. One weeding was undertaken annually in the months of October-November to remove weeds. Survival was recorded annually. Initial height was recorded immediately after planting. Further data on heights and crown diameter were recorded annually.

Biomass estimation

Component-wise biomass study was also carried out for all the three species *A. lentiformis* at 14 months and *A. amnicola* and *A. stocksii* at the age of 36 months. Using the mean heights and crown diameters as selection criteria, three average shrubs were selected for both the species for destructive sampling in all the treatments. Above ground biomass was estimated by cutting the shrub from the ground level and leaves and branches were separated to determine the fresh weight of each parts of the shrub in the field. The representative samples were taken to laboratory for estimating oven dry biomass.

Data Analysis

The data collected were analyzed using SPSS[H] statistical software package. The overall analysis of the data collected during the entire study period was carried out using General Linear Model (GLM) procedure. This analysis was performed to examine the effect of soil structures on survival, height and crown diameter. Least Significant Difference (LSD) values were also calculated for pair-wise comparison to see the effect of individual treatments on different growth parameters and values are given in the text.

RESULTS AND DISCUSSION

A. lentiformis

Survival

Periodic mean survival is summarized in Table 1. Mean survival at 22 months of age showed that maximum survival (85.2%) was recorded with G_1 treatment followed by G_0 (77.9%) and G_2 (72.2%). At 40 months of age maximum 100% survival was recorded in T_7 (100% soil GR) where as minimum 55% in nitrogen treated bushes with or without gypsum application. Overall there was no appreciable decrease in survival of bushes as compared to survival at 22 months (May 1999) despite two-failed monsoon.

Survival ranged from 45 to 83% in different treatments in at 66 months of age in March 03 (drought year). Less decrease was observed in gypsum treated bushes. Effect of treatments was not significantly influencing the survival throughout the study period.

Growth

Maximum mean height (128 cm) and crown diameter (173 cm) was attained by N_3 nitrogen level with T_{16} (G_2 + 60 g urea) treatment recorded maximum height (153 cm) and crown diameter (180 cm). The two way ANOVA results showed that mean height attained by the bushes in different treatments (gypsum as well as nitrogen levels) was statistically not different from each other (Table 2). While in the case of crown diameter effect of treatments was significant, and CD value indicate that gypsum application (T_7 and T_{13}) and N_3 nitrogen dose with or without gypsum (T_4, T_{10}, and T_{16}) attained significantly higher growth as compared to Control (T_1) at 14 months of age (Table 2).

Table 1: **Periodic percent survival of *A. lentiformis* under different treatments**

	C	N_1	N_2	N_3	N_4	N_5	Mean	C	N_1	N_2	N_3	N_4	N_5	Mean
	22 months							40 months						
G_0	83.3	83.3	100	73.3	77.8	49.5	**77.9**	83.3	77.7	83.3	83.3	66.6	49.5	**73.9**
G_1	100	77.7	83.3	77.7	100	72.2	**85.2**	100	77.7	83.3	73.3	77.7	72.2	**80.7**
G_2	88.8	66.6	72.2	83.2	66.6	55.5	**72.2**	88.8	55.5	72.2	72.2	66.2	55.5	**68.4**
Mean	**90.7**	**75.9**	**85.2**	**78.1**	**81.5**	**59.1**		**90.7**	**70.3**	**79.6**	**76.3**	**70.2**	**59.1**	

G_0- no gypsum, G_1- Gypsum @ 100% soil GR , and G_2 -Gypsum @ 150% soil GR;
C-0, N_1-9g, N_2-18g, N_3-27g, N_4-36g and N_5-45 g of N)

Treatments	N_0	N_1	N_2	N_3	N_4	N_5	Mean
	Height (cm)						
G_0	101 ± 2.40	116± 12.06	112 ± 7.31	118± 2.99	121± 5.29	107 ± 8.02	**113**
G_1	110 ± 9.84	108 ± 7.09	100 ± 5.69	114± 9.77	126± 9.71	106 ± 0.88	**111**
G_2	106 ± 8.84	101 ± 2.40	101± 3.53	153± 2.03	104± 2.19	105 ± 2.89	**111.5**
Mean	**106**	**108**	**104**	**128**	**117**	**106**	
	Crown diameter (cm)						
G_0	129 ± 2.08	150± 18.61	153 ± 15.8	174 ± 13.04	178 ± 4.51	139 ± 8.76	**154**
G_1	166 ± 8.74	133 ± 6.98	138 ± 6.17	166 ± 26.03	131 ± 6.77	149 ± 8.08	**147**
G_2	171 ± 10.54	131 ± 6.66	149 ± 10.7	180 ± 9.85	144 ± 7.79	160 ± 22.2	**156**
Mean	**155**	**138**	**148**	**173**	**151**	**149**	
CD (0.05)	**Height - 20.08**			**Crown diameter – 36.4**			

Table 2: **Growth performance of *A. lentiformis* (Mean ± SE) with different levels of gypsum and nitrogen at 14 months of age**

Aboveground Biomass

A. lentiformis responded to treatment application and all the treatments recorded higher green biomass yield as compared to control at 14 months of age but all were not significantly higher (Table 3). In G_1 treated bushes nearly all the treatment combinations recorded significantly higher biomass yield. Maximum biomass was recorded in T_4, T_{10} and T_{16} treatments where 60 g of urea was applied with different levels of gypsum. Sharma and Gupta (1986) suggested that the dose of gypsum should be 1.3 times the gypsum requirement, however, G_2 gypsum level treated bushes (where 1.5 times higher gypsum was applied) recorded lesser yield suggesting higher dose of gypsum is not suitable under present circumstances. Application of nitrogen doses increased the leaf component in different treatments. Mean percent allocation showed that percent leaf component was minimum in N_0 nitrogen level.

Table 3: **Biomass yield of *A. lentiformis* (g/ bush) with different levels of gypsum and nitrogen at 14 months of age**

Treatments	Green			Dry		
	Leaf	Branch	Total	Leaf	Branch	Total
T1 (G_0N_0)	340.0	402.0	742.0	94.8	233.0	327.8
T_2 (G_0N_1)	825.0	881.0	1706.0	214.3	572.7	787.0
T_3 (G_0N_2)	787.0	667.0	1415.0	196.9	386.6	583.5
T_4 (G_0N_3)	928.0	917.0	1845.0	273.8	541.0	814.8
T_5 (G_0N_4)	620.0	757.5	1377.5	182.2	469.7	651.9
T_6 (G_0N_5)	653.0	593.0	1246.0	172.9	367.6	540.5
T_7 (G_1N_0)	875.0	1275.0	2150.0	214.4	765.0	979.4
T_8 (G_1N_1)	1015.0	886.0	1901.0	279.3	488.7	768.0
T_9 (G_1N_2)	845.0	885.0	1730.0	207.2	522.1	729.0
T_{10} (G_1N_3)	1055.0	1111.0	2166.0	236.4	649.0	885.2
T_{11}(G_1N_4)	605.5	660.5	1266.0	175.6	377.8	553.4
T_{12}(G_1N_5)	785.5	690.0	1475.5	191.7	393.3	585.0
T_{13}(G_2N_0)	630.0	685.0	1315.0	183.0	459.0	641.7
T_{14}(G_2N_1)	635.0	640.0	1275.0	165.1	416.4	581.5
T_{15}(G_2N_2)	607.0	718.0	1325.0	151.7	416.3	568.0
T_{16}(G_2N_3)	951.5	875.0	1826.5	228.4	588.0	816.3
T_{17}(G_2N_4)	620.0	589.5	1209.5	161.2	394.9	556.1
T_{18}(G_2N_5)	630.0	614.0	1244.0	163.8	399.1	562.9
CD	**360.9**	**413.4**	**728**	**NS**	**NS**	**NS**

A. amnicola

Survival

Periodic survival data is summarized in Table 4. Bushes maintained appreciably high survival of 66.6% to 75% after 72 months on different structures facing periodic monsoon failure and water logging by whatever little rain is received including

Table 4: **Periodic percent survival (Mean ± SE) of *A. amnicola* with different treatments**

Treatments	12*	24	36	48	60	72
T_1	69.4 ± 0.7.3	91.6±4.8	91.6±4.8	91.6 ±4.8	86.1 ±5.5	72.2±7.3
T_2	72.2 ± 10.0	83.3±12.7	83.3±12.7	77.7±10.0	77.7±10.0	69.4±10.0
T_3	75.0 ± 9.6	86.1±10.0	83.3±12.7	80.5±15.5	74.9±20.2	66.6±17.3
Mean G_0	**71.2**	**87.0**	**86.1**	**83.3**	**79.6**	**69.4**
T_4	75±9.6	94.4±2.8	91.6±2.8	91.6 ±4.8	86.1±10.0	74.9±9.6
T_5	81±7.3	86.1±5.5	86.1±5.5	86±2.7	83.1 ±8.3	72.1±5.6
T_6	83±4.8	94.4±5.6	94.4±5.6	91.6±4.8	88.8±5.6	75.0±0.0
Mean G_1	**79.3**	**91.6**	**90.7**	**89.7**	**86.1**	**74**
CD at 5%	NS	NS	NS	NS	NS	NS

$T_1 = S_1$ Go, $T_2 = S_2G_0$, $T_3 = S_3G_0$, $T_4 = S_1 G_1$, $T_5 = S_2G_1$, $T_6 = S_3G_1$; S_1 = Double ridge mound, S_2 =Single ridge mound, S_3 = Bund

worst drought in 2002. Data showed that though throughout the study period gypsum treated bushes recorded slightly higher mean survival but the difference is not significantly different from control. Except for first twelve months all throughout the study DRM recorded maximum survival followed by Bund and SRM but again percent difference is not statistically significant. After 72 months SRM and Bund both recorded 70.8% survival.

Height

Periodic height data are summarized in Table 5. Mean height ranges from 51 to 75 cm in different treatments at twelve months. Maximum mean height was on DRM (69.8 cm) followed by Bund (65.9 cm) and minimum in SRM (52.5 cm). In the next twelve months maximum mean percent increment was attained by SRM (23.4%) followed by Bund (14.7%) and DRM (13.6%) but still SRM bushes were 22.3 & 16.7% shorter than DRM and Bund. In 24-36 month growth period only SRM bushes registered 3.32% growth, however, DRM and Bund bushes were still taller indicating that under given experimental conditions this may be the maximum height.

Table 5: **Periodic growth (cm) of *A. amnicola* (Mean ± SE) with different treatments**

	Height			Crown diameter		
Treatments	**12***	**24**	**36**	**12 ***	**24**	**36**
T_1	65.0 (5.08)	79.3 (2.13)	76.8 (2.94)	69.4 (4.14)	107.1 (3.44)	118.0 (4.04)
T_2	51.0 (5.02)	64.7 (2.96)	72.1 (3.30)	59.1 (7.08)	84.8 (11.75)	103.9 (5.22)
T_3	71 (6.88)	78.2 (4.17)	68.9 (4.59)	80.4 (3.81)	107.3 (9.32)	110.7 (2.15)
Mean G_0	**62.2**	**72.4**	**72.6**	**69.6**	**99.7**	**110.9**
T_4	75.0 (1.86)	79.2 (3.66)	76.4 (0.86)	79.9 (3.31)	113.8 (3.16)	116.4 (6.35)
T_5	54.0 (1.99)	64.8 (2.24)	61.9 (1.16)	64.9 (4.10)	89.7 (.63)	96.9 (2.06)
T_6	61.0 (4.61)	75.6 (2.32)	71.1 (3.57)	72.5 (1.23)	110.6 (9.47)	109.2 (1.96)
Mean G_1	**63.3**	**74.6**	**69.8**	**72.54**	**104.7**	**107.5**
Mean St	S_1- 69.8 S_2- 52.5 S_3- 65.9	S_1- 79.3 S_2- 64.8 S_3- 75.6	S_1- 76.6 S_2- 67.0 S_3- 70.0	S_1- 74.7 S_2- 62.0 S_3- 76.4.9	S_1- 110.4 S_2- 87.2 S_3- 108.9	S_1- 117.2 S_2- 100.4 S_3- 109.9
CD at 5% for St	**10.04**	**9.30**	**6.68**	9.4	16.3	8.8

*** age in months**

Crown diameter

Bushes attained 62.0 to 76.4 cm mean crown diameter after 12 months maximum on Bund and minimum on SRM (Table 5). In next twelve months bushes attained 47.8, 42.5 and 25.2% increment for DRM (110.4 cm), Bund (108.9 cm) and SRM (87.2 cm) treatments. During 24-36 months growth increment was 15.2% (Bund), 6.2% (DRM) and 0.9% for Bund. Except for Bund bushes which registered 7.1% increase, crown diameter in other two treatments registered slight decrease indicating that this may be the maximum crown diameter.

The two factor ANOVA analysis showed that gypsum application was not influencing the height and crown diameter at any stage of growth but effect of soil structures was significant (p-0.01-0.05 and 0.01-0.02) up to 48 month of age. CD values showed that in case of height DRM and Bund attained significantly higher height than SRM till 24 months after which only DRM was significantly higher. Crown diameter values of DRM and bund were significantly higher than SRM till 36 months after which difference was significant between bund and SRM bushes. Height and crown diameter difference was not significant for DRM and bund during entire study period.

Biomass yield

Component wise details of green and dry biomass of different treatment are summarized in Table 6.

Leaf yield

Maximum mean leaf yield was recorded on bund structure (0.72 and 0.25 kg shrub^{-1}) 24 & 44% and 31.5 & 44% more than for green and dry yield for DRM and SRM. However the difference was significant for only dry yield (p-0.03). Mean yield for gypsum treated bushes is 16.7% more than control but the difference is not statistically significant.

Branch yield

Branch yield (green and dry) was in same in DRM (1.34 and 0.84 kg bush^{-1}) and Bund (1.33 and 0.81 kg bush^{-1}) and significantly higher (p- 0.01) compared to SRM (0.61 and 0.38 kg bush^{-1}). Effect of gypsum application was insignificant as branch yield was nearly same for control and gypsum treated bushes. Contribution of branch component was more for control (5.7%) but the difference is not statistically significant.

Total yield

Total biomass yield (green and dry) was maximum on Bund (2.05 and 1.06 kg bush^{-1}) followed by DRM (1.92 and 1.03 kg bush^{-1}) and SRM (1.11 and 0.55 kg bush^{-1}). Structures very significantly (p-0.00) influenced the total yield but it was due to higher yield on Bund and DRM compared to SRM. The difference of Bund and DRM was not significant. Effect of gypsum application was significant for dry total yield (p-0.05) as gypsum treated bushes recorded 6% more dry biomass.

Table 6: **Component wise biomass yield (kg bush-1) of *A. amnicola* (Mean ± SE) with different treatments at 36 months**

	Green			Dry		
Treatments	**Leaf**	**Branch**	**Total**	**Leaf**	**Branch**	**Total**
DRM+ G_0	0.55 (0.10)	1.39 (0.43)	1.94	0.19 (0.03)	0.88 (0.27)	1.07
SRM + G_0	0.38 (0.07)	0.51 (0.05)	0.89	0.16 (0.03)	0.32 (0.03)	0.48
Bund + G_0	0.69 (0.10)	1.34 (0.18)	2.03	0.23 (0.03)	0.82 (0.11)	1.05
Mean G_0	**0.54**	**1.08**	**1.62**	**0.19**	**0.67**	**0.86**
DRM+ G_1	0.60 (0.04)	1.30 (0.23)	1.90	0.22 (0.01)	0.79 (0.14)	1.01
SRM + G_1	0.63 (0.06)	0.71 (0.07)	1.34	0.20 (0.02)	0.44 (0.04)	0.64
Bund + G_1	0.74 (0.10)	1.32 (0.17)	2.06	0.28 (0.03)	0.81 (0.10)	1.09
Mean G_1	**0.65**	**1.11**	**1.76**	**0.23**	**0.68**	**0.91**
Mean ST	S_1-0.58 S_2- 0.50 S_3- 0.72	S_1-1.34 S_2- 0.61 S_3- 1.33	S_1-1.92 S_2-1.11 S_3- 2.05	S_1-0.19 S_2- 0.17 S_{3-}0.25	S_1-0.84 S_2- 0.38 S_{3-}0.81	S_1-1.03 S_2- 0.55 S_{3-}1.06
CD at 5% for st	0.18	0.49	0.42	0.61	0.30	0.18

A. stocksii

Survival and Plant Growth

Periodic annual survival and growth values for *A. stocksii* are summarized in Table 7. It registered very high mean survival on DRM (87.5%) and CDM (95.8%), respectively, as compared to control (21.0% only), after 12 months of establishment. In the next two years, survival was maintained on DRM (87.5%) but it declined on CDM (50%). Structures continued to influence the survival and after 72 months, *A. stocksii* maintained the percent survival as 75% on DRM, 41.7% on CDM and 12.5% on control indicating DRM was best structure.

Table 7: **Periodic percent survival and growth of *A. stocksii* on various soil structures**

Species	*DRM*			*CDM*			*Control*		
	12*	24	36	12	24	36	12	24	36
% survival	87.5	87.5	87.5	95.8	50.0	50.0	21.0	21.0	21.0
Height (cm)	41.8	36.5	45.7	37.8	34.0	47.3	34.2	31.7	40.8
Crown diameter (cm)	89.3	76.8	89.6	83.9	81.5	91.0	52.5	41.0	68.0

** age in months*

Growth

A. stocksii attained significantly higher mean crown diameter (75.2 cm) as compared to height (38.0 cm) within 12 months of growth (Table 7). During next 12 months the height and crown decreased on all the treatments due to complete monsoon failure, At 36 months of age in a good monsoon year *A. stocksii* recorded growth increment on all the three treatments for 24-36 month growth period.

Biomass yield

Two factor ANOVA showed that choice of species and soil structures significantly influenced the green and dry biomass yield (Table 8).

Leaf yield

Both the soil structures significantly (p- 0.00) enhanced the yield but they were not different with each other. Structure wise DRM recorded maximum green and dry leaf yield (1366.7 and

381.0 g) followed by CDM (956.8 and 290.0 g) and control (475.0 and 121.0 g).

Branch yield

Soil structure enhanced branch growth also recording significantly higher branch yield (p-0.00) compared to control. DRM recorded maximum branch yield (991.7 & 631.0 g) which is 3.8 to 5.7 times more than control (263.3 & 110.0 g). While CDM (591.7 & 361.0 g) recorded 2.2 and 3.2 times more branch yield. In case of branch also *A. stocksii* has less percent moisture on soil structures.

Table 4: **Component wise Green and Dry Biomass (mean ± SE) yield g bush^{-1}**

Green				Dry			
DRM	CDM	Control	Mean	DRM	CDM	Control	Mean
Leaves							
1366.7 (223.8)	956.7 (411.6)	475.0 (95.7)	**932.8**	381.0 (62.4)	290.0 (124.6)	121.0 (24.3)	**264.0**
Branches							
991.7 (197.0)	591.7 (216.7)	263.3 (83.9)	**615.6**	631.4 (125.4)	361.0 (132.4)	110.0 (34.9)	**368.3**
Total biomass							
2358.3 (401.1)	1548.3 (623.1)	738.3 (178.9)	**1548.3**	1012.5 (180.0)	650.9 (254.5)	231.0 (180.0)	**631.3**

Total yield

Overall DRM produced maximum green and dry biomass. Species wise DRM accumulate maximum green biomass for *A. stocksii* which was 1.5 and 3.0 times more than CDM and control. Total dry biomass on all the three structures was, 1.13 tha^{-1} on DRM, 0.72 tha^{-1} on CDM and 0.26 tha^{-1} on control for *A. stocksii* .

PHENOLOGICAL OBSERVATIONS

A. lentiformis and *A. amnicola* flowered within a year in the month of October, seed setting and maturing took place (December-February). *A. amnicola* is dioecious, have separate male and female shrubs. Number of seeds (with seed coat) per gram for *A. lentiformis* and *A. amnicola* were 563 and 230, respectively. Seeds were viable, producing healthy seedlings, however, no natural germination was observed.

A. stocksii flowered in September (two months after establishment), seed matured by December. Number of seeds (with seed coat) per gram were 262. It shed leaves in summer months (March onwards) and become dormant becoming active again after receiving rain in monsoon. In a study Agha et al. (2009) reported that after rains seed germinate and survivor ship is high. Dormant plants become active and produce vegetative part immediately, flower and fruits after about 30 days and seeds after sixty days and become dormant again under natural conditions in coastal marsh along Arabian Sea coast. Natural germination for *A. stocksii* was observed through seed after one year. It was also propagating through root suckers around soil structures and is maturing into new bushes, presence of extensive rhizome system is also reported by Agha et al. (2009).

CONCLUSIONS

The research trials conducted by AFRI, Jodhpur showed that *A. lentiformis* has the potential to produce nitrogen rich fodder from highly degraded arid salt affected soils. High ash content (~40%) requires its mixing with cereal residues. Plant growth was also significantly higher on soil structures as compared to control for all the three plant species. DRM planting practice attained highest growth and biomass production for plant species under drought and salt stress conditions. However, root development was in two directions along the ridges. It was very closely followed by CDM practice. *A. lentiformis* produced maximum 3.9 tha^{-1} green biomass on CDM which is more than 2.6 tha^{-1} biomass was produced in normal plant pit planted *A. lentiformis* with gypsum, FYM, ZnSO4 Urea and Drainage at Kaparda, Jodhpur (Arya et al, 1998). However it is short lived as compared to *A.amnicola* which maintained appreciably high survival of 66.6 to 75% after 72 months on different structures facing periodic monsoon failure *A. stocksii* it has 58% survival on CDM compared to 75% on DRM for *A. stocksii* at 72 months. Growth of native vegetation in successive years indicates that bushes did not suppress the growth of indigenous flora. Thus both *A. stocksii* and *A. lentiformis* can be successfully included in the afforestation programmes for salt affected soils. It can be concluded that by adopting these mounding practices water logged salt affected areas can be successfully rehabilitated.

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Traditional Wisdom and Value Addition Prospects of Arid Food for Biodiversity Conservation in Thar Desert of Rajasthan

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INTRODUCTION

Drought is a climatic anomaly, characterized by deficient supply of moisture resulting either from sub-normal rainfall, erratic rainfall distribution, higher water need or a combination of all the factors. The escalating impacts of droughts have increasingly drawn the attention of scientists, planners and society. The vulnerability to drought in relation to the increasing needs of the growing population has become a point of great concern, especially on the food front. In Arid Rajasthan droughts and famines have been the most serious natural calamity since the time immemorial. There is a famous Rajasthani couplet which depicts that feet of famine remain in Pungal (a place in Bikaner), head in Koteda (Marwar) and belly in Bikaner. And sometimes, famine can be found in Jodhpur but Jaisalmer is its permanent residence (Bharara,1999). The inhabitants of arid Rajasthan expect one lean year in every three and one famine year in every eight years but on the other hand experience of generations has taught them well how to survive under these harsh climatic conditions. The inhabitants use a wide variety of plants and plants products as famine food with their own traditional wisdom and with less effort for value addition. Some of the important arid food plants and their value added products are discussed in this paper.

RESULTS AND DISCUSSIONS

As stated earlier, the impact of drought results in shortage of food, fodder and water, or in discrepancies between supply and demand for food, fodder and water. Therefore, under such harsh conditions, the inhabitants of arid Rajasthan, partially or fully, depend on natural vegetation for their food during prolonged droughts and famines. They collect fruits, seeds, leafy material and roots of the native plants for consumption. Experience of generations has taught them well how to survive under the harsh desert environment. Some of these native famine food plants are mentioned as:

Acacia senegal (Kumta): It is a small thorny, deciduous tree with yellowish white bark and feathery crown. It is also widely distributed throughout the arid zone. The tree is extremely hardy and drought resistant. The seeds are dried and preserved for human consumption as a vegetable (Sen and Bansal, 1979; Nat. Acad. Sci., 1980; Teel, 1985). In Rajasthan dry seeds are main component of panchkuta. In normal rainfall years, the production of seeds is 2-5 kg per tree. The fresh seeds are sold at a rate of Rs. 30 per Kg while dry seeds are sold at a rate of Rs. 60 to 80 per Kg.

Aloe vera (Mill): The word 'aloe' has its roots in the Arabic word 'alloeh', which means 'radiance'. It is a stem less or very short-stemmed succulent plant growing to 80-100 cm tall, spreading by offsets and root sprouts. The leaves are lanceolate, thick and fleshy, green to gray-green, with a serrated margin. The flowers are produced on a spike up to 90 cm tall, each flower pendulous, with a yellow tubular corolla 2-3 cm long. Its thick leaves contain the water supply for the plant to survive long periods of drought. These leaves have a high capacity of retaining the water. When a leaf is cut, a orange yellow sap drips from the open end which has a very strong laxative effect. When the green skin of a leaf is removed a clear mucilaginous substance appears that contains fibers, water and the ingredients to retain the water in the leaf. These ingredients give this "gel" its special qualities as they are known now for many centuries. Among the uses for this gel is acceleration of wound healing, use on skin burns, moisturizing dry skin and it is taken internally for peptic ulcers or gastritis. Besides medicinal properties, the flowers are boiled and cooked as vegetables.

Balanites aegyptiaca (Hingota): It is a slow growing small not very spreading spiny medium size tree or shrub, distributing in open sandy plains of Jodhpur, Pali, Sirohi, Abu Road. Flowering occurs from Dec-Mar; fruiting takes place from Mar-Jul. A mature tree yields 100 to 150 fruits. Ripe fruits eaten raw/sundried and stored like dates, made into sweetmeats or fruit juice (mixed with water) and mixed with cereals, or fermented to alcoholic beverages. Young shoots and leaves are used as vegetable, added to soups, melon seeds/peanut pastes and used as a relish (Tripathi et al., 2008).

Brachiaria racemosa (Murat): Seeds mixed with *bajra* (millet) to increase bulk; or mixed with other grains. It is noted that chapattis prepared from its flour should be consumed with buttermilk, otherwise it causes acute constipation (Joshi,1995).

Calligonum polygonoides (Phog): Locally called *'Phog'*,

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is an abundantly growing plant species on the sand dunes. The flower buds of this plant, locally called as *'Phugusi',* are cooked in fresh form and also dried in sunlight for its later use (Goyal and Sharma, 2009).

Capparis decidua (Kair): Locally called *'Kair',* is an important perennial shrub, leafless, much branched and evergreen plant used as vegetable frequently, distributed widely throughout the arid zone. It is an important famine food. The unripe green fruits are collected by women and children as a supplementary activity while grazing animals and are used as vegetable after processing. These are also sun-dried and used as vegetable along with seed of Kumat (*Acacia senegal*) and Sangri (pods of *Prosopis cineraria* i.e. Khejri). Each tree produces almost 2-3 kg green kair. Fruiting takes twice in a year but maximum fruiting occurs in March-April. The shrub is not commercially cultivated but grows naturally. Fruits are sold at the rate of Rs. 250-300 per kg. The trees flourish well during drought period (Tripathi et al, 2008).

***Cenchrus setigerus* (Anjan)**: This grass species grows on alluvial flats of Western Rajasthan and is locally called Anjan. It is a tall, thick stemmed, erect and drought hardy perennial. Its leaves are broad, long and droopy and remain green up to maturity. It has a wide adaptability, high tillering ability and is good in regeneration. It possesses a stout root/rhizome system. It gives 2 to 3 cuttings per year. It yields 70 quintals of green fodder and 30 quintals of dry matter per hectare under desert conditions. It has 8% protein and about 60% digestibility. It produces 1 to 1.5 quintal/ha seed even after one cutting of fodder. It is persistent and aggressive variety for rangelands and remains productive for four to five years under proper management systems. It is sown at the onset of the monsoon with the seed rate of 5 to 6 kg/ha (Anon. 1988). Its seeds are either eaten raw or mixed with bajra for making chapatti during drought(Joshi,1995).

C. ciliaris (Dhaman)*:* Locally called Dhaman, is a very common grass species growing on alluvial flats of Western Rajasthan. 'Marwar Dhaman' is excellent for grazing purpose due to its thin stem and leafy foliage. It is a drought hardy perennial grass which contains 9.5% crude protein and has 65% digestibility at half bloom stage. Its pasture remains productive for 4 to 5 years. It is moderately resistant to major insect pests. (Anon. 1988). Its seeds are either eaten raw or mixed with bajra for making chapatti during drought (Singh and Pandey, 1998).

Citrullus lanatus (Mateera)*:* Fruit pulp sweet and refreshing. During summer, 250-400 gm of fruit pulp eaten each time cools the body and quenches the thrust (Kumar et al., 2008). Immature tender green fruits are boiled and used with curd as raita and vegetable. The seeds are rich in protein (25-32%) and yield very nutritive oil (30-40%). Seed kernels extracted are used in preparation of sweets, beverages, snacks, bakery and ice creams (Goyal and Sharma, 2009).

***Cordia dichotoma* (*Gunda*)**: A small to moderate-sized deciduous tree with a short bole and spreading dense crown, widely distributed in arid zone, mostly cultivated**.** Tender green immature fruits are harvested for vegetable and making pickle. Ripe fruits are also eaten by children. The fruit production is 50-80 kg fruits/ tree (Tripathi et al., 2008)

Cucumis melo Var. Linn. Momordica Duthie and Fuller: –Unripe fruits of snap melon or Phoot Kakri are used to prepare curd based preparation and vegetables. Ripe fruits are used as salad and dessert and preserved in the form of jam. Milk shake of snap melon is served as refreshing drink. Unripe fruits are dehydrated for off-season use. Seed kernels are extracted extensively and after removing seed coat they are used in sweets, bakery and traditional drinks (Thandai).The mature fruits generally exert a cooling effect.

Cucumis callosus (Kachra/Kachri): The mature fruits of kachri, a drought resistant cucurbitaceous vegetable found growing abundantly in rainy season in Rajasthan are usually cooked with various vegetable preparations. It is one of the components of the delicious vegetable "panchkuta". Fruits are dried, grounded and mixed with other species to make spice premixes and mouth fresheners (Goyal and Sharma, 2009). One teaspoonful of seeds has cooling action especially in bilious disorders (Kumar et al., 2008).

Cyperus rotundus (Motha): The roots are recommended as famine food and can be eaten raw or cooked or dried and grounded to a flour. The tubers are roasted; also boiled, outer skin peeled off, and the starchy rhizome is eaten with spices (Kumar et al., 2008).

Dactyloctenium aegyptium (Makra): The rugose seed grains are eaten . They are generally cooked into a thick porridge or the husked seeds are boiled in water to a thick mush. Mixed with semi-ground *Phaseolus aconitifolius*, the grains are prepared into a dish called *Keech*, which is much relished. Bhil, one of the tribal communities of Rajasthan mix it with B*ajra* (millet), and other grains for bread-making (Joshi,1995).

Grewia tenax (Forsk.): Handful of fruits being eaten by villagers to quench the thirst during summer season.

Lasiurus sindicus (Sewan): Collected seeds are used with bajra grain as a suitable mixture.

Leptadenia pyrotechnica (Khimp): It is a much branched often leafless erect shrub distributed throughout the arid zone viz. Jodhpur, Bikaner, Jaisalmer. Tender fruit is edible (Farooq, 2007, Goyal and Sharma, 2009).

Portulaca oleracea (Luni): Fresh leaf juice is an effective thirst quencher, stem juice is applied externally to remove prickly heat.

Prosopis cineraria (Khejri): Locally called 'Kalpa Vriksha' or 'Life line of the Desert' is an excellent survivor of Thar desert and widely distributed throughout the arid zone. Camels, cows, goats and other animals browse it. Flowering and fruiting occurs during the months of March to May. The pods, locally known as 'Sangari', are used as fodder for livestock before they ripen; The pods are eaten green or dried after boiling and serve as green and dry vegetable. The preservation capacity of these pods is very high. It is one of the constituents of famous dry curry 'Panchkuta' – a mixture of five fruits and seeds (e.g. *Acacia senegal, Capparis decidua, Cordia myxa, Cucumis melo* and *Prosopis cineraria*) - prepared in Marwar. The wet curry of these pods with bajra or gram flour is famous. In normal rainfall, 5 kg of air dried pods are obtained from a 30-50 year old tree and 2-3 kg pods from a 20-30 year-old unlopped tree (Muthana, 1980). The market price of dry Sangari is Rs. 200-240/kg. A lot of local proverbs, couplets and literature are available to prove the importance of these pods. After ripening these pods become sweetish and the pulp is sweeter with pale brown colour. These pods then known as Khoka are considered as Marwari Mewa i. e. dry fruits of arid zone. These are even fed to milch animals for increasing milk production. The dry pods reduce the quest for water in summer months and generally farmers eat it in dry periods. The bark of this tree was eaten during the severe famines of 1899 and 1939. The bark was stripped off, dried, and ground with any available coarse grain. Bread is reported made from the ground bark with or without the addition of other flour.

***Salvadora oleoides* (*Meetha Jaal*):** It is an evergreen, a large shrub or small tree with short twisted trunk and drooping branches growing in habitats having medium to fine textured soil. It forms a dominant part of vegetation of Barmer, Jodhpur, Jaisalmer, Bikaner,Churu, Nagaur and Jalore. The fruit of this plant locally called 'Pilu' is edible and liked very much by the local inhabitants**.** Fruiting occurs during May-Jun. Yield- 10-15 Kg fresh fruits per tree. The tree flourishes well during the drought period (Tripathi et al., 2008).

***Trianthema portulacastrum* (*Linn*):** Juice of young roots gives a cooling effect.

Ziziphus spp.: Small evergreen, much branched tree or often a large bushy shrub distributed throughout the arid zone. Edible parts are fruits and seed cotyledons. A mature tree yields 50-80 kg fruits/ tree. Ripe fruits are gathered in beginning of winter months, dried, ground and sieved. The powered form is eaten alone or mixed with jaggary or flour.

The various species and their value addition prospects can be summarized in the table as under:

S.N.	Name of species	Family	Local Name	Plant parts used	Value Addition
1	**Acacia Senegal *(L.) willd.***	Mimosaceae	Kumta	Seeds, Gum	Dried boiled seeds as important constituent of Panchkuta, green seeds as vegetable.
2	A. **tortilis**	Mimosaceae	Israeli Baul	Gum	Pods boiled and cooked as vegetable.
3	**Aloe vera *Mill.***	Liliaceae	Guar-patha	Leaves	Florescence boiled and cooked as vegetable.
4	*Balanites aegyptiaca* (Forsk.)	Balanitaceae	Hingota	Fruits	Ripe fruits eaten raw/sundried and stored like dates.
5	**Brachiaria ramosa *Linn.***	Poaceae	Kuri, Murot	Seed grain	Grains are used to prepare 'Kheech', a very delicious preparation in rural Rajasthan.
6	*Calligonum polygonoides* Linn.	Polygonaceae	Phog	Flower	Aborted buds boiled and used in Raita.
7	*Capparis deciduas* (Forsk.) Edgew	Capparidaceae	Kair	Fruits	One of the constituents of Panchkuta vegetable, pickle.
8	Cenchrus setigerus (Vahl.*)* & *C. ciliaris* Linn.	Poaceae	Dhaman	Seeds	Seeds, ground and used as food.
9	**Citrullus lanatus *(Thunb)***	Cucurbitaceae	Matiro	Fruit, seed	Ripe fruits edible and unripe fruit as Raita,
10	**Cordia dichotoma *var. wallichii (Cl.)***	Ehretiaceae	Lassora, Chokargond	Fruits	Fruits as pickle and vegetables and eaten raw when turns yellow.
11	**Cordia gharaf *(Forsk.)***	Ehretiaceae	Gondi	Fruits	Vegetable
12	**Cucumis melo *Linn. Momordica Duthie and Fuller***	Cucurbitaceae	Snap Melon	Ripe fruits	As vegetable.
13	**Cyperus rotundus *(Linn.)***	Cyperaceae	Motha	Root tubers	Root-tubers are used as food in scarcity.
14	**Dactyloctenium aegypticum *(Linn.)***	Poaceae	Makra, Manchi	Seeds	Seed (mixed with moth to prepare Kheech.
15	**Ephendra foliate *Boiss.***	Gnetaceae	Lana, Andho-khimp	Fruits	Fruits are eaten in time of scarcity.
16	*Euphorbia caducifolia* Haines.	Euphorbiaceae	Thor	Leaves	Leaves boiled and eaten as vegetable
17	**Grewia tenax *(Forsk.)***	Tiliaceae	Gangerun	Fruits	Edible
18	**Haloxylon recurvum *(Moq)***	Chenopodiaceae	Sajji	Ash	Ash in Bikaneri bhujia
19	**Lasiurus sindicus *(Forsk.)***	Poaceae	Sevan	Seeds	Seed are ground, mixed with bajra flour to make roti.

20	*Leptadenia pyrotechnica* (Forsk.)	Asclepiadaceae	Kheep	Tender fruits	Tender fruits as Raita and vegetable.
21	**Portulaca oleracea *(Linn.)***	Portulacaceae	Kulpha, luni	Tender shoots	The tender shoots cooked as vegetable.
22	*Prosopis cineraria* (L.) Druce.	Mimosaceae	Khejri	Pods	Green and boiled dried pods as vegetables and pickles.
23	**Prosopis juliflora *(Sw.) DC***	Mimosaceae	Vilayati Babul	Gum exudation, seed powder	Mixed with flour for préparations of snacks.
24	*Rhus mysurensis* Heyne ex Wt.& Arn.	Anacardiaceae	Dansara, Dasni	Fruits	Ripe fruits edible.
25	**Salvadora oleoides *Decne.***	Salvadoraceae	Meetha Jaal	Fruits	Eaten raw or in preparation of Squash.
26	**Salvadora persica *Linn.***	Salvadoraceae	Chhotapilu, Kharajal	Fruits	Fruits pungent but edible.
27	**Solanum nigrum *Linn.***	Solanaceae	Makoi	Leaves and tender shoots	Leaves and tender shoots eaten as vegetable.
28	**Trianthema portulacastrum *(Linn)***	Aizoaceae	Satta, Hato	Tender twigs	Tender twigs as vegetable.
29	*Z. glaberrima* Santapau.	Rhamnaceae	Ghatbor	Fruits	Dried fruits are also eaten.
30	*Z. mauritiana* Lamk.	Rhamnaceae	Ber	Fruits	Fully ripe fruits dried, grounded and sieved, mixed with gur or bajra flour. Squash, Jam, Candy and honey from flower nectar. Cotyledons fried and eaten separately.
31	*Ziziphus nummularia* (Burm. f.)	Rhamnaceae	Jharber	Fruits	Fruits edible.

It is established that sustainable harvesting of alternative forest foods is not only essential for conservation of the biodiversity in Thar desert, but also for the livelihoods of many rural peoples. Data reveals that the rural people of Western Rajasthan found various forest products as the only alternative subsistence against agricultural operations during drought periods, e.g. local people collect fresh seeds of Kumathia (*Acacia Senegal*), fruits of Ber (*Zizyphus mauritiana*) and Jal (*S. Oleoides*) and sell them at 25 kg, Rs. 10 and Rs. 4 kg, respectively. The potential of some of the species flourishing well in droughts such as Khejri (*P. Cineraria*), Kumat (*A. Senegal*), Jaal (*Salvadora oleoides*), Phog(*Calligonum polygnoides*), Gunda (*Chordia dichotoma*), Hingota (*Balanites aegyptica*), etc., holds an important place as famine food. Pods of Khejri (*Sangari*), fruits of Kair and dried-boiled seeds of Kumat are the chief constituent of Panchkuta, a famous marwari vegetable. If properly managed, these products can support the families and provide commodities to run household/ cottage industries. It also has potential to generate employment during the lean period as it affects the rural livelihood directly. Therefore, the products used as alternative forest foods with proper value addition are required to be managed scientifically to get sustained yield in perpetuity.

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Reconciling Growth with Conservation towards Sustainable Development

Ashok K. Saxena *

1. INTRODUCTION

The impact of natural resource scarcity on economic growth has often been debated in the context of developed nations (Hotelling 1931, Meadows et al 1972, Dasgupta and Heal, 1979, Houthakker, 1983, Baumol 1986, Bower 1987, Cleveland 1991). In recent years the issue of resource scarcity has received renewed importance to the economic and environmental planning of developing nations (Meadows et al. 1992, World Bank 1993, Hyde et al. 1996). There are three prominent views in this debate: Classical, Neoclassical, and Biophysical.

The classical economists such as Marshall, and Ricardo, argued that fixity in the supply of arable land and a declining land quality when combined with the expansion in production will eventually constrain economic growth. In their view, natural resource scarcity will ultimately negatively impact economic growth.

Many neoclassical economists (Dasgupta and Heal 1979, Houthakker 1983, Baumol 1986, Bower 1987) however, challenged the classical paradigm and suggested that the means of escaping from increasing scarcity lies in the market mechanism. According to this view natural resource scarcity will sow the seeds of its own amelioration, since the scarcity of resources will eventually trigger a price increase which, in turn, reduces demand and stimulates a host of resource augmenting processes. These include substitution of alternative resources, increased efficiency in use of resources, increased exploration for new reserves, recycling, and technical innovations in resource exploration, extraction, processing, and transformation. To be précis, the neoclassical school argues for the efficacy of market mechanisms in ameliorating scarcity. If the resource markets are working according to the precepts of the neoclassical school, then resources are being allocated efficiently over time, and no policy intervention is required. For example, in a perfect market the scarcity caused by deforestation would result in appropriate price signals that would in turn bring about investments in the forestry and other sectors (Hyde et al. 1996) and a reduction in the demand for forest products. These would result in increased production from forests and a new economic equilibrium where the supply and demand from forests would balance each other.

The biophysical analysts view the relation between resource scarcity and its process of amelioration differently. These scholars argue that basic physical and ecological laws constrain our economic choices and are not correctly reflected in the economic models and market price signals (Ayres and Nair 1984, Cleveland et al 1984, Hall and Hall 1984, Daly and Cobb 1989, Cleveland 1991). These authors, therefore, advocate strong policy initiatives to ameliorate resource scarcity. The biophysical analysts emphasize that there are massive, yet unmeasured, throughput transfers from the environment to the economy; that is, massive quantities of natural resources are poured into the resource-harvesting process, substituting in an unmeasured way for reductions in capital and labour use and these are not adequately accounted for in the traditional market mechanisms and economic measures (Cleveland 1991). In Indian context, for example, the forestry sector of the country is measured to contribute less than 2% of measured GNP (World Bank 1993). This is because much forest produce does not go through markets (Dwivedi, 1994). Further, this figure does not take into account the numerous non-market benefits (oils, medicinal plants, silk, resins, dyes, fibers, and leaves) or the vast amounts of fuelwood, fodder, and industrial timber removed for personal use and trade that are not traded through markets. It also ignores hordes of intangible and environmental service benefits of forests not only to India but also to the rest of the world (Woodwell 1992, World Bank 1993).

Besides the absence of markets, there are situations where markets fail, especially in forestry. First, the well known existence of externality occurs in the forest process (Bojo et al. 1990, Rowe et al. 1992, Woodwell 1992,). For example, deforestation depletes forest stock, which in turn impairs the watershed functions of forests. However, this loss may not be recorded in the market system. Moreover, because of the externality cost associated with forest use, there is a divergence between the private and social costs of non-forest land uses and commercial timber harvesting, and the market fails to appropriately guide these decisions. Second, because forests produce several goods and services, the problem of valuing joint products and non-market environmental services further limits the efficacy of market solutions. Third, the conflict between the time horizon of people now living and the needs of future generations creates a bias in favour of exploiting forests now versus conserving for future. Finally, undefined, or poorly defined, and poorly implemented property rights creates open access to forests, and retards successful forestry investments. All of these failures weaken the operation of the market system (Rowe et al. 1992). Accordingly, in addition to market linkages, it is essential to understand the biophysical links that drive the deforestation process.

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This paper suggests that all three views- classical, neoclassical, and biophysical have their merits. Therefore, it is important to incorporate the linkages reflecting all the views in a system approach to any environmental problem such as deforestation. Since a system incorporates several linkages, these linkages may act as negative and positive feedbacks. Inherently, the arguments of the neoclassical writers focus on strong negative feedbacks. Increasing scarcity results in price escalation that ultimately results in decreasing scarcity. However, the success of the relationships between scarcity and the processes that may ameliorate the scarcity will depend on the strength and speed of the various responses. Accordingly, focusing exclusively on one set of linkages may lead to incorrect results and mislead the resource policy planners. Because the strength and speed of these relationships will vary from location to location, and from time to time, the merit of various solutions for ameliorating resource scarcity will vary accordingly. A system dynamics approach can capture these effects.

The case for a multifaceted approach is particularly prudent in developing economies where markets and market mechanisms in the forestry sector may not be well developed or widespread in their use and impacts. In developing countries, especially for those facing deforestation and forest biomass scarcity, either markets for forestry resources largely do not exist or if they exist, they are not fully developed. As a result, the market mechanisms may not be significantly useful in influencing the dynamics of the forest sector.

The paper presents a system framework that incorporates the linkages suggested by the economic perspective including the efficacy of market mechanisms, and those suggested by the biophysical perspective, highlighting the significance of extractive biophysical linkages. It then analyzes the role of the market in the amelioration of deforestation. Based on data for India the paper shows that the set of plausible relationships which the neoclassical school has assumed in the efficacy of the market mechanisms to ameliorate forest biomass scarcity are not effective in developing countries. There is urgent need to supplement the market process by strong policy initiatives if forests are to be conserved. The understanding of the biophysical linkages may help in determining the needed policy initiatives for amelioration of deforestation especially in developing countries

2. METHODOLOGY

A systems model is constructed wherein the forest sector interacts with four other sectors: the agriculture, livestock, socio-economic, and energy sectors that compete for forest land, or forest produce. The process of deforestation is modelled in terms of dynamic interrelationships within and among these sectors. Stella, a simulation language (see HPS 1994) is used for building the five sector model which is pictured in Figure 1.

The efficacy of market mechanisms in ameliorating deforestation is examined on two levels. First, the theoretical validity of price linkages in alleviating forest biomass scarcity is examined particularly in the context of developing nations. Second, the price linkages are modelled and the two systems profiles are compared: the profile illustrating only the biophysical linkages, and the profile incorporating both the biophysical and price linkages in the system. The first level of examination offers an opportunity to analyze if markets are functioning in the forestry sector of developing countries in general, and in India in particular. The second level of analysis will assist in discerning the impacts of market mechanisms on the dynamic profiles of key forestry stocks and hence, their effectiveness in preventing increasing scarcity of forest resources.

3. EXAMINING THE ROLE OF PRICE

The role of price in arresting deforestation is examined in two steps. In the first step, various linkages in the suggested relationships between scarcity and price signal responses are introduced as negative feedback relationships. Further, their relevance to a developing country in general and to India in

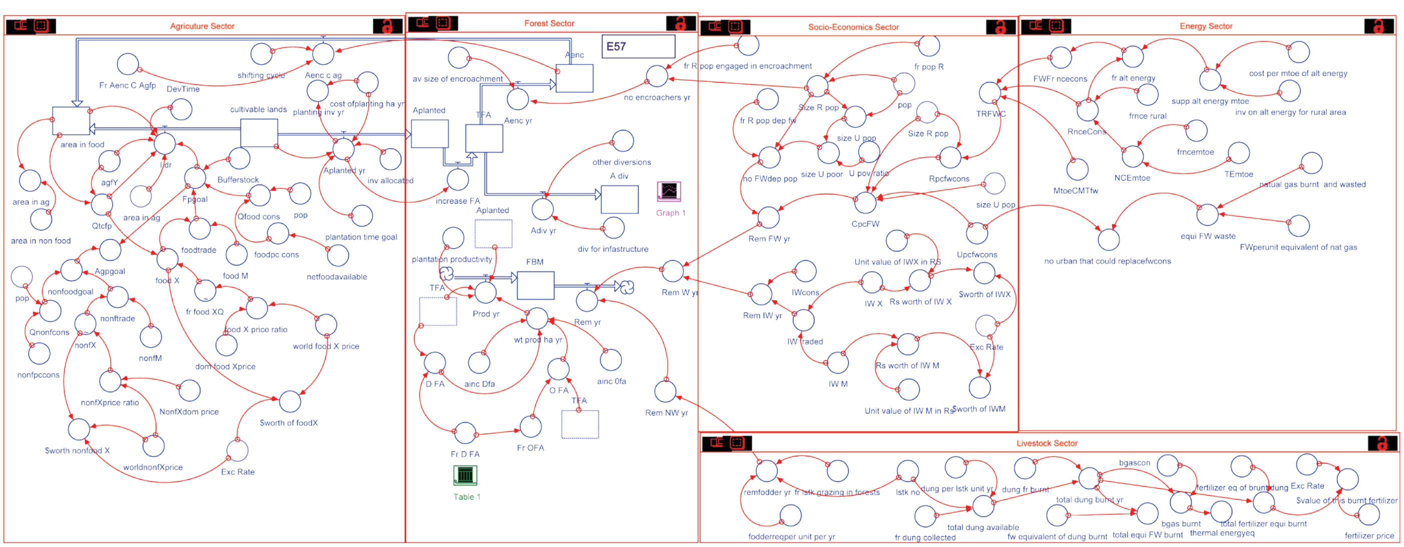

Figure 1: **A Five Sector Model of Deforestation**

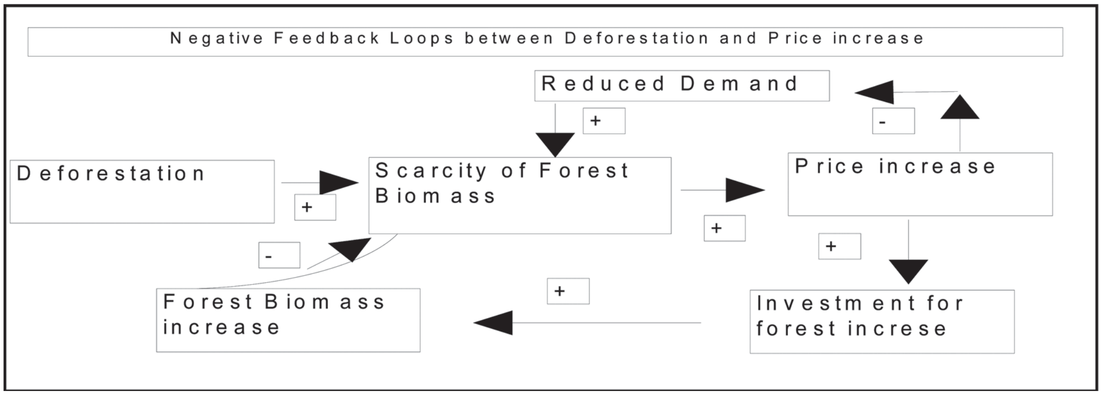

Figure 2: **Illustration of a Negative Feedback Loops between Scarcity and Price**

particular is evaluated. In the second step, the causative chain of connections between increasing prices and increasing removal representing the positive feedback relationships are discussed and introduced to represent the total effect of price increases on biomass scarcity. It is demonstrated that the outcome of the effect of price on deforestation will depend upon the speed and strength of the various responses that connect scarcity and price increases.

3.1 Negative Feedbacks

The relationship between forest biomass scarcity and the rise in prices seems to be clear. However, to make this relationship operational various assumptions must be made The various linkages assumed to make the relationship operational are represented in Figure 2.

As the process of deforestation progresses, it depletes forest biomass. The resulting scarcity is theoretically accompanied by the rise in price that decreases demand and attracts entrepreneurs to invest and to make profits from the rising prices. The increased investment flows eventually results in an increase in the production of forest biomass, and the scarcity of forest biomass is reduced. The reduction in scarcity abates further price increases. Thus, the relationships between deforestation and biomass scarcity, results in price increases, demand decreases, investment increases, and an increase in supply of forest biomass which acts to slow the original process of forest depletion. These relationships represent two negative feedback loops. On closer scrutiny, one observes that the operation of the negative feedback supply loop hinges on the operation of four linkages between these variables. The first is between deforestation and biomass scarcity, the second is between the forest biomass scarcity and price increases, the third is between price increases and increases in investment flow, and the fourth is between investment flow increases and the increase in biomass production. Unfortunately, all four of these linkages are almost non-operational in developing countries in general and in India in particular.

In addition to the supply response to the forest biomass scarcity, theoretically there is a demand response that suggests a reduction in the consumption of forest biomass due to increase in price of forest biomass. However, the demand response is weakened by the fact that much forest biomass removal is not traded though markets. In India, 90% of the forest biomass removed is for the fuel wood, but the removal is not recorded in the markets. The fuel wood is generally consumed by the poor people (Dwivedi, 1994). These people do not have income to purchase alternative forms of fuel but obtain fuel wood for free as a forest "right" or by illegally removing from the public forests. Fuelwood demand substitution is weak in a poor society and especially for the poor people, the fuelwood demand response seems to be inelastic to price response (Mercer and Soussan, 1992). It is observed that rising income rather prices are the predominant factor in fuelwood substitution (Barnes 1986). The substitution of fuelwood is further weakened by the non-availability of alternative fuels such as kerosene, especially in the rural areas, and the availability of fuelwood at no cost or at relatively low cost. Thus, the two main forces that drive the fuelwood substitution are access to dependable supplies of alternative fuels and income (Mercer and Soussan 1992). Unfortunately in most of the developing countries, and India in particular, both the forces are weak.

3.1.1 Linkage between Deforestation and Biomass Scarcity

In developing countries, particularly in the case of India, the positive relationship between the progression of the deforestation process and forest biomass scarcity is well established (World Bank 1993). However, it is possible to visualize a scenario where even when deforestation may be progressing the scarcity is not perceived or measured. There are four main reasons. First, the very nature of forests with a long gestation period results in a need for a very large inventory to produce the output on a regular basis. With a very large inventory, it is difficult to perceive scarcity when the inventory is being used up. For example, in Canada large forests areas have been logged but have not been fully planted (either by natural or artificial regeneration), and forest diversions (for infrastructure needs) have not been fully compensated. The deforestation problem is not perceived, primarily, because Canada has a very large inventory. In Canada, the average forest area per capita is very high (14.2 ha per person). Second, many forest goods and services may not enter markets, and so do not have observable prices. Therefore, the depletion of inventory is not recorded by the markets. In addition, although the inventory may be low, the market may not see the depletion of inventory because of government ownership and bureaucratic apathy. A significant percentage of unrecorded removals depress the price signals in a way that depletion of the inventory and the true physical scarcity are not reflected in the markets. For example, in India a significant percentage of fuelwood and fodder removals are unrecorded (about 80%). For example, in India the recorded fuelwood production is 40 million cubic meter, while the estimated consumption is 235 million cubic meter (Mukerji, 1994). The gap between production and consumption clearly highlights a significant percentage of unrecorded removals. Although inventory may be low, the goods may be physically scarce, but so far as the inventory exist and is being used up, goods may not turn into market scarce goods.

Finally, although forest biomass scarcity clearly exists, it is not perceived at a national scale because it does not hurt the people who make the decisions at the national level. India does not import fuelwood or fodder and hardly imports industrial wood. Rather, until the 1980s it exported more wood products than it imported (Government of India 1987). Scarcity is perceived at a local scale and mostly hurts the poor and the vulnerable groups of the society, especially women and children (Agrawal, 1986). These groups do not have purchasing power to influence the market, or sufficient time and institutions to challenge the decision making process at national or regional levels. Nor can they direct investment allocations to redress their pressing problems. Ironically, even if the planners know the problems being faced by the local population, the elite's influence, interests, and "wisdom" usually prevail. For example, investment allocations in the energy sectors in India do not address the energy problems of rural and urban poor people. Allocations are skewed in favour of the needs of tiny powerful sections of elite who are the politicians, bureaucrats, industrialists, and zamindars (Reddy and Prasad 1977). Consequently, there are both economic and political reasons that explain the weak linkages between deforestation and perception of FBM scarcity.

3.1.2 Linkage between Forest Biomass Scarcity and Price

The second linkage assumes that forest biomass scarcity is transmitted to the market; that is, the increased demand tends to push up the average forest biomass prices in forest biomass market. However, it is important to note that increased scarcity does not transmit instantaneously and automatically to the market. The delay in transmission may lead to the complete destruction of forestry resources in a locality. In that event, the forestry resources of neighboring locality are being used. And in many cases, there are increases in the resource prices, but in most of the cases the increases in prices reflect just the cost of transportation and not the cost of irreversible damages that might have occurred due to depletion. Further, it is the intervening element- "income spent", that translates physical scarcity into market scarcity, and in turn triggers the market mechanism. Unfortunately, in most of the developing world and, especially in India the poor people are primary consumers of forest biomass, and poor people do not have income. However, income is required to purchase goods from the market. In the absence of employment and income generation opportunities, it is much more economically efficient for the poor people to invest their own time and walk longer hours to gather fuelwood and fodder than to spend money on purchasing it. The poor people substitute their time, which they do have, for income, which they do not have. In economic parlance, this substitution of time for income occurs because the expected opportunity cost of time invested is less than the expected economic gain from fuelwood or fodder gathering. Under this scenario, the increased scarcity does not push up the prices; instead it translates into an increase of time investment in the collection of fuelwood and fodder. The increased scarcity therefore, increases the hardships faced by the poor. Their physical exhaustion further impoverishes them by reducing the time they might have for education, skill development, and the search for gainful employment. Thus, increased scarcity does not automatically translate into price increases, but rather into increased physical stress, further forest biomass depletion, and in turn, decreases in the opportunities for human development. As a result, many poor people find a lucrative job opportunity in illegally removing the forest biomass, especially fuelwood and industrial wood. A survey of 170 households in 9 villages in Bihar showed (fuelwood) head-loading served as a major source of income for a fifth of the households (World Bank, 1993). After satisfying their needs, they sell a fraction of the fuelwood to adjoining towns or cities at prices much below the cost of raising plantations, which continues to exacerbate forest biomass depletion and scarcity. Thus, the market in absence of appropriate management institutions and equitable socio-economic conditions, instead of providing a solution to the deforestation problem, is facilitating deforestation. Further this discussion points out a need to extend the linkage between scarcity and price. This could probably be done by providing gainful income generating opportunities so as to increase the opportunity cost of time while reinforcing it by severing the penalties associated with illegal removals of FBM.

3.1.3 Linkage between Price and Investment Flow

In a market economy, the price signals will direct the investment flow to maximize the allocative efficiency of investment. However, in most developing countries price signals do not respond to scarcity. And even if it is assumed that the price signal responds to scarcity, the investment flow to the afforestation activity does not correspond with the price increases; that is, the linkage between the price rise and investment flow may be weak or broken. This is especially true when the scarce resource is owned by the public sector and the hypothesized private sector responses are replaced by public institutions. The current allocation of investment by the planning commission and regional governments is neither related to the biomass scarcity nor to the price rises. The allocations may not be purely arbitrary; however, they are definitely not market driven.

Indeed, the strength of the linkage between the price rise and investment flow depends on the ownership pattern of a resource, and the time preferences of the resource owners. For example, about 90% of the forests are publicly owned in India, and the time preference of governments which are elected only for a short time period of five years is generally high. These governments give priority to investments with short gestation periods and emphasis on the short term economic achievements. Obviously, the public investment on forestry which itself has a long gestation period, do not attract much of public funds because of strong political reasons, and weak financial justification.

In India, forests do not seem to be important to financial planners, as the accounted financial contributions of forests to the financial flows are low. The forestry sector contributes less than 2% to the measured GNP. Public investment is low and is not related to forest biomass scarcity (World Bank, 1993). Investment for afforestation was 0.39% of the total public sector outlay in the

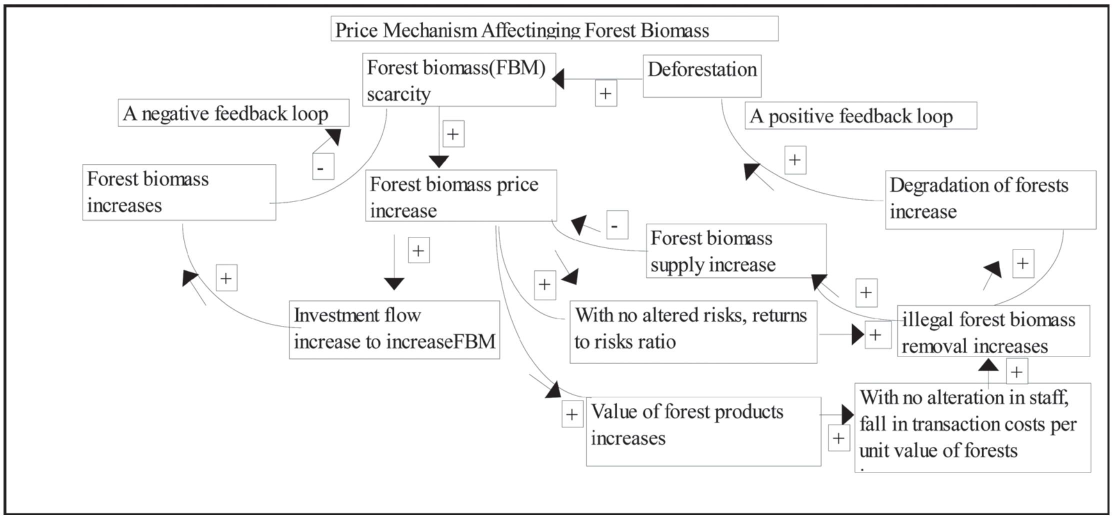

Figure 3: **Illustration of Negative and Positive Feedback Loops between Scarcity and Price**

First Five Year Plan. It varied from 0.46% to 63% of total public outlay during Second to Fifth Five Year plans. It rose to 0.71% in the Sixth, to a little over 1% in Seventh and dropped to 0.95% again in the Eighth Five Year plan (Dwivedi 1994). Outlays to forestry was less than 1% of the total public sector outlay during 1951-1995, although the price index of timber increased from 100 in 1970-71 to 2398 in 1992-93 (Saxena, 1994). In summary, the linkages between price rises and investment flows are weak in India. This is also true for other industrializing nations such as Bangladesh, Nepal, Pakistan, and Sri Lanka.

3.1.4 Linkage Between Investment Flow and Forest Biomass Flow

The assumption that increased investment flow will increase forest biomass flow seems to be working in industrializing countries only in a very restricted manner (World Bank, 1993, Chaturvedi, 1994). Perhaps because the linkage carries with it two more assumptions to make it work. The first assumption is that the investments are successful; that is, the afforestation activities result in successful plantations. The second assumption is that the plantations will survive until maturity to provide the increased forest biomass. However, it is observed that only 41% of the plantations are successful in India (Chaturvedi, 1994). The remainder either die because of natural plantation mortality (this includes transplantation shock, adverse soil and temperature conditions, and diseases) or are consumed because of heavy grazing pressures. Further, if they survive the first few years of establishment, they are prone to removal or damage by fuelwood collectors before maturity (World Bank, 1993). The gestation period between the investment flow and forest biomass outflow is long and is full of uncertainty. As a result there is no immediate increase in forest biomass, even after an increase in the investment flows in the forestry sector.

It is during the plantation maturation period that the positive feedback loops work speedily and forcefully, while the negative feedback loop remains dormant. Therefore, the relationships between increased scarcity → price increases → demand decreases → investment increases → forest biomass supply increases → and reductions in scarcity as envisioned by Neoclassical economic theory, operate in a very limited way or do not operate in most developing countries. There is a need to extend the conventional Neoclassical theoretical argument of negative feedback loops by incorporating the other positive relationships emanating from the scarcity and price rises of forest biomass.

3.2 Positive Feedbacks

As noted above, forest biomass scarcity generates another set of pressures on the forest biomass: the pressures of often illegal forest biomass removals. As deforestation continues, the forest biomass scarcity increases, and the average price increases at local levels. While the returns on illegal forest removals increases, the risks involved in forest offenses do not correspondingly increase. For example, in the state of Rajasthan, one truck load of teak (approximately $8m^3$) has an illegal market value of 4000 dollars while the maximum punishment if apprehended and found guilty is 400 dollars. Even, if the probability of being caught is 50%, it is economically rational and lucrative to illegally remove teak from the forests since the expected returns are much higher than the expected costs. This scenario is true for many locations. Therefore, with the rise in prices of forest biomass, the illegal trade kicks in at an accelerated pace. This increases the amount of forest biomass removed illegally and dampens the rise in forest biomass prices in the legal market, which thus acts as a disincentive to private forest investors. The World Bank (1993) observed that output from private fuelwood plantations cannot compete with the illegally removed fuelwood supply. Therefore, private plantations fail to be a rational economic proposition in the context of developing countries in general, and India in particular. The other adverse effect of illegal forest biomass removal is that it usually degrades the forests, further increasing deforestation and consequently the forest biomass scarcity.

Moreover, in India the salaries of forest protection staff are low, yet they are asked to control "a high return-low risk" illegal activity at considerable personal risk. There is no link between expected benefits (wages) and the increased expected costs, so there is no incentive to increase policing. In addition, to minimize the personal risk it is tempting to become involved in this economically rewarding illegal activity. The result is that collusion with offenders becomes an economically rational activity, and deforestation continues.

Figure 3, incorporates in addition to the often emphasized negative feedback loop (the relationships between the scarcity and market mechanisms that tend to decrease demand and increase investments to counteract the increasing scarcity), the other positive as well as negative loops that are operational in the forestry sectors of a developing nation. The positive loops include the relationships between the increasing scarcity of forest biomass resource, the changing (here, increasing) return to risk ratio in illegal removal of forest biomass, increasing degradation of forests, and the increasing scarcity. The additional negative loop is the relationships between increasing scarcity and increasing resource price, increasing resource price and increasing tendency to illegally remove, which in turn triggers the chain of relationships: given demand increasing supply of the resource, depresses the price of the resource, and in turn, diminishes the profitability and tendency to invest for augmenting the resource.

In summary, the market mechanism is not singly confined to the often argued and emphasized negative price loops but may extend into various other positive and negative relationships. Therefore, the role of markets will be determined by the interaction of more than one relationship. The market institution may reduce the scarcity, or may aggravate the scarcity depending upon the strength and speed of various relationships that emanates from the relationships between scarcity of resource and the price increases of the resource in the context of developing countries, particularly in the case of India. The next part of the analysis can be seen from Saxena (1997).

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Reconciling Growth with Conservation towards Sustainable Development

A. Mishra

INTRODUCTION

Istan bhogan hi vo deva, Dasyante yajna bhavitah
Tairdatt tan apradayaibhyo, Yo bhunkte stena eva sah
The Bhagwat Geeta, Chapter 3, Shloka 12

Lord Krishna says that those, who do not give back to (propitiate) natural forces in lieu of whatever they receive from them, are thieves. In this lies the essence of balance between man and nature.

Sustainable Development means meeting the needs of the present without jeopardising the needs of the future generations. The U N General Assembly constituted a commission in 1982 under the Chairmanship of the Norwegian Prime Minister Mr. Bruntland. The Commission submitted its report in 1987. The report is called the Report of The World Commission on Environment and Development (*Our Common Future, 1987*). In the beginning of the 20th century the human population on earth was limited and use of technology and machines was also limited due to nascent stage of industrialization of the world. By the end of 20th century the number of persons on earth had grown considerably and industrial development was on a high scale. There was use of technology and machines on a major scale for exploitation of natural resources. Because of large scale mining, processing of raw materials and large scale use of energy, there is rapid depletion of natural resources, pollution of air and water and health hazards due to use of chemicals. The developed countries are consuming resources and energy at a very high rate and as a result large part of the world is steeped in poverty. While there is a case for Economic Development of the entire world particularly poor nations, sustainability needs to be kept in view for the future generations.

The increasing number of people at the end of 20th century and high state of industrialization necessitating great use of technology has induced unlimited changes in atmosphere, soil, water, plant, animals, and their relationship. The rate of changes is outstripping efforts to assess and advise resulting in desertification, deforestation and pollution. There has been change in rainfall patterns and loss of several plants and animal species. Carbon dioxide and other gases being emitted in the atmosphere are reacting with the ozone layer. We have in place an International Economic system that increases inequality. It needs to be remembered that our earth is not the world. The world also includes our biosphere. Animal and Plant species are also part of the biosphere. While some of the resources could be regenerated a lot of plant and animal species cannot be regenerated once they are extinct. However, any Sustainable Management has to take into account Economic Development of the mankind also.

2. ENVIRONMENTAL SUSTAINABILITY

Environmental sustainability is the process of making sure that processes of interaction with the environment are pursued with the idea of keeping the environment as pristine as naturally possible based on ideal-seeking behaviour (Table 1).

Table 1: **Resource Consumption and State of Equilibrium in our Environment.**

Consumption of renewable resources	State of Environment	Sustainability
More than nature's ability to replenish	Environmental equilibrium	Not sustainable
Equal to nature's ability to replenish	Environmental equilibrium	Steady state economy
Less than nature's ability to replenish	Environmental renewal	Environmentally sustainable

Now it is time to break from the existing system. For that people must be involved through education, debate and public participation. The earth is one but world is not. The biosphere is being strained for sustaining far too much. Resources are being overused to service and there is growing demand on scare resources and resultant pollution. Poverty also pollutes the environment and economic growth has been achieved in ways that are globally damaging. The goals of Economic & Social Development must be defined in terms of sustainability of food, clothes, shelter and jobs (Fig 1). The present model of development has resulted in commercial forests, change in water courses, extraction of minerals on a large scale and production of heat and obnoxious gases. The major energy needs are being met by burning coal. Forest fire is also occurring. As a result 1 to 2.5 billion tonnes of carbon is being let out in the atmosphere. About one billion head of cattle are letting out 73 million tonnes of methane gas

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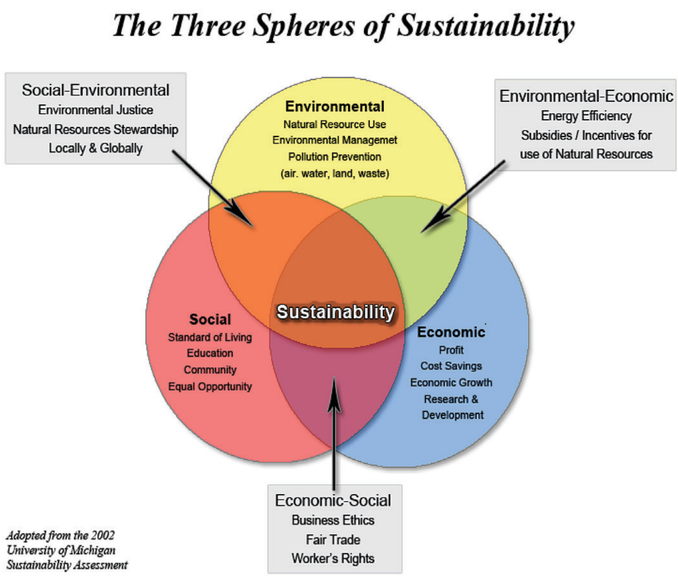

Fig 1. Source: Vanderbilt University (www. vanderbilt.sustainability_spheres.png)

in the air and apart from cattle there are also a large number of camels, horses and other animals. This is unsustainable pattern of development.

In the case of both water management and land management, two principles should apply. First, governments must anticipate and attempt to prevent resource management problems before those problems lead to severe environmental degradation. Second, wherever possible, allocation of rights to land and water should favours poor people. These principles ensure that non-market environmental values and economic assets are put in the hands of poor people. Developments that are good for the environment and for the evolution of local, regional, and national institutions need to be encouraged. Sustainable Development has been defined in many ways but the most frequently quoted definition is from *Our Common Future*, also known as the Brundtland Commission Report. As per the report "Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". It contains within it two key concepts:

- The concept of needs in particular the essential needs of the world's poor, to which overriding priority should be given;
- The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

The concept of sustainable development is rooted in this sort of systems thinking. It helps us understand ourselves and our world. The Problem we face is complex and serious and we can't address them in the same way we created them. But we can attempt to address them in a different way. Sustainability is a dynamic concept born out of the environmental debate of the last quarter century. These are growing concern nationally and internationally about biodiversity and protection of plants and animals and community based activity. It is important to view sustainable efforts from global perspective that addresses socio-economic and environmental issues. Rio summit emphasizes on economic growth and poverty alleviation for sustainable development. The basic prerequisite of sustainable development is the evaluation of a development process with focus on the enhancement of the living conditions of population as a whole with emphasis on raising the standard of living of the poor. The Agenda 21 called all countries to develop national strategies for sustainable development to translate the words and commitments of Earth summit into concrete policies and actions. The important issue in the 21st century is to create greater economic and societal well-being without deterioration of the environment and depletion of the resources.

THE INDIAN SCENARIO

- Twenty years after Brundtland Report.
- Ten years after Rio: Successes and Failures (*Rio De Janeiro, 1992-UN Conference on Environment and Development*).

Sustainable development in India encompasses a variety of development schemes in social, cleantech (clean energy, clean water and sustainable agriculture) and human resources segments, having caught the attention of both central and state governments and also public and private sectors. India's sustained efforts towards reducing greenhouses gases (GHG) will ensure that the country's per capita emission of GHG will continue to be low until 2030-31, and it is estimated that the per capita emission in 2031 will be lower than per capita global emission of GHG in 2005, according to a new study, Even in 2031, India's per capita GHG emissions would stay under four tonnes of CO_2, which is lower than the global per capita emission of 4.22 tonnes of Co2 in 2005. India has a great advantage because of the presence of a large number of micro, small and medium enterprises most of which are non-polluting. A large number of these enterprises constitute service enterprises. A lot of others have single machine operation or have limited number of machines and major activities are carried out manually.

MAJOR COMPONENTS OF SUSTAINABLE DEVELOPMENT

- Biodiversity, water and natural resource management.
- Climate Change
- Consumption, production and the environment
- Environment and development
- Environment and sustainable development Economic Issues
- Environment in Emerging and Transition Economics.
- Environmental Indicators and outlooks.
- Environmental policies and Instruments.
- Fisheries
- Green Innovation
- Sustainable Agriculture
- Trade Investment and Environment
- Transport and Environment

Effective coordination requires institutions (informal and formal rules and organizations) that under-take the following functions: picking up signals (information, feedback, anticipation of future problems), balancing, interests (transparency, voice, forums for negotiation), and executing agreed-on-decisions (commitment and enforcement mechanisms). Such institutions are often lacking or are flawed, when some interests are dispersed or when some groups in society are poor or in other ways disenfranchised, Groups that lack assets tend also to lack voice, security, and a stake in the larger society, hampering institutions' ability to perform needed coordination functions. The result is a vicious cycle in which biased institutions implement policies that lead to an increase in polarization and unequal assets distributions (Fig 2).

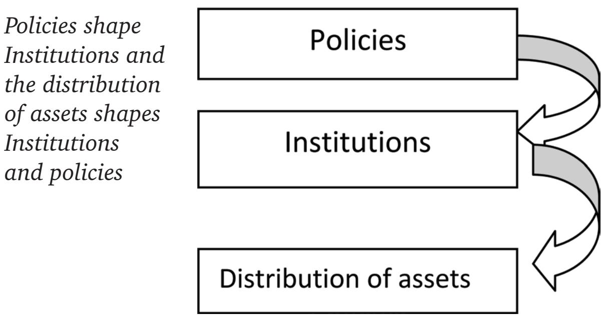

Fig. 2 Unequal Distributions of Assets

Living on fragile lands-in arid zones, on slopes and poor soils, or in forest ecosystems are an estimated 1.3 billion people, a number that has doubled over the past 50 years. The inhabitants of these fragile lands account for a large share of people in extreme poverty. Living in remote areas and working in the informal economy, these people are invisible to decision maker

Table 2: **Forest and Tree Cover of India in 2007**

Class	Area (Million ha)	% of Geographic Area(G.A.)
Forest Cover		
a) VDF	8.35	2.54
b) MDF	31.90	9.71
c) OF	28.84	8.77
Total Forest Cover Tree Cover* Total Forest & Tree Cover	**69.09** 9.28 78.37	**21.02** 2.82 23.84
Non Forest		
Scrub	4.15	1.26
Non-forest	255.49	77.72
Total Geographic Area	**328.73**	**100.00**

** Tree cover is defined as tree patches less than 1 ha with canopy density >10%*

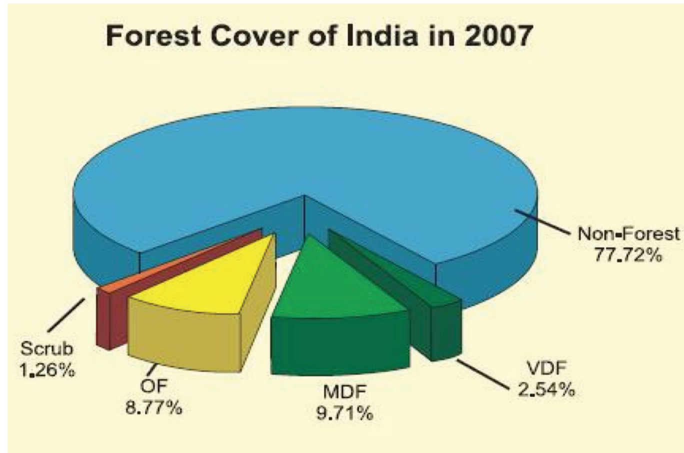

Table 3: **Change in the forest cover(Area in km2) of State/UTs between 2003, 2005 and 2007**

States/ UT	2003	2005	2007 Assessment (latest)
Andhra Pradesh	44,412	44,372	45,102
Arunachal Pradesh	67,692	67,777	67,353
Assam	27,735	27,645	27,692
Bihar	5,573	5,579	6,804
Chhattisgarh	55,992	55,863	55,870
Delhi	174	176	177
Goa	2,164	2,164	2,151
Gujarat	14,814	14,715	14,620
Haryana	1,576	1,587	1,594
Himachal Pradesh	14,359	14,369	14,668
Jammu & Kashmir	21,273	21,273	22,686
Jharkhand	22,569	22,591	22,894
Karnataka	35,246	35,251	36,190
Kerala	15,595	15,595	17,354
Madhya Pradesh	76,145	76,013	77,700
Maharashtra	47,514	47,476	50,650
Manipur	17,259	17,086	17,280
Meghalaya	16,925	16,988	17,321
Mizoram	18,583	18,684	19,240
Nagaland	14,015	13,719	13,464

Orissa	48,353	48,374	48,855
Punjab	1,545	1,558	1,664
Rajasthan	15,821	15,850	16,036
Sikkim	3,262	3,262	3,357
Tamil Nadu	23,003	23,044	23,338
Tripura	8,123	8,155	8,073
Uttar Pradesh	14,127	14,127	14,341
Uttaranchal	24,460	24,442	24,495
West Bengal	12,389	12,413	12,994
Andaman & Nicobar	6,807	6,629	6,662
Chandigarh	15	15	17
Dadar Nagar Haveli	221	221	211
Daman & Diu	8	8	6
Lakshadweep	25	25	26
Pondicherry	42	42	44
Grand Total	**677,816**	**677,088**	**690,899**

(Source: SFR 2007)

The above table shows that while there was a decline of 728 Km^2 between 2003 and 2005, the decline was arrested and forest cover increased between 2005-2007 by about 13811 km^2 i.e. an increase of about 2%. Another interesting feature is that India's forest and tree cover neutralize over 11% of global warming gas emissions at 1994 levels. The report also says that if the tree line is kept out of calculations (the tree line is altitude above which trees are unable to grow say 4,000 m). The forest cover will be about 25.5% instead of 23.84% as normally shown.

A new World Bank report ***Strengthening Institutions for Sustainable Growth: Country Environmental Analysis for India*** underlines the need for 'environmental sustainability' as the next great challenge that India faces along its path to development. The report, that was released by Dr. Prodipto Ghosh, Secretary, Ministry of Environment and Forests, at a national-level workshop in New Delhi, said that owing to high population density, India's rapidly growing economy will put unprecedented pressures on its environment and natural resources – land, water, air, soil, and forests. These pressures are projected to become the highest in the world by 2020.

The report says that the country-wise average compliance ratio of industries monitored is only at 50%. And these monitoring programmes do not cover many Small and Medium Enterprises (SMEs), which have a significant cumulative impact on the environment as a large number of these small enterprises cannot afford clean technology and pollution controls. The report thus highlights the urgent need to develop specialized environmental programmes for SMEs that take account of their constraints and help improve their environmental performance without adversely affecting their business. The report also notes that despite India's best efforts to develop alternative energy sources, coal will remain the dominant fuel for meeting the energy needs of India's growing population and economy. In fact, demand for coal will increase threefold in the coming 20 years. The report says that despite India's strong policy framework and some successes, environmental degradation has not been arrested on a large scale. India's priority should be to build an environmentally sustainable future. With India's edge in terms of human capital, knowledge, technological genius, and a sense of social responsibility, there is every opportunity for this to happen. India's environmental institutions and regulatory regime need to be significantly upgraded, in order to sustain rapid economic growth and meet surging public demand for a cleaner and healthier environment.

The report notes:

- **Environmental Sustainability** is likely to become the next great challenge along India's development path.
- **Environmental Institutions are Improving**. Yet, keeping up with increasing pressures of rapid growth and public demand for cleaner environment has been difficult.
- **Impressive Environmental Awakening** and good practice initiatives by various players are taking place. The priority is to scale up these good practices across the country and reverse/improve environmental outcomes.

Speaking on the occasion, **Mr. Rachid Benmessaoud, Operations Advisor for India, World Bank**, said,

"Keeping up with the pressures of a booming economy is a challenge. There is an urgent need to undertake a series of institutional and regulatory reforms that would help replicate and sustain good practices across the country, and improve environmental outcomes on the ground."

According to the report, one of the key constraints in implementing the much needed regulatory reforms is the deficit of trust among different stakeholders – the public, the environment regulator and the regulated community, which is rooted in the past practices." *It is critical to start working towards developing a* ***commonly shared vision*** *on the way forward, reconciling different perspectives. The Right to Information Act and increased focus on public consultation in the environment clearance process provide the foundation for more effective public participation,"* said **Kseniya Lvovsky, Lead Environment Economist and the Team Leader for the report**

The report identifies five areas for priority:

- **Strengthen** multi-stakeholder partnership and public participation
- **Expand** regulatory toolkit to match the needs of the economy and successful global practice
- **Increase capacity and accountability** of the environmental regulator to keep pace with growing mandates and demands
- **Facilitate** good envirsonmental performance through sectoral policies, procedures and incentives
- **Foster cross-sectoral coordination** for measurable area-based environmental outcomes

2010 FOREST PLAN

A draft of the Green India Mission to double India's forest cover in 10 years at a cost of Rs 44,000 crore (Rs 440 billion) was released in New Delhi on as part of the **National Action Plan on Climate Change**. As the executive summary of the draft stresses, the mission takes holistic view of 'greening' as it will not be limited to just trees and plantation but lay emphasis on restoration of eco-system and habitat diversity through development grassland and pastures, more so in arid/semi arid regions, mangroves, wetlands and other critical ecosystems. Local communities will get a key role in project governance and implementation under the mission. Besides addressing climate change through carbon sinks in forests and other ecosystems, the mission will adapt vulnerable species/ecosystems as also the forest dependant-local communities. The mission's goals include doubling the area of afforestation or eco-restoration to 20 million hectares in the next 10 years by 2020. The first year would be utilized in institution building, sensitization, capacity building and baseline research. Actual field operations will commence from the second year of the Mission.

Under this mission, afforested areas will go up to 20 million ha by 2020, reducing greenhouse gas (GHG) emissions by 6.35%. Without the mission, GHG reductions would be 1.5% less. The mission also has targets for different types of forests, such as moderately dense forests, degraded forests, grassland and scrub, mangroves, urban forest land and even degraded agricultural and fallow land. “Gram sabha and its various committees/groups including joint forest management committees, ‘van panchayats’, etc., would be strengthened as institutions of decentralized forest governance,” the draft says.

RECOMMENDATIONS

- Economic development of the people residing near the forests is as important as the management of forests. It is necessary to bring out schemes for economic development of the people particularly tribals residing near the forests.
- To reduce the dependence of tribals on forests and land, it is essential to provide them education and skills for their alternative livelihood. During a study on evaluation of schemes for tribal development, it was found that while there is a positive change in terms of economic empowerment, the level of education and literacy are still low and there is need to work on this aspect.
- For sustainable forest management, the forest managers should develop their forest plan in consultation with citizens, business organizations and other interested parties in an around the forest tracks being managed. There has to be a balance between society’s demands for forest products and preservation of forest health and diversity.
- For Sustainable Development there has to be an ecosystem approach which is a strategy for integrated management of land, water and living resources.

REFERENCES

1 Report of the World Commission on Environment and Development (Our Common Future 1987)

2 Three Sphere of Sustainability Source: Vanderbilt University (www.vanderbilt.sustainability_spheres.png)

3 UN- Conference on Environment and Development 1992

4 Forest and Tree Cover of India SFR 2007

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6 National Action Plan on Climate Change 2010

Effect of Growth Retardant on Mulberry (*Morus alba* l, s_{146} genotype) Foliage for Improvement

S. Nautiyal, R.K. Pant* and Ashutosh Mishra **

INTRODUCTION

Mulberry foliage is essential to sericulture as it constitutes the sole feed of the mulberry silkworm (*Bombyx mori*). According to Western historians, mulberry-tree cultivation had spread to India through Tibet by about 140 B.C. and the cultivation of mulberry trees and the rearing of silkworm began in the areas flanked the Brahmaputra and Ganges rivers (FAO, Bulletin-2). Mulberry has been selected and improved for leaf quality and yield over the centuries. Through silk production projects, mulberry has been taken to countries all over the world, and it has now spread from the temperate areas of northwest and central Asia, Europe and North America through the tropics of Asia, Africa and Latin America to the southern hemisphere (southern Africa and South America). There are mulberry varieties for many environments, from sea level to altitudes of 4 000m (FAO, 1990), and from the humid tropics to semi-arid lands, such as in the Near East with 250 mm of annual rainfall and the southwestern United States (Tipton, 1994). Mulberry is also produced under irrigation. Mulberry belongs to the Moraceae family (subtype angiosperms; class dicotyledons; subclass urticales). It is grown under varied climatic conditions ranging from temperate to tropical. Mulberry leaf is a major economic component in sericulture since the quality and quantity of leaf produced per unit area have a direct bearing on cocoon harvest. In India, most of the southern states have taken up sericulture as an important agro-industry with excellent results. The total area of mulberry in the country is around 2,82,244 ha. There are about 68 species of the genus *Morus*. The majority of these species occur in Asia, especially in China (24 species) and Japan (19). In India, there are many species of *Morus* found naturally, of which *Morus alba*, *M. indica. M. serrata* and *M. laevigata* grow wild in the Himalayas. Several varieties have been introduced belonging to *M. multicaulis, M. nigra, M. sinensis* and *M. philippinensis*. Most of the Indian varieties of mulberry belong to *M. indica.* Though mulberry cultivation is practiced in various climates, the major area is in the tropical zone (about 90%) covering Karnataka, Andhra Pradesh and Tamil Nadu states. It is a fast growing deciduous woody perennial plant. It has a deep root system. The leaves are simple, alternate, stipulate, petiolate, entire or lobed. The number of lobes varies from one to five. Inflorescence is catkin with pendent or drooping peduncle bearing unisexual flowers. Inflorescence is always auxiliary. Male catkins are usually longer than the female catkins. Male flowers are loosely arranged and after shedding the pollen, the inflorescence dries and falls off. There are four persistent perianth lobes and four stamens implexed in bud. Female inflorescence is usually short and the flowers are very compactly arranged. There are four persistent perianth lobes. The ovary is one-celled and the stigma is bifid. The chief pollinating agent in mulberry is wind. Mulberry fruit is a sorosis, mainly violet black in colour. Most of the species of the genus *Morus* and cultivated varieties are diploid, with 28 chromosomes (2n=2x=28). However, triploids (2n=(3x)=42) are also extensively cultivated for their adaptability, vigorous growth and quality of leaves.

The quality and quantity of the silk produced completely depend on the quality and quantity of feed supplied to silkworms. Silkworm requires certain essential nutrients like sugars, proteins, amino acids, vitamins and minerals for their normal growth, survival and also for the growth of silk gland and higher silk production of good quality. Unlike other insects, silkworm is monophagus and deriving almost all required constituents for its growth from the mulberry foliage during the growth and development processes. Krishnaswami *et al.* (1971) observed that the growth and development of silkworm larvae and cocoons characters are greatly influenced by the nutritional contents of foliage. Narayanan *et al*. (1967), Sidhu *et al*. (1969) and Kashiviswanathan *et al*. (1970) observed that the foliage of mulberry varieties, not only differ due to nutritional content but also influenced due to various agronomical practices like manuring, irrigation, spacing, system of cultivation and other cultural practices and thus effects the growth and development of silkworm and their cocoon characters. So to get a good cocoon crop the quality of mulberry leaves has to be rich in vitamins and nutrients. Though efforts are being made to improve the quality of mulberry foliage by the use of fertilizer application, better management practices and genetic improvement to achieve a gain in the harvest index but due to limited arable land, the attention has been shifted to vertical production and improvement of foliage

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quality. The production and quality of foliage can be increased by increasing the assimilation rate of the plants and directing its movement to leaves through the application of certain growth retardant i.e. CCC, which is simple, easy to use and requires in small quantity. Looking into the beneficial effects of plant growth retardants on various crop plants in improving the crop quality (Kurashi and Hashimoto, 1957, Mehta *et al*., 1975 and Bose *et al*., 1995), the present investigation was undertaken to study the qualitative and quantitative improvement of mulberry foliage under Doon Valley conditions.

The study was mainly focused on (i) how to improve moisture retention capacity of leaves and (ii) how to improve protein, chlorophyll and mineral content of leaves so that shell weight of cocoons is increased and ultimately the silk filament length.

Plant Growth Retardants have been found useful in improving foliage because they suppress the elongation of stem. Intensify the green colour of leaves and indirectly affect the flowering of plants. They retard the lengthening and division of cells in vegetative tissues and control the growth without causing any damage. The physiological function of retardants differs from that of such growth regulators as auxins, inhibitors of growth and herbicides. Growth retardants are highly species specific and therefore they are selective in action. Their use in agricultural and horticultural application is well established. Evidences indicate that certain species of plants, following growth retardant treatment, became more tolerance to adverse physical, chemical and edaphic conditions such as drought, abnormal pH changes, high salinity or alkalinity etc. Evidences are found that growth retardants delay flowering. Plant growth retardants are applied in agronomic and horticultural crops to reduce unwanted longitudinal shoot growth without lowering plant productivity. Most growth retardants act by inhibiting gibberellin (GA) biosynthesis. To date, four different types of such inhibitors are known: (*a*) Onium compounds, such as chlormequat chloride, mepiquat chloride, chlorphonium, and AMO-1618, which block the cyclases copalyl-diphosphate synthase and *ent*-kaurene synthase involved in the early steps of GA metabolism. (*b*) Compounds with an N-containing heterocycle, e.g. ancymidol, flurprimidol, tetcyclacis, paclobutrazol, uniconazole-P, and inabenfide. These retardants block cytochrome P450-dependent monooxygenases, thereby inhibiting oxidation of *ent*-kaurene into *ent*-kaurenoic acid. (*c*) Structural mimics of 2-oxoglutaric acid, which is the co-substrate of dioxygenases that catalyze late steps of GA formation. Acylcyclohexanediones, e.g. prohexadione-Ca and trinexapac-ethyl and daminozide, block particularly 3ß-hydroxylation, thereby inhibiting the formation of highly active GAs from inactive precursors, and (*d*) 16, 17-Dihydro-GA_5 and related structures act most likely by mimicking the GA precursor substrate of the same dioxygenases. Enzymes, similar to the ones involved in GA biosynthesis, are also of importance in the formation of abscisic acid, ethylene, sterols, flavonoids, and other plant constituents. Changes in the levels of these compounds found after treatment with growth retardants can mostly be explained by side activities on such enzymes. Work done by Lee, J.W. (1980) to improve mulberry foliage by foliar spray of Growth retardant CCC states that chlorophyll content was increased in all treated leaves. Keeping in view of the role of growth retardants in improving the leaf quality of mulberry, the present study was aimed to find out the suitable dose of growth retardant i.e. 2-chloro ethyl trimethyl ammonium chloride (CCC) that can bring quantitative and qualitative improvement in mulberry foliage (*Morus alba* L, S146 genotype).

MATERIAL AND METHODS

The mulberry garden of Directorate of Sericulture, Premnagar, Dehradun district of Uttarakhand was selected as the experimental site. Two plots one each having mulberry genotype S146 in the form of tree and another bushes were identified and taken into possession in the month of June 2003 for the purpose of study.

Tree Plot

The tree plot was having 4 years old 24 mulberry plants (*Morus alba* genotype S_{146}) planted at a distance of 10’ x 10’. The average height of plants was 8 feet. A crown at the top of each trunk was maintained to have more number of branches. For the purpose of investigation all the plants were numbered serially and a tag was put to each plant.

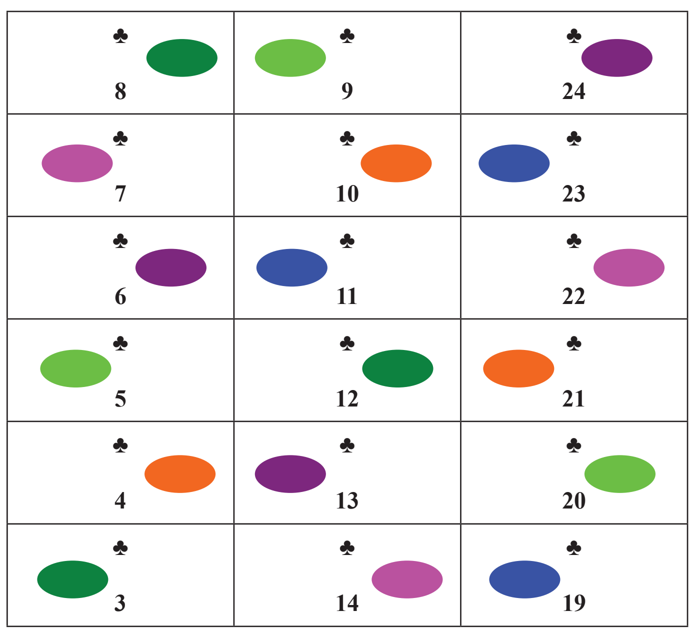
Bush Plot

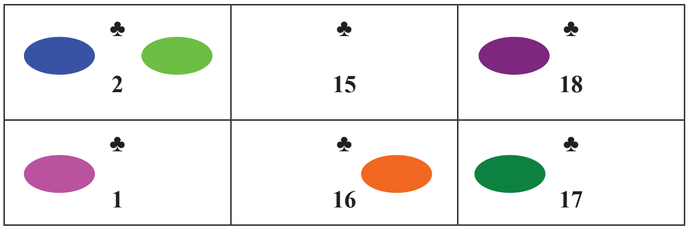
A bush plot near to tree plot having 384 mulberry bushes of same genotype S146 was selected for investigation. In case of bush plantation distance between plant to plant and row to row was 3’ x 3’. The bushes were also 4 years old. The average height of each bush was 3’. For the purpose of study, the bushes were sub-divided into 24 plots, each having 16 plants. All the sixteen plots were serially numbered and a tag was put to each sub-plot.

Experimental Design

The experimental design was randomized blocks (RBD) both for tree and bush plots.

Tree Plot: Based on the RBD, the 24 serially numbered tree plants were grouped into 6 lots each comprising of 4 plants for each treatment as indicated in the following sketch.





S.N.	Treatment	Plant numbers
1	T1-Control (Water)	4,10,16,21
2	T2-Control (water + Agrowet)	2,11,19,23
3	T3-10 ppm CCC + Agrowet	6,13,18,24
4	T4-100 ppm CCC + Agrowet	1,7,14,22
5	T5-500 ppm CCC + Agrowet	3,8,12,17
6	T6-1000 ppm CCC + Agrowet	5,9,15,20

The plant growth regulator used in the experiments was chlormequat chloride [CCC, chlormequat (2-chloroethyl-trimethylammonium chloride) i.e. 750 g l-1, Kemira Agro, Finland]. It contains 11.8% chlormequat (2-chlorethyl) trimethylammonium chloride. (1.0 lbs per US gallon). It is sold in the market as Group 1 Plant Growth Regulator. It is available in the market in a packing of Quarts, gallons and 30 gallon plastic drums. The following concentration of cycocel was used for each treatment:

(i) 10 ppm
(ii) 100 ppm
(iii) 500 ppm
(iv) 1000 ppm

Methodology

(i) Before start of foliar spray, two pruning were resorted i.e. bottom pruning during last week of June for leaf harvest during Autumn and middle pruning in December last week for leaf harvest during Spring. Pruning of all plants of both tree and bush experimental plots was resorted.

(ii) Same treatment of cultural operations, input in the shape of manure/fertilizers, irrigation was given to both tree and bush plots as per recommended package of practices.

(iii) Two silkworm rearing seasons i.e. spring and autumn are in practice in the northern part of India so these periods only were used for experimentation.

(iv) Three replications of each treatment were performed.

(v) The experiment was repeated for three seasons i.e. autumn 2003, 2004 and 2005, and spring 2004, 2005 and 2006.

(vi) Foliar spray was done after 15 days of sprouting. Spray was done during morning hours between 9.30 to 10.30 am.

Leaf yield: Leaf yield per plant was calculated in grams by multiplying the number of leaves/shoot by total number of branches per plant and weight of leaf.

Fresh wt of leaves: Leaf quality parameters were determined in fully matured (12th - 14th) index leaves from the shoot apex. 10 leaves from each treated tree/bush plot were harvested randomly at 10 am and their weight was taken treatment wise by using electronic top pan balance (Sartorius-MA 40) up to two decimal places in grams. From the weight of 10 leaves, single weight of leaf was calculated by dividing the value by 10.

Moisture retention (%) after 6 hrs of harvest: The leaves harvested for fresh weight were stored in open at room temperature in the rearing house. Every hour they were turned up down. After 6 hours of harvest weight of 10 leaves was taken by using electronic top pan balance (Sartorius-MA 40) up to two decimal places in grams. The value was divided by 10 to derive the weight of single leaf. The moisture retention after 6 hours of harvest in % was calculated by the following formula:

$$\text{Moisture Retention (\%)} = \frac{(\text{Wt of leaf after 6 hrs} - \text{Dry wt of leaf})}{\text{Leaf weight after 6 hrs}} \times 100$$

Moisture content in leaves: Moisture content in leaf was calculated by the method of Vijayan *et al*., (1996). 10 leaves from all replications were plucked randomly at 10 am and weighed immediately by using electronic top pan balance (Sartorius-MA 40) up to two decimal places in grams. Thereafter the leaves were dried perfectly at 80°C for 48 hours in a hot air oven to determine the total moisture content. Moisture % was calculated by the following formula:

$$\text{Moisture\%} = \frac{(\text{Wt of Fresh leaf} - \text{Wt of dry leaf})}{\text{Wt of fresh leaf}} \times 100$$

The experiment was repeated thrice and average data on different leaf quality traits were computed. Average of three crops data were recorded replication wise from each treatment and calculated.

Bio-chemical Analysis of Leaves

Protein content

Leaf samples collected were dried and used for analyzing total protein content by adopting the method of Lowry *et al*., (1951).

Regents used			
1	Solution A	Copper sulphate ($CuSO_4.H_2O$) -	0.5%
		Sodium potassium tartarate ($Na_3C_6H_5O_7.2H_2O$) -	1%
2	Solution B	Sodium Carbonate (Na_2CO_3) -	2%
		Sodium hydroxide (NaOH) -	0.4%
3	Solution C	Solution A -	1 ml
		Solution B -	50 ml
4	Solution D	Folin-Ciocaltu Phenol regent -	10 ml
		Distilled water -	10 ml

0.1 ml of leaf samples were taken in test tubes and to it distilled water was added in order to make the volume 1 ml. After which 5 ml of solution C was added and they were incubated at room temperature for about 1 to 10 minutes. After this incubation 0.5 ml of solution D was added and again the test tubes were incubated in dark at room temperature for 30 minutes. After incubation the absorbance was taken at 750 nm.

The concentration of proteins in the samples was calculated from standard curve of Lowry prepared by taking varying concentrations i.e. 0.2, 0.4, 0.6, 0.8 and 1 ml of BSA (1mg/ml) instead of samples and repeating the process described earlier.

Estimation of Sugars

Procedure: One gram of leaf sample was taken and boiled in 95% alcohol for 5 minutes. The aliquot was left for overnight. Next morning decanted and supernatant was collected. Second time again boiled it (3-4 minutes) in 80% alcohol and decanted. This process was repeated 3 to 4 times. The residue left was dried at 100 ^{o}C and dry weight recorded. All supernatants were combined and evaporated to dryness on water bath and kept in vacuum dessicator overnight. The dry weight of this and also previous dry weight of material were recodred for the total dry weight on which sugars were estimated. Made a known aliquot volume and centrifuged it.

Estimation of Total Sugars: For estimation of total sugars a known quantity (25-50 ml) of above aliquot was taken in a porcelain dish and alcohol was quickly evaporated on a water bath taking care not to let the aliquot dry out completely. Subsequently 1 ml of saturated lead acetate solution was added to precipitate colloidal substances to avoid chlorophyll interferences during colour development and material of the supernatant solution was filtered through Whatman No 40 filter paper in to a beaker containing 3 ml of saturated disodium hydrogen phosphate, to precipitate the excess of lead as lead phosphate. After 2-3 washings the filtrate was again filtered through Whatman No. 40 filter paper and the cleared filtrate made up to volume of 100 ml in a volumetric flask.

Hydrolysis of Non-Reducing Sugars: An aliquot (10-20 ml) of the clarified extract was hydrolyzed on a water bath for half an hour with 0.5 N HCl using 1ml of HCl for every two ml of the extract. After cooling, the excess acid was neutralized with 0.5 NaOH using a drop of methyl red indicator. The aliquot was made slightly acidic by adding a drop of 0.1 N oxalic acid and the known volume was made 25 ml with distilled water and estimation of total sugar was done by the method described by Somogyi (1945).

Estimation of reducing Sugars: Reducing sugars was estimated according to Somogyi (1952) method as adopted by Nelson (1944). Samples containing 20-70 μ g/microgram reducing sugars per 1 ml was taken in a test tube and mixed with 1.0 ml of Somogyi copper reagent and heated in boiling water bath for 12 minutes. After cooling the samples with running tap water, 1.0 ml of arsenomolybdate regent was added and the final volume was made up to 10 ml with distilled water. The colour intensity was measured in an EEL calorimeter using IIfrid 625 (green/ filter) transmitting between 505 and 595 mμ (530 mμ). Standard solution of 0.50μg/ml were prepared and stored by dissolving, glucose or fructose in saturated benzoic acid (Folin, 1929).

RESULT AND DISCUSSION

The effect of growth retardant i.e. CCC has been observed highly significant over control in all most all variables studied, however, statistical analysis of data in respect of each variable revealed as under:

Higher green leaf yield was recorded in all plants treated with CCC over control. The data revealed that the length of shoot has decreased in all treatments over control and it was statistically highly significant. During spring season, the highest decrease was observed with 1000 ppm (1.43%) followed by 500 ppm whereas during autumn season the highest decrease was recorded with 500 ppm (6.37%) followed by 100 ppm (Fig. 1).

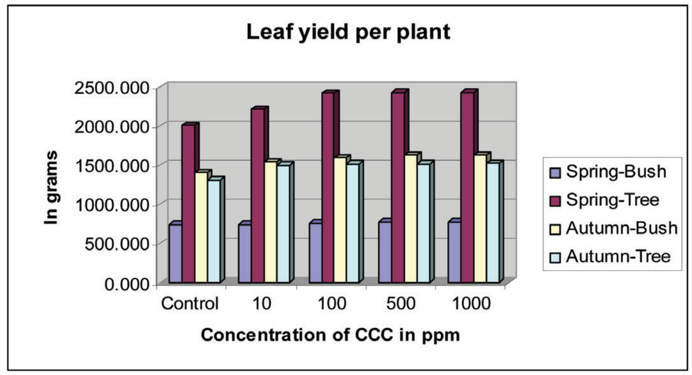


Figure 1: **Effect of CCC on mulberry leaf yield**

Number of leaves/shoot: The data obtained in respect of number of leaves/ shoot indicate significant increase in treated plants over control. Season wise, plantation wise data recorded in respect of control and treated plants are presented in Table 1.

Highly significant increase in number of branches/plant was recorded in all plants treated with CCC over control during spring and autumn seasons. In both seasons, highly significant increase was recorded in plants treated with 1000 ppm (28.42% during spring and 35.61% during autumn) followed by 500 ppm and 100 ppm.

From the above data, it has been observed that all concentrations of CCC are effective in bringing significant increase in number of leaves/shoot over control irrespective of season and type of plantation. In bushes higher significant increase is recorded during autumn season (10.26%) than spring (5.05%) with 1000 ppm. In trees higher significant increase (21.69%) is observed during autumn than spring (18.52%) with 1000 ppm. With increase in concentration of CCC, increase in number of leaves/ shoot is recorded with all treatments irrespective of season and type of plantation though not in exact proportion except in bush plants of spring with 100 ppm.

Leaf area: The data recorded in respect of leaf area in bush plants reveal neither any visible increase nor decrease over control in any of the seasons. However, negligible decrease of 0.01% was recorded in bush plant of spring season over control in 500 and 1000 ppm. Season wise, plantation wise values obtained in respect of leaf area are presented in Table 2.

In tree, during spring season, the control value of leaf area recorded is 196.670 sq cm, whereas 196.024 sq cm in 10 ppm, 196 sq cm in 100 ppm, 195.880 sq cm in 500 ppm and 195.875 sq cm in 1000 ppm. There is statistical decrease in all treatments over control. In tree, during autumn season, the control value recorded is 187.445 sq cm, whereas 185.23 sq cm in 10 ppm, 184.29 sq cm in 100 ppm, 184 sq cm in 500 ppm and 180.14 sq cm in 1000 ppm. The percentage decrease over control works out to 1.18% in 10 ppm, 1.68% in 100 ppm, 1.83% in 500 ppm and 3.89% in 1000 ppm.

It is observed from above data analysis that CCC has brought reduction in leaf area and the significant decrease of 3.89% has been recorded in 1000 ppm in tree during autumn season.

Leaf Moisture content: The data recorded in respect of leaf moisture content reveal significant increase in all treatments over control irrespective of season and type of plantation.

It may be seen from the above data that in bush plants of spring season the control value of leaf moisture content is recorded as 63.650%, whereas 69.200% in 10 ppm, 71.740% in 100 ppm, 73.170% in 500 ppm and 73.990% in 1000 ppm over control. Significant increase is recorded in 1000 ppm. The percentage of increase in leaf moisture content over control is 8.72% in 10 ppm, 12.71% in 100 ppm, 14.96% in 500 ppm and 16.25% in 1000 ppm. Significant increase in moisture content is also recorded for bush plants of spring season. The control value recorded as 64.165% and 68.025%, 70.382%, 73.020% and 71.556% respectively for 10 ppm, 100 ppm, 500 ppm and 1000 ppm over control. The value of 1000 ppm showed a decrease of 2.28% over 500 ppm in tree plant during spring season.

Analysis of above data reveals that as the concentration of CCC increased, the leaf moisture content also increased though not in exact proportion, except in bush of autumn season (with 1000 ppm) and tree of autumn (with 500 ppm). The values obtained are graphically presented in Fig. 2.

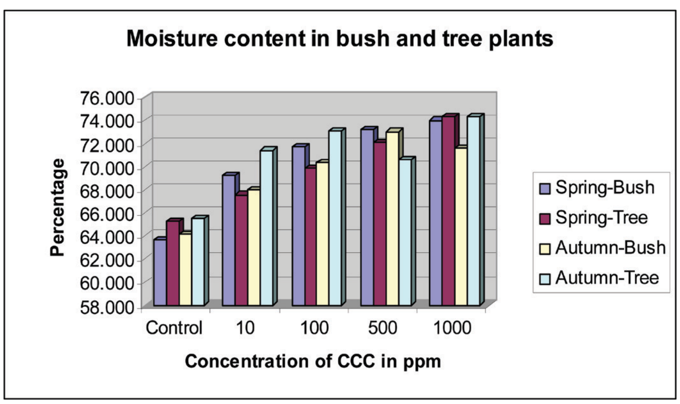


Figure 2: **Effect of CCC on leaf moisture content of mulberry leaf**

Leaf moisture retention capacity (%): Leaf moisture retention capacity is an important factor to store the leaves for longer period without adversely affecting its nutritive value to use it as silkworm feed. The data recorded in respect of leaf moisture retention capacity after 6 hours of harvest indicate significant increase in all treatments.

From the above data it is observed that CCC has made significant increase in leaf moisture retention capacity of leaves after 6 hours of harvest. But the increase in leaf moisture retention capacity has shown no order of increase with increase in concentration of CCC. The values obtained are graphically presented in Fig. 3.

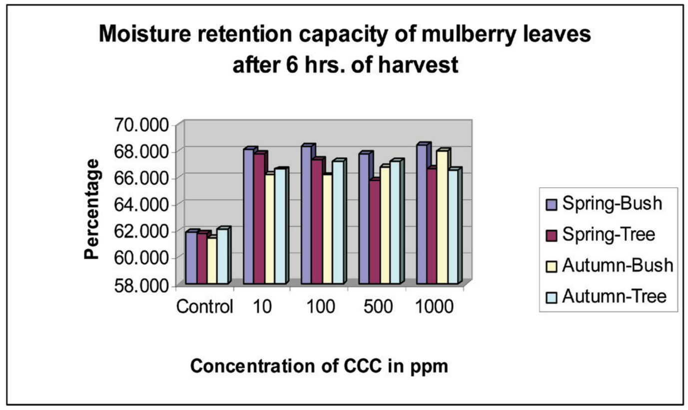


Figure: 3 **Effect of CCC on leaf moisture retention capacity**

Total sugar: The values obtained in respect of total sugar in respect of both bush and tree for both seasons are presented in Table-3.

It may be seen from above data table that in bush plant, during spring season, the control value of total sugar content is recorded as 9.480%, whereas 9.836% in 10 ppm, 9.885% in 100 ppm, 9.978% in 500 ppm and 10.032% in 1000 ppm. The significant increase in total sugar content over control works out to 3.77% in 10 ppm, 4.28% in 100 ppm, 5.27% in 500 ppm and 5.82% in 1000 ppm. In bush during autumn, the control value of total sugar recorded is 8.955%, whereas 9.272% in 10 ppm, 9.382% in 100 ppm, 9.490% in 500 ppm and 9.565% in 1000 ppm. The significant increase over control recorded is 3.55% in 10 ppm, 4.78% in 100 ppm, 5.97% in 500 ppm and 6.81% in 1000 ppm.

In tree during spring season, the control value of total sugar recorded is 9.185%, whereas 9.347% in 10 ppm, 9.450% in 100 ppm, 9.848% in 500 ppm and 9.857% in 1000 ppm. The percentage increase over control works out to 1.76% in 10 ppm, 2.89% in 100 ppm, 7.21% in 500 ppm and 7.32% in 1000 ppm. During autumn in tree plant the control value recorded is 8.915%, whereas 9.313% in 10 ppm, 9.384% in 100 ppm, 9.460% in 500 ppm and 9.510% in 1000 ppm. The percentage increase over control works out to 4.46%, 5.27%, 6.11% and 6.67%, respectively in 10 ppm, 100 ppm, 500 ppm and 1000 ppm.

It may be seen from above data analysis that CCC has increased sugar content in mulberry leaves. The content of total sugar increased with increase of concentration of CCC though not in exact proportion.

Protein Content: Protein is an essential element of sericulture industry as the silk is made up of animal protein, which comes from mulberry leaves that are fed to silkworms to spin cocoons. Therefore feeding protein rich mulberry leaves to silkworms yield better quality silk cocoons. Significant increase in protein content is recorded with all plants treated with CCC over control. The data obtained in respect of protein content are presented in Fig. 4. It is observed from the table under reference that in bush plant during spring season, the control value of protein is 23.820%, whereas 23.910% in 10 ppm, 24.201% in 100 ppm, 25.750% in 500 ppm and 25.748% in 1000 ppm. The percentage increase in protein content over control works out to 0.38% in 10 ppm, 1.60% in 100 ppm, 8.10% in 500 ppm and 8.09% in 1000 ppm.

In bush plant during autumn season, the control value of protein content recorded is 21.975%, whereas 23.230% in 10 ppm, 24.030% in 100 ppm, 24.050% in 500 ppm and 24.160% in 1000 ppm. The percentage of increase works out to 5.71%, 9.35%, 9.44% and 9.94% respectively in 10 ppm, 100 ppm, 500 ppm and 1000 ppm.

In tree plant during spring, the control value of protein content recorded is 23.190%, whereas 23.680% in 10 ppm, 24.960% in 100 ppm, 24.970% in 500 ppm and 25.080% in 1000 ppm. The percentage increase recorded over control is 2.11%, 7.63%, 7.68% and 8.15% respectively in 10 ppm, 100 ppm, 500 ppm and 1000 ppm. In tree during autumn season, the control value of protein content recorded is 22.915%, whereas 23.700% in 10 ppm, 23.960% in 10 ppm, 24.090% in 500 ppm and 24.856% in 1000 ppm. The percentage increase works out over control is 3.43% in 10 ppm, 4.56% in 100 ppm, 5.13% in 500 ppm and 8.47% in 1000 ppm.

The analysis of data reveals that CCC is effective in improving the protein content of leaves. With increase in concentration of CCC, increase in protein content is also observed though not in exact proportion except in bush during spring with 1000 ppm (8.09%) over 500 ppm (8.10%). The values obtained are graphically presented in Fig. 4.

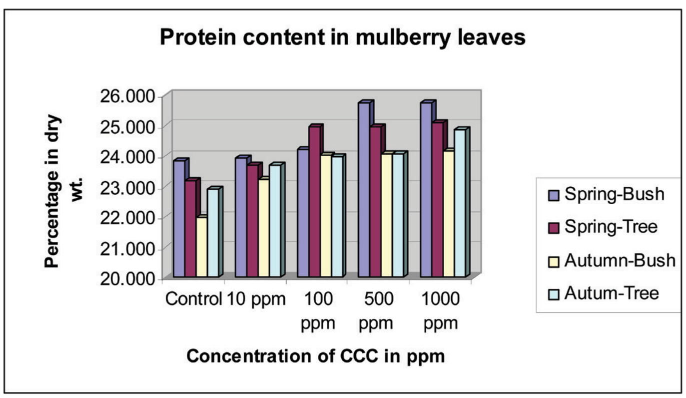


Figure 4: **Effect of CCC on protein content of mulberry leaves**

Crude Fiber: Significant decrease in crude fiber content is recorded with all CCC treated leaves over control irrespective of type of plantation and season. Season wise, plantation wise values obtained in respect of crude fiber percentage is presented in Table 4.

It is observed from above data table that the control value of crude fiber content in bush during spring is 6.985%, whereas 6.649% in 10 ppm, 6.542% in 100 ppm, 6.151% in 500 ppm and 6.150% in 1000 ppm. The percentage decrease over control works out to 4.81% in 10 ppm, 6.33% in 100 ppm, 11.93% in 500 ppm and 11.95% in 1000 ppm. In bush plant during autumn season, the control value of crude fiber content recorded is 6.955%, whereas 6.712% in 10 ppm, 6.623% in 100 ppm, 6.349% in 500 ppm and 6.244% in 1000 ppm. The percentage decrease over control recorded is 3.49%, 4.77%, 8.70% and 10.22% respectively in 10 ppm, 100 ppm, 500 ppm, and 1000 ppm.

Similarly in tree during spring, the control, value of crude fiber recorded is 7.010%, whereas 7.008% in 10 ppm, 6.923% in 100 ppm, 6.643% in 500 ppm and 6.200% in 1000 ppm. Significant decrease of 1.24%, 5.24% and 11.55% is recorded with 100 ppm, 500 ppm and 1000 ppm respectively. In tree during autumn season, the control value recorded is 7.180%, whereas 6.790% in 10 ppm, 6.770% in 100 ppm, 6.459% in 500 ppm and 6.380% in 1000 ppm. The percentage of decrease works out to 5.43%, 5.71%, 10.03% and 11.14% respectively with 10 ppm, 100 ppm, 500 ppm and 1000 ppm.

From the data analysis, significant decrease in crude fiber content has been observed in CCC treated plants over control. The decrease increases with increase in concentration of CCC though not in exact proportion.

Increase in mulberry leaf area has been recorded due to treatment of CCC. Increase in leaf area has also been reported in some plants by Gray (1957), Humphreys (1958), Sarkar *et al.* (1986) in *Trigonella foenum graecum* and *T. carniculata*, Murya *et al.* (1988) in *Cuminis sataivas*. Ohnishi (1985) studied the effect of Gibberellic acid under different conditions and found significant positive result on mulberry leaf area expansion. Reports show that the overall development of leaves is subdued initially by growth retardants which are subsequently compensated by over production. The significant improvement of leaf area is also in accordance with the findings of Shant *et al.* (1985). They obtained increased leaf area with increased concentration of GA3 in O*lea cuspidate* Wall. (Maurya and Dhar, 1988). The above findings support the study here too. These findings suggest that CCC will be helpful to increase the mulberry foliage.

The results indicate that leaf moisture content and leaf moisture retention capacity of leaves after 6 hrs of harvest have significantly improved due to treatment of CCC. It may be because GRs cause a favourable change in Relative Water Content and leaf water potential and maintain water status and play a role in improving the plant water status, which in turn improve its palatability for silkworm. Hence, the moisture content in the leaves may serve as one of the criteria in estimating their quality. It was observed that availability of moisture content in the leaves enhances the feeding efficiency of the larvae which in turn increases the growth rate. Leaves possessing higher moisture content and higher moisture retention capacity are identified as good quality leaves (Bongale and Chaluvachari, 1995; Sujathamma and Dandin, 2000). It was reported that higher leaf moisture content is significantly associated with the growth and nutritional parameters of silkworm (Rahmathulla, 2004). As it relates to moisture retention capacity, it plays an important role in keeping the leaves fresh for longer period because the leaves with higher moisture remain fresh and acceptable to silkworms for longer time. Higher moisture retention value may be due to lower number of stomata per mm^2, thick cuticle, maximum thickness of upper and lower epidermis

Table-1: **Effect of different concentration of CCC on number of leaves/ shoot of mulberry plant**

Plant	Season	Particular	Control	Concentration of CCC			
				10 ppm	100 ppm	500 ppm	1000 ppm
Bush	Spring						
		Number of leaves/shoot	29.890	30.032	31.120	31.230	31.400
		% increase over control		0.48	4.12	4.48	5.05
	Autumn	Number of leaves/shoot	38.390	40.780	39.998	41.438	42.328
		% increase over control		6.23	4.19	7.94	10.26
			Control	10 ppm	100 ppm	500 ppm	1000 ppm
Tree	Spring	Number of leaves/shoot	34.780	36.668	40.000	41.109	41.221
		% increase over control		5.43	15.01	18.20	18.52
	Autumn						
		Number of leaves/shoot	36.890	39.110	43.780	44.559	44.891
		% increase over control		6.02	18.68	20.79	21.69

Table-2: **Effect of different concentration of CCC on leaf area of mulberry plant**

Plant	Season	Particular	Control	Concentration of CCC			
				10 ppm	100 ppm	500 ppm	1000 ppm
Bush	Spring						
		Leaf area (Sq cm)	168.280	168.270	168.275	168.260	168.250
		% decrease over control		0.00	0.00	0.01	0.01
	Autumn	Leaf area (Sq cm)	173.165	173.160	173.158	173.160	173.155
		% decrease over control		0.00	0.00	0.00	0.00
Tree	Spring						
		Leaf area (Sq cm)	196.670	196.024	196.00	195.880	195.875
		%decrease over control		0.32	0.34	0.40	0.40
	Autumn						
		Leaf area (Sq cm)	187.445	185.230	184.29	184.00	180.14
		% decrease over control		1.18	1.68	1.83	3.89

Table-3: **Effect of different concentration of CCC on leaf sugar content of mulberry plant**

Plant	Season	Particular	Control	Concentration of CCC			
				10 ppm	100 ppm	500 ppm	1000 ppm
Bush	Spring	Total sugar %	9.480	9.836	9.885	9.978	10.032
		% increase over control		3.77	4.28	5.27	5.82
	Autumn	Total sugar %	8.955	9.272	9.382	9.490	9.565
		% increase over control		3.55	4.78	5.97	6.81
Tree	Spring	Total sugar %	9.185	9.347	9.450	9.848	9.857
		% increase over control		1.76	2.89	7.21	7.32
	Autumn	Total sugar %	8.915	9.313	9.384	9.460	9.510
		% increase over control		4.46	5.27	6.11	6.67

Table-4: **Effect of different concentration of CCC on the leaf crude fiber content of mulberry plant**

Plant	Season	Particular	Control	Concentration of CCC			
				10 ppm	100 ppm	500 ppm	1000 ppm
Bush	**Spring**						
		Crude fiber %	**6.985**	6.649	6.542	6.151	6.150
		% decrease over control		4.81	6.33	11.93	11.95
	Autumn	**Crude fiber %**	**6.955**	6.712	6.623	6.349	6.244
		% decrease over control		3.49	4.77	8.70	10.22
Tree	**Spring**						
		Crude fiber %	**7.010**	7.008	6.923	6.643	6.200
		% decrease over control		0.00	1.24	5.24	11.55
	Autumn						
		Crude fiber %	**7.180**	6.790	6.770	6.459	6.380
		% decrease over control		5.43	5.71	10.03	11.14

and maximum thickness of palisade tissue as observed by Geok and Dunn (1975) and Sharma (1987).

The leaves treated with CCC were found more greener and thick than control. The thickness of leaves and the ratio of palisade to spongy parenchyma are found to be related to moisture conservation and net assimilation rate which contribute to the quality of leaves (Hesketh *et al*., 1985).

This makes the leaves thicker and darker in colour. In mulberry, Lee (1980) reported that foliar spray of CCC increases chlorophyll content in mulberry. Tezuka *et al*., 1980 have also reported increase in photosynthetic activity and chlorophyll a and b content in kyoho grapes with the treatment of CCC.

The carbohydrate content was also found higher in all treated plants than control ones. In silkworm larva, the amount of carbohydrate ingested is approximately 3 to 4 m moles and about 70% of this amount is absorbed. The degree of increase in fat body glycogen and haemolymph trehalose is dependent on the carbohydrate content of food (Horie and Watanabe, 1980). High carbohydrate content in mulberry leaf is necessary for the healthy growth of the silkworm (Singhal *et al*., 2001). Increased carbohydrate content of mulberry leaves is favourable for healthy growth of silkworm larvae (Anonymous, 1975). Carbohydrates of mulberry leaves are reported to be the chief source of energy and for synthesis of lipids and amino acids for silkworm (Hiratsuka, 1917 and Horie, 1978). It has been reported by Hiratsuka (1917) that mulberry leaves contain plenty of carbohydrates, which are found to be in silkworm mainly as glycogen. He further suggested that a greater part of the carbohydrate content of mulberry leaves is used for physiological combustion and for making fat of the silkworm body. The results revealed that growth retardants, had pronounced influence on biosynthesis of carbohydrates in the leaves. Paleg (1960), Develin and Witham (1986) also reported increase in sugar and starch content, which ultimately increased the quality and yield of mulberry.

Protein content was also found increased in all leaves treated with CCC over control. It is reported that about 70% of the silk protein produced by silkworm are directly derived from the protein of mulberry leaves (Narayanan *et al*., 1967; Krishnaswami *et al*., 1970; Petkov and Dona, 1979 and Fukuda *et al*., 1959). Protein and amino acids are the two major components required by silkworm for synthesis of silk. Horie (1978, 1980) reported that 20-25% optimum dietary protein level is required by silkworm larvae for better growth. Sachar (1967), Varmer and Ho (1976), Santosh Kumari (1990) reported increase in protein and free amino acid content due to growth regulator (GA) application. Flecher and Osborne (1965) also reported that GA enhances the protein synthesis. Debata *et al*. (1981) reported enhanced photosynthetic efficiency in rice. Kalita *et al.* (1983) reported enhanced protein content in mung varieties due to some growth regulators. These findings are supporting the present result in mulberry variety and indicate that increasing concentration of CCC on mulberry plant improved the quality of foliage through enhanced protein synthesis and biological activity. Sacher (1967) and Broughton and Mc-comb. (1967) showed the similar result regarding the enhanced synthesis of protein in variety of plant tissues. Protein content was higher in growth retardant (GA) treated mulberry plants than control plants, which is similar to the result of Linser *et al*. (1965) and Santosh Kumari *et al*. (1990). In mulberry leaf the protein content has been reported to have a direct correlation with the production of efficiency of cocoon shell in silkworm (Machii and Katagiri, 1991. Enrichment of mulberry leaves with protein supplements strongly favoured the larval growth, development and cocoon production in silkworm (Sunderraj *et al*., 2002).

It can be concluded that CCC as a growth retardant is capable of improving mulberry foliage both quantitatively and qualitatively. Though treatments of all concentrations are effective but 1000 ppm concentration is capable of bringing higher significant improvement in mulberry foliage in both bushes and tree forms that too in both of the seasons i.e. spring and autumn but higher significant results in cocoon yield and silk filament, the ultimate end product is achieved with 500 ppm. Farmers can use any of the concentrations of CCC based on their economic strata. Therefore, CCC can be used as a tool to improve the quality and quantity of mulberry foliage for production of good quality silk.

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Multifunctional Agro-forestry Systems in India: Science-Based Policy Options

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INTRODUCTION

Land-use options that increase livelihood security and reduce vulnerability to climate and environmental change are necessary. Traditional resource management adaptations, such as agro-forestry systems, may potentially provide options for improvement in livelihoods through simultaneous production of food, fodder and firewood as well as mitigation of the impact of climate change[1,2]. Reframing the challenge in another way, agro-forestry systems may provide part of the answer to a central challenge for sustainability on how to conserve forest ecosystems and farmland biodiversity as well as the services that they provide while simultaneously enhancing food production for an increasing population under the condition of land and water scarcity[3-45].

Livelihoods improvement is not just about the positive change towards better quality of life and human well-being but it takes into account the local and global change which determines livelihoods[6]. The adverse impact of climate change may be more severely felt by poor people who are more vulnerable than rich. Appropriate policy responses combining the agroecosystems as key assets can strengthen adaptation and help build the resilience of communities and households to local and global change[7,8]. There is, thus, a need for intensified management and governance efforts to generate products and services in agroecosystems. Tree growing in combination to agriculture as well as numerous other vegetation management regimes in cultural landscape including in farms, watersheds and regional landscape can be integrated to take advantage of services provided by adjacent natural, semi-natural or restored ecosystems[9]. Increasing the livelihood security and reducing the vulnerability call for societal adaptation[10]. Such adaptations are possible when combined with traditional resource management systems. Agro-forestry as a local adaptation, therefore, is a promising area of interest for scientists, policy-makers and practitioners. This review examines the multifunctional agro-forestry systems in India as a potential option for livelihoods improvement, climate change mitigation and adaptation, and biodiversity conservation in agroecosystems. The synthesis of the available literature also helps to identify remaining uncertainties and thus the future directions for management and research.

TREES IN AGROECOSYSTEMS

Agro-forestry systems in India include trees in farms and a variety of local forest management and ethnoforestry practices.[11] India is estimated to have between 14,224 million[12] and 24,602 million[13] trees outside forests, spread over an equivalent area of 17 million ha[14], supplying 49% of the 201 million tonnes of fuelwood and 48% of the 64 million m^3 of timber consumed annually by the country[15]. Forest Survey of India earlier has estimated that 2.68 billion trees outside forests exist over an equivalent area of 9.99 million ha. More recent estimates suggest that an equivalent area of 92,769 km^2 (i.e., 2.82% of the geographical area) is under tree cover in India[16]. The current growing stock has been estimated to be about 1.616 billion cubic metres[17]. For these calculations the tree cover has been defined as tree patches less than 1 ha with the canopy density >10%.

In some states where good analyses are now available, the Haryana and Kerala are a case in point. With merely 3.5% of Haryana's area under forests, the state has become self-sufficient in small wood, fuelwood and industrial timber by establishing large-scale plantations on farmlands. Trees in agroecosystems have increased the extent of area under forest and tree cover to 6.63%[18]. These plantations sustain about 670 wood-based veneer, plywood and board, manufacturing units, one large paper mill and about 4 300 sawmills that depend on agro-forestry produce. Similarly, the case of Kerala suggests that the state has a surplus of 0.027 million m^3 of wood in terms of consumption. While the total wood production in the state is 11.714 million m^3, the forests provide only about 10% and trees in home gardens and mixed cropping multi-tier agro-forestry system contribute to the remaining 90%[19].

AGRO-FORESTRY SYSTEMS AS CARBON SINKS

Land management actions that enhance the uptake of CO_2 or reduce its emissions have the potential to remove a significant amount of CO_2 from the atmosphere if the trees are harvested, accompanied by regeneration of the area, and sequestered carbon

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is locked through non-destructive (non-CO_2 emitting) use of such wood. Agro-forestry for carbon sequestration is attractive because[20]: (i) it sequesters carbon in vegetation and in soils depending on the pre-conversion soil C, (ii) the more intensive use of the land for agricultural production reduces the need for slash-and-burn or shifting cultivation, (iii) the wood products produced under agro-forestry serve as substitute for similar products unsustainably harvested from the natural forest, (iv) to the extent that agro-forestry increases the income of farmers, it reduces the incentive for further extraction from the natural forest for income augmentation, and finally, (v) agro-forestry practices may have dual mitigation benefits as fodder species with high nutritive value can help to intensify diets of methane-producing ruminants while they can also sequester carbon[21].

Evidence is now emerging that agro-forestry systems are promising management practices to increase aboveground and soil C stocks to mitigate greenhouse gas emissions. The C sequestration potential of tropical agro-forestry systems in recent studies is estimated between 12 and 228 Mg ha^{-1} with a median value of 95 Mg ha^{-1}. Other estimates based on the global status of the area suitable for the agro-forestry (585-1215 x 10^6 ha), suggests that 1.1-2.2 Pg C could be stored in the terrestrial ecosystems over the next 50 years[22]. Another estimates of C stored in agro-forestry systems, derived from a recent review of studies with global coverage, range from 0.29 to 15.21 Mg ha^{-1} yr^{-1} aboveground, and 30 to 300 Mg C ha^{-1} up to 1-m depth in the soil[23].

In India, average sequestration potential in agro-forestry has been estimated to be 25tC per ha over 96 million ha[24] but there is substantial variation in different regions depending upon the biomass production. However, compared to degraded areas agro-forestry may hold more carbon. For example, above ground biomass accumulation in a central Himalayan agro-forestry system has been found to be 3.9 t $ha^{-1}yr^{-1}$ compared with 1.1 t $ha^{-1}yr^{-1}$at the degraded forestland[25]. The strip-plantations in Haryana sequestered 15.5 t ha^{-1} carbon during the first rotation of 5 years and 4 months[26]. In agroecosystems of Indo-Gangetic Plains about 69% of soil carbon in the soil profile is confined to the upper 40 cm soil layer where C stock ranges from 8.5 to 15.2 t C ha^{-1}. Agricultural soils of Indo-Gangetic Plains contain 12.4 to 22.6 t ha^{-1} of organic C in the top 1 m soil depth[27]. The role of trees outside forests in carbon balance has been considered only recently, reporting that trees outside forests in India store about 934 Tg C or 4 Mg C ha^{-1}, in addition, to the forests[28]. The net annual carbon sequestration rates for fast growing short rotation agro-forestry crops such as poplar and Eucalyptus have been reported to be 8 Mg C $ha^{-1}yr^{-1}$ and 6 Mg C $ha^{-1}yr^{-1}$ respectively[29]. Poplar-based agro-forestry systems in Saharanpur (UP) and Yamunanagar (Haryana) store 27- 32 t ha^{-1} carbon in boundary system and 66-83 t ha^{-1} in agrisilviculture system at a rotation period of 7 years[30]. Studies from Punjab suggest that at a rotation of seven years, poplar timber carbon content could be 23.57 t ha^{-1} and an equal amount may be contributed by roots, leaves and tree bark[31]. In smallholder bamboo farming system in Barak Valley, Assam[32], a traditional homegarden system, C estimate in aboveground vegetation ranged from 6.51 (2004) to 8.95 (2007) Mg ha^{-1} with 87%, 9% and 4% of the total C stored in culm, branch and leaf respectively. The mean rate of C sequestration was 1.32 Mg $ha^{-1}yr^{-1}$.

In tropical homegardens of Kerala, average aboveground standing stocks of C ranged from 16 to 36 Mg ha^{-1}, where small homegardens often have higher C stocks on unit area basis compared to large- and medium-sized ones[33]. In soils, Within 1 m profile, soil C content ranged from 101.5 to 127.4 Mg ha^{-1}. Smaller-sized homegardens (<0.4 ha) with higher tree density and plant-species richness had more soil C per unit area (119.3 Mg ha^{-1}) of land than larger-sized ones (>0.4 ha) (108.2 Mg ha^{-1})[34]. Studies in Khammam district, Andhra Pradesh, on technical potential for afforestation on cultivable wastelands, fallow, and marginal croplands with Eucalyptus clonal plantations found baseline carbon stock to be 45.3 t C/ha, mainly in soils. The additional carbon sequestration potential under the project scenario for 30 years has been estimated to be 12.8 t C/ha/year inclusive of harvest regimes and carbon emissions due to biomass burning and fertilizer application. If carbon storage in harvested wood is considered, an additional 45% carbon benefit can be accounted[35].

In terms of potential, currently area under agro-forestry worldwide is 1,023 million ha[36], and areas that could be brought under agro-forestry have been estimated[37] to be 630 M ha of unproductive croplands and grasslands that could be converted to agro-forestry worldwide, with the potential to sequester 586 Gg C yr^{-1} by 2040. In fact 5 to 10 kg C ha^{-1} can be sequestered in about 25 years in soils of extensive tree-intercropping systems of arid and semiarid lands to 100-250 kg C ha^{-1} in about 10 years in species-intensive multistrata shaded perennial systems and homegardens of humid tropics[38]. Such estimates for India based on holistic studies are not available, and therefore research and synthesis is required. Another major uncertainty, and thus an issue for future research, is that even the estimates that are available globally, are mostly derived through biomass productivity and often do not take into account the carbon sequestration in soils[39]. The potential of agro-forestry systems as carbon sink varies depending upon the species composition, age trees and shrubs, geographic location, local climatic factors, and management regimes. The growing body of literature reviewed here indicates that agro-forestry systems have the potential to sequester large amounts of above and belowground carbon compared to tree-less farming systems. In order to exploit the mostly unrealized potential of carbon sequestration through agro-forestry in both subsistence and commercial enterprises innovative policies, based on rigorous research results, are required.

ENHANCING SOIL FERTILITY AND WATER USE EFFICIENCY

Trees in agroecosystems can enhance soil productivity through biological nitrogen fixation, efficient nutrient cycling, and deep capture of nutrients and water from soils[40]. Even the trees that do not fix nitrogen can enhance physical, chemical and biological properties of soils by adding significant amount of above and belowground organic matter as well as releasing and recycling nutrients in tree-bearing farmlands[41]. Ecological intensification of cropping systems in fluctuating environments often depends on reducing the reliance on subsistence cereal production, integration with livestock enterprises, greater crop diversification, and agro-forestry systems that provide higher economic value and also foster soil conservation. Maintenance and enhancement of soil fertility is vital for the global food security and environmental sustainability. Although India is self-sufficient in terms of food production currently, but for a population expected to rise further[42], country will need to enhance both the food production as well as tree biomass. The next green revolution and concurrent environmental protection will have to double the food production[43]. Maintaining and enhancing the soil fertility of farmlands to grow food grains as well as tree biomass can help meet the demand in future. Ecologically sound agro-forestry systems such as intercropping and mixed arable-livestock systems, involving legume-based rotations, which reduce water runoff and improve soil fertility can increase the sustainability of agricultural production while reducing on-site and off-site consequences and may be a road to sustainable agriculture[44,45]. Although tree species have potential to conserve moisture and improve fertility status of the soil in agro-forestry systems, legumes are the most effective for promoting soil fertility. In addition, deep rooted species could reduce competition for nutrients and moisture with crops by pumping from deeper layers of soil[46].

Agro-forestry may hold promise for regions where success of green revolution is yet to be realized due to lack of soil fertility. A useful path, complementary to chemical fertilizers, to enhance soil fertility is through agro-forestry. Alternate land use systems such as agro-forestry, agro-horticultural, agro-pastoral, and agro-silvipasture are more effective for soil organic matter restoration[47]. Soil fertility can also be regained in shifting cultivation areas with suitable species. For instance, a field experiment to study the N_2 fixation efficiency suggests that planting of stem cuttings and flooding resulted in greater biological N_2 fixation, 307 and 209 kg N ha^{-1} by *Sesbania rostrata* and *S. cannabina*, respectively. Thus, *S. rostrata* can be used as a green manure by planting the stem cuttings under flooded conditions[48]. Even in the dry regions, the mean annual litter fall by neem trees can be 6059 kg ha^{-1} at the density of 400 trees ha^{-1} with potential return of 98, 2.25, 32 and 131 kg ha^{-1} of available nitrogen, phosphorous, potassium and calcium[49]. Through a combination of mulching and water conservation, trees in agroecosystems may directly enhance the crop yields of coarse grains. For instance, in the arid region of Haryana, the effect of *Prosopis cineraria*, *Tecomella undulata*, *Acacia albida* and *Azadirachta indica* on the productivity of *Hordeum vulgare* (barley) was found to be positive. *P. cineraria* enhanced the grain yield by 86.0%, *T. undulata* by 48.8%, *A. albida* by 57.9% and *A, indica* by 16.8% over the control. Biological yield was also higher under the trees than that in the open area. The soils under different tree canopies were rich in organic carbon content, moisture availability and nutrient status[50]. Recent studies have found that multiple-use species such as *Bambusa nutans* has potential to help in soil nutrient binding during restoration of abandoned shifting agricultural lands (jhum fallows) in north-eastern India under the *B. nutans*. A comparison of jhum cultivation and agro-forestry suggests that agro-forestry is an option to address the challenges of slash-and-burn[51].

A study of nutrient cycling, nutrient use efficiency and nitrogen fixation in *Alnus*–cardamom plantations in the eastern Himalaya found that nutrient standing stock, uptake and return were highest in the 15-year-old stand. Annual N fixation increased from the 5-year-old stand (52 kg ha^{-1}) to the 15-year-old stand (155 kg ha^{-1}) and then declined with advancing age. Thus, *Alnus*–cardamom plantations performed sustainably up to 15–20 years[52]. Significant improvement in soil biological activity has been reported under different tree based agroforestry systems in Rajasthan[53]. For instance, soil microbial biomass C, N and P under agro-forestry varied between 262–320, 32.1–42.4 and 11.6–15.6 $\mu g\ g^{-1}$ soil, respectively, with corresponding microbial biomass C, N and P of 186, 23.2 and 8.4 $\mu g\ g^{-1}$ soil under a no tree control. Fluxes of C, N and P through microbial biomass were also significantly higher in *P. cineraria* based land use system followed by *Dalbergia sissoo*, *Acacia leucophloea* and *Acacia nilotica* in comparison to a no-tree control[54]. In *Prosopis cineraria* and *Tecomella undulata* systems optimum density of trees rather than maintaining random trees in farming system are more useful[55]. Such improvements are vital for long term productivity and sustainability of the soil in tropics, where level of soil biological activity is low due to lower soil organic matter. Trees with their comparatively deeper root system improve ground water quality by taking up the excess nutrients that have been leached below the rooting zone of agricultural crops. These nutrients are then recycled back into the system through root turnover and litterfall, increasing the nutrient use efficiency of the agroecosystems[56]. There is robust evidence that agro-forestry systems have potential for improving water use efficiency by reducing the unproductive components of the water balance (run-off, soil evaporation and drainage)[57]. Examples from India[58] and elsewhere show that simultaneous agro-forestry systems could double rainwater utilisation compared to annual cropping systems, mainly due to temporal complementarity and use of runoff in arid monsoon regions[59,60]. For instance, combination of crop and trees use the soil water between the hedgerows more efficiently than the sole cropped trees or crops, as water uptake of the trees reached deeper and started earlier after the flood irrigation than of the *Sorghum* crop, whereas the crop could better utilize topsoil water[61]. Integration of persistent perennial species with traditional agriculture also provides satisfactory drainage control to ameliorate existing outbreaks of salinity[62]. Agro-forestry systems can also be useful for utilization of sewage-contaminated wastewater from urban systems[63] and biodrainage to prevent water logging in canal-irrigated areas[64,65].

It must be pointed out that although agro-forestry systems may reduce crop yield for a variety of reasons, there may be a trade-off. For instance, studies on traditional agro-forestry system in central India[66] found that effect of residual nitrogen on the yield of rice crop after removal of 15-year old *Acacia nilotica* trees resulted in increase in the crop yield (12.5 t ha^{-1}) that was almost equal to the reduction in the crop yield suffered during 15 years of the tree growth in agro-forestry system. Yield reductions may also be compensated in the long run by microclimate modification[67]. A short-term on-farm experiment conducted in Khammam district of Andhra Pradesh found intercrop yields were 45% of the sole crop in eucalyptus system and 36% in *Leucaena* system during the two years. Yet, study found that *Leucaena* variety K636 and eucalyptus clonal based agro-forestry systems are profitable alternatives to arable cropping under rainfed conditions[68]. Economic analysis in agro-forestry in Andaman found that net profit from the black pepper was negative for the first and second cropping year in the beginning, but okra alone compensated it. From the third cropping year black pepper alone not only compensated its establishment cost, but also earned a reasonably good income. Moreover, net return in black pepper over the seven cropping years of the experiments not only compensated the negative returns from the system, but also made the alley cropping system 4.46 times more profitable than without the black pepper[69]. Even when trees are not removed through total harvest, the species combination may be designed for nutrient release that benefits crops. Chemical characteristics and decomposition patterns of six multipurpose tree species, viz., *Alnus nepalensis, Albizzia lebbek, Boehmeia rugulosa, Dalbergia sissoo, Ficus glomerata* and *F. roxburghii* in a mixed plantation established on an abandoned agricultural land in a village at 1200 m altitude in Central Himalaya is a case in point. These species gave the highest rates of N and P release during the rainy season. Thus, *kharif* crops (rainy season crops) are unlikely to be nutrient stressed even if leaf litter is the sole source of nutrients to crops in mixed agro-forestry. A diverse multipurpose tree community provides not only diverse products but may also render stable nutrient cycling[70].

AGRO-FORESTRY AS AN ADAPTATION

Agro-forestry systems can be useful in maintaining production during both wetter and drier years. During the drought deep root systems of trees are able to explore a larger soil volume for water and nutrients, which will help during droughts. Furthermore, increased soil porosity, reduced runoff and increased soil cover lead to increased water infiltration and retention in the soil profile which can reduce moisture stress during low rainfall years. Tree-based systems have higher evapotranspiration rates and can thus maintain aerated soil conditions by pumping excess water out of the soil profile more rapidly than other production systems. Finally, tree-based production systems often produce crops of higher value than row crops. Thus, diversifying the production system to include a significant tree component may buffer against income risks associated with climatic variability[71], in synergy with climate change mitigation and support to help vulnerable populations adapt to the negative consequences of climate change[72]. In drought-prone environments, such as Rajasthan, as a risk aversion and coping strategy, farmers maintain agro-forestry systems to avoid long-term vulnerability by keeping trees as an insurance against drought, insect pest outbreaks and other threats, instead of a yield-maximizing strategy aiming at short-term monetary benefits[73]. Numerous examples of traditional run-off agro-forestry discussed in this article and elsewhere are other examples of adaptation to climate variability[74-75 76 77 78]. Adaptation to climate change is now inevitable. Research on agro-forestry as an adaptation to climate change and as a buffer against climate variability is still evolving. Main pathway through which agro-forestry may qualify as an adaptation to climate change is through diversifying production systems and increasing the sustainability of smallholder farming systems. The role of agro-forestry in reducing the vulnerability of agroecosystems—and the people that depend on them—to climate change and climate variability needs to be understood more clearly.

BIODIVERSITY CONSERVATION

The literature on the role of agroforests in biodiversity conservation is growing rapidly. A large body of research in India[1] and elsewhere[79] suggests five major roles of agro-forestry in conserving biodiversity: (i) agro-forestry provides habitat for species that can withstand a certain level of disturbance in agroecosystems; (ii) agro-forestry helps preserve germplasm of socially useful and associated species; (iii) agro-forestry helps reduce the rates of conversion of natural habitat by providing goods and services alternative to traditional agricultural systems that may involve clearing natural habitats; (iv) agro-forestry provides connectivity and acts as stepping-stone by creating corridors between habitat remnants and thereby conservation of area-sensitive plant and animal species; and (v) agro-forestry helps conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat. Society needs to craft synergies among sustainable livelihoods, the Kyoto Protocol, the Convention on Biological Diversity, and other international instruments. Genetic diversity of landraces and trees in agroecosystems is particularly of immediate concern as there is a danger of erosion in ethnocultivars as well as knowledge that has generated such diversity[80]. Using agro-forestry systems as carbon sinks, and by designing a suitable emissions trading system, the Kyoto Protocol provides a new source of financial support for protection and management of biological diversity[81].

Continued deforestation is a major challenge for forests and livelihoods. In addition, decreasing biological diversity through species reduction in managed agro-forestry systems is also emerging as a challenge. Although agro-forestry may not entirely reduce deforestation[82], but in many cases it acts as effective buffer to deforestation. Trees in agroecosystems in Rajasthan and Uttaranchal have been found to support threatened cavity nesting birds, and offer forage and habitat to many species of birds[83]. These systems also act as refuge to biodiversity after catastrophic events such as fire[84]. Agro-forestry also leads to a more diversified and sustainable rural production system than many treeless farming alternatives and provides increased social, economic, and environmental benefits for land users at all levels. What constitutes enough biodiversity in agroecosystems depends upon the goal in question and will differ depending on whether the aim is to increase yields to support livelihoods improvement or deal with salinity, ground water levels, soil erosion, leaching of nutrients or weed control. If we are concerned about conserving important biodiversity, then protected areas are the preferred choice, and biodiversity conservation may not be a primary goal of agro-forestry systems. Nevertheless, agro-forestry systems, in some cases, do support as high as 50-80% of biodiversity of comparable natural systems[85], and also act as buffers to parks and protected areas[86] as natural vegetation alongside agro-forestry allows noncrop-crop spillover of a diversity of functionally important organisms[87]. The landscape mosaics created by the interplay of rainwater harvesting as an adaptation to climate change and consequent growth of vegetation in agro-forestry systems[88,89] acts as corridor providing avenues for dispersal and gene flow in wildlife population[90,]. An example of buffer is provided by agro-forestry around Hyderabad-Secunderabad. Biomass assessment within 100 km radius of twin cities suggests that annual increment of trees and forests in the region approximately equals with the estimated annual wood and fuelwood intake of the cities and villages[91]. This supply has acted to buffer the pressure on natural forests.

Tree diversity indeed can be large in some Indian village ecosystems. Study in Sirsimakki village of Karnataka by Shastri *et al*.[92] found 952 individuals belonging to 93 species in just 1.7 ha of agroecosystem. An additional 44 species on non-agricultural lands in the village ecosystem that included *soppina bett*a, minor forest and reserve forest were found. The overall agroecosystem had more trees (556 trees/ha) and diversity (diversity index 3.5) compared to the non-agro ecosystem that had 354 trees/ha and a species diversity of 3.87. The overall village ecosystem tree density of 418.8 per ha, with 144 species in 2238 individuals in the sampled area of 5.34 ha is a useful resource. Furthermore, home-gardens, with tree species varying between 20 and 40 on each unit with an average area of 376 m^2, support in all 93 tree species counted in just 1.7 ha. In southern States of India, 269 tree species were recorded in the 544 farms sampled over 61 districts of Karnataka, Kerala and Tamil Nadu[93]. Arecanut agro-forestry systems of south Meghalaya conserve 160 species of plants (83 tree species, 22 shrub species, 41 herb species and 14 climber species) in addition to cash income, medicine, timber, fuelwood and edibles for household consumption and sale[94]. Indeed, numerous regions of India can be designated as agricultural biodiversity heritage sites based on the crop diversity and numerous tree species in traditional agro-forestry systems to enhance food security and adaptation to climate change[95].

Recent investigations involving biodiversity and crop productivity data for smallholder tropical agroforests elsewhere suggest that moderate shade, adequate labour, and input level can be combined with a complex habitat structure to provide high biodiversity as well as high agricultural yields and thus supporting both conservation and food security[96]. We must provide a caution here. There is a growing corpus of research demonstrating that while there are some wildlife-friendly and biodiversity-rich farming systems that support high species richness, a large proportion of wild species cannot survive in even the most benign farming systems[97]. To conserve those species, protection of wild lands will remain essential. Thus, although not a substitute for continuous and intact natural systems, fragments of all sizes and shapes, nonetheless, have conservation relevance. Feeding the world is possible without agriculture further engulfing natural ecosystems but considerable changes in policies, institutions and practices are necessary to make that happen[98].

BIOLOGICAL PEST CONTROL

Agro-forestry systems create landscape structure that is important for the biological pest control. In small-scale, subsistence agriculture in the tropics, traditional farming practices have evolved that provide a sustainable means of reducing the incidence and damage caused by pests including nematodes. The biodiversity inherent in multiple cropping and multiple cultivar traditional farming systems increases the available resistance or tolerance to nematodes[99]. In structurally complex landscapes, parasitism is higher and crop damage lower than in simple landscapes with a high percentage of agricultural use[100]. In understanding the effect of complexity, it is also important to evaluate the quality of seminatural areas surrounding croplands in terms of agroecological functions for natural enemies and pests[101].

BREAKING THE POVERTY AND FOOD INSECURITY CIRCLE

Agro-forestry could contribute to livelihoods improvement in India where people have a very long history and accumulated local knowledge. India is particularly notable for ethnoforestry practices and indigenous knowledge systems on tree-growing. In terms of household income central Indian upland ricefields provide an illuminating economics[102]. The farms often have an average of 20 *Acacia nilotica* trees per ha. of 1 to 12 years of age. Small farms have more tree-density. At a 10 years rotation, these trees provide a variety of products including fuelwood (30 kg/tree), brushwood for fencing (4 kg/tree), small timber for farm implements and furniture (0.2 m^3), and non-timber forest products such as gum and seeds. Thus, trees account for nearly 10% of the annual farm income—distributed uniformly throughout the year than in rice monoculture—of smallholder farmers with less than 2 ha farm holding. The combination of Acacia and rice traditional agro-forestry system has a benefit/cost (B/C) ratio of 1.47 and an internal rate of return (IRR) of 33% at 12% annual discount rate during a ten- year period. In northeast Indian state of Meghalaya the guava and Assam lemon based agrihorticultural agro-forestry systems (i.e. farming systems that combine domesticated fruit trees and forest trees) gave 2.96 and 1.98-fold higher net return respectively in comparison to farmlands without trees. Average net monetary benefit to guava based agro-forestry systems was Rs. 20,610/ha (US$ 448.00) and (Rs. 13,787.60/ha or US$ 300.00 to Assam lemon based agro-forestry systems. Such systems are most useful livelihoods improvement strategies in the rainfed agriculture of Meghalaya[103]. Similarly, The net present value for the different agro-forestry models on six years rotation in Haryana varied from Rs. 26626 to Rs. 72705 ha^{-1} yr^{-1} whereas the benefit:cost ratio and the internal rate of return varied from 2.35 to 3.73 and 94 to 389%, respectively. Thus, agro-forestry has not only uplifted the socioeconomic status of the farmers but also contributed towards the overall development of the region[104].

In order to maximize the trade-off in yield of crops and wood some new models are now emerging. For instance in regions such as Andhra Pradesh, where annual rainfall is around 1,000 mm and soils are fairly good, eucalyptus at a density of 1,666 plants per ha can be planted in uniformly spaced wide-rows (6 m) or paired rows at an inter-pair spacing of 7-11 m for improving intercrop performance without sacrificing wood production[105]. Likewise, in Rajasthan, yield of the annual crops can be optimized in combination with *Prosopis cineraria* at optimum tree densities of 278 trees/ha at 6 and 7 years, 208 trees/ha at 10 year and <208 trees/ha at 11 years of age[106]. Studies on *Tecomella undulata* L. (Rohida) intercropped with *Cyamopsis tetragonoloba* (L.) Taub (Clusterbean), *Vigna radiata* (L) (mungbean), *Pennisetum glaucum* (L.) R.Br. (pearl millet) suggest that seedling density of 833 stem ha^{-1} and 417 stems ha^{-1} were optimum for total production at the age of four and five years, respectively[107]. Beyond that age, 287 stems ha^{-1} was most favourable for crop production at the age of 6-7 years and 208 stem ha^{-1} at 10-11 years[108]. Neem (*Azadirachta* *indica* A. Juss) and understorey crop black gram (*Phaseolus mungo*) experiments suggest that crop yield under the tree canopy decrease but are compensated by increase in wood volume and fruit yield of neem and thus giving higher economic returns[109]. There are numerous non-timber forest products collected from the wilderness for subsistence and cash income. Often, harvesting is unsustainable because of a lack of knowledge about silviculture of species and destructive exploitation strategies driven by market forces. Domestication of such species aimed at commercialisation and production of valued products can reduce the pressure on natural ecosystems[110,111].

Domestication of forest fruit trees and other species grown in agro-forestry systems offer significant opportunity for livelihoods improvement through the nutritional and economic security of poor people in tropics[112]. The wild edible plants form an important constituent of traditional diets in the Sikkim Himalaya where about 190 species are eaten and almost 47 species are traded in local market. Wild edible fruit species have high carbohydrate content ranging between 32 and 88%[113]. Such fruit trees can be taken up for domestication in agroecosystems on priority action. Trees in agro-forestry systems can provide host to globally valued products, and thus, support livelihoods locally. A study of 8 year old agro-forestry intervention in Palamau District of Jharkhand found that community dependent solely on rainfed farming and animal husbandry definitely gains positively by agro-forestry interventions[114]. Suitable community plantations of non-timber forest products in tribal areas such as Jharkhand can potentially serve dual purpose of conserving the useful species as well as livelihoods improvement of local people[115]. Such programmes in tribal areas have enhanced likelihood of success as communities are dependent on the wild resources for livelihoods. In Jharkhand, trees in agroecosystems are particularly valued as host to insects that yield marketable products such as silk[116], lac products[117], honey[118]. Woodcarving industry is emerging as an important source of income to local artisans worldwide[119]. Promotion of species used in woodcarving industry facilitates long term locking-up of carbon in carved wood and supports local knowledge, therefore, strengthens livelihoods. For example, Jodhpur in Rajasthan has emerged as a major centre of woodcarving exporting the woodcrafts worth Rs. 60 million annually facilitated by the traditional knowledge and skills, and growing tourism. Suitable agro-forestry programmes may enhance the availability of wood in agroecosystems thereby improved ability of developing countries to participate in the growing global economy[120].

ENHANCING ADOPTION OF AGRO-FORESTRY INNOVATIONS

An intriguing aspect in India is the low adoption of agro-forestry system beyond what has already existed for millennia. It has been hypothesised that part of the problem can be related to the location-specificity of agro-forestry systems. This begs the question that even as agricultural systems are site specific, yet modern agricultural technologies have gained widespread adoption in India. Many answers have been postulated to this problem[121]: The problem can unlikely be the site-specificity of agro-forestry, but perhaps due to lack of a science base in agro-forestry. It could also be that the scientific principles of successful indigenous systems have not been yet adequately understood or recognized nor are the 'modern' agro-forestry technologies based on sound scientific principles. It could be that there are serious disincentives to agro-forestry adoption in terms of social, cultural, economic, and policy issues. We still need to develop a better understanding of the role of risk and uncertainty, insights into how and why farmers adapt and modify adopted systems, factors influencing the intensity of adoption, village-level and spatial analyses of adoption, the impacts of health morbidity on adoption, and the temporal path of adoption[122].

There are some successful cases such as poplar-based agro-forestry systems, but there is a general lack of robust and comprehensive studies that could provide insights on the critical adoption factors on agro-forestry systems in India. Some of the dominant conclusions available in the studies for various contexts are as follows:

- **Western Himalayan region:** In Himachal, a combination of biophysiscal and social factors including farm size, agroclimatic zone, soil fertility, mobility and importance of tree for future generations and use of indigenous knowledge of farmers are key factors which may influence tree growing[123]. Expert-designed agro-forestry programmes are often not adopted if they are not built on existing experience in traditional agro-forestry systems. Adoption could be enhanced by integrating agro-forestry into other economic and agricultural developments programmes[124]. Perceptions of the change in the forest area around the village, restrictions on felling of trees from their own land (regulations controlling the use of on-farm tree resources)[125] and restriction on transport of the wood were the most important psychological factors affecting agro-forestry adoption[126]. Higher availability of fuelwood from State forests could lead to lower levels of agro-forestry adoption. 'Need' may not be a necessary condition to motivate farmers to adopt agro-forestry, rather, it is accessibility of tree products which influence agro-forestry adoption[127]. Furthermore, training of foresters in agro-forestry has remained oriented towards learning silvicultural aspects rather than social issues. Re-orienting the training curriculum towards learning extension and agricultural besides the silvi-technical skills is required. There is also a need for interaction between foresters and farmers, better co-ordination with other departments and absolving agroforesters of their policing role. Foresters perception is that restriction on felling green trees growing on private land and selling them in the market is the most important factor restraining agro-forestry adoption. Provision of incentives to the villagers for tree growing on private land was the major factor from the foresters' perspective that will encourage tree growing on private land[128].
- **Northern region:** Additional income and an emergency source of cash have been cited to be the farmers' major reasons for adopting agro-forestry in Uttar Pradesh[129].
- **Bundelkhand region**: Farmer's willingness to adopt agro-forestry has been found to increase with time through constant persuasion and developmental activities such as water harvesting. Efficient land use and high production and income producing capability are the main motives of farmers to adopt agro-forestry[130].
- **Central region:** The ease of management of the indigenous system, the autogenic regeneration and robust

nature of the *Acacia nilotica* trees and the multiple products and services the species provides, and easy marketability of the products are the major factors that encourage farmers to adopt the system. As the farmers have secure ownership rights to their land, that they invest in long-term measures such as plantings and management[131]. State-led programmes with subsidies, on the other hand, did not benefit the poor thus a need for instituting measures to compensate the poor[132].

- **Eastern region:** Adoption of agro-forestry is determined by the farmers' attitude to agro-forestry, which in turn is likely to be shaped by information received through farmer-to-farmer and farmer-to-extension contact. The customised mode of communication for each target group is crucial[133]. Common assumption that only large landowners with a substantial income are innovators is not true. The likelihood of adopting agro-forestry is dependent on the progressive attitude of farmers, availability of lands, membership of village organizations, their wealth status and, more importantly, their perceived risk concerning agricultural production[134,135].
- **North-eastern region:** In Nagaland, the strategy with farmer-led testing, where farmers themselves selected agro-forestry technologies, implemented the field tests and assumed responsibility for disseminating the results locally has been found to be very successful in stimulating replication of the agro-forestry[136].
- **Southern region:** Consideration of differences in

Table 1: **Regional examples of soil fertility enhancement in multifunctional agro-forestry systems in India.**

No	Region	Challenge	Changes observed due to agro-forestry
1.	Himalayas (Kurukshetra)[152]	Improvement of sodic soils	Increase in microbial biomass, tree biomass and soil carbon; enhanced nitrogen availability
2.	Himalayas[33]	Restoration of abandoned agricultural sites	Biomass accumulation (3.9 t ha^{-1} in agroforests as compared to 1.1 t ha^{-1} in degraded forests); improvement in soil physico-chemical characteristics; carbon sequestration
3.	Western Himalayas[153]	Reducing soil and water loss in agroecosystems in steep slopes	Contour tree-rows (hedgerows) reduced runoff and soil loss by 40% and 48% respectively (In comparision to 347 mm runoff, 39 Mg ha^{-1} soil loss per year under 1000 mm rainfall conditions)
4.	Sikkim Himalaya[154,155]	Enhancing the litter production and soil nutrient dynamics	Nitrogen-fixing trees increased N and P cycling through increased production of litter and influenced greater release of N and P; nitrogen-fixing species helped in maintenance of soil organic matter, with higher N mineralization rates in agro-forestry systems
5.	Indo-Gangetic plains (UP)[156]	Biomass production and nutrient dynamics in nutrient deficient and toxic soils	Biomass production (49 t ha^{-1}/decade)
6.	Himalayas (Meghalaya)[157]	Enhancing tree survival and crop yield	Crop yield did not decrease in proximity to *Albizzia* trees
7.	Western India (Karnal)[158]	Improvement of soil fertility of moderately alkaline soils	Microbial biomass C which was low in rice-berseem crop (96.14 gg^{-1} soil) increased in soils under tree plantation (109.12 gg^{-1} soil); soil carbon increased by 11-52% due to integration of trees and crops.
8.	Western India (Rajasthan)[159]	Compatibility of trees and crops	Density of 417 trees per ha was found ideal for cropping with pulses
9.	Central India (Raipur)[160]	Biomass production in N & P-stressed soils	*Azadirachta indica* trees were found to produce biomass in depleted soils.
10.	Central India[161]	Soil improvement	Decline in proportion of soil sand particles; increase in soil organic C, N, P and mineral N
11.	Southern India (Hyderabad)[162]	Optimality of fertilizer use	
12.	Southern India (Kerala)[163]	Growing commercial crops and trees	Ginger in interspaces of *Ailanthus triphysa* (2500 trees ha^{-1}) helps in getting better rhizome development of ginger, compared to solo cropping

resource constraints in farming systems and risk-taking attitudes of farmers towards their allocation decisions is likely to enhance the successful adoption of agro-forestry[137]. Farmers with higher income have often been the main beneficiaries of agro-forestry promotion, but adoption of home gardens has been successful for both income groups[138]. Removing many barriers would also be required as farmers are often averse to plant more indigenous timber trees and multipurpose trees due to lack of institutional support mechanisms, inadequate attention to land tenure questions, non-availability of quality planting stock, and policy constraints. Removing contradictions existing between the dichotomous approaches adopted in the agriculture and forestry sectors is also required. Forest policies that impose restrictions on timber harvest from farmlands under the garb of protecting natural forests act as disincentive for maintaining tree-based mixed production systems on farmlands[139].

These insights notwithstanding, there is no specific policy for agro-forestry in India. Indeed, little research is available to inform about what kinds of approaches and institutions operating under what kind of conditions are most effective in producing and mobilizing scientific knowledge to inform action on agro-forestry systems[140,141]. Learning from comparative analysis of natural resource management programmes under the auspices of the Consultative Group on International Agricultural Research (CGIAR) and sustainability science can be instructive[142,143]. Gap between knowledge and action can be bridged by combining different kinds of knowledge, learning, and boundary spanning approaches; by providing all partners with the same opportunities; and by building the capacity of all partners to innovate and communicate[144]. The seven propositions that may be adapted after appropriate testing in the context of agro-forestry in India are as follows[144]:

- **Problem definition:** Projects are more likely to succeed in linking knowledge with action by employing processes and tools that enhance dialogue and cooperation between those who possess or produce knowledge and those who use it, with project members together defining the problem they endeavor to solve.
- **Programme management:** Research is more likely to inform action if it adopts a "project" orientation and organization, with leaders accountable for meeting use-driven goals and the team managing not to let "study of the problem" displace "creation of solutions" as its research goal.
- **Boundary work:** Projects are more likely to link knowledge with action when they manage boundaries between scientists and practitioners. The boundary is a negotiated space that protects the integrity of each side—the science and practice. Bridging it requires special structures for joint accountability across the boundary[145]. Particularly important aspects are arrangements regarding participation of stakeholders, accountability in governance, and the use of 'boundary objects' such as maps, policy-briefs, workshops etc[146,].
- **Systems integration:** Projects are more likely to be successful in linking knowledge with action when they recognize that scientific research is just one "piece of the puzzle," apply systems-oriented strategies, and engage partners best positioned to help transform knowledge cocreated by all project members into actions (strategies, policies, interventions, technologies).
- **Learning orientation:** Research projects are more likely to be successful in linking knowledge with action when they are designed as much for learning as they are for knowing. Such projects are essentially experimental, expecting and embracing failures so as to learn from them throughout the project cycle. Such learning demands that risk-taking managers are not discouraged; rather they are rewarded, funded and regularly evaluated by external experts.
- **Continuity with flexibility:** Getting research into practice requires strengthening links between organizations and individuals operating locally, building strong networks and innovation and response capacity, and cocreating communication strategies and boundary objects and products.
- **Manage asymmetries of power:** Efforts linking knowledge with action are more likely to be successful when they manage to "level the playing field" to generate hybrid, cocreated knowledge and deal with the often large asymmetries of power felt by stakeholders.

CAVEATS AND CLARIFICATIONS

All nature-society interactions have trade-offs and agro-forestry systems are no exception. Although agro-forestry is an effective land use option, it requires some careful planning and studies on the remaining challenges such as farm yield decline under agro-forestry systems. There may not be an entirely convincing rationale for the argument that agro-forestry systems are the answer for livelihoods improvement. Nevertheless, this review does provide some pointers in that direction. Although, large body of research in India has demonstrated the potential of agro-forestry[1], and some practices have been widely adopted, the vast potential is yet to be fully exploited[147,]. Research is needed to further refine the key points of agreement and also to fill the crucial knowledge gaps (**Table 2**). There is, evidently, a major gap in our understanding on the extent to which agro-forestry systems contribute to rural livelihoods improvement in comparison to other land use systems. Future research is required to remove many of the uncertainties that remain, and also carefully test the main functions attributed to agro-forestry against alternative land-use options in order to know unequivocally to what extent agro-forestry served these purposes.

Agro-forestry practices are strongly dependent on access to land within the community. Households that do not have ownership to lands may not be able to benefit from the agro-forestry interventions for livelihoods improvement, unless market regimes permit their inclusion through value addition services. Trees in variety of ethnoforestry and agro-forestry systems contribute to food security, rural income generation through diversity of products and services, and can enhance nutrient cycling, improve soil productivity, soil conservation and soil faunal activities. Nonetheless, trees in agro-forestry systems can also cause competition with the associated food crops. Agro-forestry may, thus, reduce the yield of the agricultural produce in farmlands. Interestingly, the species that did not negatively affect the yield, are indigenous trees occurring in traditional agro-forestry systems, and they are economically more useful for providing multiple benefits. Selection of such species to enrich agro-forestry systems shall be useful for local and national food

Table 2: **Unresolved challenges for future agro-forestry research and innovations in India**

Crop yields: Increase or decrease?	Although some traditional agro-forestry systems do increase crops yields near trees, there are instances where fast growing trees have reduced crop yields in the short-term. Context-specific long-term studies are required to resolve this issue.
Nutrients: additional supply or redistribution?	Mature and scattered agro-forestry trees are associated with improved soil nutrient supply in traditional agro-forestry systems, it is not known if trees additionally supply nutrients by increasing the total quantum of nutrients in agroecosystems or just redistribute the available quantity horizontally and vertically.
Water-Tree interaction: high water uptake or no change?	High water use by fast-growing species and therefore alleged groundwater depletion is a common concern in dry regions that remains unresolved. Do trees actually extract more groundwater or use the residual water available either through irrigation, or use the rainwater when crops have been harvested? It may be possible that rather than letting the rains be lost as runoff, agro-forestry may increase the utilization of rainwater by extending the growing season. Furthermore, it is not clearly understood if trees harvest and accumulate water from surrounding area and release it during the soil-moisture stress. If this is so then, agro-forestry as an adaptation to monsoon variability may actually benefit the crops.
Climate change mitigation and adaptation	Studies on the carbon sequestration potential are limited both by their location-specificity as well as uncertainty related to sequestration in biomass and soils. Often, the rate of carbon sequestration is derived from the growth of above ground biomass. In addition, role of agro-forestry in as an adaptation to climate change needs to be explored further.
Soil amelioration and conservation	Agro-forestry systems with mature trees capable of yielding enough litter are known to conserve soils and ameliorate soil nutrient status, but knowledge on the full range of species and their attributes useful for all the agro-climatic regions and problem-soils in India are required.
Genetically improved trees	Genetically improved trees may provide more biomass and other products valued by the society, but presently research results in this field mostly remain in the laboratory. A full mechanism starting from developing and registration of clones, decentralized certification, and mass multiplication of suitable stock to ensure availability to farmers is required.
Multiple-use species adapted to multiple agro-climatic conditions	Multiple-use species with a wide range of geographic and climatic adaptation can enhance the success and spread of agro-forestry. This is a crucial area of research involving multi-location research in all the climatic regions in India.
Domestication of useful species	Many wild populations of species that yield commercially-valued products are getting depleted, research efforts are required to domesticate these species and integrate with the agro-forestry systems in India.
Policies to promote linkages between markets and tree-growers	On the one hand smallholder systems in India supply about 50% of wood and fuelwood demand, on the other here are still many restrictive regulations that potentially deter farmers from growing trees in agroecosystems and selling these in markets. This issue needs to be addressed.
Value addition innovations	Non-timber forest products have the potential to improve livelihoods of poor farmers, but vigorous efforts are needed to provide knowledge on the on-farm value addition innovation.

security. Not all species desirable for livelihoods improvement can be grown without designing an optimum species combination. Many fruit-yielding species that are although suitable to tolerate highly alkali soil (pH > 10) become susceptible to water logging. Their otherwise desirability for agro-forestry systems due to high potential for livelihoods improvement requires special techniques for planting. For example, pomegranate (*Punica granatum*) trees are unable to tolerate water stagnation. To avoid mortality due to water stagnation during the monsoon the raised and sunken bed technique may be necessary for agro-forestry practices on highly alkali soil[148].

Designing a sustainable tree mixture for agro-forestry systems is another challenge. In agro-forestry differences in functional group composition do have a larger effect on ecosystem processes than does functional group richness alone. Thus, much time and expense need to be invested in finding species or genetic varieties that combine in more diverse agroecosystems to improve total yield. For instance, a five year field experiment of tree mixtures for agro-forestry system in tropical alfisol of southern India involving mango (*Mangifera indica*), sapota (*Achrus sapota*), eucalyptus (*Eucalyptus tereticornis*), casuarina (*Casuarina equisetifolia*) and leucaena (*Leucaena leucocephala* found that growth of sapota can be enhanced by 17% when grown in mixture with leucaena. But a reduction of 12% in the growth of mango may occur when co-planted with casuarina or leucaena[149]. Eucalyptus is incompatible with mango and sapota because these species suffer due to Eucalyptus. Furthermore, because many species suffer from root competition and thus selection of tree species with either low root competitiveness or trees with complementary root interaction is of strategic importance in agro-forestry systems[150].

THE FUTURE

Although numerous issues are involved as discussed here, agro-forestry systems are of multifunctional value. In India and other developing countries the path to sustainable development could be a decentralized planning and implementation of strategies that promote local biomass production in agro-forestry systems. Such decentralized systems in India can provide critical inputs for livelihoods improvement and sustainable development. Along with mitigating the climate change agro-forestry systems can at least partially meet the energy needs of 1 billion people in India through bioenergy options by a prudent use of agricultural residues and biomass generated in agro-forestry systems. Biomass energy-based supply options can create rural wealth and employment necessary for livelihoods improvement and sequester large amount of carbon in a decentralized manner. Such a strategy would also ensure ecological, economic and social well-being. Thus, energy and food self-sufficient taluka (a small administrative unit) can be a new model of rural development in India[151]. Agro-forestry options for carbon sequestration are although attractive, as discussed earlier, they presents critical challenges for carbon and cost accounting due to dispersed nature of farmlands and dependence of people on the multiple benefits from agro-forestry. Additionally, important concerns regarding monitoring, verification, leakage and the establishment of credible baselines also need to be addressed. Another challenge is incentives that promote tree-growing by rural people. Not everyone is willing to adopt agro-forestry. We shall need effective strategy for connecting science to decision making to extend innovations among the people to adopt and maintain agro-forestry.

CONCLUSION AND RECOMMENDATIONS

In order to use agro-forestry systems as an important option for livelihoods improvement, climate change mitigation and adaptation, and sustainable development in India, research, policy and practice will have to progress towards: (i) effective communication with people in order to enhance the agro-forestry practices with primacy to multifunctional values; (ii) maintenance of the traditional agro-forestry systems and strategic creation of new systems; (iii) enhancing the size and diversity of agro-forestry systems by selectively growing trees more useful for livelihoods improvement; (iv) designing context-specific silvicultural and farming systems to optimize food production, carbon sequestration, biodiversity conservation; (v) maintaining a continuous cycle of regeneration-harvest-regeneration as well as locking the wood in non-emitting uses such as woodcarving and durable furniture; (vi) participatory domestication of useful fruit tree species currently growing in the wilderness to provide more options for livelihoods improvement; (vii) strengthening the markets for non-timber forest products, (vii) and addressing the research needs and policy for linking knowledge to action. Prevalence of a variety of traditional agro-forestry systems in India offers opportunity worth reconsidering for carbon sequestration, livelihoods improvement, biodiversity conservation, soil fertility enhancement, and poverty reduction.

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Agro-forestry in Perspectives of Biophysical, Socio-economic, Ecological and Sustainable Biomass Production

S. P. Singh *

1. INTRODUCTION

Agro-forestry is a collective name of land-use systems in which woody perennials (trees, shrubs, etc) are grown in association with herbaceous plants (crops, pastures) and/or live stock in a special arrangement, a rotation, or both, and in which there are both ecological and economic interactions between the tree and non-tree components of the system. Thus, agro-forestry has been defined in many ways depending upon its objective and requirement. In India, many location specific agro-forestry systems have been evolved because of diverse biophysical, ecological and socio economic factor across the country. The farmers' aims in adoption are: (i) to increase total yield from the land; (ii) to widen the range of produce and thus spread risks; and (iii) to preserve their livelihood and survival by conserving resources.

The objectives of the farmer can be stated in socio-economic terms as:

(i) Productivity (the output of valued product per unit of resource input);

(ii) Stability (Constancy of productivity in the face of small disturbing forces arising from the normal fluctuations and cycles in the surrounding environment); and

(iii) Sustainability (ability of the system to maintain productivity when subject to a major disturbing force, i.e. stress or shock).

The concept of vulnerability of the land use system may also be used, where diversity of produce reduces the degree to which the system is vulnerable to stresses, shocks or trends (its 'sensitivity') and increase its ability to recover ('resilience'). From the ecological perspective, a change in farming custom of this kind concerns the ways in which an individual plant (the tree species) can affect its neighbours (the crop species) by modifying their environment. The modifications that can result may have a positive consequence for the neighbouring plants, due to amelioration of the environment, or a negative consequence, due to deleterious effects on the environment. Clearly, the aim in moving to an agro forestry practice is to maximize the positive consequences, thus enhancing productivity and conserving resources (Table 1).

Interpreting the socio-economic concepts in ecological terms, the key issues are (i) over yielding (ii) reduction in yield variance, and (iii) maintenance of resources. All of this may result from increasing species diversity either in space or in time.

Table 1: **The land users' objectives in adopting agro-forestry**

Objectives	Socio economic concept	Ecological concept
Increase total yield	Productivity	Over yielding
Multiple products	Stability (reduced vulnerability)	Reduced yields variance
Preserve lively hood	Sustainability	Maintenance of resources

2. COMPONENTS OF AGRO-FORESTRY SYSTEM

According to nomenclature advocated by King (1970), agro forestry is the generic term which embarrasses the components like silvo-agriculture, agrisilviculture, silvipasture and multipurpose trees in production system. These are as below:

2.1 Silvo-agriculture

Cultivation inside forests is the oldest agro-forestry system which is still practiced extensively in many parts of tropical world. Shifting cultivation extensively used in North- eastern India, *taungya* cultivation practised in U.P., Forest Farming for Rural Poo (FFRP) scheme of Orissa, Group Forestry Scheme of West Bengal are some of the examples of silvo-agriculture evolved in response of agro ecological and socio-economic environment of India.

2.2 Agrisilviculture

This system includes the traditional agro forestry system of raising trees in agricultural field in different agro climatic regions of India particularly in the arid and semi arid regions of Rajasthan, Gujarat, Punjab and Haryana. The villagers grow trees on their farms mainly to increase soil productivity and sustain

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land capability because soils in these regions are deficient in organic matter and their water holding capacity is generally low. In addition, trees are grown to reduce the adverse impact of low and variable rainfall because in case of contingencies such as failure of agriculture crop due to drought, they fall back on trees grown on their farms, as a source of consumption material for both human beings and their cattle.

2.3 Silvi pastoral system

Planting of multipurpose trees with grasses and legumes in an integrated system and their utilization through cut and carry of forage in early years followed by *in situ* grazing is known as silvi-pastoral system. This system aims at optimizing land productivity, conserving plants, soils and nutrients and producing forage, timber and it involves re-plantation, substitution or intervention in the existing vegetation by desirable species. The tree selection is based on its easy regeneration capacity, coppicing ability, fast growth, nitrogen fixing, rotation and high nutritive value. Silvi pastoral system is the age old naturally existing system and at optimum level but with great imbalances in ecological system caused by man.

2.4 Multipurpose forest tree production system

This is the system regenerated and managed for their ability to produce not only wood but leaves and /or fruits that are suitable for food and /or fodder. This would, therefore, also include the use of nurse crops, cover crops and inter–planting of useful species in forestry plantations. There may be a list of other components including agro-silvo-horticulture systems. Silvi-olericultural system and other multipurpose system having combinations of forest trees, plantation crops, horticulture and agriculture crops, pasture grasses, etc.

It must be appreciated that the components of agro-forestry mentioned above need not be mutually exclusive. In fact, silvi-pastoral system followed on marginal lands may improve the site sufficiently to enable agri-silviculture system to be followed in due course. The agri-silviculture system may change to multipurpose forest tree production system after forest trees have got established making it difficult for agricultural crops to grow due to closure of canopy. Alternatively agricultural crops may continue to be growth if the tree species can be pruned or thinned without affecting the ultimate production.

3. BIOPHYSICAL PERSPECTIVE

Productivity of the field is an important factor for deciding the model of any agro forestry system. In low productive fields, the farmers may be encouraged to plant more trees per unit area, even by sacrificing a part of the crop yield. In drought prone area, income from trees can be higher and more assured than food crops without substantially affecting the total production. During the year of drought, when the food crops fail, the farmers can cut the trees to sustain themselves, instead of looking for the food assistance from the government. However, on fertile irrigated land, it is advisable to restrict the density of trees at a level at which the arable crop yield are not reduced.

Land Equivalent Concept (LER) indicates the bio productivity of a combine system and generally the model which yields higher LER value will be taken to the fields. It has been observed that with the introduction of several fast growing tree species and high density plantation practices, LER value is likely to be better with more area under tree cover. Temporal and spatial components are very important issues of agro forestry system. Almost all controlled competition experiment has used annuals (especially crops and weeds) or herbaceous perennials (especially grassland species), and the experiments have lasted one or very few years. Agro-forestry, however, involves long lived plants; if there is over yielding then there is an implication of greater, perhaps most efficient, exploitation of the resources, which is only beneficial if it can be sustained. Over yielding and protection of the resource base are thus interrelated, because over yielding is only desirable if it can be sustained, and that requires continued resource supply over time. Spatial relations of individuals are critical within plant populations. Immediate neighbours, which may interfere with the growth of a plant in the field can be divided into three categories like: interclonal, intergenotypic and interspecific. The interclonal neighbours are parts of the same genet, for example the shoots on a tree that can differ phenotypically in age or size, and make different demands on environmental resources. The inter-genotypic neighbours are genets derived from different seeds and therefore usually of different genotypes, while the interspecific neighbours are genets of different taxa. Agro-forestry system allows niche differentiation, which consequently weakens competition for resource base. This results in greater productivity per unit area. For example, a cereal crop in monoculture may yield 4 tonnes/ha, dropping to 3 tonnes/ha when grown among trees, but the tree may additionally yield 2.5 tonnes/ha fuelwood and similar amount of fodder, resulting in a total of 8 tonnes/ha – double the original yield of the land.

Ecological interactions can be separated into (i) physical and (ii) biological (intraspecific and interspecific) processes. These are analogous to the abiotic and biotic components of the ecosystem. The biological component encompasses the principal type of interactions that occur between species, namely (i) competition (–, –) (–, 0), (ii) predation (+,–), (iii) mutualism (+, +), and commensalisms (+, 0). Harper (1977) listed the following as some of the ways in which the presence of one plant will affect the growth of other ones:

- Reducing light intensity,
- Changing light quality,
- Transpiring limited water changing the humidity profile,
- Absorbing limiting nutrients providing limiting nitrogen,
- Sheltering or excluding predates (or sheltering the predators of predators),
- Favouring or reducing pathogenic activity,
- Encouraging defecation or urination in the neighborhood,
- Providing rubbing posts and so encouraging local tumbling,
- Raising the soil level (accumulation of organic matter),
- Liberating selective toxins,
- Changing soil reaction.

As discussed above, a plant thus influence its neighbours by changing their environment either directly (e.g. by effect on resource levels or by toxins) or indirectly (e.g. by affecting micro-climatic conditions and attracting animals).

4. SOCIO-ECONOMIC PERSPECTIVE

Agro-forestry as an essential tool for sustainable agriculture and land husbandry has been universally acknowledged. Agro-forestry can also be defined as a sustainable land management system, which increases the overall yield of land. Combine the production of crops and forest plants and /or animals simultaneously or sequentially on the same unit of land. Several models have been developed by ICRAF, Nairobi, and research institutions elsewhere, and some have gained wide popularity like the *Acacia albida* model in Africa, the shelter belt model and *Pauvlonia* alley cropping models in China, live hedges of *Calliandra, Gliricidia, Leucaena* and *Sesbania* in S. E. Asia etc. Some of the recognized models in India include the Poplar alley cropping and *Eucalyptus* shelter belt in North India. *Leucaena* model in S. India. *Prosopis cineraria* model in Rajasthan, *Thespesia populnea* and *Melia azedarach* on field bunds model in Maharashtra. Among these, the last two models have found much favourable amongst the small and marginal farmers in their respective geographical regions. The important species, which are of multiple uses, provides good financial return and adapted to various edapho-climatic zones of MP and Chhattisgarh are *Acacia nilotica, Azadirachta indica, Dendrocalamus strictus, Prosopis cineraria, Sesbania grandiflora* and *Eucalyptus tereticornis.*

On a small or marginal farm/land holding, there seems to be much reluctance on the part of the farmer. A system will be economically viable and sustainable in the long run only if LER is high and crop yields do not fall drastically. Experience in India and elsewhere have shown that oven a highly promising model like alley cropping with high LER and little reduction in crop yields has been rejected by the farmers and finally we have ended up promoting planting of trees on farm bunds and boundaries. Surveys conducted in Maharashtra and Karnataka have revealed that farmers could be motivated to adopt planting of, MPT's like *Melia azedarach,* Mango, etc., on farm boundaries and field bunds. Our own surveys in agro-forestry practices in Chhattisgarh region of MP have revealed similar trends, though farmers in these areas do retain trees like *Acacia nilotica, Madhuca indica. Butea monosperma* etc., on their field bunds. Once the farmers have agreed to the concept of planting field bunds and boundaries it is up to the researchers to suggest what species are suitable to a given locality? What is the ideal spacing? How to manage the trees? What are the ways to reduce border effect?

The species when promoted to the small/marginal farmer should be attractive in monetary terms and have some fodder value. Bearing some edible nuts/fruits/flowers and which should raise the general nutritional level of his family too. Therefore, choice of species is of paramount importance in agro-forestry systems or poverty alleviation. A few very important points enlisted below have to be kept in mind before proposing, accepting or rejecting tree component as any mistake is likely to persist for a longer duration unlike in agricultural crops.

- Suitability to locality,
- Ability to fix atmospheric nitrogen,
- Easy decomposition of litter,
- Early maturing tree crops,
- Multiple uses with high returns,
- Easy to establish,
- Species with coppicing ability,
- Noninterference with arable crops,
- Fast growth and short gestation period,
- Non–Allopathic affects on arable crops,
- Ability to generate employment, and
- Specific preference of the farmer.

Again there has been an inherent tendency among researchers to work on better or more fertile and well endowed land since they yield research results more quickly. There are specific agro-forestry systems that may be adapted to poor quality land owned by poor farmers, which has attracted little interest of researchers mainly due to greater demands on resources such as soil fertility, water, etc. Certain agro-forestry practices by marginal farmers or tribal forest villages in Chhattisgarh region of Madhya Pradesh like the planting and maintenance of *Butea monosperma* on paddy field bunds for lac cultivation is noteworthy and deserves more detailed research inputs. Further, small farmers using trees in agro-forestry practices are more interested in specific or multiple uses of an individual tree rather than on biomass production and prefer to grow their trees in home lots and fields for a multitude of uses like wind break, shade, fuel wood, food, green manure and fodder. Certain MPT's like *Tamarind, Neem*, *Jatropha curcas* and *Bamboo* especially *Dendrocalamus strictus* are becoming increasingly popular among poor farmers in recent years. Hegde (1993) has worked out the cost benefit analysis of certain species (Table 2).

Table 2: **Cost benefits analysis of some species.**

Name of species	Common name	Duration years	Net/ tree/ year	No. of trees/ year	Net/ha/ year
Melia azedarach	Persian lilac	9	9.74	2500	24,350
Leucaena leucocephala	Subabul	9	13.58	2500	34,575
Dendrocalamus strictus	Bamboo	10	23.33	625	14,381
Azadirachta indica	Neem	75	50.00	200	10,000
Tamarindus indica	Tamarind	50	463.00	45	20,835

Dendrocalamus strictus with 150 clumps per hectare can realize an IRR (Internal Rate of Return) of 20%. In the case of *Azadirachta indica* (neem), nearly 75% of the total seed yield is usually wasted in the field itself at the time of collection, the value of which is estimated to be Rs. 1000 million per year. It is also estimated that if exploited commercially on a large scale, the value of neem seed oil can shoot up to Rs. 50–60 per kg from the present value of Rs. 11 (Hegde, 1989).

4.1 Small size of operational land holdings

Out of the total land holding of 89.4 million, marginal and small holdings account for 56.59 and 18.01%, respectively in

India. The marginal and small category farmers mostly practice a form of subsistence agriculture and they have strong reservations about planting trees of any kind on their farm lands for fear of decline in food grain production (Table 3).

Table 3: **Distribution of operational holding in India 1980-81.**

Category	Size of holding (ha)	No. of holding (million)	Percent of total holding (%)	Average operational holding (ha)
Marginal	Below 1.0	50.5	56.49	0.39
Small	1.1–2.0	16.1	18.01	1.43
Semi–medium	2.0–4.0	12.5	13.98	2.76
Medium	4.0–10.0	8.1	9.06	5.97
Large	Above 10.0	2.2	2.46	17.24
Total		**89.4**	**100**	**27.79**

Source: NIRD (1985).

4.2 Lack of irrigation facilities

More than 60% of the arable area falls in the arid and semi arid agro climatic zone with highly infertile, degraded soils subject to problems of soil erosion, salinity and alkalinity etc.

4.3 Low literacy levels

In states like Bihar (38.54%), Orissa (48.55%), Arunachal Pradesh (41.22%) and Madhya Pradesh (43.45%) have a low literacy percentage. The farmers find it difficult to imbibe new technologies and remain persist with traditional farming practices thus contributing to low productivity rates.

4.4 Unproductive cattle and poor quality fodder

A numerically high proportion of unproductive cattle, lack of good quality forage, grasses, leaf fodder and high concentrate feeds coupled with a reluctance to switch over to improved breads has resulted in low productivity of livestock.

4.5 Use of cow dung cakes as fuel

It has been estimated that nearly 1/3 of the total dung available in India is used as fuel. This loss is enormous when worked out in terms of NPK and other soil benefits. It is equivalent to 12 million tonnes of coal and Rs. 6,000 crores worth of industrial fertilisers.

4.6 Lack of market infrastructure and extension

So far the markets for agro-forestry products have been concerned; it is confined to pole timber, raw material for paper, pulp, rayon.

5. ECOLOGICAL AND ENVIRONMENTAL PERSPECTIVE

The twentieth century stated with biological mass acre. With the result, depletion of nature and natural resources, genetic erosion, deterioration of ecological, environmental and social factors took place. Poverty and hunger continue to cause suffering and death. According to the Brundtland Commission Report (1987), poverty is among the important causes responsible for environmental degradation. Therefore, destruction and degrading of forests take a heavy toll of soil and water resources of the country and make recourses less productive (Fig 1). Current land use data (NWDB, 1991) indicate that 40% of the geographical area of the country is degraded or wastelands. Further, global warming and ozone depletion have been placed on the global agenda. Country wise data on per capita CNP change in forest cover and green house emissions shows that high commercial energy consumption in developed countries is associated with high green house emissions.

The alarming trends of environmental degradation need to be reversed through agro-forestry including afforestation on wasteland using multipurpose and nitrogen fixing trees. Establishing plantations of fast growing trees in marginal lands in the tropics has been one of the most widely touted measures to mitigate the green house effect. There is an urgent need is raising trees on homestead and farmland. Therefore, agro-forestry is the right approach to maximize land use and economic returns especially for the rural poor. Agro-forestry, indeed, is a new name for an ancient land use practice where in land is used for agriculture, forestry and animal husbandry; the three basic needs at the subsistence level of farming. These three are independent and go together because at the grass root level, they are inseparable because of being land bared. It is an integrated self sustainable land management system, which involves deliberate relation introduction of woody components including trees shrubs, bamboos, cane, medicinal plant, spices, etc. with agricultural crops including pasture/livestock simultaneously or sequentially on the same land management unit and at the same time meeting the ecological requirements as well as socio-economic needs of the people. Further, agro-forestry, in contrast to traditional forestry, offers a number of advantages in response to population pressure, rather than creates pressure on forests; it does not need any surveillance while traditional forestry needs surveillance to prevent illegal grazing, cutting and clearing; it is multipurpose and meets both food and non food needs; conserve environment and needs no unfamiliar technology.

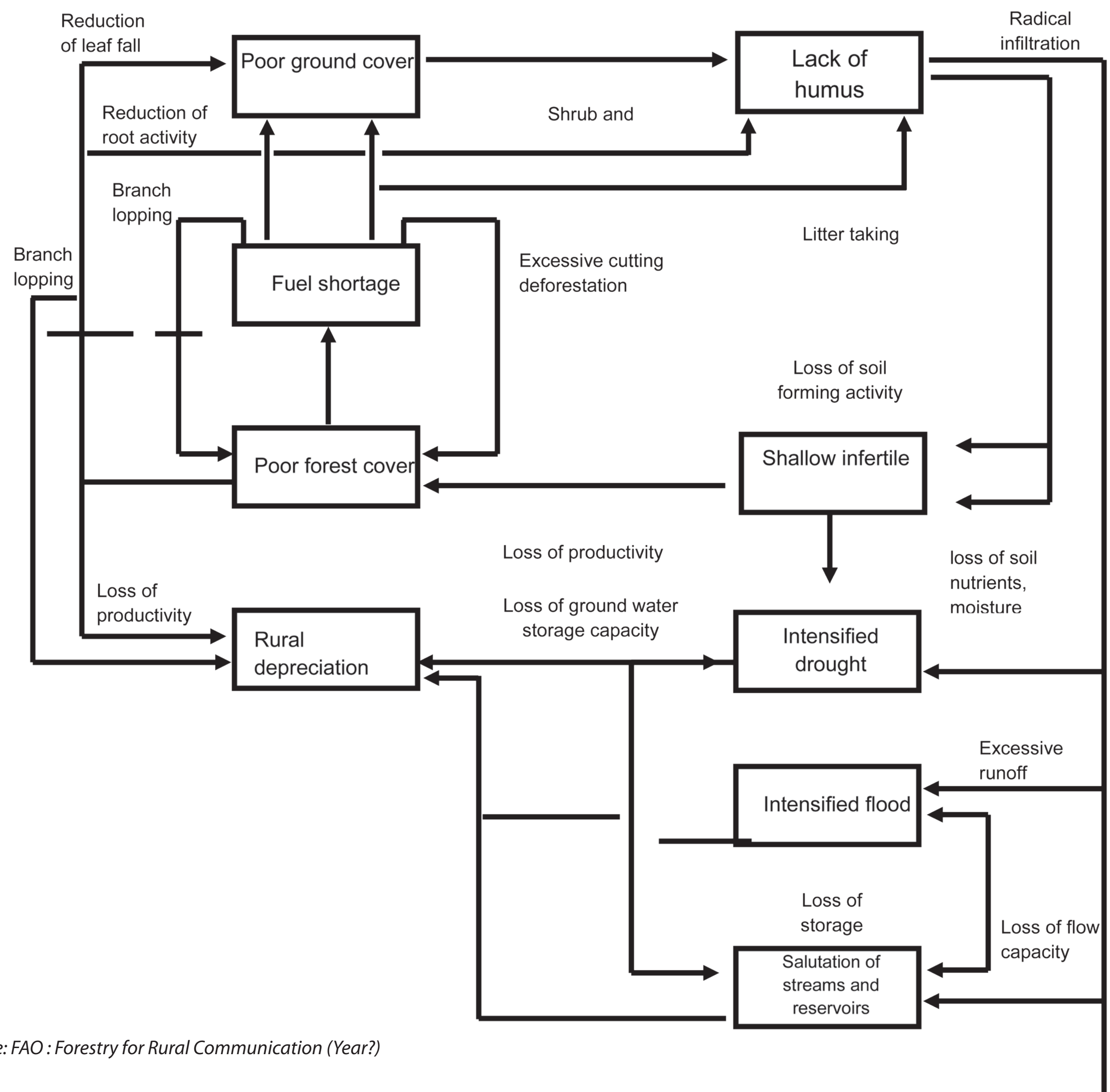
Agro-forestry systems with their elements of inter cropping are in essence ecological models similar to the natural systems and have, therefore, an element of sustainability associated with them. These systems have lasting production on account of the fact that they help in recycling or organic residues, biological nitrogen fixation, and mineral fertilization. This happens all the time in an intercropping system involving nitrogen fixing trees. Their litter fall improves level of nitrogen and organic matter in soil and consequently its overall fertility. In words of Prof. Swaminathan, "agro-forestry is an economic ecologic and evolutionary necessity for ameliorating the situation at the subsistence levels".

According to an estimate, silvi-pastoral system can reduce the soil loss account to 1.26 tonnes/ha/yr against the soil loss of 17.78 tonnes/ha/yr occurs on the bare soil. The improved infiltration rates, further enrich the underground streams to improve the irrigation and drinking water resources. This also ensures increase in number of species of grasses, legumes, trees and animals. It assists the process of rehabilitation and assures maximum resource conservation. It has also been observed that major soil nutrients get enriched under silvi-pastoral system compared to intensively cultivated. While annual herbage removal is common, this system promises healthy environment and enrich biodiversity which is an important support system on the earth. The system promises employment to rural youth in the activities of animal production, collection, processing and manufacturing value added products from the trees and grasses and collection and trading of quality seeds and other materials. The establishment and management of silvi-pastoral system can employ on an average 10 year cycle of 120 mandays/ha/yr. Thus considering 50 million ha (country's wasteland or degraded lands) for development it can provide employment to about 16.5 million people annually. The other activities of processing, etc., can add another five million people to this activity. The increased numbers of activity days assure higher returns from the land based activities. In addition, it also adds the recreational and aesthetic value.

6. SUSTAINABLE BIOMASS PRODUCTION

In agro-forestry system, trees help maintain soil fertility and support growing of the associated crop. There are about 650 woody species reported to be capable of fixing atmospheric nitrogen. Based on available knowledge, there appear to be three main tree mediated processes that determine nutrient cycling in tropical agro-forestry system. These are: (i) increased input of N through biological nitrogen fixation (BNF) by trees; (ii) enhanced availability of nutrient resulting from production and

Figure 1: **Cycle of destruction in forest lands**



Source: FAO : Forestry for Rural Communication (Year?)

decomposition of substantial quantities of tree biomass; and (iii) greater uptake and utilization of nutrients from deeper layers of soil by trees. Additionally, agro-forestry system offer possibility for reducing the loss of soil and therefore, nutrients through erosion. However, under field condition, it is difficult to isolate the effect of nutrient cycling of trees as it reflects the tree crop interaction. There appears to standardize methods in quantifying N fixation especially in older trees, the extent of benefit that is actually realized by using NFTs in agro-forestry systems. Large variations exist in agro-forestry tree species in their biomass decomposition patterns. There is a need to study the biomass added by trees in agro-forestry system.

The present day forestry in India is passing through a crucial stage. The forests are shrinking under acute socio-economic, political and heavy biotic pressure. It is universally accepted that we are very poor in forest management and productivity of our forest. The growing stock in the country varies from 7 M^3/ha in Karnataka to as high as 277 M^3/ha in Himachal Pradesh. The average growing stock is about 79 M^3/ha, while the world average is 110 M^3/ha. India's forest productivity (0.7 M^3/ha/annum) is much below the world average of 2.1 M^3/ha/annum (Ref). The contribution of the forestry sector to the total GNP is almost stagnant at roughly 1.5%. This adversely affected both tribal and rural poor, who are basic inhabitants of the forests. Further, deforestation leads to reduction of per capita forest accounting for 0.1 ha, this is against the country's basic need of 0.47 ha for every individual. Depletion of forest cover and increasing population growth (of human and cattle) together resulted to widen the gap between demand and supply of fuel wood timber, fodder and forest produce. Estimate consumption in India is about 175 KWH. Fuel wood is the dominant cooking fuel in India and about 80% of the rural energy comes from the renewable biomass. The supply and demand gap in case of fuel wood is estimated to about 190 million M^3 and in case of industrial wood it is about 15 million M^3. The country's fuel wood demand by 2000 AD will be 300–350 MT of which 80% will be required in the rural sector (we are already in 2011?). As fuel wood becomes scarce, dried cow dung is burned to keep the pot boiling. An estimated 100 million metric tons of dried cow dung cakes representing 500 million tones of freshly collected dung are burnt away every year, which is a shear waste of valuable organic fertilizer. Even if, 400 of the 500 million tones cow dung burnt every year is diverted to manuring, we will produce 15–20 million tones of additional food grains every year.

Most reports on fodder status in the country show alarming gap between demand and supply. The latest for 1991 reports the demand for 662 to 770 MT (metric tonnes or million tonnes), while production remains around 5.0 MT from all resources (NMWD, 1991). It is recognized that half of the forest lands in the country have poor or no forest cover and this situation is getting worse day by day. Besides this, about 93.69 M (million ha?) non-forest areas in the country have been identified on wasteland. This vast area is not only unutilized but also poses a serious threat to agriculture, through soil erosion, best, pathogens and weeds.

Agro-forestry is the right approach promising scope to meet both fuel and fodder needs consistent with improvement of soil fertility. Although, biomass is the major produce of agro-forestry, yet there is plenty of scope to produce variety of commodities to generate additional employment and profits. The following are the important products of agro-forestry:

- In the open arid and semi-arid land of the North-western zone, hot swift winds blow away millions of tones of precious top-soil, for which nature has taken hundreds of years to build. If trees are planted as shelter-belts, they divert the wind up to a distance of about 20 times the height of the trees.
- In the arid areas of Rajasthan and Gujarat, Khejri *(Prosopis cineraria)* is found to be the best tree for growing with crops like pearl millet, clusterbean, mungbean and mothbean. Another useful shrub is *bordi* or *Jhad ber* (*Ziziphus nummularia*) and 'Seb' variety of *ber* or jujube (*Ziziphus mauritiana*) is an ideal fruit tree suited to semi-arid regions.
- A good pasture could be raised in between the trees of *Prosopis cineraria* and *Acacia tortilis* planted at a density as high as 400 plants per hectare (these soil does not support such high population under agro-forestry. It may not be more than 200 tree ha^{-1}). The leaves can be used as an animal feed as well as mulch, which improve the soil structure, reduce evaporation, increase the moisture-holding capacity and enrich the organic carbon and nutrient content of the soil.
- Trees can be raised to protect shade-loving species, condiments, medicinal and plantation crops in humid and sub-humid areas, fuel, timber, pulp, fodder, food, medicinal herbs, oils and cakes, gum, wax, resin, lac, green manure, soap substitute and perfume. Excepting fuel wood, fodder and food, most of other items are neglected by the farmers due to lack of organized marketing network and technical know-how of processing the products.
- Out of the 89.4 million holdings in India, 50.5 million holding (56.5%) are categorized as marginal with an average of 0.39 ha per family. About 18.0% of the holdings are small, with an average of 1.43 ha per family. Small and marginal holders, who are in majority (74.5%), cannot earn enough from their land to make living and in the villages most of them live below or just above the poverty line. Their holdings, which are in several fragments located in different locations cause a lot of problems and are further aggravated by the erratic monsoon upon which most of these holdings are dependent. Agriculture under such situations is not profitable and the unfortunate farmers who live under perpetual poverty do not take any initiative to prevent the degradation of their lands, fields, unless such activity provides them immediate direct immediate benefit. Agro-forestry is certainly an ideal programme for these farmers because they can earn an additional income from the trees, while improving soil productivity.

7. RESEARCH NEEDS

Considering the above discussion, following areas are identified to carry out systematic research in the field of agro-forestry:

- Research on tree-crop interactions under different combination patterns of tree, crop etc,
- Research on tree – crop interactions to work out insect pest problems of agricultural crops,
- Research on management practices of tree species in agro-

forestry system to enhance yield of agricultural crop,

- Research on quantifying N fixation ability of tree species in agro-forestry systems,
- Study the biomass and carbon sequestration potential of trees in agro-forestry system,
- Work out combination of agri-silviculture and silvi-pastoral system on degraded forest lands and waste lands to enhance site productivity as well as to reduce human and cattle pressure on forests,
- Research on optimizing economic and ecological returns by developing ecological models for difficult and problematic lands.

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Differential Responses of Pruning Intensity on *Dalbergia sissoo* Roxb. based Agrisilviculture System under Rainfed Tropics

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INTRODUCTION

Dalbergia sissoo Roxb. (Shisham) is a suitable tree for agro-forestry system; it is a good timber species, moderately fast growing, has nitrogen fixing ability, clean bole, and protein rich fodder leaves. The species is popular for afforestation / reforestation both in social forestry and agro-forestry programmes in different parts of India. However, the shade intensity of the tree has strong negative effects on the performance of under storey crops. Light is a critical factor affecting the performance of field crops under agro-forestry interventions. It is the general apprehension of the farmers that trees in association with crops in agro-forestry will compete strongly with crops for nutrients and moisture (Dhyani *et al*., 1990). There are some silvicultural operations which can reduce tree canopy and facilitate entry of sunlight amongst which pruning is one of them. Pruning has became an essential practice for reducing both above and below ground competition with associated crops (Fownes and Anderson, 1991; Sinclair *et al.,* 1998), supplying organic materials to the soil and providing mulch during the cropping season (Mafongoya *et al*., 1998 and Kadiata *et al*., 1998). Prunings provide woody biomass for fire wood, leaf biomass and fodder. In pruning the removal of some part of the tree or crown will obviously reduce the competition ability of tree because crown management will facilitate more light to reach crops underneath and reduce demand of moisture and nutrients. So, management practices are extremely necessary to get optimum production from an agrisilviculture system. Pruning reduces the competitive ability of the trees which allows the crop to take advantage of the higher nutrient availability under the alley cropping system (Hagger *et al*., 1993). The aim of this study was to find out suitability of different paddy varieties with *D. sissoo* under different pruning intensities.

MATERIAL AND METHOD

The investigation was carried out at Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, India to study the effect of different intensities of puruning of *Dalbergia sissoo* Roxb. in an agrisilviculture system. The experiment was conducted during the 2010 kharif season. Twelve years old *Dalbergia sissoo* planted at 5m × 5m was intercropped with paddy varieties. The treatment combinations involved five treatments viz. four pruning intensities (i.e. no pruning, 25%, 50% and 75% pruning) and one open (without tree i.e. crop only) in main plot and three paddy varieties (viz. IR-36, MR-219 and WGL-32100) in sub-plot. It was laid out in strip plot design with four replications. The soil of the experimental field was medium black, clay loam with pH 5.93, medium in nitrogen (288.1 kg/ ha), high in phosphorous (20.38 kg/ha) and potash (170.45 kg/ha).

The essential major plant nutrients viz.; nitrogen, phosphorous and potash were given in optimum doses. The half of the nitrogen (50 kg/ha) and full quantity of phosphorous (50 kg P_2O_5) and potash (40 kg K_2O/ha) applied at the time of sowing as basal dose and remaining half nitrogen (50 kg/ha) applied 30 days after sowing as topdressing on standing crop. Sowing of paddy was done in lines 20 cm row to row and furrows of 5cm depth were opened with the help of pickaxe. The tree species had been planted in the year 1998 at a spacing of 5m x 5m. The optimum agronomic practices were followed during experimentation. Harvesting of paddy varieties was done manually with the help of sickle on 12.11.2010 (IR-36), 15.11.2010 (WGL-32100) and 20.11.2010 (MR-219) when they attained maturity.

RESULTS AND DISCUSSION

The data pertaining to grain yield and straw yield (Table 1) clearly showed that grain yield and straw yield of paddy were significantly influenced by different pruning intensities of *Dalbergia sissoo* and different paddy varieties.

Grain Yield and Straw Yield (q ha^{-1})

Different pruning treatments showed significant effect on grain yield of paddy. The highest grain yield of paddy was recorded when grown under open condition (39.86 q ha^{-1}). Among pruning intensities significantly maximum grain yield was recorded under 75% pruning (32.50 q ha^{-1}) followed by 50% pruning (27.16 q ha^{-1}) and 25% pruning (20.97 q ha^{-1}). No pruning recorded significantly lowest grain yield (15.06 q ha^{-1}). The percent reduction in grain yield under no pruning, 25%, 50% and 75% pruning as compared to open condition was 62.21%, 47.39%, 31.86% and 18.46%, respectively.

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Table 1: **Grain yield, straw yield and harvest index of paddy as influenced by different pruning intensities and different varieties in agrisilviculture system**

Treatments	Grain yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})	Harvest Index
Pruning intensities			
P_0 - No pruning	15.06	56.04	19.31
P_1 - 25% pruning	20.97	66.60	23.86
P_2 - 50% pruning	27.16	77.74	25.88
P_3 - 75% pruning	32.50	85.89	27.40
Open -No tree	39.86	97.90	28.92
SEm±	1.29	3.32	1.11
CD (P = 0.05)	3.75	9.69	3.24
Paddy Varieties			
V_1-IR 36	26.88	75.70	25.64
V_2-MR 219	29.37	83.08	25.20
V_3-WGL 32100	24.08	71.71	24.39
SEm±	0.31	1.59	0.59
CD (P = 0.05)	0.91	4.65	NS

Different paddy varieties showed significant effect on grain yield. Variety MR-219 gave significantly higher yield (29.37q ha^{-1}). Variety IR-36 gave yield of 26.88 q ha^{-1} which in turn was significantly superior to WGL-32100 (24.08 q ha^{-1}). The reduction in grain yield under WGL-32100 and IR-36 was 8.47% and 18.01%, respectively. Interaction between pruning treatment and paddy varieties was not found significant.

Straw yield of paddy was significantly affected by different pruning treatments. Open condition recorded significantly higher straw yield (97.90 q ha^{-1}) as compared to different pruning treatments and no pruning. Among different pruning treatments, 75% pruning recorded significantly higher straw yield (85.89 q ha^{-1}) closely followed by 50% pruning (77.74 q ha^{-1}) which in turn was significantly superior to 25% pruning (66.60 q ha^{-1}) and no pruning (56.04 q ha^{-1}) which recorded the lowest yield. The percent reduction in straw yield under no pruning, 25%, 50% and 75% pruning over open (no tree) was 42.75%, 31.97%, 20.59% and 12.26%, respectively.

Paddy varieties showed significant effect on straw yield. Among different paddy varieties, variety MR-219 recorded significantly higher straw yield (83.08 q ha^{-1}) which in turn was significantly superior to IR-36 (75.70 q ha^{-1}) and WGL-32100 which recorded the lowest straw yield (71.71q ha^{-1}). The percent reduction in straw yield under WGL-32100 and IR-36 as compared to MR-219 was 13.68% and 8.88%, respectively. Interaction between pruning treatment and varieties was not found significant.

In the present study crop grown under open condition (without tree) recorded significantly highest grain yield as compared to grown with trees with pruning treatment. Sharma (2003) reported similar results. Among different pruning intensities, grain yield increased with increasing with pruning intensities and 75% pruning recorded significantly higher grain yield. The probable reason might be due to more availability of light in 75% pruning. Canopy pruning increased the availability of photosynthetically active radiation and reduced the competition for light which increased the rate of photosynthesis in crop plants resulting in accumulation of more photosynthesis in plant and their translocation from source to sink. Handa and Rai (2001-02) tried 10, 25, 50 and 75% canopy pruning of different tree species and reported better performance of under storey crop with 75% canopy pruning of tree. It was also suggested by Prasad and Prasad (1997) that in an agro-forestry system, reduction in intercrop yields could be minimized by proper pruning of tree component. Upadhyaya and Nema (2003) reported that in Acacia based agrisilvicultrue system different pruning intensities (20, 40, 60 and 80%) improved light penetration and significantly increased yield of paddy was obtained in 80% pruning intensity. Ram Newaj *et al.* (2005) reported that soybean yield was 132.5% higher in 70% pruning than tree attained to grow normal (unpruned). The reduction in growth and yield of field crops due to adverse effect of tree species in agro-forestry system than their pure cropping have also been reported by Goyal *et al.*(2001); Pandey *et al.* (2001); Puri *et al.*(2001); Shamughavel *et al.,* (2001); Islam *et al.*(2006); Karwar *et al.*(2006) and Dhillon *et al.*(2007). Significantly higher straw yield of paddy was recorded when grown without tree (open condition) as compared to crop grown with tree under different pruning treatments. Open condition gave taller plants and more number of tillers/meter row length, therefore higher straw yield was found in per hectare basis. The straw yield may be as result of growth especially during the vegetative phase of the plant.

Regarding paddy varieties MR-219 gave significantly higher grain yield than IR-36 and WGL-32100. The probable reason of higher grain yield in MR-219 due to higher grain yield attributing characters viz., number of effective tiller/MRL, length of panicle and plant height and number of grains/panicle. Light availability is the most important limiting factor for the performance of under storey field crops particularly where upper storey tree forms a dense over storey canopy (Miah *et al*., 1995). Canopy pruning reduced shading effect and increased light availability to understorey paddy crop which increased the yield attributes of their intercrops. A similar result was also reported by Bargali *et al.*(2010).

The straw yield is the resultant of plant height and tillering behaviour of the crop. Variety MR-219 gave significantly higher straw yield than IR-36 and WGL-32100 due to higher plant height and number of tillers/MRL.

Harvest Index

Harvest index was significantly affected by different pruning treatments. Significantly higher harvest index was recorded under open condition (28.92) at par with 75% pruning (27.40) and 50% pruning (25.88). No pruning recorded significantly lowest harvest index (19.31). This may be due to different pruning intensities resulting in different grain and biological yield. In open condition more grain and grain+straw ratio was found than the other treatments. This may be due to proportionately more production of grain as compared to other pruning treatments. Different paddy varieties showed no significant effect on harvest index.

Growth of Shisham (*Dalbergia sissoo*)

Growth performance i.e. height, DBH, pruned biomass, cylindrical volume and stand biomass of 12 years old, shisham as influenced by different pruning intensities and different paddy varieties are presented in Table 2.

Table 2: **Morphological characters and biomass of *D. sissoo* as influenced by different pruning intensities and different varieties under agrisilviculture system**

Treatment	Height (m)	DBH (cm)	Pruned biomass (Kg ha^{-1})	Cylindrical volume (m^3 ha^{-1})	Stand biomass (Kg ha^{-1})
Pruning Intensities					
P_0- No pruning	9.16	19.81	-	116.43	89716.1
P_1- 25% pruning	9.88	19.91	189	124.12	95571.7
P_2- 50% pruning	9.78	17.53	675	97.31	74861.2
P_3- 75% pruning	8.23	14.21	825	60.05	46861.2
SEm±	0.83	0.8	48	3.16	5884.0
CD (P=0.05)	NS	2.46	165	9.78	18302.1
Paddy verities					
V_1-IR 36	9.51	19.40	734	115.06	90829.5
V_2-MR 219	9.10	18.33	720	99.12	76314.5
V_3-WGL 32100	9.31	18.26	786	101.18	77950.4
Tree only- no crop	9.23	15.41	761	79.5	61240.2
SEm±	0.47	1.33	60	5.34	4111.0
CD (P = 0.05)	NS	NS	NS	17.06	13137.2

Tree Height

Different pruning intensities and paddy varieties showed no significant effect on tree height. However tree height under different pruning intensities vary from 8.23 m to 9.88 m. Similar results was also reported by Batra and Kumar (1994) and Couto and Gomes (1995).

DBH

Different pruning intensities showed significant effect on DBH. The 25% pruning recorded significantly higher DBH (19.91cm), closely followed by no pruning (19.81cm) and 50% pruning (17.53cm). The 75% pruning recorded significantly thinner stem diameter (14.21 cm). The reason may be explained that heavy pruning leads to greater removal of leaf area than light pruning and strongly reduces the overall carbohydrate production of a tree. In pruning, not only the leaves are removed, but also some unproductive wood is also removed. This implies that pruning reduces both the production and the consumption of the carbohydrates, which affect the tree growth adversely. It may be the reason in the present study that growth of tree under 75% pruning was lesser than 50% pruning, 25% pruning and unpruned trees. Percent reduction in diameter due to increase in pruning intensity from 25 to 50 and further to 75% was 12.06% and 28.06%, respectively. Similar findings have been reported by Fujimori and Waseda(1972), Karani(1978) and Dakin, 1982). Tree growth in terms of dbh, height and crown diameter was lowest in 75% pruning and height in unpruned trees. It has generally been observed that the impact of pruning on tree growth increases with the intensity of pruning (Pinkard and Beedle, 1998; Pires *et al*., 2002; Pinkard *et al*., 2004 and Chandrasekhar, 2007). Different paddy varieties showed no significant influence on DBH of *D. sissoo*.

Pruned Biomass (Kg ha^{-1})

Quantity of pruned biomass increased with increasing pruning intensities. Significantly higher pruned biomass was recorded in highest pruning intensity i.e. 75% pruning (825 kg ha^{-1}) followed by 50% pruning (625 kg ha^{-1}) and 25% pruning (189 kg ha^{-1}). The reason is simple that more foliage was removed in 75% pruning which increased the pruned biomass. Similar results have also been reported by Zeng (2001) and Uotila and Mustonen (1994). Different paddy varieties showed no significant effect on pruned biomass.

Cylindrical volume (m^3 ha^{-1})

Different pruning intensities showed significant effect on cylindrical volume of tree. The 25% pruning recorded significantly higher cylindrical volume (124.12 m^{3}ha^{-1}) closely followed by no pruning (116.43 m^{3}ha^{-1}) but significantly superior to 50% pruning (97.31 m^3 ha^{-1}) and 75% pruning which recorded significantly lowest cylindrical volume (60 m^{3}ha^{-1}). Cylindrical volume is ultimate product of height and DBH of tree. Significantly higher DBH was recorded in 25% pruning for which more cylindrical volume was recorded. Also another fact is that trees are commonly pruned by removing leaves and branches from lower part of the crown which changes the stem shape to a more cylindrical form and increases the clear bole length, resulting in more biomass allocation in bole than other components. Shepherd (1986) and Muhairwe (1994) have hypothesized that pruning changes stem shape to a more cylindrical form. Pinkard *et al.* (2004) reported that stem volume was only significantly reduced over the period of the experiment by 70% pruning. Cylindrical volume of trees under different paddy varieties showed no significant difference among them but recorded significantly higher cylindrical volume as compared to control (without crop).

Stand Biomass (Kg ha^{-1})

Different pruning intensities showed significant effect on stand biomass of the tree. At the age 12 years, significantly higher stand biomass was recorded in 25% pruning (95571.7 kg ha^{-1}) closely followed by no pruning (89716.1 kg ha^{-1}) and was significantly superior to 50% pruning (74861.2 kg ha^{-1}). The pruning intensity of 75% recorded lowest (46861.2 kg ha^{-1}) stand biomass. Stand biomass of tree when grown with different paddy varieties and without crop showed significant difference. Significantly higher stand biomass was recorded when different paddy varieties viz., IR-36 (90829.5 kg/ha), WGL-32100 (77950.4 kg/ha) and MR-219 (76314.5 kg/ha) grown with tree which were at par among themselves but significantly superior to tree alone (61240.2 kg/ ha) without crop. The results clearly showed that more pruning reduced biomass production and this reduction has positive correlation with amount of pruning. Most likely, this reduction may be due to the diminished overall photosynthesis of pruned trees, because pruning of branches leads to a decrease in remaining leaf area and to a decrease in the number of buds from which new branches and leaves can be produced. Biomass production in N_2- fixing leguminous trees might be influenced by frequency and height of pruning. Similar results also reported by Duguma *et al*., (1988) and Sanginga *et al*., (1994).Due to decreased assimilate production, the growth of pruned trees is generally reduced (Pinkard *et al*., 1999 and Bandara *et al*., 1999).

Growing of trees with different varieties of paddy showed no significant effect on tree height and DBH. The reason may be the fertilizer, irrigation and cultural practices applied to the crops was utilized by crop itself and negligible amount utilized by trees, hence showed no effect on growth parameters of tree. Karwar *et al*., (2006) reported that intercropping of arable crops didn't influence visible antagonistic effect on the growth of trees. Koshta and Khare (2003) also reported in guava based agro-forestry system, height, DBH and canopy spread were significantly unaffected by growing of different rice varieties as intercrops.

Dalbergia sissoo based agrisilviculture study revealed that at 50% pruning intensity of tree recorded higher paddy yield in addition to biomass yield of woody component which may be recommended under rainfed agroecosystem.

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Soil Nutrient Budget under Plantation of *Leucaena leucocephala* to Reclaim the Wasteland Lands of Chhattisgarh Plain

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INTRODUCTION

Out of the India's total (329 m hectare) geographical area, 57% land presently suffers from various kinds of degradation problems (Paroda, 1998). In Chhattisgarh plains, out of total geographical area of state, more than 20% of land is under red lateritic wasteland, (Verma *et al*., 1998). These lands have gentle slopes with undulating topography (Pofali and Bhattacharjee, 1970) with full of gravels and sub-soil layers, which forms hard and compact pans at places (Singh and Totey, 1985). Rehabilitation of such type of degraded lands can be done by afforestation with multipurpose trees species. The choice of species and variety plays a key role in such degraded land, not only to produce biomass for community uses but also improve the soil condition. Although, a number of multipurpose trees are recommended for such land areas, the exotic species *Leucaena leucocephala* is the most promising multipurpose fast growing tree species, not only meeting the demands of local communities for fuel, fodder and timber but also improving the soil by efficient nutrient cycling as short rotation forestry (Khosla *et al*., 1985). Subabul (*Leucaena leucocephala* belongs to family leguminosae (Mimosoideae). It is native of Central America and introduced in India, during 1973-75 (Gogate and Dhaundiyal, 1986). The K-8 and K-28 varieties were widely planted in Indo-Gangetic plains and Deccan Plateau as social/agro-forestry and wasteland plantations. The present study is focused on exploring the potentiality of the tree species as short rotation forest management on red lateritic soils (Bhata lands).

MATERIALS AND METHODS

Seedling of *Leucaena leucocephala* was raised in nursery and the uniform healthy seedlings were planted at 1x1m spacing during rains of monsoon. The plantation site was prepared with proper lay out and the pits of 30x30x30 cm size were dug and filled with mixture of FYM +Black soil + sand (1:1:1 ratio).

Plantation was observed annually for survival percentage, growth of tree's height, collar diameter (CD) and diameter as breast height (DBH). Clear felling of plantation was done at the age of 11 years but in stands that represent the average height, CD and DBH of the plantation, care was taken to measure the biomass accumulation in different components viz; bole, bole bark, branch, twig and leaves. Root of felled tree was excavated as per the standard methods (Ghosh and Chattopadyaya, 1972 and Chandra *et al*, 1979). Analysis of nitrogen, phosphorus, potassium and combustible energy in different component of trees *i.e.* root, bole, bole bark, branch, twigs and leaves was done by standard analytical methods (AOAC, 1975). After felling the tree coppicing behaviour of stumps was also studied. The dry matter production of herbage species in adjacent open and under the plantation area was observed by using 2x2m quadrats. Soil samples were collected at 0-15, 15-30, 30-60 and 60-100 cm depth under the tree and in adjacent open area. The composite samples were analyzed for WHC, pH, organic carbon, available nitrogen, phosphorus and potash as per the standard methods of Jackson (1973). All the data collected were analyzed for their standard deviation for biotic components and analysis of variance ratio for a-biotic components.

***Site details*:** Chhattisgarh state has been divided into three distinguished agro-climatic zones *viz;* Northern hilly region, Chhattisgarh plains and Bastar plateau. The present study site comes under the "*Chhattisgarh plains*" and is located at 21°4' N latitude, 81°39' E longitude with an j altitude of 298 m above the mean sea level. Soil of Chhattisgarh plains varies from lateritic/ *Entisols* (20%), Sandy loam/ *Inceptisols* (45%), clay loam / *Alfisols* (10%) and clayey / *Vertisols* (25%). The soil depth varies from 20 cm in *Entisols* to 100 cm in *Vertisols*, with light undulation and general slopes of 2%. A typical-semi-arid condition of soil appears just after the rainy season due to shallow soil and high rate of percolation. Red lateritic soil *Entisols* locally known as *Bhata* land and as land use classification pattern it comes under marginal wastelands. The experimental site, "Baronda Research Farm", located at 30 km from main campus on Raipur-Balodabazar state highway and has only 10 km aerial distance.

***Climate*:** The climate of study site is dry sub-humid tropical with an average yearly rainfall of 1250 mm. Most of the rainfall (>80%) is received during monsoon season from June to first fortnight of September and a few showers are expected during winters and occasionally during summer months. The average number of rainy days varies from 65 to 79. The mean monthly

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maximum temperature ranges from 27.3°C in December to 42.3°C in May. The mean minimum temperature varies from 13.2°C in December to 28.3°C in May. The maximum temperature goes beyond 45°C in May and minimum below 10°C in December. The relative humidity varies between 70-90% from mid June to March end. Sunshine period in a day is more than 9 hours in summer and less than 7 hours in winter. Evaporation remains higher during April to June (10-13 mm day $^{-1}$) and low during July to February (2.4 to 5.0 mm day $^{-1}$).

RESULTS AND DISCUSSION

Leucaena plantation as high density (1x1m) was consistently observed for its survivorship, height, CD and DBH growth up to clear felling and data pertaining tree biomass, along with NPK nutrients and combustible energy were presented from figure 1 to 9. The physical and chemical characteristics of the soil at different depth under plantation area and adjacent barren area were shown in figure -10.

Survivorship**:** *Leucaena leucocephala* is an exotic species for this country as well as for the undulating entisols wastelands of Chhattisgarh, therefore survivorship of the species was not found impressive and it was 90% initially and stabilized more or less at 60% after 11 years of plantation.

Tree growth**:** *Leucaena leucocephala* as high-density short rotation of plantation crop on red lateritic wastelands showed fast growth rate for its height, collar diameter and diameter at breast height (Fig. 1). The plantation attained 10.51m total height with MAI of 1.0 m yr^{-1} where the CAI was highest during the growth period of 1 to 2 (1.71 m) and 3 to 4 years (2.16 m). Collar diameter achieved 11.50 cm growth with MAI of 0.99 cm however CAI of 1.83cm was recorded maximum during 10th yr of growth. The DBH was recorded 8.57cm with MAI of 0.76 cm though CAI more than 1cm was during 3, 4, 8 and 11 year of growth.

Tree biomass**:** Fresh and dry weight accumulation in plantation of *Leucaena leucocephala* was recorded for all the components *viz;* bole, bole-bark, branch, twigs, foliage and root (Fig. 2). The total dry matter accumulation in a tree was 45.49 $\pm$ 2.35 kg tree^{-1}, where the biomass contribution by different components showed that maximum contribution in tree biomass was shared by bole wood (25.08$\pm$6.87 kg tree^{-1}) with bole bark of 2.52$\pm$0.69 kg tree^{-1}. In high density plantation, the close proximity ceases the formation of lateral branches and thus finally the 7.5 $\pm$ 6.15.and 2.71$\pm$ 1.70 kg tree^{-1} dry matter was found accumulated in branches and twigs respectively (Fig. 2). The biomass accumulated in foliage at was very less *i.e.* 0.93$\pm$0.84 kg tree^{-1}. Roots excavated washed and weighed carefully gave 6.75$\pm$1.81 kg tree^{-1} biomass. Over all share of dry matter accumulation was found in order of bole-wood (55.13%) > branch (16.49%) > root (14.84%) > twigs (5.96%) > bole-bark (5.54%) > foliage (2.04%) respectively (Fig. 9).

Herbage biomass**:** The dry matter production of under storey herbage crop was severely affected by the growth of tree as compared to adjacent open field *i.e.* without tree plot (Fig. 3). The dry matter yield was consistently higher in open (47.2 kg ha^{-1}) than under tree (9.1 kg ha^{-1}) respectively during the 4th year of plantation, and it decreased with advancement of time, but the decreasing trend was very rapid in open than under tree and it reached to 15.6 and 7.1 kg ha^{-1} respectively before the clear felling of plantation. Vegetation of tender plant species invading in the plantation area gets successively established and stabilized as microclimate shifts with the age and growth of tree canopy. Naugraiya and Pathak (2001) reported in their study that production of herbage biomass is governed by species composition, which gradually shifted to unproductive, shallow, hardy perennial species resulting in production of less biomass per unit area when area left over for a period (Fig.3).

Coppice growth**:** Coppicing is a genetic potential of woody species to regenerate and give colonal reestablishment of a second productive cycle. The coppicing behaviour of trees is certainly influenced by the edaphic and climatic status of the sites as well as age and management practices of the growing tree (Singh and Gupta, 1990). After felling of the tree at 6 cm height from the ground 91% stumps of the felled trees were survived and produced coppice shoot with an average of 5 shoots stump per stump (Fig. 4). After one year of coppicing the maximum shoot height was recorded 162.4 cm, and of which only two healthy shoots were allowed to grow and rest were removed, which produced 296 and 142 gm stump^{-1} dry wood and foliage, respectively. The coppice shoot behaviour in *Leucaena leucocephala* was also studied with more or less similar results when grown in silvipasture system in wastelands of central India (IDRC, 1994).

Nutrient harvest**:** Whenever any growing vegetation removed from its growing sites simultaneously many macro and micro nutrients are also removed in the form of organic substances, stored in different tissues, thus a harvested tree represents it's potential to synthesize the organic material of different molecules and its bonded energy. Total nitrogen, phosphorus and potash stored in a whole tree were 92.5, 19.7 and 693.5 gm tree^{-1}, respectively (Fig. 5). The distribution of Nitrogen in trees was in order of bole wood (32.2%) > branch (22.7%) > root (20.4%) > twigs (13.2%) > foliage (6.81%) > bole bark (4.4%), where it was maximum in bole 30.09 gm tree^{-1}and minimum in foliage (4.03 gm tree^{-1}), similar trend was observed for Phosphorus *i.e.* 12.8 gm tree^{-1} in bole and 0.08 gm tree^{-1} in foliage as well as for Potash *i.e.* 361 gm tree^{-1} in bole and 36.8gm tree^{-1} in foliage, respectively (Fig. 6). In case of phosphorus and potash the maximum quantity was shared by bole wood (62.4 & 34.2%) followed by branch (14.3 & 29.9%), root (11.5 & 19.8%) respectively while these were less than 7% in twigs, bole bark and foliage (Fig.7). Thus overall, the maximum nutrients quantity was stored in bole, root and branches *i.e.* woody components where schlerenchymatous tissues are comparatively more (Fig. 9).

Energy harvest**:** Solar energy is captured, synthesized and stored in high bond molecular forms in the cells and ultimately in the tissues or dry matter and it turned in to heat energy on combustions, this energy is useful for mankind for various purposes (Fig. 8). Thus on harvesting of tree biomass we also harvest the energy, which was estimated by bomb calorie meter. The total energy harvested though harvesting of 10.5 years of growth of *L.leucocephala* was 170999 Kcal tree^{-1}, out of which maximum energy was stored in bole-wood (96,909 Kcal tree^{-1}) followed by roots (36,111 Kcal tree^{-1}) and branches (24,458 Kcal tree^{-1}), while foliage bears minimum combustible energy (211 Kcal tree^{-1}). In the combustion of a dry *L. leucocephala* tree after the growth of 10.5 years the share of combustible energy by different tree components was in order of bole wood (56.7%) > root wood (21.1%) > branches (14.3%) > bole bark (4.11%) > twigs (3.68%) > foliage (012%) (Fig. 9). Similar trend of storing combustible energy in different components of *Eucalyptus tereticornis* were observed by Naugraiya *et al* (2005). The storage of combustible energy depends on molecular status and its density in various and their tissues as per genitical inheritant and climatic inhabitant's potential of growing plants

***Soil ameliorations*:** Plantation area gradually changed in its physical and chemical properties as compared to adjacent open barren area where plantation was not done (Fig. 10). The water holding capacity ranged between 26.1 to 33.3% and 22.37 to 29.85% in plantation and open area respectively and in both the cases it was minimum at 0-15 cm soil depth and it increased with increasing the soil depth up to 30 to 60 cm depth (33.4%) and 60 to 100 cm (29.85%) in plantation and open site respectively. Thus the changes were occurred more at 15 to 30 cm (22.8%) followed by 30 to 60 cm soil depth (19.1%) with minimum at 60 to 100cm depth (4.9%) as compared to open field. Organic carbon was recorded maximum under tree at 0 to 15 cm depth (1.10%) and it decreased up to 0.26% at 60 to 100 cm depth. with increasing soil depth. Similar trend was seen in open field with maximum at upper layer (0.70%) and minimum at lower layer of soil (0.20%). The organic content increased by 57% at from 0 to 30 cm depth. Level of nitrogen was recorded higher under *Leucaena* by 111.7% and 58.1% at 0 to 15 cm and 60 to 100 cm soil depth, respectively, than open field where the maximum available nitrogen was recorded 313.6 kg ha^{-1} at 0 -15 cm depth under the *Leucaena* and minimum at 60-100 cm depth in open field (119.0 kg ha^{-1}).

Phosphorus in form of P_2O_5 was recorded maximum under *Leucaena* at 0 -15 cm soil depth and minimum in open field at 60 -100 cm depth in open field (23.9 kg ha^{-1}). Potassium available in soil was ranged 160.4 kg /ha at 60-100 cm depth to 258.4 kg /ha at 0-15 cm depth under *Leucaena* where its quantity was increased by 68.9, 50.4,31.7 and 21.0% than open field at 0-15, 15-30, 30-60 and 60-100 cm soil depth respectively (Fig. 10). The red lateritic soil is reported very poor in respect to organic matter (Singh and Totey, 1985) and this was reflected periodically in the growth and productivity status of plant species (Roy *et al*, 1998). The cultivation of woody species gave comparatively poor performance but their presence in such soil play an important role to enhance the organic contents gradually over a period, which not only help to change soil properties but also provide nourishment to growing species (Singh and Singh, 1998). Agrawal (1996) also worked out similar results of tree plantation in their soil-water conservation studies in red lateritic soil of Chhattisgarh plain (Naugraiya and Puri, 2001).

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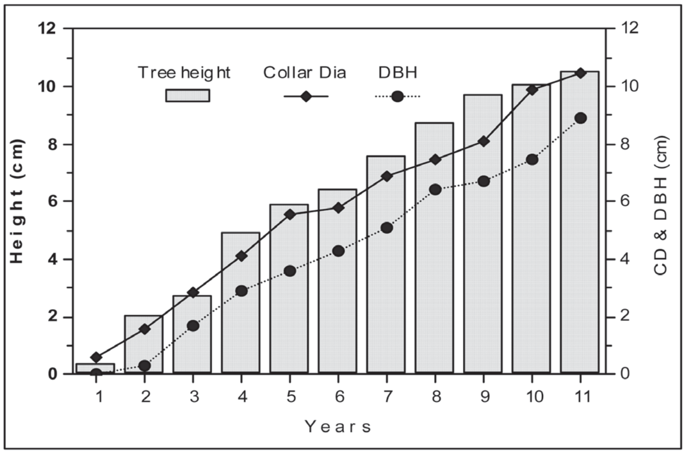


Fig.1- Performance of *L.leucocephala* at 10 yrs of growth

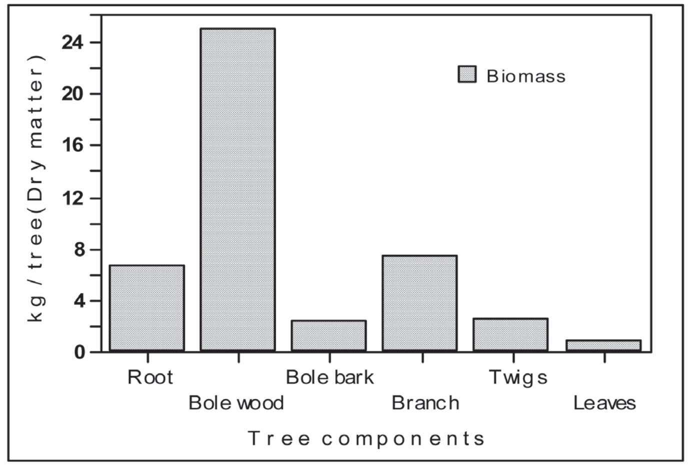


Fig.2- Biomass Production of *L.leucocephala* at 10 yrs of growth

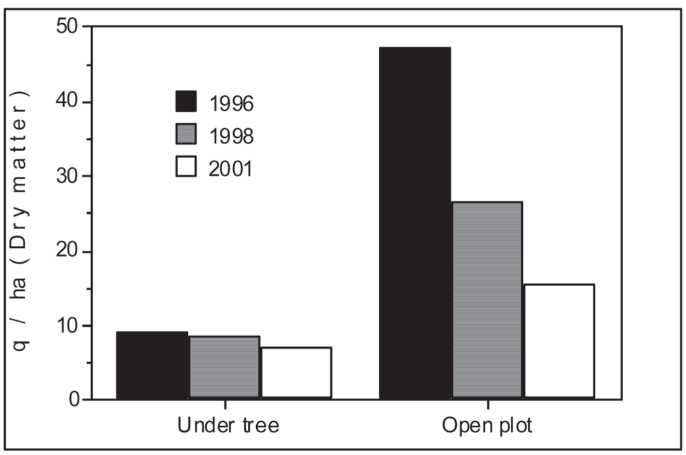


Fig.3- Biomass production of under storey herbage vegetation

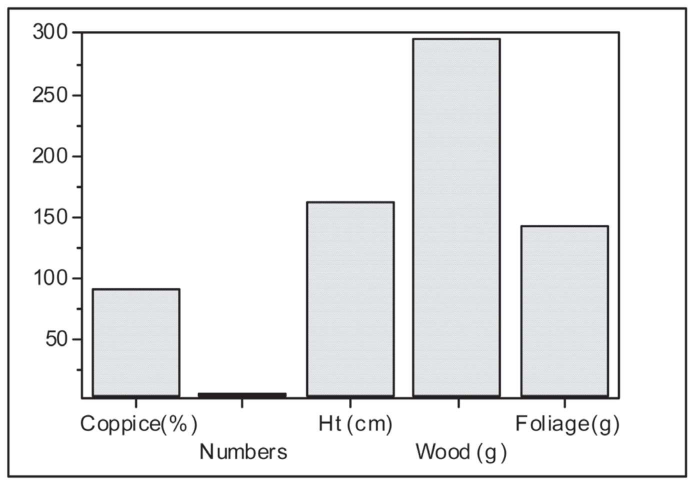


Fig.4- Coppice behaviour of *L.leucocephala* at 10 yrs of growth

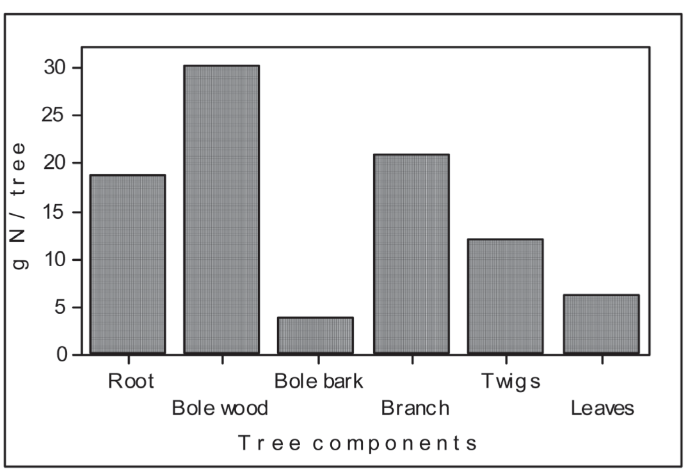


Fig.5- Harvesting of Nitrogen in *L.leucocephala* at 10 yrs of growth

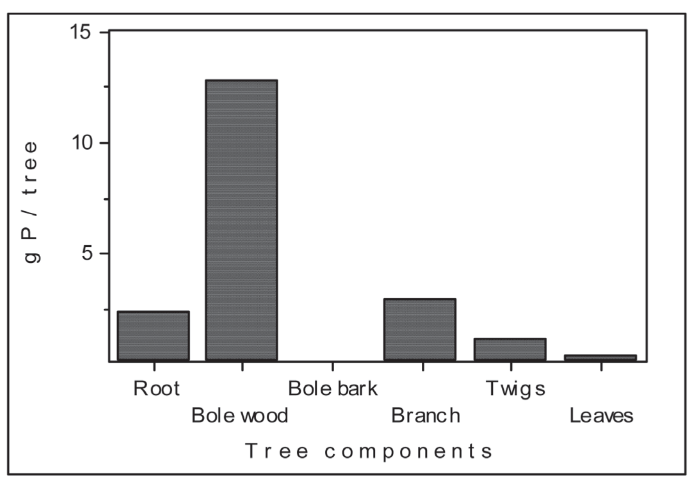


Fig.6- Harvesting of Phosphorus in *L.leucocephala* at 10 yrs of growth

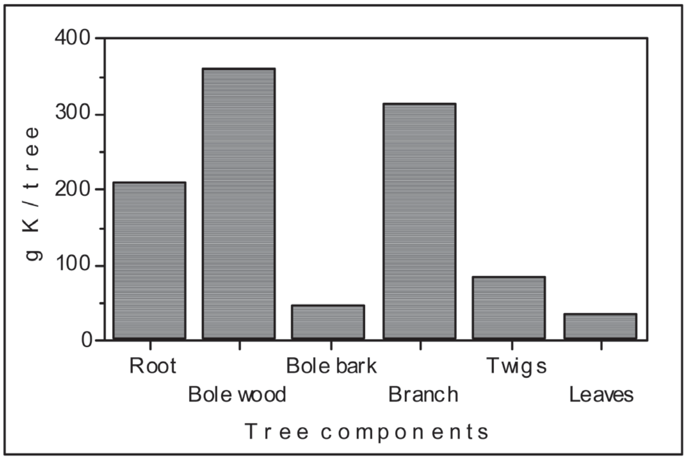


Fig.7- Harvesting of Potassium in *L.leucocephala* at 10 yrs of growth

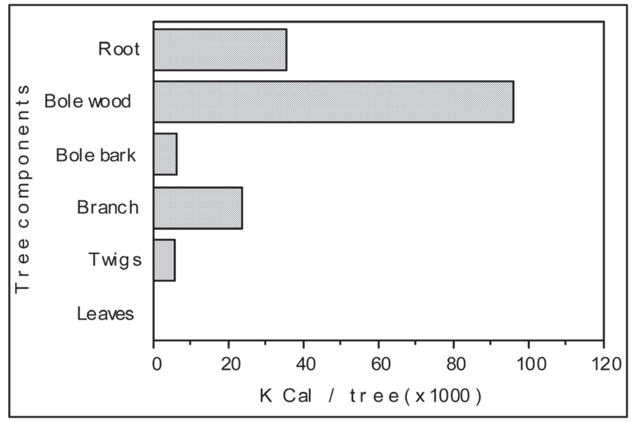


Fig.8- Harvesting of combustible energy in *L.leucocephala* at 10 yrs of growth

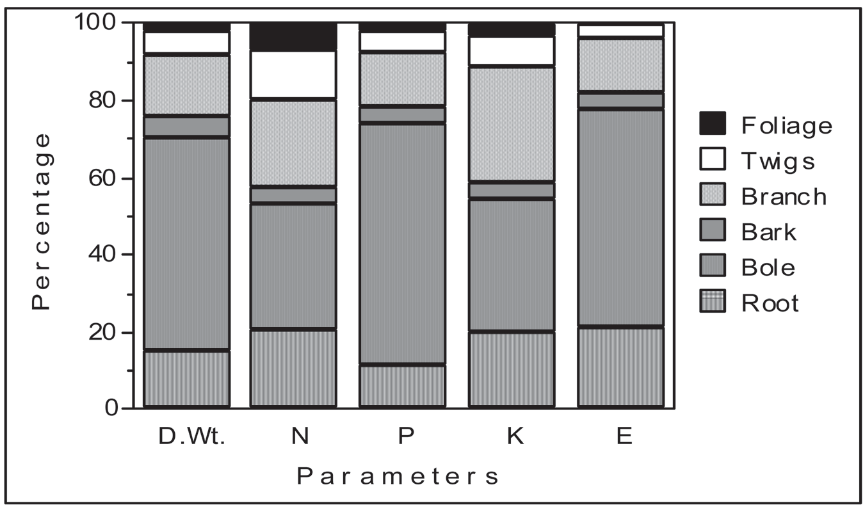
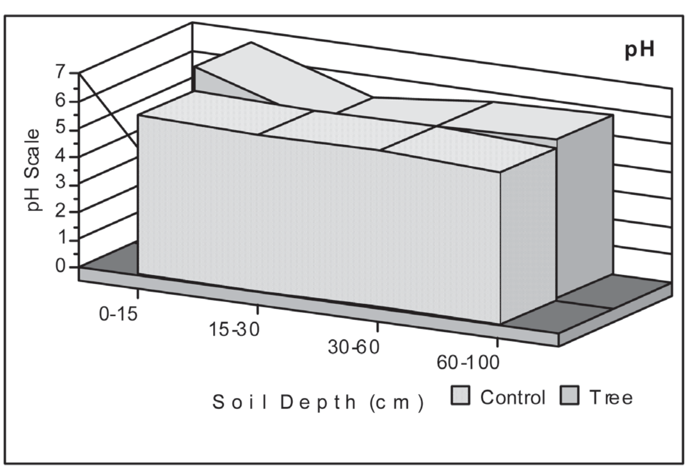
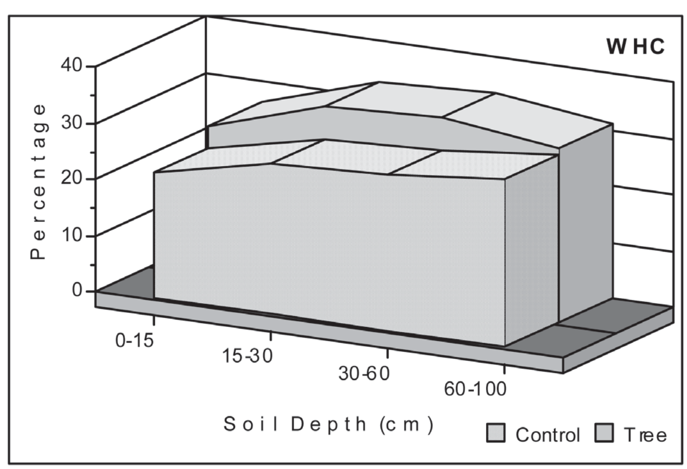


Fig.9- Distribution of biomass, N, P, K and combustible energy in different parts of *L.leucocephala*





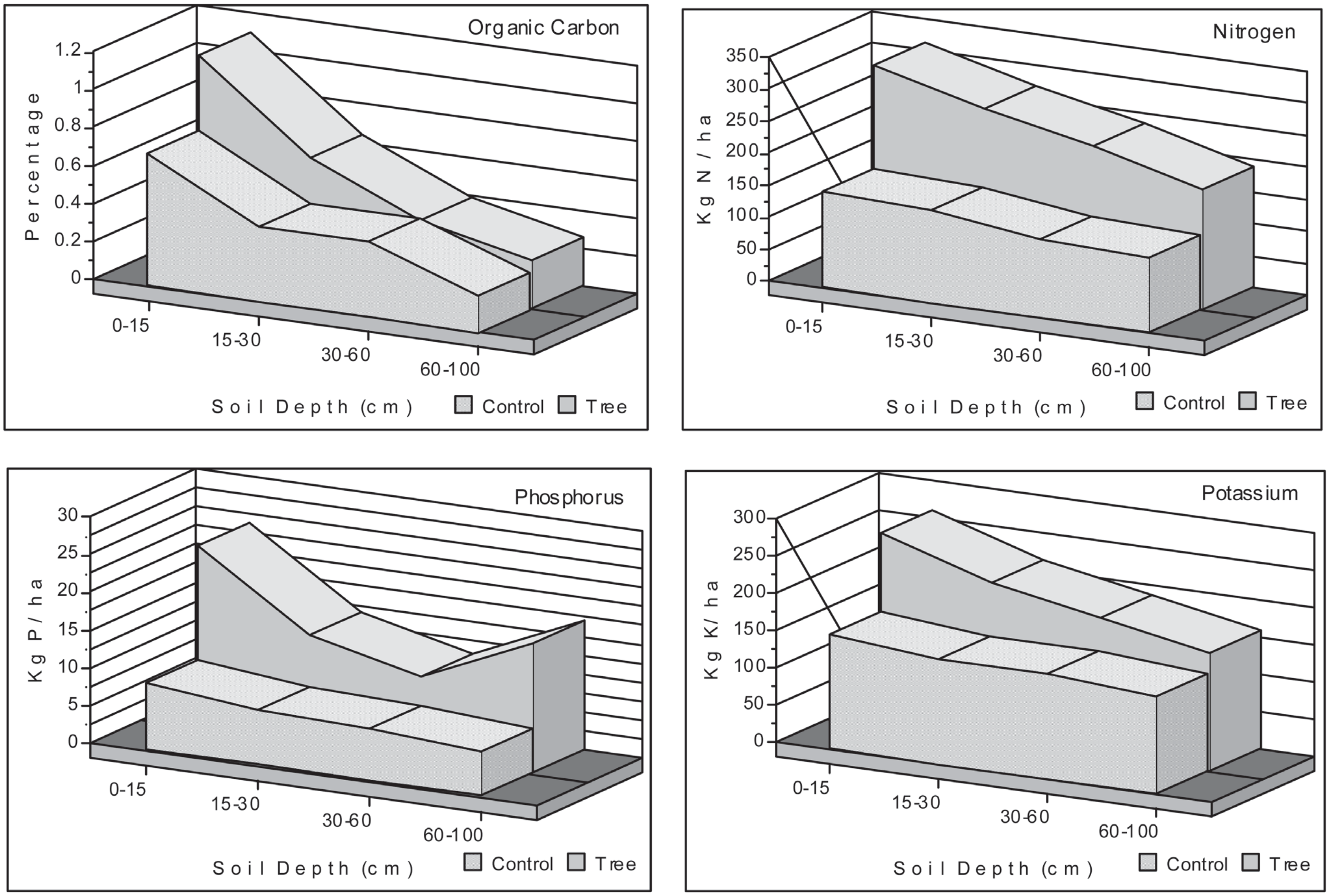


Fig.10- Effect of *L.leucocephala* on Soil properties after 10 yrs of growth

Harvesting of *Calotropis procera* Flowers from Different Agro-climatic Zones of Rajasthan for their Medicinal Use

Mala Rathore * and R.K. Meena

INTRODUCTION

Medicinal plants constitute a resource, which has been used traditionally by Indians for the last two millennia. It is reported that in India, 4,635 ethnic communities, including over one million folk healers, use around 8,000 species of medicinal plants (Hariramamurthi *et al*, 2007). They are also increasingly becoming economically important due to the growing demand for herbal products in the domestic and global market. Over 90% of the medicinal plants traded in India are harvested from the wild, most of them in an unsustainable manner (FRLHT, 2007). Due to an increasing demand for medicinal plants and a loss and fragmentation of natural habitats, around 300 species of Indian medicinal plants have been assessed as under threat in the wild (based on International Union for Conservation of Nature (IUCN) Red List Criteria). Around 1,000 species are estimated to be facing various degrees of threat across different biogeographic regions in the country (FRLHT, 2007). In addition to the threat to medicinal plants, gradual erosion of traditional knowledge and health practices is leading to loss of conservation concern on the part of local communities.

By means of the secondary metabolite biosynthetic pathways, plants produce a wide range of compounds of various chemical classes which probably are effective in their defence against infection (Harborne, 1999). The activity of medicinal plants is due to the presence of these secondary metabolites. The biosynthesis of these compounds although controlled by genetic factors is affected strongly by environmental influences. As a result there are fluctuations in the concentrations and quantities of secondary metabolites with age, season and region. *Calotropis procera* is an erect, tall, large, much branched and perennial shrubs or small trees that grow to a height of 5.4 m. It belongs to family Asclepiadaceae and is found in most parts of the world in dry, sandy and alkaline soils and warm climate. In India it is found widely distributed up to an altitude of 1050 m from Punjab, Rajasthan to Assam and Kanyakumari. It grows well on rubbish heaps, waste and fallow lands, roadsides, sand dunes and as a weed in agricultural lands (Sastry and Kavathekar, 1990).

In the sandy desert soils of Rajasthan, *Calotropis procera,* a soft wooded evergreen perennial shrub with conspicuous purplish pink flowers is one of the most common and most impressing plants (Bhandari, 1990; Shetty and Singh, 1987). The plant, commonly called as Aak, is well known for its medicinal use. *Calotropis* is used as a traditional medicinal plant (Rastogi and Mehrotra, 1991; Oudhia and Dixit, 1994;) with unique properties (Oudhia and Tripathi, 1997, 1998). Traditionally, it is used alone or with other medicinals to treat common diseases such as fevers, rheumatism, indigestion, cough, cold, eczema, asthma, elephantiasis, nausea, vomiting, diarrhoea (Caius, 1986; Das, 1996). According to Ayurveda, dried whole plant is a good tonic, expectorant, depurative, and anthelmintic, and is also used as Homoeopathic drug (Ghosh, 1988; Ferrington, 1990). Flowers of *Calotropis procera* are bitter, digestive, astringent, anthelmintic, tonic, anti-inflammatory, spasmolytic, stomachic, hepatoprotective and antioxidant. They have been used in traditional medicine in treatment of cold, asthma, catarrh, anorexia, inflammations and tumours (Agharkar, 1991; Warrier *et al,* 1996). *Calotropis* flowers are available throughout the year and collected as per need of the Industry. It was proposed to study the variation of secondary metabolites in flowers of *Calotropis procera* in different regions of Rajasthan so as to identify the best region for their collection.

MATERIALS AND METHODS

On the basis of climatic conditions and agricultural produce, Rajasthan has been divided into nine Agro-Climatic Zones (ACZ). *Calotropis procera* has been reported to be distributed in all the zones of Rajasthan. The flowers were collected in single season (winter) so as to nullify the effect of seasonal temperature. Reconnaissance surveys were undertaken to different places in various ACZs in January-February 2007 and flowers were collected (Table 1). The fresh weight of flowers was taken and they were dried in shade and dry weights recorded (Table 2). The flowers were pulverized and extracted with petroleum ether 60^0-80^0 followed by extraction with methanol and the total extractives (Petroleum ether extractives, PEE, and Methanol extractives, ME) were determined. The extracts were filtered and concentrated to dryness and yield of total extractives determined. ACZ IIIA is a zone with slightly higher rainfall. On the western side, the region is flanked by the low Aravalli hills which extend from the south-west to the north-east. The annual rainfall of the region varies from 50 to 60 cm with an increasing trend towards the east. Zones IA and IIA are both with less rainfall (10-40 cm). Zone IA comprises of the most arid part of the state. Zone IIA falls in the

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Transitional Plain. The area is covered with sand dunes and inter-dunal sandy plains. The relative humidity is generally high in ACZ V. The annual rainfall varies from 60 to 85 cm. The development of canal irrigation system with a series of dams and barrages has made this area rich in agricultural production. Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar dams together with Kota Barrage have generated enough resources of canal water for irrigation (Govt. of Rajasthan, 1994).

The extracts were analysed for sterols and alkaloids using standard procedures (Harborne, 1973; Trease and Evans, 1989 and Sofowora, 1993). Total sterol and alkaloid content was estimated by method of Akihisa *et al*, 1990 and Higuchi and Bodin, 1961.

TABLE 1: **Collection of *Calotropis procera* flowers from different Agroclimatic Zones of Rajasthan**

Agro-Climatic Zone	Districts lying in the zones	Place of collection
IA(Arid Western Plain)	Bikaner, Jodhpur, Jaisalmer, Barmer	Jaisalmer
IB(Irrigated North-Western Plains)	Ganganagar, Hanumangarh	Suratgarh
IIA(Transitional Plain of Inland Drainage)	Sikar, Jhunjhunu, Churu, Nagaur	Churu
IIB(Transitional Plain of Luni Basin)	Pali, Jalore, Sirohi	Pali-Sirohi
IIIA(Semi-arid Eastern Plain)	Jaipur, Ajmer, Tonk, Dausa	Jaipur
IIIB(Flood Prone Eastern Plains)	Alwar, Bharatpur, Dhaulpur, Sawaimadhopur, Karauli	Alwar
IVA(Sub-humid Southern Plains & The Aravalli Hills)	Sirohi, Udaipur, Rajsamand, Chittorgarh, Bhilwara	Udaipur
IVB(Humid Southern Plains)	Dungarpur, Banswara, Chittorgarh	Banswara
V(Humid South-Eastern Plains)	Jhalawar, Kota, Bundi, Baran, Sawai madhopur	Kota

Statistical Analysis

The data was analyzed through one way ANOVA using SPSS software.

RESULTS AND DISCUSSION

Higher dry weights were recorded in ACZ IA, ACZ IB, ACZ IIB and ACZ V. These are the regions falling in arid zone except ACZ V Lowest dry weight was found in flowers from ACZ IV B.

TABLE 2: **Fresh, dry weight & moisture contents of *Calotropis procera* flowers from nine different Agroclimatic Zones**

Agro-Climatic Zone	Fresh weight (Kg)	Dry weight (Kg)	Moisture (%)
IA	6.5	0.935	85.6
IB	10	1.04	89.6
IIA	11	1.16	89.5
IIB	12	1.82	84.8
IIIA	10	0.845	91.6
IIIB	8	0.712	91.1
IVA	8	0.832	89.6
IVB	4.5	0.328	92.7
V	14	1.624	88.4

The results showed that maximum content of PEE was found in ACZ IIIA. Minimum content of PEE was found in ACZ IA and ACZ IIA.

Results show that the trend for PEE is in accordance with the earlier reports that more moist and cooler conditions lead to higher fat storage (Si *et al*, 1999; Tripathi *et al*, 1997). The yield of ME was maximum from ACZ V (16.16%) and ACZ IA (12.93%). Minimum ME was obtained from ACZ IIIA (7.05%) and IB (7.65%). As can be seen from the results that but for ACZ V, the amounts of PEE and ME are inversely related. The higher values in ACZ V are thus attributed to leaching/dilution effects. Maximum yield of total extractives was from ACZ V (17.71%) and minimum from ACZ IB (9.43%).

TABLE 3: **Yield of total extractives of *Calotropis procera* flowers in petroleum ether and Methanol**

ACZ	Petroleium ether extract (%)	Methanol extract (%)	Total Extractives (%)
IA	1.42	12.93	14.35
IB	1.78	7.65	9.43
IIA	1.41	11.38	12.79
II B	1.61	12.09	13.70
IIIA	1.98	7.05	9.03
III B	1.51	13	14.51
IVB	1.74	9.96	11.70
IVA	1.67	9.85	11.52
V	1.55	16.16	17.71

Screening of the ME showed the presence of alkaloids and sterols. Thus, quantitative estimation of sterols and alkaloids was carried out. Maximum content of sterols and alkaloids was obtained from ACZ IA. The maximum amount of total sterols obtained was 2.65% and total alkaloids was 8.03% from this zone. These results confirm the higher extractives from ACZ V due to leaching effect of water.

TABLE 4: **Yield of total sterols and alkaloids in different Agroclimatic zones of Rajasthan**

S.N.	ACZ	Total Sterols (%)	Total alkaloids (%)
1	IA^{e6}	2.65	8.03
2	IB^{a3}	1.19	3.97
3	IIA^{d4}	2.17	5.26

4	II B^{e1}	2.63	3.05
5	IIIA^{c3}	1.92	4.09
6	III B^{e5}	2.54	6.65
7	IVB^{c2}	1.95	3.63
8	IVA^{b1}	0.83	3.08
9	V^{d2}	2.31	3.63

Common superscripts show no significant difference between means (a-e for sterols; 1-6 for alkaloids)

Table 5: **ANOVA table for sterol & alkaloid content in *Calotropis procera* flowers in different agroclimatic zones of Rajasthan**

Source of variation	df	Total sterols		Total alkaloids	
		F value	P value	F value	P value
Agroclimatic zones	08	81.952	0.000	1029.62	0.000
Error	18				

Duncan multiple range test (DMRT) was applied to compare the means at 5% level of significance. The analysis shows that there exists significant difference between the steroid content in various agroclimatic zones viz. F=20.163, p=0.000.Similarly, there exists significant difference between the alkaloid content in various agroclimatic zones viz. F=1029.62, p=0.000.

CONCLUSIONS

Significant regional variations in secondary metabolite content were found to occur in flowers of *Calotropis procera* with maximum content found in flowers from ACZ IA. For obtaining optimum concentration of active constituents in *Calotropis procera* flowers these should be harvested from Jaisalmer region in Rajasthan. *Calotropis* flowers have high medicinal value and have been traditionally used in treatment of a number of human ailments. The annual collection is about 500-1000 kg per year from Rajasthan. Present results can be used for collection of quality raw material in sustainable manner for the Ayurvedic formulations.

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Performance of Different Agro-forestry Systems in Semi-arid Ecosystem

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INTRODUCTION

Increasing human and livestock populations have caused rapid degradation of soil, forest vegetation and water resources. Agro-forestry has become vital in terms of balancing the conflicting issues of conservation of natural resources and their usage in sustaining agricultural development and rural livelihood. Agro-forestry plays an important role in the economy of arid and semi-arid regions due to high risk involved with arable farming, which is affected by low and highly variable rainfall, low soil fertility and high wind velocity. The farmers are allowed growing scattered trees and shrubs in their agriculture fields or grazing fields to sustain their life. The trees provide fodder, fruit, vegetable, fuelwood, timber and fiber for sustaining rural livelihood. Agro-forestry provides the fodder, fuelwood and timber to the rural people.

Agro-forestry is a farming system integrating crop and /or livestock with trees and shrubs. The resulting biological interactions provides multiple benefits i.e. diversified farm income, increased biological production, better water quality and improved habitat for both humans and wildlife. Not all forms of agro-forestry/ systems of management may be of general relevance, but the options available from the traditional practices enable their manipulation to meet location-specific requirements. Therefore, performance of various agro-forestry systems was studied in semi-arid part of Haryana.

MATERIAL AND METHODS

Experimental site

Different agro-forestry models were developed at Chaudhary Charan Singh Haryana Agricultural University Regional Research Station, Bawal, located in the low rainfall zone of the southern Haryana (28.1°N, 76.5°E and 266 m above mean sea level). In general, May-June are the hottest, while December-January are the coldest months of the year. The site is characterized by inadequate precipitation (300-500 mm) during monsoon (July – September) and is also quite erratic. The number of rainy days in a year varies between 15 to 25. During summer, the maximum temperature reaches as high as 47°C. Whereas, during peak winter months of December and January, the average minimum temperature is recorded around 4-5°C, which at times, reaches as low as 0°C. Between October and March, weather remains almost dry except occasional light showers. Thereafter, it is quite dry till June. High temperature along with peak evapotranspiration rate of 5.3 mm/ day is observed from July to October and 2.7 mm/day from November to February. The maximum evapotranspiration rate of 14 mm/day is recorded in the month of June. The experimental details of different models are given below:

1. Agri-silviculture system

a). Prosopis cineraria (Khejri) based Agro-forestry model:

Two separate experiments were conducted in 20 years old trees of *Prosopis cineraria* planted at a spacing of 6 x 5 m. In the inter spaces of trees, the field crops were sown on a plot size of 5x4 m^2 with 4 replications in experiment I and 5 replications in experiment II. In experiment I, during rainy season (Kharif) the field crops cowpea (*Vigna unguiculata*), clusterbean (*Cyamopsis tetragonoloba*) and pearl millet (*Pennisetum americanum*) were grown separately for grain as well as fodder, whereas buffel grass (*Cenchrus ciliaris*) was raised only for fodder. While in winter (Rabi), todia (*Brassica tournefortii*) for fodder followed all the Kharif crops, except buffel grass. In experiment II, mustard (*Brassica juncea*) and taramira (*Eurica sativa*) were grown for grain in winter on conserved moisture in kharif fallow plots. The crops were grown as per the recommended package of practices for the region. The trees were lopped once a year during September-October, before sowing of winter crops.

b). Jatropha based Agro-forestry model

Three months old nursery raised bare rooted seedlings of Jatropha were planted at a spacing of 4x3 m. The plants were raised following agro-techniques recommended for the region (Kaushik and Kumar, 2004). Ten gram Urea, 120 gram SSP and 16 gram MoP was applied at the time of transplantation. Weeding and cleaning in plant basin was undertaken as and when required. Plants were protected against termite by applying chlorpyriphos @ 10 ml per plant with irrigation water. Proper training and pruning of plants was also performed. The cultivation of crops in the interspaces of plants was started after one year of planting, pearl millet (*Pennisetum americanum*) and daincha (*Sesbania aculeata*) were grown separately for grain as well as fodder whereas watermelon (*Citrullus lanatus*) was raised only

* CCS Haryana Agricultural University Regional Research Station, Bawal 123051, Haryana, India

for fruit yield and also repeated with same treatments during next year. The crops were raised as per recommended agronomy of the region. The plants were pruned once a year during February. During the period of experimentation, the crops were raised under rainfed conditions without any supplemental irrigation.

2. Agri-silvi-horticulture system

Two agri-silvi-horti models were studied:

1. The combinations of different tree species namely shisham (*Dalbergia sissoo*) + aonla (*Embilica officinalis*), shisham (*Dalbergia sissoo*) + guava (*Psidium guajava*), khejri (*Prosopis cineraria*) + aonla (*Embilica officinalis*) and khejri (*Prosopis cineraria*) + guava (*Psidium guajava*) were planted during October 2000 at a spacing of 6 x 6 m. Young budded plants of *P. guajava*, *E. officinalis* and seedlings of *D. sissoo* and *P. cineraria* raised in polythene bags were used as planting material. The plants were raised following cultural practices recommended for the region. Plants were protected against termite by applying endosulfan/ chlorpyriphos (2 ml/L) with irrigation water. After establishment of trees the crop sequences viz., ridgegourd (*Luffa acutangula)*-tomato (*Lycopersicon esculentum)*, moongbean (*Vigna radiata)* - fallow and clusterbean (*Cyamopsis tetragonoloba)* - fallow were raised in the interspaces of the trees. Ridgegourd and tomato were raised with drip irrigation while moongbean and clusterbean were raised as rainfed.

A single lateral drip line was placed on the soil surface in each tree row. Each tree was serviced by two drippers (emitters) having discharge rate of 4.01/h. During the first 6 months after planting, all trees were irrigated equally to ensure the uniformity of plant growth. The trees were subjected to three drip irrigation treatments viz., T_1 (100% ETc), T_2 (70% ETc) and T_3 (40% ETc) with three replications per treatment distributed in split plot design. The water applied in T_1 was considered sufficient to fully satisfy the needs of the crop (100% ETc). Irrigation treatments were based on crop evapotranspiration (ETc, mm), considering rainfall and was derived from class A Pan Evaporation (D&P; 1977) placed in the proximity of a standard meteorological station adjacent to the experimental field. The total amount of irrigation (litre/plant) applied in T_1 was calculated as:

Water requirement = KP x KC x EPAN x canopy area (Dorrenbos and Pruitt, 1977)

Where KP is the pan coefficient and KC the crop coefficient. EPAN is pan evaporation. Canopy area was increased generally in accordance with the increase in crown spread.

2. Treatments comprised of four silvihorticulture systems i.e. *Dalbergia sissoo*, + *Morus alba, D. sissoo+ Embilica officinalis, Azadirachta indica + E. officinalis* and *Azadirachta indica + Morus alba* in 2:1 ratio and four crops i.e. pearl millet (*Pennisetum americanum*) and clusterbean (*Cyamopsis tetragonoloba*) in kharif and Raya (*Brassica juncea*) and chickpea (*Cicer arietinum*) in rabi season were raised in interspaces of various silvihorticulture systems. The crops were raised under rainfed conditions. The cultivation of the crops was started after one year of establishment of trees. In half of the planted area, kharif crops i.e. pearl millet and clusterbean were raised and in remaining half, the rain water was conserved in soil for raising raya and chickpea crops in Rabi season. The above crops were also raised as sole crops.

3. Silvipastoral: The treatments comprised of two years old three top-feed tree species, namely, *Cholophospermum mopane* (Mopane), *Acacia bivenosa* and *Hardwikia binnata* (Anjan tree) alongwith control (no tree) and five fodder crops: pearl millet (*Pennisetum americanum*) cowpea (*Vigna unguiculata*), buffel grass (*Cenchrus ciliaris*), peralmillet + cowpea (2:1) buffel grass + cowpea (2:1). The fodder crops were raised in interspaces of trees during kharif season under rainfed conditions. Six month old seedlings of tree species were planted at a spacing of 6 x 6 m during July 1997. Weeding and cleaning in plant basin was undertaken as and when required. Plants were protected against termite by applying chlorpyriphos @ 10 ml per plant with irrigation water. Proper training and pruning of plants was also performed

RESULTS AND DISCUSSION

1. Agri-silviculture system

a) Prosopis cineraria (Khejri) based Agro-forestry model

The green fodder yield of all the fodder crops was influenced by the tree component khejri during all 3 years of study. In kharif season, the fodder yields of all crops except buffel grass were significantly higher, when grown in association with trees as compared to sole cropping. The fodder yield was maximum in pearl millet and minimum in buffel grass when the fodder crops were grown either sole or in association with trees. The average increase in yield of green fodder due to canopy cover of the trees was of the order of 24.1%, 25.4% and 12.3% in cowpea, pearl millet and clusterbean, respectively (Table1). In winter season, there was no significant variation in fodder yield of *B. tournefortii* when it followed cowpea, clusterbean or pearl millet in kharif. In general the fodder yield of *B. tournefortii* was higher under trees as compared to sole cropping (Table 1).

The grain yields of both kharif as well as rabi crops were higher under trees than sole cropping during all the years of study except 3rd year when the difference in mustard yield was non – significant between sole cropping and in association with khejri. On mean basis, amongst kharif crops, pearl millet yielded highest, whereas in rabi, mustard yielded more than taramira under both the systems of planting (Table 2&3).

Maximum net returns (Rs. 15197/ha) and benefit-cost ratio (3.73) was obtained when pearl millet in kharif followed todia in rabi under khejri trees (Table 4). In the crop sequences, wherein kharif crops for grain were grown in rotation with fodder todia in rabi, association of khejri with cowpea-todia sequence earned maximum net returns (Rs.13579/ha) and benefit-cost ratio (3.34) followed by cluster bean-todia (Table 5). Whereas in Rabi, when grown under khejri, mustard earned net returns of Rs. 21377/ha with a benefit –cost ratio of 4.48 against taramira which earned Rs. 10,732/ha with a benefit- cost ratio of 2.76 (Table 3).

In khejri-based agri-silvicultural system, the crop grown between the interspaces of trees showed more yields than sole cropping. This may be due to less competition between trees and crops for moisture and light, as khejri is a deep rooted tree species with its monolayered tree canopy (Bisht and Toky, 1993). It may also be ascribed to improved soil fertility (Young, 1989) and ameliorative influence of shade in hot-dry environment.

Kumar et al. (1992) also recorded higher yields from pearl millet, clusterbean and cowpea in association with khejri.

b) Jatropha based Agro-forestry model

The fodder (green and dry) yields of all crops were not influenced by the Jatropha plants during both the years of study. However, maximum green fodder yield was recorded in daincha (24.00 and 24.10 t/ha during the 1st year and 2nd year, respectively) followed by pearl millet which was significantly higher than other crops. The trend of variation in dry fodder yield of forage crops in association with Jatropha was similar to green fodder yield. Daincha showed maximum biomass (7.59 and 7.65 t /ha during the 1st year and 2nd year, respectively) in association with Jatropha which was at par with sole cropping of daincha (Table 6). This might be due to less competition between trees and crops for light, moisture and nutrients during the initial years of growth of Jatropha. These results are in agreement with the findings of Kaushik and Kumar (2003a). Kaushik et al., 2000 also observed that yields of different arable crops were not significantly influenced in association with tree species.

The grain yield for all arable crops was at par with and without Jatropha. Maximum grain yield (1.35 t/ha, 1st year and 1.30 t/ha, 2nd year) was harvested from pearl millet in association with Jatropha which was statistically at par when the pearl millet was raised as sole (Table 7). These results are in agreement with those of Kaushik et al. (2002), Khattak et al. (1980) and Kaushik and Kumar (2003) who reported at par or higher yields of wheat, pearl millet, cluster bean, with trees in different agro forestry systems.

2. Agri-silvi-horticulture system

The yields of different field crops grown in the interspaces of different tree species were at par, indicating that the silvi-horti system (different tree combinations) of 2-year age did not affect the yield of inter crops. Irrigation treatments influenced the yield of tomato and ridgegourd significantly. Maximum tomato yield (46.22 t/ha) was obtained when the plants were irrigated on the basis of 100% ETc. The yield of moongbean and clusterbean was non-significant under all the irrigation levels (irrigation applied only to trees) as these crops were grown as rainfed. (Table 8 and 9).

The yield of arable crops was similar under different tree combinations. This might be due to less crown area and low interception of light by trees in the initial years. Earlier Evans et al., (1976) have argued that although growth of plant species is controlled by various environmental factors, but among these light is most important. These results are in agreement with the finding of Gill (1998) and Kaushik et al, (2002).

Ridgegourd - tomato sequence was most remunerative with the all the tree species followed by clusterbean - fallow sequence. However, negative returns of Rs 1300 were obtained under 70% irrigation level with *D. sissoo* and *P. guajava* tree combination for clusterbean- fallow rotation. Negative returns from moongbean-fallow rotation may be due to drought as the -crop was raised rainfed (Table 10).

The economic viability of a system is the most important consideration for adoption of any technology at the farmer's field. Among various crops ridgegourd-tomato rotation under all the tree species gave maximum net returns. This might be due to higher yield of these crops. Moongbean-fallow, gave negative returns. This might be due to less yield of moongbean because of the drought. These results are in agreement with the findings of Suresh and Rao (1989), Kaushik et al., (2002).

The present study proves that the different tree species did not affect the yields of arable crops during the establishment period. *D. sissoo* and *P. cineraria* can be established with 40% ETc of water replenishment. The irrigation levels influenced the yield of tomato and ridgegourd. The most economic crop sequence was ridgegourd-tomato. Further studies are in progress to work out the water requirement and irrigation scheduling of different agri-silvi-horti systems.

The average grain and straw yields of pearl millet, clusterbean, raya and chickpea were maximum under sole cropping, but were statistically at par to those obtained from interspaces of various silvihorticultural systems (Table 11). The results clearly indicated that different tree combinations did not offer any competition with the associated arable crops up to initial four years of their plantation. These results are in agreement with the findings of Gill (1998). Jaimini and Tikka, 1998 also reported higher yields of different crops in khejri based agri-silviculture system.

The net returns from all the crops were appreciably higher under sole cropping than silvi-horticultural systems. The lower net returns from arable crops in agri-silvi-horti system were mainly due to the fact that during the initial three years, tree/fruits required an average cost of Rs. 3812/ha/year for their establishment without any economic return. Among various crops raya gave higher gross as well as net returns both under sole cropping and silvi-horticulture systems (Table 12).

3. Sivipastoral system

The top-feed tree species did not show any effect on fodder yield of crops as compared to control. However, cowpea+pearl millet showed maximum yield under all the tree species, which was significantly higher than the other crops (Table 13).This might be due to less competition between trees and crops for light, moisture and nutrients during the initial years of growth of tree species. Maximum firewood 0.20 t/ha and 0.27 t/ha produced by *A. bivenosa* during 1st and 2nd year, respectively. *A. bivenosa* also yielded maximum fodder yield (2.5q/ha). The small twigs harvested through prunings start yielding some firewood from 2nd year itself. Rai (1999) reported similar firewood production under silvipastoral system.

SUMMARY

Integration of trees with agricultural crops has been in vogue since time immemorial. In recent years efforts have been made to grow trees and crops together so as to get the best advantage of their association for improved soil fertility, controlling erosion, maintaining physical properties, promote efficient nutrient cycling, leading to higher biomass productivity and sustainability. The need of agro-forestry has been necessitated in many parts of the country, which face several agricultural and ecological problems, predominant of which are soil degradation, large scale deforestation, increasing population pressure of human beings and livestock, and decreasing land: man ratio. Increasing human and livestock populations have caused rapid degradation of soil, forest

vegetation and water resources. Agro-forestry has become vital in terms of balancing the conflicting issues of conservation of natural resources and their usage in sustaining agricultural development and rural livelihood. Agro-forestry plays an important role in the economy of arid regions due to high risk involved with arable farming, which is affected by low and highly variable rainfall, low soil fertility and high velocity wind. The question, therefore, is how to optimize productivity and ensure sustainability. In particular, the practices need to be oriented towards ecologically sound and farmer-based solutions. Not all forms of agro-forestry/ systems of management may be of general relevance, but the options available from the traditional practices enable their manipulation to meet location-specific requirements. Therefore, performance of various agro-forestry systems was studied in semi-arid part of Haryana. The different agro-forestry systems viz. agri-silvi, agri-silvi-horti and silvi-pastoral were developed and their performance along with economics is presented in this paper. All the agro-forestry systems were found economical during their initial years of establishment

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Table 1: **Green fodder yield (t/ha) of different crops grown sole and in association with khejri trees**

Crop sequence	Kharif				Rabi			
	1st year	2nd year	3rd year	Mean	1st year	2nd year	3rd year	Mean
With khejri								
Cowpea-todia	10.01	10.45	13.52	11.33	24.32	19.43	18.03	20.59
Pearl millet -todia	13.84	12.57	18.15	14.85	23.09	18.86	16.52	19.49
Clusterbean-todia	6.10	7.32	8.51	7.31	23.95	18.10	17.22	19.76
Buffel grass-buffel grass*	4.25	6.22	7.78	6.08	-	-	-	-
Sole cropping								
Cowpea-todia	8.16	8.87	10.34	9.12	21.83	17.96	16.54	18.78
Pearl millet -todia	10.73	10.15	14.57	11.82	20.11	15.22	13.83	16.39
Clusterbean-todia	5.22	6.10	7.27	6.20	20.75	16.88	15.77	17.80
Buffel grass-buffel grass*	5.07	6.51	8.03	6.54	-	-	-	-
CD (5%)	1.14	1.05	1.20	-	1.84	1.47	1.32	-

**Perennial grass was dormant in rabi*

Table 2: **Production (t/ha) of different grain crops rotation with fodder todia in rabi grown sole and in association with khejri**

Crop sequence	Kharif				Rabi			
	1st year	2nd year	3rd year	Mean	1st year	2nd year	3rd year	Mean
With khejri								
Cowpea-todia	0.85	0.98	0.92	0.92	9.90	7.92	7.65	8.49
Pearl millet -todia	1.20	1.35	1.26	1.27	8.96	7.00	6.00	7.32
Clusterbean-todia	0.87	0.78	0.81	0.82	10.00	6.96	7.00	7.98
Sole cropping								
Cowpea-todia	0.70	0.85	0.80	0.78	9.00	7.60	7.00	7.86
Pearl millet -todia	1.00	1.14	1.05	1.06	8.34	6.00	5.96	6.76
Clusterbean-todia	0.79	0.62	0.67	0.69	8.75	7.25	6.45	7.48
CD (5%)	0.06	0.13	0.11	-	0.54	0.23	9.19	-

Table 3: **Grain yield (t/ha) and economics of oilseed crops grown as sole or in association with khejri**

Crop sequence	Kharif 1st year	2nd year	3rd year	Mean	Economics Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net Income (Rs/ha)	B : C ratio
With khejri								
Fallow-mustard	1.55	1.40	1.30	1.42	6133	27510	21377	4.48
Fallow-taramira	0.99	0.93	0.84	0.91	6108	16840	10732	2.76
Sole cropping								
Fallow-mustard	1.25	1.19	1.12	1.18	4468	141600	9692	3.17
Fallow-taramira	0.74	0.70	0.61	0.68	4443	4760	317	1.07
CD (5%)	0.22	0.19	0.20	-	-	-	-	-

Table 4: **Economics (Rs./ha)of fodder crops grown alone and in association with khejri (mean of 3 years)**

Crop sequence	Cost of cultivation	Gross income	Net income	B:C ratio
With khejri				
Cowpea- todia	5641	20046	14405	3.55
Pearl millet - todia	6675	20772	15197	3.73
Clusterbean - todia	5795	18591	12796	3.21
Buffel grass - grass	6303	12276	5973	1.95
Sole cropping				
Cowpea- todia	3976	8370	4394	2.10
Pearl millet - todia	3910	8463	4553	2.16
Clusterbean - todia	4130	7200	3070	1.74
Buffel grass - grass	4638	1962	2676	0.42

Table 5: **Economics (Rs./ha) of Kharif crops in relation with rabi todia (fodder) grown alone and in association with khejri (mean of 3 years)**

Crop sequence	Cost of cultivation	Gross income	Net income	B:C ratio
With khejri				
Cowpea- todia	5791	19370	13579	3.34
Pearl millet - todia	6185	15550	9365	2.51
Clusterbean - todia	5945	18670	12725	3.14
Sole cropping				
Cowpea- todia	4126	7800	3674	1.84
Pearl millet - todia	4520	4240	-280	0.94
Clusterbean - todia	4280	6900	2620	1.61

Table 6: **Fodder yield (t/ha) of different crops grown sole and in association with Jatropha**

Crop	Fodder yield (t/ha) Green 1st year	2nd year	Mean	Dry 1st year	2nd year	Mean
With Jatropha						
Cowpea	17.50	17.65	17.57	5.06	5.15	5.11
Pearl millet	20.20	20.00	20.10	6.25	6.09	6.17
Cluster bean	17.00	16.90	16.95	5.20	5.00	5.10
Dhiancha	24.00	24.10	24.05	7.59	7.65	7.62
Sole						
Cowpea	17.80	17.40	17.60	5.20	5.12	5.16
Pearl millet	20.30	21.00	20.65	6.32	6.51	6.41
Cluster bean	16.80	17.30	17.05	5.10	5.23	5.16
Dhaincha	24.20	23.90	24.05	7.48	7.35	7.41
CD (5%)	1.04	1.64		1.35	1.11	

Table 7: **Grain yield (t/ha) of different crops grown sole and in association with Jatropha**

Crop	Yield (t/ha) 1st year	2nd year	Mean
With Jatropha			
Cowpea	0.84	0.77	0.81
Pearl millet	1.32	1.32	1.32
Cluster bean	0.85	0.94	0.90
Dhaincha	0.90	0.88	0.89
Watermelon	12.64	13.00	12.80
Sole			
Cowpea	0.86	0.81	0.84
Pearl millet	1.35	1.30	1.33
Cluster bean	0.89	0.91	0.90
Dhaincha	0.92	0.88	0.90
Watermelon	12.52	12.85	12.67
CD (5%)	0.52	0.48	-

Table 8: **Yield (t/ha) of intercrops (kharif) as affected by different trees and irrigation scheduling under drip irrigation system (average of 2 years)**

Trees	Irrigation scheduling (ETc)								
	100%			70%			40%		
	Moong bean	Cluster bean	Ridge gourd	Moong bean	Cluster bean	Ridge gourd	Moong bean	Cluster bean	Ridge gourd
Shisham + Guava	0.36	0.88	5.26	0.35	0.92	5.06	0.34	0.86	4.76
Shisham + Aonla	0.36	0.90	5.23	0.36	0.85	4.93	0.31	0.91	4.68
Khejri + Guava	0.39	0.93	5.30	0.33	0.85	5.00	0.37	0.90	4.60
Khejri + Aonla	0.30	0.90	5.18	0.35	0.89	5.09	0.34	0.88	4.66

CD (5%)	Moongbean	Clusterbean	Ridgegourd
Trees	NS	NS	NS
Irrigation	NS	NS	215
Tree x Irrigation	NS	NS	NS

Table 9: **Yield (t/ha) of tomato (rabi) as affected by different trees and irrigation scheduling under drip irrigation system**

Tree species	Etc		
	100%	70%	40%
Shisham + aonla	46.14	43.60	34.57
Shisham + guava	45.97	43.94	34.17
Khejri + guava	46.07	43.40	33.54
Khejri + aonla	46.22	43.80	34.40

CD at 5%	Tomato
Tree	NS
Irrigation	11.80
Interaction	NS

Table 10: **Economics (Rs/ha) of the agri-sivli-horti system developed under drip irrigation after 2-years of plantation**

Tree species	ETc								
	Cucurbit-tomato			Clusterbean-Fallow			Moongbean-Fallow		
	100%	70%	40%	100%	70%	40%	100%	70%	40%
Shisham + Aonla	162955	152193	116113	1260	1100	-20	-5500	-5270	-5600
Shisham + Guava	164393	153413	118233	-500	-1300	300	-6430	-6750	-5600
Khejri + Guava	164833	150433	135837	1100	300	1100	-5230	-5990	-6470
Khejri + Aonla	164873	154833	119033	300	-20	-340	-6670	-6470	-5990

Table 11: **Grain and straw yields of different crops under various tree combinations (mean of 3 years)**

Tree species	Mean grain yield (t/ha)				Mean straw yield (t/ha)		
	Pearl millet	Clusterbean	Raya	Chickpea	Pearl millet	Clusterbean	Chickpea
D. sissoo+ M. alba	1.001	0.725	1.008	0.959	3.612	1.844	2.053
D. sissoo+ E. officinalis	1.007	0.732	1.030	0.940	3.594	1.870	2.096
A. indica + E. o fficinalis.	1.561	0.748	1.034	0.979	3.708	1.900	2.080
A. indica + M. alba	1.073	0.764	1.054	0.989	3.732	1.930	2.107
Sole crop	1.104	0.800	1.092	0.100	3.836	1.965	2.139
CD (5%)	NS	NS	NS	NS	NS	NS	NS

Table 12: **Economic returns (Rs./ha) of different crops under various tree combinations (mean of 3 years)**

Tree species	Mean gross returns				Mean net returns			
	Pearlmillet	Clusterbean	Raya	Chickpea	Pearlmillet	Clusterbean	Raya	Chickpea
D. sissoo+ M. alba	7512	10528	13447	13007	147	3066	5267	4827
D. sissoo+ E. officinalis	7434	10756	13740	12847	069	3294	5560	4667
A. indica + E. officinalis	7668	10977	13794	13252	303	3515	5614	5072
A. indica + M. alba	7756	11198	14060	13394	391	3736	5880	5214
Average	7593	10865	13768	13125	228	3403	5573	4945
Sole crop	7961	11587	14567	13554	4408	7937	10199	9034

Table 13: **Green fodder yield of crops under top feed tree species**

Tree species	Fodder Yield (t/ha)														
	Pearlmillet			Grass+ Cowpea			Buffel Grass			Cowpea			Cowpea + Pearlmillet		
	1st	2nd	Mean	1st	2nd	Mean	1st	2nd	Mean	1st	2nd	Mean	1st	2nd	Mean
C. Mopane	13.11	13.00	13.10	5.45	1.21	8.79	5.90	122.0	9.05	8.92	12.33	10.63	14.00	18.53	16.26
A. bivenosa	12.63	11.30	11.97	5.27	1.28	9.04	5.62	140.0	9.81	8.63	11.20	10.00	13.79	18.27	16.03
H. binnata	13.00	14.40	13.67	5.18	1.44	9.79	5.89	150.0	10.45	8.82	11.20	10.01	13.64	18.50	16.07
Sole	12.99	14.57	13.78	5.50	1.39	9.75	6.01	150.7	10.54	8.93	10.90	9.92	13.97	18.73	16.35
Mean	12.92	13.33	-	5.35	1.33	-	5.86	140.7	-	8.83	11.41	-	13.85	18.52	-

CD (5%)	1999	2000
Tree Species	NS	NS
Crops	1.09	1.81
Interaction	NS	NS

Impact of *Lemon Grass* and *Dalbergia sissoo* based Agro-forestry System on Red Lateritic Wastelands in Chhattisgarh

Sajiwan Kumar* and M. N. Naugraiya

INTRODUCTION

The role of forests as a repository of medicinal plants has been neglected and destructed by unscientific harvesting and collection of herbal plants. Forests also eliminate the need for extra land, as medicinal plants grow as part of the system. Medicinal and aromatic plants can be cultivated on agricultural lands as well as afforested areas with the agro-forestry cropping system. Their cultivation as cash crop, or associate crop, may save expenditure on several costly inputs and also help intercrop. It would lead to increased cash return from forest plantation and help to generate employment in rural area. The magnitude of benefits like nutrient re-cycling, minimization of soil water evaporation, provision of food, wood and fertilizer (Green manures) has been attributed through the land use system of agro-forestry (Myers, 1980).

Out of the India's total 329 million hectare geographical area, 187.7 m ha (57%) land suffers from various kinds of degradation problems (Paroda, 1998) which come under wastelands. Rehabilitation of such type of degraded lands can be done by revegetation with multipurpose trees/woody species/ perennial plants (Naugraiya and Puri, 1997). The importance of tree plantations is already known for their ability to restore soil fertility and for amelioration of microclimatic conditions (Singh *et al.* 2002).

The leguminous tree *Dalbergia sissoo* and Lemon grass crop are grown in Entisols under rainfed condition with least management to produce biomass for community uses but in this paper the improvement of soil health has been worked out and presented.

MATERIAL AND METHODS

The study site falls under the central region of Chhattisgarh plains agro-climatic zone. The plantation of *D. sissoo* at the spacing of 5x5 m was established in the year 1998, while under storey crop of *C. flexuosus* was transplanted by root slips at a distance of one meter spacing in July 2007 as an intercrop in interspaced. The fertilizers of Nitrogen (30 kg N/ha) in form of Urea, Phosphorus (20 kg P/ha) in form of SSP and Potassium (20 kg K/ha) in form of Potash were applied in two split doses during planting, i.e. July/ Aug and followed by 45 days after planting.

The tree growth characteristics *viz.,* Height, CD, DBH, Crown width and length were measured every year. Crop of *C. flexuosus* was harvested three times in a cropping season viz; September, December and February during two consequent years and herbage dry matter and oil production of both the year. The soil samples were collected at depth of 15 to 30 cm randomly from each treatment and bulk samples were analysed for its physico-chemical properties as per standard methods (Piper, 1950).

RESULTS AND DISCUSSIONS

Climate: The climate of study site is dry humid sub-tropical with an average annual rainfall of 1250 mm. About 80% of the annual rainfall is received from south- west monsoon during June to mid August. Number of rainy days varies from 65 to 79 days. The mean monthly maximum temperature varies from 13.2^{0}C in December to 28.3^{0}C in May with maximum temperature goes beyond 45^{0}C in May and minimum below 10^{0}C in December. The relative humidity lies between 70-90% from mid June to March end.

Soil: Physico-chemical features of the Entisols locally known as Bhata land, it is also known as Red Lateritic soil, as land use classification pattern point of view, and it comes under marginal wasteland. The soil having high percentages of gravels and sub soil layers are hard and compact, forming even lateritic pans at places (Singh and Totey, 1985). In red lateritic soil, the content of organic matter are found in fewer amounts, which is responsible for causing moisture and thermal stress, which affect microbial activity and the availability of nutrients and subsequently affect the growth of plant (Gupta and Sharma, 2009). Low pH, low N, high K and low P with low organic matter are the basic characteristics of Entisols.

PERFORMANCE OF DALBERGIA SISSOO

The performance of *D. sissoo* under agro-forestry system and as sole stand was recorded during 2007-09 and presented in Table 1.

The average tree growth performance was found higher in trees grown as sole crop than intercrop. Tree height was 7.13 and 8.55 m during July 2007 and 2009 respectively as sole crop, while

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it was 6.89 and 7.71 m respectively under agro-forestry system. The average growth of diameter at breast height was 6.78 and 9.30 cm during July 2007 and 2009, respectively, as sole crop, while it was 6.30 and 8.66 cm, respectively, under agro-forestry system. Crown length was 3.74 and 5.55 cm during July 2007 and 2009 respectively as sole crop; similarly under agro-forestry system it was 3.40 and 4.76 cm, respectively. The growth of crown width (North-South direction) was 3.55 and 4.75 m during July 2007 and 2009 respectively as sole crop, while it was 3.19 and 4.20 m, respectively, under agro-forestry system. Similar pattern was also recorded in case of Crown width (East-West direction) growth 2.94 and 4.32 m during July 2007 and 2009 respectively as sole crop; whereas under agro-forestry system it was 2.76 and 3.88 m respectively. Tree growth was found consistently higher in sole plantation of *D.sissoo* because of available soil nutrients had been utilized only by trees only in compare to plantation in agro-forestry system where resources of soil had been shared by Lemon grasses which were cut three times in a season. Similar results were observed by several workers when MPTs grown as in sole tree crop under agrisilviculture system (Roy and Gill, 1991); tree under silvipastoral system (Umrao, 2004). Raizada and Padmaiah (1993) also reported that growth of height, collar diameter and DBH in tree displayed the potential of tree species particularly in degraded red lateritic soil.

PERFORMANCE OF CYMBOPOGON FLEXUOSUS

The dry matter and oil production of *C. flexuosus* as sole and intercrop with *D. sissoo* under rainfed condition of red lateritic land is presented in Table 2.

Dry Matter Production: The reduction of dry matter and oil production of *C. flexuosus* were observed under agro-forestry over sole cropping during both the cropping years. The total dry matter production was found 16.83 and 56.69 q ha $^{-1}$ for first year and 19.36 and 86.36 q ha $^{-1}$ for second year under agro-forestry system and sole crop of *C. flexuosus,* respectively (Table 2), which was 1.19 and 1.50 times higher in sole crop and under agro-forestry system, respectively, during second year of cropping. The increment of production during second year was found to be regular phenomenon because perennial grass successively proliferate in the coming next year (Naugraiya, 1985).The reduction in biomass production of *C. flexuosus* and other aromatic grass species was also reported by Yadava (2000) and Faiz Mohsin (2005) under young plantation of Poplar (G-3) as well as under *Eucalyptus* plantation. In some case the allelopathic effect and competition for water and nutrients may also responsible for reduction in yield under agro-forestry (Chavda 2002).

The number of harvests in a year depends on the climatic factors such as temperature, rainfall and humidity and level of soil fertility as well as cultivation and management practices. The maximum dry matter (56.69 q ha^{-1}) and oil (76.68 kg ha^{-1}) production of *C. flexuosus* was observed in first harvest (September) of first cropping years and it was found similar trend in second year with increment of 53.11 and 19.53 per cent (Table 2). Because first harvesting (September) have moderate PAR and temperature with high relative coupled with suitable soil moisture resulting high rate of photosynthesis in the plants particularly C_4 plant species (Beech, 1977).

Oil Production: The extraction of essential oil from the plant was found higher in crop grown in sole crop/open area (21.48 kg ha $^{-1}$) as compared to grown in agro-forestry/shade (76.68 kg ha $^{-1}$) for first year of cropping and it was increased 1.47 to 1.37 times respectively in second year of cropping, which ultimately reflected the production of essential oil per unit area (Table 2). However the total oil production was found to be depended on biomass (fresh and dry) production. Singh *et al.* (1989) observed significant reduction in oil yield of Palmarosa and Lemon grass under the Poplar and Eucalyptus trees as compared to the control, thus the effect of tree/shade on reduction of total oil production may be visualized apparently (Chauhan, 2000).

Overall oil content was extracted higher in summer season *i.e.,* harvest in February which is initial stage of summer days in Chhattisgarh. Gupta *et al.* (1978) found that the similar result in my study, the oil content in Lemon grass was more in summer. This may be due to in summer plants may be expected to contain less moisture and therefore more oil on fresh weight basis. Light favours the formation of oil and stimulates the bio-chemical and physiological reactions during the biosynthesis of oil (Singh M., 2001).These findings are in conformity with those of (Mohsin and Singh, 2007).

Growth and production of herbs and oil was found in decreasing order during second (December) and third (February) harvesting schedule because the relative humidity and soil moisture was found to be consistently decreasing. Both immature and over mature crops give low yield and oil of poor quality (Farroqi and Sreeramu, 2001). Oil content was slightly less in first and second harvests than third harvest, which may be due to the rainy season. In case of decline in herbage, dry matter and oil production of *C. flexuosus* with intercropping of tree might be due to decreased the vital activities of plant with increasing the comparative dryness in climate as well as in plants (Duriyprapan and Britton, 1982) in red lateritic soil, another reason for significant reduction in yield might be attributed to the lower fertility status build-up in root zone during the second and third harvesting schedules.

IMPACT ON SOIL

The physical and chemical properties of soil under rainfed cropping system of *D. sissoo + C. flexuosus* based agro-forestry and sole crop of *C. flexuosus* in Entisols was studied along with features of adjacent barren land for two cropping season year are presented in table-3.

Soil pH was ranged 5.27 to 6.12 means it tends to acidic in nature (Table 3). The pH level in sole crop of *C. flexuosus* was slightly less acidic as compared to agro-forestry with statistically insignificant in both the year (Table 3). In sole Lemon grass pH was (6.12) followed by agro-forestry system (5.92), adjacent barren land (5.42) and least in the soil of sole plantation of *D. sissoo* soil pH (5.25). The second year it decreased (6.53%), (5.23 %) and (2.85%) respectively in soil of sole Lemon grass, agro-forestry system and sole tree but in case of adjacent barren land pH increased (0.18%). Thus the pH of soil was found to be influenced by tree canopy but it ranged in limit. The decrease of pH towards neutral point under agro-forestry can be attributed to accumulation and subsequent decomposition of organic matter which releases balancing chemicals responsible for diluting the acidity (Haan, 1977). Whereas higher acidic pH value in soils under agriculture or sole cropping system were found to be regulated in the crop field due to high concentration of $CaCO_3$ (Dasai, 2006)

Water holding capacity in soil was found statistically significant with the maximum under agro-forestry system, and minimum (31.75%) in soil of adjacent barren land. In the second year of cropping, water holding capacity of soil increased (1.09%), (9.09%) and (1.73%) respectively in agro-forestry, sole plantation of *D. sissoo* and adjacent barren land whereas soil from sole of *C. flexuosus* decreased (7.94%). In the agro-forestry system and sole of *D. sissoo* has maximum water holding capacity and moisture percentage due to finer texture and high organic carbon content of soils (Semwal, *et al.* 2009). In general maximum water holding capacity decreased down the soil profile under vegetation as well as in barren land (Raina and Gupta, 2009). It was an expected trend since the porosity of under tree trends to remain high as compared to open field. Favourable influence of soil organic matter on water holding capacity has also been reported by Greenland, (1981).

Organic carbon in soil was found statistically insignificant with the maximum under sole of *C. flexuosus* (0.61%) followed by agro-forestry (0.55%), sole *D. sissoo* (0.48%) and minimum in barren land (0.33%%). It increased (16.39%), (23.63%), (20.83%) and (6.06%) respectively in second year cropping season. Thus the organic carbon in the soil was found to be influenced by the density of vegetation particularly perennial species Gupta and Sharma, (2009).The concomitant rise of organic carbon in the soil under agro-forestry and decline in the soil of open space or barren land (Dutta *et al.* 2004). Similar results were found in agro-forestry system and sole cropping system during two year observations. Organic matter is the most capable and potent substance greatly influence the soil composition due to humus deposition in manmade forest (Verma *et al.*1982). Organic matter plays an important role in improving the physical, chemical and biological health of soil; it brings favourable changes in terms of the soil air, water holding capacity, structure, porosity, bulk density, colour, nutrient storage and availability, cation exchange capacity and microbial population and activity (Kononova, 1996). The increase in organic carbon content therefore is an index of improvement of soil fertility.

The available NPK nutrient in soil showed different utilization and accumulation pattern under different cropping system. The results were found statistically significant with maximum availability of NPK under sole crop of *C. flexuosus* and minimum in soil of adjacent barren land. The soil of sole plantation of *D. sissoo* showed the higher level of nutrient availability as compare to other in both the cropping years. Nitrogen increased by 2.5%, phosphorus 27.74% whereas potassium increased by 25.15% as compared to previous year of cropping under agro-forestry system. The pattern of nutrient distribution in different land utilization system was found in similar pattern of current study by Sharma *et al.,* (2007) and Arunchalam *et al.* (1994), with the remark that high vegetation sites had decomposed humus content which further added more nutrient to the soil to maintain mineral richness and fertility as compared to disturbed or less vegetation sites because the accumulated litter underwent decomposition at a faster rate.

This might be due to higher availability of nutrient in to plant growth and accumulation of leaf litter and residue in upper surface. Enrichment of soil with nutrients in agro-forestry system indicates improvement in soil fertility due to presence of *D. sissoo* which is also a nitrogen fixing tree as compared to sole cropping of *C. flexuosus*. The availability of nutrients (NPK) depends to large extent upon the amount and properties of organic matter (Haan, 1977). Highest available nutrients (NPK) content were found in sole crop of *C. flexuosus*, this might be due to the fact that there was an appropriate availability of nutrients to enhance the biomass and ultimately accumulation of leaf litter higher organic matter with high microbial activities causing high rate of decomposition and mineralization. Singhal and Pawar, (1991) for P in their study cropping pattern of Poplar based Agro-forestry system and Singh (1999) for NPK in their study impact of various land use on soil properties. Over all greater proportion of nutrients at all site occurred in the surface soil, reflecting the massive input of nutrients to the soil through litter fall.

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Table 1: **Performance of *Dalbergia sissoo* under Agro-forestry system and sole cropping system**

Treatment	Height (m)			DBH (cm)			Crown Length (cm)			Crown Width NS (m)			Crown Width EW (m)		
	July 2007	July 2009	MAI	July 2007	July 2009	MAI	July 2007	July 2009	MAI	July 2007	July 2009	MAI	July 2007	July 2009	MAI
SOLE	7.13	8.55	0.71	6.78	9.30	1.26	3.74	5.55	0.90	3.55	4.75	0.60	2.94	4.32	0.69
	±1.12	±1.52		±1.32	±1.10		±1.08	±1.23		±0.53	±0.25		±0.64	±0.61	
AFS	6.89	7.71	0.41	6.30	8.66	1.18	3.40	4.76	0.68	3.19	4.20	0.50	2.76	3.88	0.56
	± 1.29	±1.34		±1.42	±1.23		±1.15	±1.35		±0.48	±0.49		±0.52	±0.44	

**MAI during the study period 2007 to 2009*

Table 2: **Performance of *C. flexuosus* under agro-forestry system during two cropping year (2007 to 2009)**

Cropping system	Harvesting Schedule I		Harvesting Schedule II		Harvesting Schedule III	
	Dry matter ($q\ ha^{-1}$)	Oil production ($kg\ ha^{-1}$)	Dry matter ($q\ ha^{-1}$)	Oil production ($kg\ ha^{-1}$)	Dry matter ($q\ ha^{-1}$)	Oil production ($kg\ ha^{-1}$)
Cropping year 2007 - 08						
Sole crop	56.69	76.68	50.76	62.69	32.92	38.88
AFS (intercrop)	16.83	21.48	13.37	18.94	9.50	7.13
CD (at 5%)	**7.84**	**12.39**	**7.83**	**3.5**	**1.84**	**1.65**
Cropping year 2008 - 09						
Sole crop	86.80	91.66	70.81	88.35	53.87	65.44
AFS (intercrop)	19.36	26.34	16.35	25.39	11.67	18.20
CD (at 5%)	**7.02**	**4.30**	**5.69**	**3.93**	**1.92**	**0.67**

Table 3: **Impact of Lemon grass+ Shisham based cropping system on Entisols**

Treatment	pH	WHC (%)	Org. C (%)	Available N ($Kg\ ha^{-1}$)	Available P ($Kg\ ha^{-1}$)	Available K ($Kg\ ha^{-1}$)
Cropping system (2007-08)						
Sole crop	6.12	36.13	0.61	163.57	15.81	84.02
AFS (Intercrop)	5.92	45.62	0.55	151.89	11.82	80.02
Sole Tree	5.25	35.20	0.48	122.35	13.26	76.11
Adjacent Barren Land	5.42	31.75	0.33	108.76	10.39	72.35
CD (5 %)	**NS**	**2.85**	**NS**	**7.43**	**0.80**	**3.53**
Cropping system (2008-09)						
Sole crop	5.72	33.26	0.78	182.97	18.52	108.04
AFS (Intercrop)	5.61	46.12	0.68	155.76	15.04	100.15
Sole Tree	5.17	38.40	0.54	140.78	14.42	84.36
Adjacent Barren Land	5.43	32.36	0.35	112.16	11.18	78.45
CD (5 %)	**NS**	**1.43**	**NS**	**6.15**	**2.99**	**2.57**

Agro Forestry and Social Forestry initiatives taken by ABC Paper Limited, Saila Khurd (Hoshiarpur)

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INTRODUCTION

Agro-forestry research was initiated in the country about two decades ago; since then, considerable progress has been achieved. Agro-forestry, i.e. growing trees with food crops and grasses, is believed to have been practiced during Vedic era (Ancient period, 1000 BC) but agro-forestry as a science is introduced only recently. Systematic research in agro-forestry geared up after the establishment of the International Council for Agro-forestry (ICRAF) in 1977, which was renamed in 1991 as the International Centre for Research in Agro-forestry (Tewari, 1998).

The biggest challenge faced by the wood based industries is the raw material shortage. A conservative forest policy (Anon., 1990) coupled with promotion of farmers/industries linked plantation activities on under-utilized cultivable and marginal agricultural lands is helping to mitigate the crisis, whereas gap between demand and supply is still wide. This necessitates as business model of farm forestry, in order to expand the area under farm and Agro-forestry plantation in larger way. At present farm forestry is the only answer for pulp and paper industry to increase the resources base in the generation of the much needed (Kulkarni,2008), while simultaneously ensuring the sustainable livelihood for farmers and thereby raising socio-economic status of the local populace and more importantly, improving the environment and maintain the ecological balance (Sasidharan,2010).

Most of the pulp wood is eventually coming from farm forestry planted by small and marginal farmers especially for commercial purpose. Now it needs only to provide a base for increasing yield with supply of genetically proven planting material along with best package of practice (Kulkarni, 2001). Commercial plantation is also helping farmers now a day as there is acute shortage of labour force, which is essential part of agriculture. It is inevitable that smaller/ marginal planted area will have to serve more people in the future. Now there is trend to go for larger commercial plantations (Anon., 2009) by all type of farmers including land lords.

The paper business of the Group, which was earlier being carried on as a Division of Amrit Corporation Limited has been vested in ABC (Amrit Banaspati Company) Paper Ltd. under the scheme of restructuring. The paper mill was set-up in the year, 1980 in the state of Punjab, 108 kms from Chandigarh. The ABC Paper is located at Saila Khurd, Distt. Hoshiarpur, a small village, which is a backward areas, situated on the main National Highway connecting Chandigarh-Hoshiarpur-Pathankot. The unit has all the locational advantages viz.

- Proximity to road and rail;
- Abundant availability of raw materials;
- Closeness to paper market; and
- Nearness to main cities like Chandigarh, Ludhiana, Jalandhar and Hoshiarpur.

As one of the largest wood-free paper plant, it uses only agro-wastes like wheat, rice-straw, kana grass etc. to manufacture fine quality printing and writing paper. ABC Paper is focusing on branded printing and writing paper, which is extensively used in the printing of books, trade directories and even as newsprint. ABC Paper has a name for its products, which are well accepted in the market. The major products as on date are writing and printing paper, coloured cream wove computer stationary paper, ledger and newsprint. ABC Paper is the leader in the Cream Wove paper in agro-based segment. The paper produced by ABC Paper is typically used in the manufacture of note books, publications, text books, computer stationery, goods receipts and invoice books (both coloured paper and white paper), pamphlets, newspaper supplements, diaries and calendars etc. These products, particularly, note books manufactured by using the paper produced by ABC Paper are also exported. The ABC Paper has in-built capacity of 450 TPD (tonne per day) of finished paper with an annual production of 1.64 lakh tonnes per year.

SOCIAL AND AGRO-FORESTRY INITIATIVES BY ABC PAPER

Under the social forestry schemes farmers were encouraged to grow *Eucalyptus* clones of high yielding on boundaries of agricultural fields and on either side of irrigation channels. Planting of eucalypts is said to have changed the land use pattern of Punjab. ABC is actively engaged and promoting social and farm forestry activities through large scale plantations of *Eucalyptus*

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and Poplar clones to promote agro-forestry in this region especially in the north region of Punjab state. To promote social forestry ABC provides good quality seed, pesticides, etc., free of cost to the farmers for developing nurseries. We are have set up three decentralized Kisan nurseries in the nearby catchment area of mill and producing 9-10 lakh poly bags saplings through hybrid seed of *Eucalyptus* every year. Quality seeds were procured from certified agencies and government organization and distributed to farmers free of cost also appropriate seed treatment in order to speed up the germination.

ABC Paper Limited has taken initiatives to develop social and agro-forestry successfully and started its activities since 2009 with an objective of greening the environment along with ensuring the sustained supply of raw material to the industry as company is now focusing to ensure wood from its vicinity as raw material for paper making. The activities started with a small target of 2.5 lakh clonal plants production per year which was accelerated in subsequent years. Now this has been increased up to 5 lakh per year with a distribution target of 4 lakh per year thanks to overwhelming response and keen interest of the farming community.

AGRO-FORESTRY THROUGH CLONAL PLANTATION

Clonal plantation which yield double the productivity compared to seedlings in shorter period is proving a boon to the farmers. ABC Paper is also engaged to promote farm forestry activities through introduction of clonal plantation of superior clones of *Eucalyptus* and Poplar on farmer's land in a block plantation manner. Beside this farmers are showing their keen interest to adopt clonal plantation in intercropping pattern to get more return from plantation as well as from the crop. This practice would be helpful to develop agro-forestry in Punjab. For the promotion and development of agro-forestry we launched 'Model cum Demonstration Plots Scheme' with the aim to promote agro-forestry through clonal *Eucalyptus* plantation in farmer's field on large scale in district Hoshiarpur (Punjab). Under this scheme we provided gall free superior planting material of *Eucalyptus*, pesticides micronutrients, manual of guidance and technical supervision at the time of plantation free of cost. We have successfully established four Model-cum-Demonstration plots of *Eucalyptus* clones for the promotion of clonal forestry. Among these, three were established in farmer's field and one in Krishi Vigyan Kendra, Bahowal (Hoshiarpur) in the first phase (Fig 1).

In the second phase, we will set up 10 Model Plots in joint collaboration with the farmers' community. For this, ABC has also developed infrastructure to develop *Eucalyptus* clones and their propagation. Around 4 lakh clonal plants are supplied to the farmers annually. We also provide technical guidance to get more return from plantation and also give buyback guarantee to the farmers. Till date we have covered about 200 ha area under clonal *Eucalyptus* plantation and plan to covere 500 ha area by the year 2011-12. This initiative will give new dimension to increase income source for poor farmers through high yielding clonal plantation activities along with soil in water conservation.

WHY DO MANY WOOD BASED COMPANIES AROUND THE WORLD PLANT CLONAL PLANTATIONS?

Clonal forestry and plantations plays a significant role in many forestry plantation operations around the world, and is now common practice in Acacia, *Eucalyptus*, Poplar, and Pine plantations. The Australia, South Africa, Brazilian and Indonesian hardwood industry is a notable exception.

Well executed clonal plantations confer many advantages over traditional seedling plantations. Clonal plantations are based on superior individuals that have been selected by the plant breeder for their superior genetic qualities.

Qualities selected by the breeders for the mass production of elite clones may include:

- Increased growth rate
- Superior vigour
- Superior form/shape (e.g. Apical dominance for sawn log production)
- Increased timber volume/yield
- Superior timber (e.g. strength, durability, density, paper quality)
- Pest and disease resistance
- Drought resistance
- Suitability to specific soil types
- Suitability to specific climatic zones
- Salt tolerance

TARGETED AREAS FOR AGRO-FORESTRY DEVELOPMENT IN NORTHERN PUNJAB

The following type of land can be used for Agro-forestry development:

- Cultivated land/Agriculture land
- Field boundaries
- Pockets with in cultivated where cultivation is not possible
- Old fallows
- Kandi Region
- Along with farm roads and canal/nallahs sides affected by erosion
- Beside this other areas like community or Panchayat land, etc., in which agro-forestry may be included.

AGRO-FORESTRY THROUGH CLONAL *EUCALYPTUS*

Eucalyptus species has enormous application widely used for many purpose like Pulp industry, Board industry, Fuel wood, Furniture wood. *Eucalyptus* is recognized as a commercial crop in India and widely cultivated on farm lands, waste land by the farmers of Punjab on large scale. It has become a way to earn the money through its cultivation on farm land. ABC Paper Limited, Saila Khurd has also adopted vegetative means of propagation of *Eucalyptus* species under its tree improvement programme with an objective of productivity improvement of plantations per unit area. As the demand of raw material is drastically increasing day by day so to meet this it is very essential to grow superior clones of *Eucalyptus* on large scale capable of yielding high percentage. This method of vegetative propagation offers following advantages:

- Conserve the genotype of the donor tree in its propagules.
- Increase in genetic gain by selection and multiplication of both additive and non additive gene effects.
- Helps in developing fast growing, disease resistant and uniform plantations.
- Helps in productivity and yield enhancements.

ABC has developed a good market through selling of their clones of high yield in different areas of Punjab to increase productivity of raw material since last 2 years. Farmers are cultivating these clones on their farm land and getting full value of their crop at the time of harvesting using intercropping with Wheat and other seasonal crop. Farmers are however showing their interest to grow clonal *Eucalyptus* with intercrop of Wheat, Peanut. Beside this we are also promoting famers to take extra income and benefits using intercrop of seasonal crop and medicinal plants like Aloe and Tulsi.

AGRO-FORESTRY MODELS OF POPLAR

The development of poplar agro-forestry and associated research in India was reviewed earlier by many workers (Newman, 1997). The development of poplar agro-forestry and associated research in India has gained much attention to the commercial growers and researchers in India. The model of agro-forestry development involving partnership between, the private sectors and the government is worthy of further research for application in the rests areas of India and to other countries. A number of suggestions are given for further research in the context of optimizing the system for resource poor farmers. These include changes in trees and crop varieties, tree spacing and utilization of small diameter logs, and other Poplar products. ABC Paper Mills have taken the initiative in this direction since 2009 to develop superior clones of Poplar. We are developing good quality saplings of Poplar of high yield with good return. We are producing more than 1.5 lakh of superior saplings of Poplar in 15 acres of own land in the mill campus. Now we have introduced joint scheme for Poplar nursery with collaboration of farmers of Punjab through agreement on simple terms and conditions. Under this scheme we will provide quality material (ETP's) to farmers free of cost for nursery development. During development we will also provide full technical support and guidance to farmers to take benefit and develop an ideal nursery. Now the farmers of Punjab are showing their interest in growing clonal *Eucalyptus* with intercrop of Wheat, Peanut and Poplar with intercrop of Sugarcane, Paddy and other seasonal crop like Mattar (*Pisum sativum*) and turmeric and getting a good return from their crops.

BAMBOO FOR AGRO-FORESTRY

Bamboo is also known as Green Gold and good friend of poor people. The most important use of bamboo is as raw material in pulp, paper and rayon industries. Increasing demand of wood has gained attention for growers and researchers to develop bamboo on large scale to meet the growing demand. There are certain limitations of propagation of bamboo like low viability of seeds due to poor germination and lots of barrier by using vegetative means of propagation i.e. cuttings. For this tissue culture protocol for large scale propagation of important species of bamboo, i.e., *Dendrocalamus hamiltonii,* suited for pulp and paper industry has also been developed (Arya *et al.* 2009). Suitability of important bamboo species has also been evaluated for various grades of pulp and paper and for different pulping process (Guha, 1961; Guha *et al.*, 1975; Guha and Pant, 1961; Karnik, 1961, Sharma *et al.*, 2009, Sharma *et al.*, 2009). As a result of these investigations use of bamboo pulp is expected to increase in future. The future role of bamboo chemical pulp may be as cheaper substitute of long fibre pulp, which is always as essential part of furnish in a better quality paper. Bamboo as woody grass plant is uniquely suited to agro-forestry (Sharma *et al.,* 2009). Many farmers of Punjab and Himachal showed keen interest to grow bamboo on their farm land for a good and long return. Important uses of bamboo in agro-forestry development are summarized in Table 1.

Table-1: **Suitability of Bamboo in Agro-forestry development**

Agro-forestry function-Primary use	Agro-forestry Products-Value added
Intercropping	Timber and craft wood
Constructed wetlands	Livestock
Living Screen	Bamboo shoots may be a good source of food
Riparian vegetation filter	Fibre crop for pulp and paper industry

EXTENSION AND MOTIVATIONAL EFFORTS

We have successfully established strong extension network in association of local influential person including NGO and Government research centre. Farmer's meets are being organized at different villages to develop awareness among the farmer communities regarding the economic benefit available through pulpwood plantation. As a part of extension programme, farmer exposure visits are being organized to our R&D centre, our major field trials in farmer's field as well as in our campus area on large scale and model demonstration plots which were established with collaboration of farmers and government research organization. This type of efforts will develop confidence in the farmers by observing our activities in the area of clonal development and plantation in a scientific way to increase the productivity and to ensure raw material security for future.

We also actively participate in different exhibition activities and Kisan Melas organized by State Agriculture University, Research centres like KVK's (Krishi Vigyan Kendra) time to time in different parts of Punjab and give demonstration to the farmers regarding the economic and environmental benefits of our plantations. To promote agro-forestry in North Punjab especially in Kandi region we are actively working with different research centre. In this direction we are getting good response from farmer's side. Details of farmers/ extension meetings are given in Table 2.

Table-2: **Details of Kisan Ghoshtis/Meetings arranged and participation of Farmers**

No.	Particulars	No. of meetings organized	No. of farmers attended
1	Janjowal & Jaijon	2	15
2	Farmers Visits at ABC	10	550
3	Meetings in Collaboration of KVK's, Bahowal	3	258
4	Hoshiarpur and Adjoining areas	4	350
5.	Ballowal-Shaunhkri	3	570
6.	Chak-Naryal	1	10
	Total	**22**	**1748**

SCENARIO OF CLONAL PLANT PROPAGATION

Clonal propagation of hardwoods, especially eucalypts, can be a totally different scenario and at the other extreme end of the spectrum regarding difficulty, technology and capitalization. This impacts on price, and so at face value there is a perceived price barrier (by the grower) working against the establishment of hardwood clonal plantations, even though a closer study of the full economic picture may show otherwise. Clonal propagation technology is used for mass production of true to type quality planting stock in which all the genetic superiority of the parent tree is retained.

The mean annual increment of *Eucalyptus grandis* plantations in Brazil before attempting genetic improvement and clonal forestry in 1967 was 15 m^3 /ha/yr, but when selected clones were introduced, the yield increased up to 70 m^3 /ha/yr. Such clones under intensive management have yielded even up to 100 m^3 / ha/yr (Zobel, 1993).

ECONOMIC AND SOCIAL EFFECTS OF *EUCALYPTUS* PLANTATIONS

FAO's Forestry Paper "The ecological effects of *Eucalyptus*", published in 1985, (Poore and Fries, 1985) was concerned with the environmental effects of *Eucalyptus* plantations, although it recognized that environmental effects had social consequences. The economic and social effects are now seen as being the consequences not only of the effect of *Eucalyptus* plantations on the site and its environs but also of political decisions affecting the forest sector and in particular the supply of wood for industry.

The objectives of political interventions in the forestry sector are generally to increase the forest resource through the establishment of plantations. It is the unintended social consequences, real or imagined, that have led to criticisms of such programmes, and by an irrational leap of presumed logic, to condemnation of the genus *Eucalyptus*. In reading the literature on forest plantations worldwide there is increasing emphasis on sustainable land use practice. In this connection plantations must be considered not just for the production of timber or fuel wood but for other outputs and for the services that can be provided by trees. While the eucalypts have many benefits, including fast growth and the ability to coppice, their harvest is largely limited to woody products such as fuel wood, poles, pulp wood and timber although honey and oils are also produced in some instances. Their services include protection of 7 crops and of the soil, but their fast growth often leads to competition with adjacent crops and the elimination of the undergrowth covering the soil-an effect compounded by the practice in many countries of collecting the litter beneath the trees.

This is not to say that forestry in sustainable land uses is not possible with *Eucalyptus* plantations but it is necessary in planning any plantations to be clear about their objectives and of the consequences of selecting a particular tree species. If species of *Eucalyptus* meet the criteria of the objectives while not creating unfavourable ecological or socio-economic effects then the plantations should be evaluated against those criteria, not against some other list of potential benefits that lie outside the objectives. "Most ecological effects can only be evaluated with reference to what society wants" (Poore and Fries, 1985). If society wants industrial round wood cheaply, quickly and of a particular technical specification, then plantations of *Eucalyptus* may well is the answer, with other goods and services provided from elsewhere. If society wants multiple benefits from the same piece of forest land, then the eucalypts are not likely to provide the answer, and society must select another option and be prepared to pay the cost.

Recognition of the need for sustainable forestry practices is leading to the involvement of people in plantation programmes, particularly to participating in them, to better matching of species and provenances with site, to establishment practice that are less damaging to the soil, such as the use of lighter equipment or the elimination of fire in site preparation, to quantification of benefits, such as employment or the provision of social services, to measurement of the effects of plantations on the environment, particularly on ground water and soil fertility, and to evaluation of the plantations in the local or national economics, rather than from the point of view only of financial returns

The participation of people in rural development through forest plantations is now emphasized more strongly than ever. Examples include the out grower scheme established by the Paper Industry Corporation of the Philippines for the provision of up to one third of its pulpwood requirements, where the company provides seedlings (including *Eucalyptus deglupta*), loans and advice (Bass, 1992). Another example of the involvement of out growers is the CEASA scheme in Spain, which in its first year involved 500 farmers. The scheme includes the extension of agro-forestry techniques and the production of honey, oil and timber as well as pulpwood (Wilson, 1992).

EUCALYPTUS CLONAL PROPAGATION AT ABC PAPER CLONAL HI-TECH CLONAL NURSERY

Average productivity in natural seed derived plantations is low due to high genetic variability and other major issues like unavailability of quality seeds and gall infestation. As much as

80% of productivity is contributed by just about 20% of the plants. Hence it is very important to have only the highly productive member of the plantation to improve the productivity per unit area.

In order to improve per unit area productivity of the farmer we have introduced clonal propagation of Superior *Eucalyptus* clones selected after a long field investigation in Punjab area.

MATERIALS AND METHODS

SELECTION OF CPTs (CANDIDATE PLUS TREES)

To promote clonal forestry through clonal propagation and development of superior planting stock of *Eucalyptus* for high yield in short time span we selected 100 numbers of CPTs of *Eucalyptus*. Multilocation trials were conducted in randomized block design of above CPTs in our agro climatic condition to check and assess the suitability. We have measured periodically increment of above CPTs in terms of total height, girth and total wood volume. After close study on these CPTs and on the basis of data collected we have started the mass multiplication of about 10 superior individual. We have 2 numbers of mist chamber, 1 hardening chamber, and one clonal mini garden producing about 5 lakh clonal plants annually (Fig 2).

PREPARATION OF NODAL CUTTINGS OR COPPICE CUTTINGS

The young and juvenile healthy coppice cuttings/mini cuttings harvested from our clonal mini garden were cleaned with alcohol and then washed thoroughly and cut with secateurs in to two noded cuttings with pair of leaves. The leaf area is reduced to less than half the original leaf size to minimize transpiration rate. The cuttings then treated with contact and systemic fungicide (Diathane M45 or DM-45, Bavistin). After this these treated cuttings were washed with fresh water. The lower portion of cuttings then treated with auxins i.e. IBA (Indole-3 Butyric acid) at 5000 ppm concentration in talcum powder. Cuttings were placed in root trainer/hycotrays filled with vermiculite.

Media for Clonal cuttings Propagation

We are using vermiculite for clonal propagation. Vermiculite is just nothing but a micaceous mineral, which can expand when heated. When expanded it is very light in weight. It is neutral in reaction with good buffering properties and in soluble in water, can observe large quantity of water. It contains enough magnesium and potassium to supply the plants. It is also known as support media for coppice cutting and help to cuttings to maintain in standing position after inoculation.

(a) Mist Chamber Operation:

State of art Mist Chamber covered with UV rays stabilized polythene of 200 micron size. Mist Chambers are provided with temperature, humidity controllers and forced circulation systems. The root trainer/hycotrays containing 40 nos of blocks of 95cc with two noded treated cuttings placed in to Mist Chamber for 40-45 days for root and shoot initiation in Nodal cuttings. Temperatures of 35^0C-40^0C with 80-85% humidity is maintained inside the mist chamber for better results.

(b) Hardening and Acclimation Process in Hardening Chamber:

After successful rooting and shooting of juvenile cuttings inside the mist chamber i.e. after 40-45 days, rooted cuttings are then placed to hardening chamber covered with 75% agro shade net for 30 days for proper hardening and acclimatization with local climate prior to transfer in open environment.

(c) Transfer in Open Nursery:

The rooted cuttings are then placed in open nursery for 2-3 months till they attain suitable height of about 30-45 cm. These young plantlets were nurtured with macro and micro nutrients regularly through spray pump. This practice is necessary for proper elongation and proper growth of young plantlets prior to field transfer.

CLONAL MINI GARDEN / MINI CUTTINGS TECHNOLOGY FOR RAPID MULTIPLICATION OF *EUCALYPTUS* CLONES

Initially we multiply the clonal plants from coppice shoots derived from the mother plant of 1.5-2 years old. The process is cumbersome and involves huge land area for clonal multiplication purpose. The development of micro-cutting technology for *Eucalyptus* allowed the concept of super intensive management of producing vegetative propagules to be achieved at commercial scale as for cuttings systems for large scale production of vegetative propagules *ex vitro*. Originally the system was based on mini hedges established through rooted mini cuttings, grown in small series of technical and Economical benefits as well as good root quality. Despite representing great advance over coppice cuttings in the open field mini cuttings in container faced some limitations. The open mini hedges (cuttings which were collected from Clonal Multiplication area or gene bank) were hostages of climate, and the problem related to adequate maintenance of nutritional status and leaf disease continued, especially during winter. The main problems were: reduced photosynthesis rate, reduced nutritional uptake and high level of nutrition loss by leaching during the periods of excessive rainfall, or even during irrigation. These limitations led to development of an indoor Mini Cutting system.

We have installed naturally ventilated poly house covered with UV rays stabilized 200 micron polythene provided with fertigation system, temperature and humidity controllers. We have planted superior mother plants in raised bed filled with pure sterilized sand at 15 cm x 15 cm spacing. We are providing the required fertilizer dosage through fertigation system to the plants. We are also providing constant humidity and temperature to the plants. Every month we are getting about 15-20 juvenile coppice shoots from a single mother plant. The adequate fertilizer dosage and nutritional status in the plant will help in increasing rooting percentage in Mist Chamber.

INTRODUCTION OF CLONAL MINI HEDGE (MINI CUTTING) TECHNOLOGY

The idea came up with the observations that rooting ability of stem-cuttings decreases with ontogenetic ageing and the decline may be faster than reported in the literature. In *E. grandis* for example, the rooting competence decreased from the fourteenth node up Patton & Willing, (1974), while it took longer in the *E. delgupta* Assis *et al*. (1992) observed that clones of *E. saligna, E. grandis* and *E. urophylla* that had equally high proportion of stem-cutting rooting *in vitro,* showed differential levels of decline in the rooting percentage when managed in clonal hedges. This indicated that some factor related to clone growth, encompassing period between planting and cutting harvest (6 months), could be responsible for these differences. Preliminary tests done at Klabin Riocell showed, independent the species, almost 100% rooting of the very young mini-cuttings obtained from the cotyledonary leaf pair and the same tendency was maintained in the difficult to root species like *E. citriodora, E. cloeziana*, *E. paniculata, E. dunnii,* and *E. globules*. However, with age, ranging from few days to some months, the cuttings harvested from such young plants showed a marked reduction in their rooting ability and in some cases ability was totally lost. These observations suggested that the rooting potential reaches the maximum value at the high juvenility level and is similar in all species tested. But the decrease in the rooting ability with seedling age differed among species, which was similar to that found in the older material in the field. This suggests that, at some stage, part of the juvenility obtained through rejuvenation process in vitro (Goncalves *et al.* 1986) and /or on basal sprouts of cut adult trees (Hartney, 1980) is being gradually eroded during the growth of the clones in the clonal hedges. Results were obtained from trials established to define substrate, growth substances, environmental condition for rooting etc. One of the most significant findings of this new technology was complete elimination of the use of growth substances usually required for the rooting of stem-cutting (Assis *et al*.1992). These substances did not increase rooting of micro-cuttings, instead in some cases reduced it, indicating that the endogenous auxin concentration in the juvenile tissues was sufficient to promote rooting. Based on these results, a super-intensive system of *Eucalyptus* propagation *ex vitro* was established in 1965.

The main feature of the technique is the use of juvenile plants or plants rejuvenated in vitro, as source of vegetative propagules. Shoot apices are used as micro-cuttings, which are placed to root in a green house equipped with temperature and humidity control. The actual size of micro-cuttings is about 7 to 8 cm with two to three leaf-pairs. Presence of the shoot apex is important for quality of the root system, because its presence induces taproot-like system. The micro-stumps left after micro-cutting harvest, sprout rapidly producing new micro-propagules, which can be harvested for use with in a period of 15 days in the summer and 30 days in the winter. Since its first use, the micro-cutting technique is improving continuously by incorporating new research findings. The evidence of evolution of this technique are well documented in publications of Assis *et al*. (1992); Xavier & Comerio (1996); Assis (1997); Wendling *et al* (2000); Higashi *et al.* (2000), and Campinhos *et al.* (2000).

The technical contributions, reciprocally exchanged through a pre-competitive development model and intense information exchange, were the bases for the fast evolution of this new concept of cloning *Eucalyptus* in large scale.

ADVANTAGES OF MINI-CUTTINGS

Compared to the traditional stem-cutting rooting, mini-cutting has many advantages leading to operational, technical, economical, environmental and quality benefitswhich can be summarized as follows:

- ❖ Choice of a culture substratum allowing the production of the best cuttings, independently of local soils characteristics.
- ❖ Operationally, the labor demanded and cost is markedly reduced, due to elimination of labour intensive treatment in similar indoor areas at much lower costs.
- ❖ Reduction of risks by pathogens whose expansion is controlled in field-grown stock plants, resulting in reduced fungicide application.
- ❖ Mini-cuttings produce better quality root system with a tendency for a taproot-like system in contrast to the predominate lateral root growth habit in the stem-cutting system.
- ❖ Better controls of stock plant environment, less exposure to the sun and other environment regime variations of field-grown stock plants.
- ❖ The area culture and installation proximity, reducing stress risks between the instant of the crop and the installation of the cuttings in rooting conditions.
- ❖ Increasing of stock plants density and their productivity/ surface.
- ❖ Best physiological conditioning of vegetative material allowing increasing appreciably rooting rate even for clone reputed refractory in traditional conditions.

RESULTS AND DISCUSSIONS

In the era of global markets, the development of social and farm forestry plantation for industrial purpose must aim for among other objectives, increasing industrial competitiveness in the distinct markets segments they interact with. In such a scenario, forestry based companies must consider the mode in which the forestry raw material can affect their competitive capacity. The modern concept of competitiveness includes producing products to meet the customer's requirements at low costs, in a sustainable manner and with minimum impact on the environment. Therefore, developing tree breeding programmes to obtain quick gains, and also developing cloning systems to have a well established vegetative propagation method becomes important. The vegetative propagation methods should rapidly transform genetic gains obtained through breeding or genetic transformation, in to benefits for the industry.

One of the most efficient tools to acquire these objectives is the combination of interspecific hybridization and establishment of clonal forestry derived from superior hybrid individuals.

The traditional *Eucalyptus* clonal technology using coppice cuttings from 1.5 to 2 years old plants is cumbersome also requires about 2 years starting multiplication of *Eucalyptus*. The traditional clonal technology is also liable for insect infestation like Gall insect, little leaf, etc.

From 320 sq.m. naturally ventilated poly house (mini hedge house), we are getting about 15,000 mini juvenile cuttings per month and 180,000 per annum (about 20-22 cuttings/plant). We need to maintain about 8,000 mother plants in clonal multiplication area in the field covering an area of about 10 acres of land. The survival of coppice cuttings, about 62-65%, has increased to 85-88% by using mini hedge technology. The mini hedge technology has also reduced time required for rooting from 45 days to 35 days which helps in increasing production capacity of clonal plants. By use of mini hedge technology anyone can introduce/ produce new clone with in the period of 2 months. On the other hands traditional technology takes at least 1.5 year for the same. The cost of clonal production will reduce drastically by using mini hedge technology hence we can provide cheaper clones to the farmers to take up plantation by using genetically superior seedlings. This will increase yield by 2-3 times as compared to normal seedlings.

CONCLUSION

To meet the increasing demand for timber in the future, fast growing Eucalyptus plantations are expected to make great contribution. In this direction, clonal Eucalyptus has shown promising future with fast growth and development by giving 3-5 times more biomass than the seedlings plants. The quality as well as quantity of wood products achieved from the commercial plantation through clonal *Eucalyptus* through scientific management is one of the major achievements. Farmers, who do not follow the scientific method of plantation do not get encouraging results, whereas farmers who follow the right and scientific package of practices have got excellent returns in quantity and quality and achieved high yield with good economic returns as compared to seedling *Eucalyptus*. This is an eye opener to the farming communities and local inhabitants for large scale take over of *Eucalyptus* clonal plantation which may directly and indirectly benefit the pulp and paper industries in the coming years from the point of raw material security.

Mini hedge technology has gained lots of attention for commercial growers who are actively engaged in clonal production of *Eucalyptus*. Excellent results are coming from this effort. It would also be proven a boon for commercial growers of *Eucalyptus* to enhance production level in short time period with less requirement of land. The use of mini hedge technology has resulted in significant increase in clonal plants productivity in same number of mist chamber area. Number of days required for rooting of cuttings inside the mist chamber will also be reduced from 45 days to 35 days. Number of days required to produce/ introduce new clones will also be reduced from 1.5 years to 2 months. This would also increase rooting percentage inside the mist chamber from 65% to 85%. The early production of quality material of clonal eucalyptus using mini hedge technology will provide an opportunity to the farmers of Punjab to grow Eucalyptus on their farmlands. This would also improve and increase the level of agro-forestry and forest cover in Punjab. Farmers would benefit from plantation of clonal *Eucalyptus* on their farmland, either in block or using intercropping pattern, to get extra income from the plantations.

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Minor Forest Produce for Livelihood in Chhattisgarh and National Perspective

A. K. Singh *

INTRODUCTION

A large population of the country specially the tribals, residing near the biodiversity rich forests have been traditionally dependent on the forests for their socio-cultural-economic needs. The MFP has been playing major role for the income generation of the communities residing adjoining the forest areas. Considering the importance of MFP, the meeting of MFP requirement of rural and tribal population was included in the basic objectives of the National Forest Policy of 1988. It has been mentioned in the policy that MFP should be protected, improved and their production enhanced with due regard to generation of employment and income. The development of marketing institutions for MFP is part of the strategy. However the important role of MFP in providing health security to rural population and raw material to the pharmacies of traditional systems of medicine is missing in the national forest policy.

Chhattisgarh State was formed on 01.11.2000 with the division of erstwhile Madhya Pradesh. Remote areas of Bastar and Surguja are also part of Chhattisgarh. After the formation of State of Chhattisgarh conservation, development, non-destructive harvesting and processing and value addition at local level of the MFP was included in Chhattisgarh Forest Policy of 2001 and Chhattisgarh State Minor Forest Produce (T&D) Co-operative Federation Ltd. was assigned the task of implementation of the policy.

CONTRIBUTION OF MFP IN RURAL ECONOMY

C.G.M.F.P. Federation assigned the study entitled "Contribution of NTFP's in Rural Economy in Chhattisgarh" to the Livelihood School BASIX Bhopal in 2010 as no systematic information was available on this aspect. The income generated by MFP collection has been summarised in Table-1. A few important observations of the study are as follows

(i) On the average NTFP collection contributes to 23% of the income of the house hold of NTFP collector which is second to the 44% contribution of the agriculture only but out of the sale/services income, agriculture contributes to 38% and NTFP collection contributes to 28% of the total income. This emphasises the importance of NTFP income in the life of forest dependent communities.

(ii) On the average 79 days per year and 5 hours per day are spent in NTFP collection by the collectors. The collector on the average travels 4.40 kilometres per day. This observation brings out the fact that the considerable time and energy is spent in the collection of NTFP.

Table 1: **Social Category Wise Annual NTFP Collection**

Social Category	Total price of NTFP items used by Household in Rs.	Total price of NTFP items collected by the Household for commercial purposes in Rs.	Total value of NTFP items collected by the household in a year in Rs.
General	1122.84	4761.32	5884.16
OBC	890.93	4635.65	5526.58
SC	844.72	3956.08	4800.81
ST	1201.79	8156.33	9358.12
Average	1107.2	7034.57	8141.77

BACKGROUND OF MFP TRADE OF CHHATTISGARH/ MADHYA PRADESH

Prior to 1964 there was no legal provision regarding the purchase rate to be paid to the collector of MFP. The purchaser of the forest unit used to decide the rate. To save the MFP collector from exploitation, M.P. Tendu Patta Adhiniyam 1964 for tendu leaves and M.P. Vanopaj (Vyapar Viniyamn), Adhiniyam 1969 for salseed, myrobalans and a few species of gums were enacted to create state monopoly on the trade. The result was that the collectors got the rate fixed by the Government and the Government revenue also increased. The remaining species remained non- nationalized and the system of sale of unit to the contractor continued till 1986. This contractor system was abolished in 1986 and the collectors became free to sell the collected MFP to any purchaser at mutually agreed rate.

FOREST PRODUCE COOPERATIVE SOCIETIES IN CHHATTISGARH

The National Forest Policy of 1988, also suggests for the

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strong institutional support for the trade of MFP. Accordingly three tier cooperative structure was established in 1988 consisting of primary forest produce cooperative society of actual collectors of MFP only, forest division level district forest produce cooperative union with primary societies as members and state level CGMFP (Trade & Development) Federation Ltd. with District unions as members. There is also the provision for reservation of scheduled caste, scheduled tribe and backward castes in the societies. The president of the primary cooperative society of the scheduled area is tribal only. Two seats are reserved for women in all the three tiers of the cooperative structure. The president or the vice president of the primary cooperative society is a woman only. The last election of Board of Directors of the Primary Societies, District Unions and State Federation was held in 2008.

The main objective for the establishment of cooperative structure was to ensure the active participation of the collector in collection, storage and marketing of MFP and accordingly the collectors get the payment of collection price and incentive wages through their elected society. Since these societies have only the collectors of MFP as the members, they are better representative of the stake holders than the gram sabhas who have non collectors of MFP also as the members.

MFP TRADE VOLUME IN CHHATTISGARH

As mentioned earlier that some species are nationalized in Chhattisgarh and their trade is fully regulated by the Acts and many of the species are non-nationalized though they also constitute substantial volume both in terms of money and quantity. The estimated annual value of MFP in Chhattisgarh is given in Table-2 and the information about important non nationalized MFP is given in Table-3.

Table 2: **Annual Trade of Raw MFP in Chhattisgarh**

S.N.	Category of MFP	Species/ Produce	Estimated value of Raw Material in Rs. Crores
1.	Nationalized	Tendu leaves, Sal seed, Harra, Gums-Kullu, Dhawda, Babul, Khair	500
2.	Non - Na-tionalized	Imli, Mahua, lac, Kosa, Mahul Leaves, chironjee, Baibiding, Kalmegh, Aon, etc.	500
Total			**1000**

Table 3: **Important Non-nationalised MFP of Chhattisgarh**

No.	Name of Pro-duce	Approx. Annual Pro-duction (Lakh Quintals)	Approx. Value (Rs. in crores)
1.	Mahua flower	5	110.00
2.	Tamarind	5.10	91.80
3.	Lac	0.85	90.00
4.	Mahua Seed	3	45.00
5.	Charota seed	7	42.00
6.	Niger seed	0.1	40.00
7.	Kosa	6 crores no.	18.00
8.	Aonla	0.31	12.40
9.	Baibiding	0.12	6.00
10.	Mahul Leaves	0.52	5.20
11.	Van Tulsi	0.4 0	4.40
12.	Honey	0.05	3.50
13.	Dhawai flowers	0.26	2.60
14.	Ber fruits	0.3	2.43
15.	Bel	0.16	2.40
16.	Nagarmotha	0.15	2.10
17.	Baheda	0.29	2.03
18.	Karanj Beej	0.30	2.00
19.	Kalmegh	0.14	1.90
20.	Palas flowers	0.22	1.54
21.	Malkangni	0.03	1.00
22.	Other's	1.00	13.64
Total			**500.00**

Tendu Leaf Trade in Chhattisgarh

Tendu leaf is the most important nationalized MFP of Chhattisgarh (Table 4).

Table 4: **Trade of Tendu Leaves in Chhattisgarh**

Collection Season	Collection Rate (Rs. / S.B.)	Collected/ Sold (Lakh St. Bags)	Collection Wages (In Rs. Crores)	Sale Price (In Rs. Crores)	Gain (In Rs. Crores)
2006	450	14.72	66.24	140.02	55.53
2007	500	17.18	85.96	325.59	207.89
2008	600	13.78	82.77	197.61	87.34
2009	650	14.67	95.33	256.41	120.75
2010	700	15.45	108.15	335.31	176.94
2011	800	13.57	108.52	355.31	202.70

Tendu Leaves Tendering System of C.G. and M.P.

The system of sale of tendu leaves through tender is unique based on purchase capacity and priority. A large number of traders and manufacturers from all over the country participate in these tenders. The data for the first tender of last five seasons shown in the Table 5 highlights the competition.

Table 5: **Participation in Tenders of Tendu Leaves Sale in Chhattisgarh**

Collection Season	Lots put to Tenders	No. of Tender-ers	Total No. of Offers by Tenderers	Purchase Capacity (Rs. Crores)	Average No. of offers for lot
2007	929	518	17698	799.34	19.05
2008	931	289	9073	355.4	9.75
2009	931	401	12527	545.75	13.46
2010	931	435	13284	722.77	14.27
2011	931	359	13096	848.06	14.07

The details of the tenderers along with their offers are fed into a computer software. The final decision on the tenders is taken by an Inter Departmental Committee constituted by government notification. It is unfortunate that in spite of such a fair and competitive system of sale of Tendu leaves which has stood the test of time, aspersions are caused by some non-government individuals and persons even sitting in the Government.

Salseed Trade in Chhattisgarh

After tendu leaves, salseed is the next important nationalized species. It's market rate and annual production fluctuates very widely resulting in loss also in some years as evident from Table 6.

Table 6: **Trade of Salseed in Chhattisgarh**

Year	Collection Rate (/Q)	Collected Quantity (Lakh Q.)	Collection Wages (In Crores)	Sale Price (In Crores)	Average Sale Price Per Quintal	Expendi-ture (In Crores)	Gain (In Crores)
2006	500.00	0.488	2.44	3.59	735.55	2.49	1.10
2007	500.00	6.06	30.32	59.09	974.39	30.93	28.16
2008	1000.00	0.899	8.99	12.64	1407.39	9.10	3.54
2009	1000.00	8.864	88.64	51.07	582.21	100.41	-49.34
2010	500.00	1.34	6.72	6.76	502.85	6.94	-0.18
2011	750.00	0.392	2.94	3.72	960.33	2.96	0.76

Trade of Harra and Kullu Gums

The collection rates of other nationalized species like Harra (Myrobalans) and Kullu Gums are also increasing as evident from **Table 7.**

Table7: **Collection Rate of Harra (Myrobalans) and Kullu Gums (Rs. Per Quintal)**

Name of the Produce	2007-08	2008-09/ 2009-10	2010-11	2011-12
Harra	275.00	375.00	450.00	1000.00
Kachriya of Harra	687.50	937.50	1125.00	2000.00
Bal Harra	1925.00	2625.00	3150.00	3500.00
Kullu Gum Grade-I	15400.00	17000.00	22000.00	27000.00
Kullu Gum Grade-II	11000.00	11000.00	15000.00	20000.00

IMPLEMENTATION OF PESA

As per the spirit of PESA the entire value of the nationalised MFPs realised from purchasers is ploughed back to the MFP collectors as basic price and incentive wages etc. in C.G. Primary Co-operative Societies are the basic unit for calculating the amount of profit. Each society compensates for losses incurred in the previous years and there is no cross subsidisation. This results in competitive spirit among primary co-operative societies so as to earn maximum income through quality control. The whole profit earned from the trade of tendu leaves up to 2007 season was distributed in the following manner in C.G.

1.	70% of profit as incentive wages to the collector of tendu leaves.
2.	15% of profit for village resources development by Primary Co-operative Societies.
3.	15% of profit for development of forest and Forest Produce.

Since at present the lots of funds are available such activity from MNREGA, CAMPA, etc. the profit earned from the trade of tendu leaves from 2008 season is being distributed in the following manner in C.G.

1.	80% of profit as incentive wages to the collector of tendu leaves.
2.	15% of profit for purchasing, processing and storage of non-nationalized MFPs by Primary Co-operative Societies.
3.	5% of profit for the fund created to temporarily meet the loss of the Societies from the trade.

The detail of the distribution of the profit of trade is given in Table-8. There is no Government royalty on non-nationalised minor forest produce and the collector gets the full sale proceeds of nationalised MFP. So the trade of MFP in Chhattisgarh and M.P. is in accordance with the spirit of PESA. Though PESA is applicable only to scheduled areas, there is no discrimination between scheduled areas and remaining areas, in Chhattisgarh and M.P. A.P. and Maharashtra States have also started distributing profits of tendu leaf trade to the collectors. Besides, the Chhattisgarh Government has allotted about Rs. 60 crores from its budget to compensate for the losses from trade of nationalised salseed in the interest of MFP collectors which is much more than the PESA stipulates.

In most of the states more than 90% of the MFP's like Mahua fruits and flowers, Tamarind, Aonla, Kosa, Baheda, Honey, Wax, Medicinal plants, etc. are non-nationalised on which forest dwellers are having de facto ownership rights since decades, as they are free to collect, process and sell in the open market, but this has not benefitted them because there is no organized marketing for these produce in rural area and tribal families are exploited in isolated local markets by the middle men. The best way to enhance the income of the forest dwellers is to provide strong marketing support along with the full usufruct.

Table 8: **Distribution of profits of trade of tendu leaves (salseeds in 2007)**

Year	Incentive Wages to the Collectors (in Rs. Crores)	Amount for Infrastructural Development Works (in Crores)	Amount for Development for Forests (in Crores)	Amount for Trade, Storage and Value Addition of Non-nationalised MFPs (in Crores)
2001	28.64	6.69	6.69	---
2002	39.95	8.59	8.59	---
2003	33.31	7.10	7.10	---
2004	25.37	5.58	5.58	---
2005	24.48	5.25	---	---
2006	31.54	6.76	---	---
2007	116.32	22.69	---	---
2008	65.75	---	---	12.35
2009	94.27	---	---	17.67
2010	138.66	---	---	26.00
2007	19.81	4.26	4.26	---

Union Ministry of Panchayati Raj appointed a committee headed by Shri A.K. Sharma on the implementation of PESA only which in its report observed/ recommended the following –

i. The three-tier society based federal system for the collection of MFP at the village, intermediate and district level as in M.P. and Chhattisgarh states appears to be the best democratic and decentralized system that comes closest to the soul of the PESA. It is recommended that various states may consider adoption of this system as an option.

ii. The committee recommended minimum statutory price (MSP) for MFP and a regulatory authority at the state level to oversee the minimum statutory price for MFP. Each PESA state must declare every year a comprehensive list of MFP along with their procurement price dealt with by their FDCs/TDCs/FEDs.

Though the profits from the trade of tendu leaves is fully returned to the collectors in Madhya Pradesh., Chhattisgarh, Andhra Pradesh and Maharashtra and no revenue is earned by State exchequer from non nationalized species, non implementation of provisions of PESA in respect of MFPs in the Scheduled Areas is being talked about as one of the causes of the spread of Left Wing Extremism and the perception of some people, both outside and inside the government, perhaps is that it is really so. This perception is perhaps based on account of lack of information/ miss-information and is ill founded.

The demand of doing away with extant State regulations and three tier co-operative structure and vesting full and final authority in respect of MFPs to the Gram Sabhas is not being raised by the MFP collectors, or by the forest committees of the local inhabitants, or by the elected Panchayats, or by the elected representatives of the tribal areas in Chhattisgarh, but by the outsiders who are not well acquainted with the existing system in place and the benefits thereof. If the state intervention is withdrawn and Gram Sabhas are authorized to handle the MFPs on their own, they will not be able to undertake the required activities and discharge the responsibilities. Small, petty and other intermediates are sure to enter the system bridging the gap between the Gram Sabhas and the end-users and in the process, each intermediary i.e. sub district, district and state level would mop his own commission / profit in the chain. In such a new system, total gain of the MFP collectors will reduce drastically.

SOCIAL WELFARE OF THE M.F.P. COLLECTORS OF CHHATTISGARH

Since MFP collectors are generally very poor, it is not sufficient to ensure fair price of their produce. The collectors are in dire need of social security also. The following social welfare schemes have been launched in the State.

Footwear Distribution

The collectors of MFP generally visit the forest area bare foot. To protect the feet of tendu leaf pluckers from vagaries of the nature, one pair of footwear is distributed to each family every year from the funds of State exchequer as given in Table 9.

Table 9: **Footwear Distribution to Tendu Leaf Pluckers**

Year	Footwear Distributed (In Lakh Pair)			Purchase Rate per Pair (In Rs.)	Amount Received from State Govt. (In Rs. Crores)
	Male	Female	Total		
2006-07	7.90	4.63	12.53	88.00	11.345
2007-08	9.30	3.30	12.60	76.40/81.70	13.00
2008-09	---	12.82	12.82	63.36	8.00
2009-10	---	13.22	13.22	52.98	10.00
2010-11	13.76	---	13.76	105.00	10.00
2011-12	---	11.45	11.45 (Distribution in progress)	125.00	10.00

Jan Shree Group Insurance

Jan Shree Group Insurance Scheme for all the tendu leaf plucker's family head was started from 01.05.2007. The 50% amount of the insurance premium is paid by Government of India and 75% and 25% of the balance 50% amount is paid by State Government and Federation respectively. The family head or his nominee gets following amount on his death/disability:-

- Normal death – Rs. 20000/-
- Partial disability due to accident – Rs. 25000/-
- Accidental death or permanent disability – Rs. 50000/-

Two children of the family head studying between 9^{th} and 12^{th} class and in ITI get scholarship @ Rs. 1200/- per year under the Shiksha Sahyog Scheme. The details of the benefits are given in Table 10.

Table 10: **Insurance and Scholarship Claims of tendu leaf pluckers**

Financial Year	No. of Claims Settled	Amount Paid to the Claimants (In Rs. Crores)	No. of Student Received Scholarship	Amount Paid as Scholarship (In Rs. Crores)
2007-08	2143	4.49	42319	2.40
2008-09	6883	14.65	119764	7.05
2009-10	4252	8.86	26068	1.97
2010-11	7390	15.77	67926	8.15
2011-12 (Up to 30.06.2011)	4397	9.39	---	---

Group Insurance Scheme

Group Insurance Scheme for the tendu leaf pluckers started from 1992. Pluckers between the age of 18 and 60 years except the head of the family are insured.

The collector/nominee of deceased gets as follows :-

- Normal death – Rs. 3500/-
- Partial disability due to accident – Rs. 12500/-
- Accidental death or permanent disability – Rs. 25000/-

Brilliant Student Motivation Scheme

(a) The following cash awards are being given from year 2011-12 to one boy and one girl of every primary forest produce cooperative society obtaining highest marks in class VIII, X and XII,

Examination	Award Amount
Class VIII	Rs. 2000/-
Class X	Rs. 2500/-
Class XII	Rs. 3000/-

(b) To encourage the professional education like Medical, Engineering, Law & MBA etc, one student in every primary society will be given Rs. 10000/- in first year and Rs. 5000/- every year from 2nd year to fourth year. The alternate year is earmarked for girl student only. The above four social welfare schemes are very beneficial to the MFP collectors and are very popular among collectors of MFP with the result that the forest dependent communities feel that State Government is concerned about their social security.

DEVELOPMENT OF RESOURCE - PEOPLE'S PROTECTED AREAS (PPA)

The basic objective of establishment of PPA's is to enhance the production of MFP and their sustainable harvesting to provide income to forest dependent communities and ensure ecological security. Each PPA consists of 3000 ha of forest area rich in NWFP. Every year, 1000 ha of this area is brought under in-situ conservation. The Resources survey is carried out every year by laying sample plots in the month of September – October in in-situ conservation areas to collect the information about three canopies especially ground flora. The following main activities are being carried out with the involvement of forest committees.

- Soil and moisture conservation of forest area.
- Assisted natural regeneration in forest area.
- Protection against fire & grazing of forest area.
- Sustainable harvesting and primary processing of MFP along with training of villagers and staff.
- Establishment of herbal hospitals

NON-DESTRUCTIVE HARVESTING OF MFP

Forest dwelling community has been traditionally collecting MFP/ medicinal plants to earn livelihood without adequate concern towards sustainability. There is a lot of pressure of overexploitation of medicinal plants mainly due to demand from the Ayurveda industry. It is desirable that MFP should be properly conserved, sustainably managed, and harvested non-destructively. To overcome the problem of destructive harvesting, Federation developed manual for non-destructive harvesting methods of commercially important species for trade. The medicinal plant/MFP collectors, local SHGs, Forest committees, Primary Cooperative societies are being actively involved and trained every year in sustainable and non destructive harvesting of forest produce. The research projects for development of sustainable harvesting practices of Bhui-aonla (*Phyllanthus amarus*), Arjuna (*Terminalia arjuna*), Salparni (*Desmodium gangeticum*) and Baichandi (*Dioscprea hispida*) have been given to TFRI, Jabalpur by Federation. Sustainable and non-destructive harvesting practices should be developed for all the commercial species by Forest Research Institute, Dehradun. There is a need to have legal provisions also for enforcement of sustainable harvesting practices.

RESOURCE SURVEY OF MFP, ETHNOBOTANICAL SURVEY AND ESTABLISHMENT OF VANAUSADHALAYA IN CHHATTISGARH

The resources survey field work and data entry for the year 2007, 2008 and 2010 have been completed in 2358, 2460 and 79 plots respectively and analysis is in progress. The software for resource survey was developed by Forest Survey of India Dehradun. This survey gives an insight on availability of MFP in Chhattisgarh.

Ethnobotanical Survey has been completed in 21 areas of the state, 418 traditional healers were interviewed and 3401 traditional herbal formulations used for various purposes were documented. Team of Ayurveda experts has validated 2359 herbal formulations, out of which 47 herbal formulations were identified for further research from Central Council for Research in Ayurveda and Siddha (CCRAS), New Delhi. Out of 47 herbal formulations 09 formulations have been sent to CCRAS, New Delhi for further research and validation. CCRAS, New Delhi has initially started work only on four formulations due to business of the organization in other engagements.

To promote traditional herbal health care, 50 traditional healers have been identified and accordingly 50 vanausadhalaya (Herbal Dispensary) are being constructed, to provide the treatment for common ailments in various remote areas of Chhattisgarh on the basis of ethnobotanical survey.

VALUE ADDITION OF MFP & MARKETING IN CHHATTISGARH

NWFP based Microenterprises are established to promote collection, processing and marketing of minor forest produce. The main activities include raw MFP procurement and sale, honey collection and processing, production of herbal products and retail marketing of herbal products. Each Microenterprise is managed by a group of SHGs working at different levels. SHGs work at village level, haat bazaar and storage level and Sanjeevani level and are involved in procurement, value addition and marketing. Federation provides financial assistance to local SHGs for establishing NWFP based Microenterprises. Village level SHGs purchase the produce from collectors at fix price, pack and resale the same to Haat bazaar level SHG at the fix price. Haat bazar level SHGs are incharge of temporary storage and sale centre and they purchase above produce at fixed rate and resale the same at NWFP mart at a predetermined rate. The SHGs get commission over collection price and transportation charges. Forty NWFPs have been shortlisted for collection and accordingly purchase price declared by Federation.

The following main processing activities are being carried out in C.G.

1. Four Honey processing units have been set up.
2. Tamarind deseeding and packaging in the bricks of different sizes.
3. One Tamarind candy unit has been established in Jagdalpur.
4. Mahul leaf processing to prepare plates and cups.
5. Chironjee processing and packaging in to packets.
6. Preparation of murabba, candy and syrup from Bel and Aonla.
7. Production of 37 herbal medicines.
8. Tikhur and Baichandi processing and packaging.
9. Brooms from Phul bahari grass.
10. Lac processing.

Various types of basic and technical trainings are organized to enhance the skill and knowledge of beneficiaries and staff for the development of microenterprise. Technical support for obtaining drug license, quality testing, labelling and packaging, Good Manufacturing Practices(GMP) and development of Standard Operating Procedure (SOP) are provided by Federation to SHGs.

Six NWFP Marts and 42 Sanjeevani Retail Outlets have been established in the State and products are sold under registered brand name "Chhattisgarh Herbal". The brand is promoted using punch line “Quality Forest product” and slogan for “Being Healthy”.

The following research projects have been assigned by Federation to develop value added products to CFTRI, Mysore.

- *Aegle marmelos* (Bael) Fruit - Murabba, Spread and RTS Beverage
- *Curcuma angustifolia* (Tikhur) Rhizome – Powder

The project to develop the most appropriate primary processing technique for Bael has been given to TFRI, Jabalpur.

EUROPEAN COMMISSION PROJECT

CGMFP Federation is implementing an integrated project of Rs. 21.20 crores namely NWFP based Livelihood Activities in Chhattisgarh with the financial assistance of European Commission State Partnership Programme. The project components are collection and value addition of MFP, resource inventory, capacity building, management information system, marketing, certification, traditional knowledge and R&D.

LAC CULTIVATION IN CHHATTISGARH

Lac host plants like Kusum, Palash and Ber are found abundantly in forest and non-forest areas of the State. Lac cultivation provides employment and sustainable income at the door step of the beneficiary. The cultivation of lac is very lucrative. A Kusum tree produces about 30 kg of lac per year yielding an income of about Rs 4,500 and a Palash tree produces 4 kg of lac per year providing an income of Rs 300. State level Inter Departmental Cell headed by Hon'ble Forest Minister has been constituted for promotion of cultivation, processing and marketing of Lac in CGMFP Federation. Special efforts were made to promote lac cultivation since 2004-05. The capacity building through training and supply of brood lac were the main support to the beneficiaries. The result was that the production of lac increased by 58% in two years and Chhattisgarh produced 7198 MT of lac in year 2008-09 which was the highest in the country.

Lac development scheme has been started from the State budget with annual provision of about Rs. 2.00 crore. Six Lac Facilitation Centres headed by executives have been established to provide technical support to the cultivators. About 200 twelfth pass local rural youth trained in lac cultivation work as lac facilitator to perform extension activities. Besides primary cooperative society managers also carry out extension work. Twenty Lac cultivation micro enterprises have been established, in which about 7067 beneficiaries cultivate lac on approximate 18498 Kusum trees, 20099 Palash trees and 4770 other host trees. Lac training centre is also being established in Kanker at cost of Rs 1.00 Crore.

C.G.M.F.P. Federation is also implementing a livelihood project sanctioned by Ministry of Rural Development, Govt. of India, New Delhi under special SGSY scheme of Rs.14.98 crores for poverty alleviation based on lac cultivation and processing in Chhattisgarh for 13000 beneficiaries.

Lac has good demand in export. Lac cultivation and processing should be promoted in M.P., Maharashtra, C.G., Orissa and Jharkhand having large number of lac host trees to provide substantial income at the door step with a little effort cultivation of lac ensures protection of host trees against felling also.

CERTIFICATION

National Programme on Organic Production

Organic farming/collection is gaining gradual momentum all over the world. The ill-effects of chemicals used in cultivation and growing environmental awareness have changed the mindset of health conscious consumers who are willing to buy organic produce at premium prices in many countries including India, resulting in the increased demand of organic produce. Since the trend of rising consumer demand for organics is becoming discernible, sustainability in cultivation/wild collection is very important. The Ministry of Commerce of G.O.I. has launched the National Programme on Organic Production (NPOP) to promote organic production and cultivation.

The forest areas are ‘organic’ by default also. Tribals have been using traditional methods of cultivation and many tribal areas are yet to come under the intensive use of chemical fertilizers and pesticides to enhance production. The abject poverty amidst tribal prevents them from affording inorganic fertilizers and chemical pesticides even if they were willing to do so. Thus, the forest and tribal habitation maps of the Country overlap largely with organic areas.

An autonomous body CGCERT i.e. Chhattisgarh Certification Society, India, Raipur has been accredited by Ministry of Commerce, Govt. of India for organic certification for export as per NPOP in September 2009. Certificate of Authorization (CA) was granted by AGMARK, Ministry of Agriculture GOI, Faridabad for domestic selling of organic products on 10th January 2011. CGCERT is the 1st Certification Body (CB) granted CA for domestic organic certification in the country. CGCERT has now registered 31 operators from Chhattisgarh and Madhya Pradesh.

So there is a need to promote organic certification of wild collection and cultivation in and around forest areas throughout the country to ensure better prices to the forest dependent communities in a sustainable manner.

Certification Scheme for Medicinal Plants

The National Medicinal Plant Board (NMPB) and Quality Council of India (QCI) have launched a Voluntary Certification Scheme for Medicinal Plants (VCSMP) in 2010. The National Medicinal Plant Board (NMPB), Department of AYUSH and World Health Organization (WHO) have prepared India specific Guidelines on Good Agriculture Practices (GAP) and Good Collection Practices (GCP) for medicinal Plants. The objective of the scheme is to enhance confidence in the quality of India’s Medicinal Plant Produce and make available good quality raw material to the AYUSH Industry.

The scheme will benefit :-

(a) Medicinal plant producers/collectors/group of producers or collectors.
(b) Traders/Manufacturers of herbal medicine/AYUSH Industry.
(c) AYUSH Consumers due to the assured quality of medicinal plant/herbs.

CGCERT is planning to take accreditation as certification body for this scheme also.

MINISTRY OF TRIBAL AFFAIRS, G.O.I. SCHEME OF MFP

The Scheme of 'GIA to STDCCs for MFP Operations introduced by the Central Government in the year 1992-93, provides for funding of State Tribal Development Corporations/Federations for the following activities:

1. Increasing the quantum of MFP handled by setting off operational losses, if need be.
2. Strengthening the share capital base of the Corporation for undertaking MFP operations.
3. Setting up of scientific warehousing facilities, wherever necessary.
4. Establishing processing industries for value addition with the objective of ensuring maximum returns on the MFPs for the tribals.

The Central Government provided Rs. 9.52 crores to C.G.M.F.P. Federation, Chhattisgarh from 2004-05 to 2010-11. The scheme is good but fund flow is irregular and allotment in the scheme is meagre compared to the requirement of the country.

INTRODUCTION OF MINIMUM SUPPORT PRICE FOR MFP

The 10th Report of the Standing Committee of members of parliament on Social Justice and Empowerment (2005-06) felt an urgent need for bringing the MFP under the ambit of Minimum Support Price (MSP) so that the tribals get proper value for the forest produce collected by them. Ministry of Panchayati Raj of Govt. of India has constituted a committee to ensure fair price to the MFP collectors in 2010. MoEF, GOI has decided to purchase Mahua flower and seed, Lac, Imli, Myrobalans and Salseed on support price initially. Procurement of MFP should be aimed at ensuring remunerative and best possible prices to collectors of MFP and not merely the support price. Constitution of collection units specifying the geographical area for each species is the first step to start procurement. In my opinion there are following three options:

Procurement Option – 1

Sale of units in advance of collection to purchasers (traders). Purchase price fixed by the Government to be paid by the purchaser to the collector at predecided collection centres/ bazaars.

Advantages	Disadvantages
1. Financial requirement is not much.	1. Sale of all units in the beginning years is doubtful.
2. Traders will ensure quality of the produce and it may increase the sale price.	2. Sale price of forest produce may be influenced by the local small traders, as it may be difficult for big traders to manage many small collection centres.
3. No. problem of transport and godowns.	
4. Overhead expenditures are not much.	

Procurement Option – 2

Sale of produce after purchase of NWFP by institution authorized by the Sate Govt. at a price fixed by the Government at predecided collection centres/bazaars.

Advantages	Disadvantages
i) Stored NWFP may get good price in tenders because big traders from different states will participate in the tender.	i) Requirement of financial resources is very high and overhead expenditures are more in comparison to Option-1 but much less then Option-3

	ii) Need of huge storage facilities.
	iii) Transportation management is needed.
	iv) Difficulty in ensuring quality of the produce.

Nationalisation of NWFP is essential to eliminate the malpractices of middle men at collection centres and the profit in option 1 & 2 can be distributed as incentive wages, as is being done for tendu leaves in many states

Procurement Option – 3

Purchase of MFP by Govt./Federation/Corporation at support price at pre-decided collection centres fixed by the Govt. Trader can also purchase MFP if the collectors want to sell to him at mutually agreed rate.

Advantages	Disadvantages
i) Collectors may be benefited when market prices are lower than support price.	i) Possibility of good quality material going to the traders and bad quality material coming to the Govt.
	ii) If the market price of the produce is much more than the support price, then local traders will purchase it from collectors and sell it in the bigger markets at much higher price than paid to the collector.
	iii) If market price is less than the support price, Govt. will have to procure huge quantity and incur losses. Even the local middlemen will try to push their stock in Govt. purchase.
	iv) Manpower, financial resources and storage facility requirements will be very high.
	v) Large overheads, specially when the purchase volume is low.

It is worth mentioning that no big trader of Bastar area trade in tendu leaves in spite of huge production in the area. They trade mainly in Mahua and Imli because of much higher profit in the trade of non-nationalized species to the traders due to exploitative practices. Traders in Chhattisgarh oppose the option 1 and 2 but favour the option 3. In my opinion proposed option 1 is the best for the procurement of MFP, as it has been successful for tendu leaves. This option ensures the best possible competitive price to the collector by way of procurement wages and incentive wages.

ROLE OF ORGANIZATIONS OF GOVT. OF INDIA

Ministry of Tribal Affairs

At present funds flow for MFP operation is small and irregular. The Ministry should provide sufficient funds every year for procurement and value addition of MFP and construction of storage godowns on the basis of forest area, tribal population and potential of MFP production. There is a lot of support for agriculture sector in terms of various subsidies/ support price but MFP procurement is little supported though the poorest of the poor specially tribals are engaged in MFP collection.

Tribal Marketing Federation of India (TRIFED)

TRIFED is a national apex co-operative body which is supposed to promote the interest of tribals through MFP operations but at present there seems to be a little contribution from this organization. As far as procurement of MFP is concerned the field operations should be left to CGMFP Federation and similar organizations in other States as the state organizations have vast network of societies throughout the state. TRIFED should establish or facilitate in establishing modern processing units in urban and rural areas to enhance the return from MFP to tribals.. At present there is a lot of potential of export of raw herbs and herbal products. TRIFED should play active role in undertaking marketing in general and export in particular.

Ministry of Environment & Forests

MOEF should initiate special scheme for In-Situ conservation of NWFP/medicinal plant rich forest areas. This scheme should have components of resource inventory, conservation, good collection practices, capacity building of collectors of NWFP, JFM committees and Primary Cooperative Societies and processing and value addition of NWFP. Appropriate and proactive guide lines should be issued under Forest Conservation Act to promote the cultivation of MFP/Medicinal plants in forest areas. Sustainable harvesting and good collection practices of NWFP should be developed in ICFRE, IIFM and other institutes. Legal provision for National Transit Permits should be made to avoid unnecessary delays/ inconvenience in transit of forest produce due to change of T.P. at State borders.

Ministry of Health

Collect information on source and quantity of the various raw MFP consumed by the pharmaceutical companies to facilitate better cultivation and collection planning of medicinal plants. At present the Sal fat, which is cocoa butter equivalent, is not allowed to be used in chocolate manufacturing in India, though it is allowed in Japan and European countries. If the permission is granted under Prevention of Food Adulteration (PFA) Act in India, Sal fat can fetch much better price resulting in better remuneration to a large number of collectors of Sal seed of C.G., M.P., Jharkhand and Orissa. Department of AYUSH should evolve some recognition system for traditional healers for better utilization of traditional knowledge.

Ministry of Commerce & Industries

Ministry should insist on MFP based industries to supply information of species wise consumption of MFP as raw material to develop MFP database at National Level required for developing strategy to promote domestic trade and export. Ministry should facilitate the smooth export of NTFP. Probably SHEFIXIL, Kolkatta is not proactive enough to promote the exports of MFP other than Lac.

Ministry of Agriculture

In view of the large production of tree borne oil seeds from Mahua, Sal, Karanj and Neem in Madhya Pradesh, Maharashtra, Chhattisgarh, Orissa, Jharkhand and Andhra Pradesh and dependence of a large population for livelihood, a Tree Borne Oil Seed Research Institute of ICAR to develop value added products should be established in Raipur.

CONCLUSION

1. In view of the above, it is clear that C.G. and M.P. Govt. are providing the collectors of M.F.P. more than what PESA stipulates. I am of the view that if the extant State regulations and three tier co-operative structures, which have stood the test of time are done away with, there will be complete anarchy and MFP collector families of Chhattisgarh and M.P. would suffer loss of income. Therefore, I strongly feel that the present trade system of nationalized species in C.G., M.P., A.P., Maharashtra and Orissa should continue.
2. The Govt. of India should provide financial assistance for purchase of non-nationalised species similar to purchase of agriculture produce as their value and volume are substantial to ensure fair price to the collectors. The forest produce collectors deserve the priority as they constitute the poorest strata of the society. However the detailed mechanism for the purchase of forest produce will be quite different from that of agriculture produce and may be state specific.
3. The role of established existing institutions of the States like Forest committees, Cooperative societies and State level Corporations/ Federations in MFP trade should continue and strengthened.
4. The State Govt. must have full jurisdiction to regulate the trade of MFP through State rules and regulations to protect the interest of the collectors as they are still very vulnerable to exploitation by middlemen.
5. The ownership of MFP should be interpreted as full right of the collectors on usufruct only. Ownership should not be interpreted literally, as the forests, whose owner is Government and MFP, are intricately mixed and forests perform much more important regional/ national/ global environmental functions.
6. The State Govt. should have full powers to enforce sustainable harvesting principles which include restriction on the quantity of harvesting even to ban the exploitation of endangered species. Sustainable and non-destructive harvesting practices should be developed for all the commercial species by Forest Research Institute, Dehradun. The working plans should incorporate effective sustainable NTFP management also. There is a need to have legal provisions for enforcement of sustainable harvesting practices.
7. The processing and Value addition of MFP should be promoted in all States like Chhattisgarh, Madhya Pradesh and Andhra Pradesh.
8. Maximum number of lac host trees i.e. Kusum, Palash and Ber, etc., should be brought under lac cultivation.
9. Organic production and certification of MFP under NPOP and Certification of Medicinal Plants under VCSMP should be promoted.
10. The Social Welfare Schemes in Chhattisgarh for M.F.P. collectors like insurance and distribution of shoes can be adopted by other States also.
11. The herbal hospitals benefiting the society from traditional knowledge should be established in biodiversity rich areas of the Country. If some recognition system is evolved by Department of AYUSH, Ministry of Health GOI, the healer will feel dignified.
12. GOI should make legal provisions for National Transit Permits to ensure smooth movement of forest produce throughout the country.
13. Interministerial NTFP board in MoEF Govt. of India should be constituted to provide necessary State specific support and subsidy to state organizations like MFP Federation/Tribal Corporations, for conservation and development of MFP, fair price procurement, value addition, certification, marketing and capacity building, etc., in MFP sector.
14. The various Ministries of GOI should play proactive role as specified above.

Bamboo Shoots: Standardization of Harvesting Time for Obtaining Quality Produce to Augment its Utilization

A.K. Pandey and Vijayalakshmi Ojha *

INTRODUCTION

Bamboo shoots are young and tender culms of bamboo that are consumed for various food items after harvesting (Daphne, 1996; Caitlin and Miles, 2000; Tamang, 2005; Bal *et al.*, 2008; Pande and Pandey 2008). The freshly harvested shoot is cream yellow in colour, bitter in taste and has a strong smell. All species of bamboo shoots available worldwide are not edible. There are a number of bamboo species available in India and many of the species are used for edible purpose. *Dendrocalamus strictus* and *Bambusa bambos* are the commonly occurring species in central India. The other species are *B. nutans, B. tulda, D. giganteus* and *D. hamiltonii*. However, *Dendrocalamus asper* an important edible species of Thailand (Fu *et al.,* 1987) has been introduced in India for shoot production. In central India, bamboos are not commercially cultivated for its edible shoot production. Generally people harvest bamboo shoots from nearby forests. However, in some places it is also harvested from cultivated sources (plantations and home gardens). *D. longispathus, D. brandissi, B. balcoa, B. polymorpha, B. pallida* and *Melocanna baccifera* are used for edible purpose in North east region (Bhatt *et al.*, 2004). Other than these, *Arundinaria aristata, A. hirsuta, B. glaucescens, B. longispiculata, B. vulgaris, Cephalostachyum capitatum, C. fuchsianum, D. hookeri and Oxytenanthera albocilita* are the edible species found in southern India (Shanmughavel, 2004). The shoots are consumed in raw, dried, canned, boiled and fermented form. The shoots are seasonal, perishable and available for a short period.

Worldwide, bamboos have an estimated total potential approximately US$10 billion. In the international market, China earns US$130 million every year from exports of edible bamboo shoot, with imports of US around 44,000 tonnes accounting for 14.5% of the total world imports (Lobovikov, 2003). It has been observed that every year US imports 30,000 tonnes of canned bamboo shoots from Taiwan, Thailand and China to be consumed as food items (Daphne, 1996). At present over 2 million tonnes of edible bamboo shoots are consumed in the world in each year (Vaiphei, 2005; Yang *et al.*, 2008), where about 20-30 million tonnes of bamboo shoots are utilized for production of canned bamboo shoots annually (Bhatt *et al.*, 2003; 2005 a; b). India's size of domestic bamboo economy currently is estimated at 2,000 million Indian rupees. The market potential of bamboo in India will increase to 26,000 million Indian rupees by 2015, thus enabling five million families of artisans and farmers, crossing the poverty line (Farooquee *et al.*, 2007).

Bamboo shoots are becoming one of the preferred food products in the world, but there is hardly any organized bamboo shoot processing and marketing industry. Depending upon the species, bamboo shoots are usually 20-30 cm long and taper to a point. A bamboo shoot at the time of harvest normally weighs more than 1 kg. However, their size and weight depend considerably upon the location, depth, pH and nutrition of the soil, irrigation and drainage conditions, climate, rainfall, temperature and soil type. Cold tolerance is a limiting factor in the growth of certain bamboo species (Kigomo 2007; Dollo *et al.*, 2009).

Various constituents like acids, proteins, carbohydrates, starch, fat, dietary fibre, vitamins and minerals have been systematically analyzed and reported by various authors (Lee and Takahashi 1966; Goering and Van Soest, 1970; Bradford, 1976; Baker *et al.*, 1980; Reiss, 1993; Nirmala *et al.*, 2008). The shoots are low in fat content, but contain considerable amount of carbohydrate, total phenols and are a good source of potassium, vitamin B6, thiamine, riboflavin, niacin, vitamin C and dietary fibres like hemicelluloses, cellulose, pectin and lignin (Tripathi, 1998; Park and John 2009).

Phenolic compounds, commonly referred to as polyphenols, are secondary metabolites and their distribution is almost ubiquitous (Pereira *et al.,* 2009). These are present in all plants because they are multifunctional and act as free radical terminators, metal chelators, and singlet oxygen quenchers (Kris-Etherton *et al.,* 2002). Experimental evidence shows that phenols possess anti-inflammatory, antimicrobial, antithrombotic, cardioprotective, and vasodilatory effects (Middleton *et al.,* 2000; Yang *et al.,* 2001; Mamani- Matsuda *et al.,* 2004; Manach *et al.,* 2005) that are important for good health and disease prevention. These beneficial effects of phenols are due to their strong antioxidant activity wherein they scavenge oxygen radicals and other reactive species (Rice-Evans *et al.,* 1997; Parr and Bowell 2000; Heim *et al.,* 2002; Dini *et al.,* 2006).

Besides bamboo shoots also contain cyanogenic glycoside taxiphyllin, which is toxic in nature (Ferreira et al., 1995; Fu *et al.*, 2002; Sarangthem and Singh 2003). HCN is a crash product of cyanogenic glycosides which breakdown upon disruption of the plant cell. Many authors and organizations (Simeonova and Fishbein, 2004; ATSDR, 2006; Satya *et al.*, 2009; NMBA, 2009) have assessed these glycosides. The amount of cyanides present

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in shoots varies depending upon the species. Generally, the shoots contain 0.3 to 0.8% HCN (Poulton, 1983; Tripathi, 1998; Anonymous, 2004). Out of which, up to 0.16% is contained in the tip reducing to 0.01% at the base (Haque and Bradbury, 2002). The new shoots are free from acrid taste and are brilliant for human consumption. However, these glycosides increase with the age/ maturity of shoots (Anonymous, 2004). Thus, it is necessary to harvest shoots, at right time, before the lethal concentration gets accumulated. The information regarding the harvesting time of bamboo shoots is scarce and less scientific validation has been done with respect to the nutritional status in different aged bamboo shoots. Therefore, present study was carried out to standardize the harvesting time of bamboo shoots in central India for obtaining quality produce.

MATERIALS AND METHODS

The species selected for the study were *B. tulda, D. strictus* and *D. asper*. The study was carried out at the Non Wood Forest Produce (NWFP) Division of Tropical Forest Research Institute (TFRI) during July- August, 2010. The newly emerging shoots of different age, ranging from 2-20 days, were collected from the NWFP nursery and Botanical Garden of TFRI and brought to the laboratory. The collection was done during morning hours as transpiration is less. The outer sheath was peeled and length, diameter at the base, weight of fresh shoots before and after removing sheaths was recorded to determine the percentage of edible portion. For *D. asper*, 8-18 days, *D. strictus*, 2-16 days and *B. tulda*, 4-20 days old shoots were selected as shoots before the particular mentioned day were much leafy and doesn't contain considerable amount of edible portion and shoots after the day mentioned were much woody with less soft portion. After peeling off the sheaths, the inner soft portion of shoots was taken and analyzed for their nutritional, anti-nutritional and phenolic acid composition to determine the suitable age for harvesting of bamboo shoots.

The nutritional analysis of the shoots was determined by using standard established methods. The total carbohydrate content was analyzed spectrophotometrically by Anthrone's method (Hedge and Hofreiter, 1962), total proteins by Lowry's method (Lowry et al., 1951), total phenols by using Folin- Ciocalteau method (McDonald et al., 2001), ascorbic acid by titrimetric method (Raghu et al., 2007), cyanogens as hydrocyanic acid equivalents spectrophotometrically (Hogg and Ahlgren, 1942), all minerals and phenolic acids (Gallic acid, caffeic acid, vanillic acid, chlorogenic acid and ellagic acid) by the methods given by Jacobs 1999 and Shrivatava et al., 2009 with little modifications. Antioxidant activity was carried out by the method described by Nickavar *et al*. (2006) with slight modifications.

Estimation of phenolic acids (Shrivatava *et al.*, 2009 with some modifications)

SAMPLE AND STANDARD PREPARATIONS

2.5 g of sample (fresh bamboo shoot) was taken in a conical flask containing 50 ml of 2 N hydrochloric acid (HCl). The content was then kept in a boiling water bath for 30 minutes, cooled and filtered. The filtrate was transferred to a separating funnel and extracted with 100 ml (50, 25 and 25 ml) of diethyl ether. The combined ether layer was washed with distilled water and dried over anhydrous sodium sulphate. The residue thus obtained was dissolved in 10 ml of HPLC grade methanol and filtered through a 0.22μm disc filter before injecting in HPLC. Standard solutions (1mg/ml) of gallic acid, vanillic acid, caffeic acid, chlorogenic acid and ellagic acid (all purchased from sigma) were prepared by dissolving in HPLC grade methanol and filtered through a 0.22μm disc filter.

CHROMATOGRAPHIC EQUIPMENT AND CONDITIONS

A Waters (Milford, USA) gradient HPLC instrument equipped with two 515 pumps and controlled by an interface module PC2, manual injector valve (Rheodyne), reverse phase C18 (100 × 4.6 mm i.d.) X bridge HPLC column (Waters, Milford, USA) and Waters 2996 PDA (Photo Diode Array) detector was used for HPLC analysis. Waters Empower software was used to control the equipment and analyze the data. Mobile phase consisted of water, methanol and acetic acid in the ratio 60:40:0.4 having a flow rate of 1.6 ml/min. 5μl of sample and standard were injected.

ANTIOXIDANT ACTIVITY

The evaluation of the free radical scavenging activity of each of the extract was carried using the DPPH (2, 2-diphenyl-1-picrylhydrazyl) assay. Five gram of dried and powdered plant material was taken in a conical flask containing 100 mL of 2 N hydrochloric acid (HCl). The content was kept in a boiling water bath for 30 min, cooled and filtered. The filtrate was transferred to a separating funnel and extracted with 150 mL (50x3) of diethyl ether. The combined ether layer was then washed with distill water and dried over anhydrous sodium sulphate. The residue thus obtained was dissolved in 10 mL methanol and various concentrations of sample extracts were prepared in methanol. One mililiter of 0.3 mM DPPH in methanol was added to 2.5 mL solution of the extract or standard and allowed to stand at room temperature in dark for 30 min. The change in colour from deep violet to light yellow was then measured at 518 nm using spectrophotometer. Blank consisted of 1 mL methanol and 2.5 mL of each sample solution, negative control contained 1 mL DPPH solution and 2.5 mL methanol. Gallic acid was used as standard.

The decrease in absorbance by the DPPH radical with increase in concentration of the extract which manifested in the rapid discolouration of the purple DPPH, suggest that samples have antioxidant activity due to their proton donating ability (Adesegun *et al*., 2007). The decrease in absorbance was then converted to percentage antioxidant activity using the following formula:

Antioxidant activity (%)=
$[Abs_{control}-(Abs_{sample} - Abs_{blank})/Abs_{control}]$x 100

STATISTICAL ANALYSIS

Data were subjected to statistical analysis using SPSS (Version 14.0) software. Data are expressed as mean ± SD (n=3). One way analysis of variance (ANOVA) was performed. Statistically best treatment was determined using Duncan's Multiple Range Test at $p < 0.05$ level of significance.

RESULTS AND DISCUSSION

Edible portion, nutritional and phenolic acid composition of bamboo shoots of *D. asper* harvested on different days of harvest is presented in Table 1. The percentage of edible portion (53.50 ± 8.48) and total phenols (1.32 ± 0.1) initially increased with maximum on 12th day and then decreased. Concentration of carbohydrates and cyanogens increased with respect to harvesting days (maturity), however, the percentage of proteins decreased. Ascorbic acid, phosphorous, calcium and magnesium did not vary significantly, however there was a slight variation in the concentration of sodium and potassium. Concentration of gallic acid and chlorogenic acid initially increased up to 14th day however, the concentration of gallic acid became constant and that of chlorogenic acid decreased. Concentration of caffeic and vanillic acid was found to increase with the days of harvest, while the concentration of initially increased up to 14th day and then decreased.

Table 2 depicts the edible portion, nutritional and phenolic acid composition of bamboo shoots of *D. strictus* harvested on different days. The percentage of edible portion and total phenols initially increased and then decreased. Highest percentage of edible portion was found on 12th day (62.23 ± 6.59) and that of total phenols on 6th day (2.97 ± 0.19). Concentration of carbohydrates and cyanogens increased with respect to days of harvest (maturity), however, the percentage of proteins decreased. The concentration of ascorbic acid, phosphorous, calcium and magnesium did not vary significantly, however there was a slight variation in the concentration of sodium and potassium. Concentration of gallic acid, caffeic and vanillic acid increased with maturity, while the concentration of chlorogenic acid initially increased till 10th day and then decreased.

Table 3 represents the edible portion, nutritional and phenolic acid composition of bamboo shoots of *B. tulda* harvested on different days. The percentage of edible portion, proteins and total phenols initially increased and then decreased. Highest percentage of edible portion (53.72 ± 4.68) and proteins (1.29 ± 0.14) was found on 14th day and that of total phenols on 18th day (2.51 ± 0.14). Concentration of carbohydrates and cyanogens increased with respect to harvesting days (maturity). The concentration of ascorbic acid, phosphorous, sodium and magnesium did not vary significantly, however there was a slight variation in the concentration of potassium and significant in calcium. Concentration of gallic acid and chlorogenic acid initially increased till 16th and 10th day respectively while the concentration of vanillic acid decreased and that of caffeic increased with respect to harvesting days.

Radical scavenging activity of bamboo shoots harvested at the optimum age (average of the best days at which shoots should be harvested) is presented in Table 4. *D. asper* with a lower EC_{50} of 40.64 ± 0.09 (effective concentration) possess maximum antioxidant activity followed by *B. tulda* and *D. strictus*.

Harvesting time determines the quality of shoots. If the shoots are harvested too early then it will provide very small sized shoots with more leafy portion, while, late harvesting makes the shoots woody and tough having higher concentration of cyanogenic glycosides/ cyanides as it is reported to increase with maturity (Fu *et al.*, 2002; Anonymous, 2004). Thus it is very important and necessary to harvest shoots at right stage of their maturity. In our study it was found that there was an increase in the content of carbohydrates and cyanogens while other nutrient components showed an overall decrease with age/ maturity. Our findings corroborate with the findings of other researchers, Hu *et al.* (1986) reported a reduction of proteins, carbohydrates, fat, vitamins and mineral content in the older shoots of *Phyllostachys pubescens* as

Table 1: **Edible portion, nutritional and phenolic acid composition of different aged shoots of *Dendrocalamus asper***

Constituents \ Days of harvest	8 day	10 day	12 day	14 day	16 day	18 day
Edible portion (g/100g)	46.81 ± 3.61 a	51.53 ± 8.19 a	53.50 ± 8.48 a	52.60 ± 5.21 a	52.30 ± 6.08 a	48.70 ± 8.84 a
Dietary fibers (g/100g)	0.72 ± 0.03 f	1.68 ± 0.04 e	2.34 ± 0.04 d	2.89 ± 0.03 c	3.35 ± 0.05 b	3.86 ± 0.03 a
Carbohydrates (g/100g)	1.44 ± 0.20 c	1.60± 0.08 b c	1.90 ± 0.23 a, b	2.12 ± 0.28 a	2.13 ± 0.22 a	2.21 ± 0.17 a
Proteins (g/100g)	1.21 ± 0.10 a	1.2 ± 0.10 a	1.18 ± 0.09 a	1.14 ± 0.19 a	1.10 ± 0.15 a	0.86 ± 0.19 b
Total phenols (g/100g)	0.77 ± 0.04 d,e	0.92 ± 0.12 c	1.32 ± 0.10 a	1.09 ± 0.15 b	0.89 ± 0.15 c, d	0.71 ± 0.13 e
Cyanogens (g/100g)	0.016 ± 0.001 a	0.018 ± 0.000 b	0.019 ± 0.001 b	0.018 ± 0.000 b	0.020 ± 0.002 c	0.021 ± 0.001 c
Ascorbic acid (g/100g)	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a
Sodium (g/100g)	0.04 ± 0.01 a,b	0.04 ± 0.02 a	0.06 ± 0.01 a	0.05 ± 0.02 a	0.04 ± 0.01 a, b	0.02 ± 0.0 b
Potassium (g/100g)	0.49 ± 0.02 a	0.5 ± 0.02 a	0.5 ± 0.01 a	0.45 ± 0.02 b	0.42 ± 0.02 c	0.4 ± 0.0 c
Phosphorous (g/100g)	0.01 ± 0.01 a	0.01 ± 0.01 a	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a
Calcium (g/100g)	0.16 ± 0.01 a	0.16 ± 0.02 a	0.16 ± 0.0 a	0.15 ± 0.01 a, b	0.14 ± 0.02 b, c	0.14 ± 0.02 c
Magnesium (g/100g)	0.12 ± 0.01 a	0.12 ± 0.02 a	0.12 ± 0.0 a	0.12 ± 0.01 a	0.12 ± 0.02 a	0.12 ± 0.03 a
Gallic acid (mg/g)	0.048 ± 0.017 a	0.052 ± 0.020 a	0.057 ± 0.017 a	0.067 ± 0.023 a	0.067 ± 0.015 a	0.067 ± 0.031 a
Chlorogenic acid (mg/g)	0.077 ± 0.022 d	0.183 ± 0.018 c	0.277 ± 0.025 c	0.58 ± 0.026 b	0.29 ± 0.020 b	0.184 ± 0.027 a
Vanillic acid (mg/g)	0.009 ± 0.015 c	0.02 ± 0.011 c	0.22 ± 0.020 c	0.47 ± 0.016 b,c	0.88 ± 0.017 a,b	1.262 ± 0.018 a
Caffeic acid (mg/g)	0.382 ± 0.019 f	0.508 ± 0.012 e	0.665 ± 0.033 d	2.07 ± 0.023 c	4.41 ± 0.026 b	4.47 ± 0.028 a

Data presented as mean ± SD (n=3). Values denoted by different letters differ significantly at p≤ 0.05 compared with the underground shoots. Nirmala *et al.,* (2007) who conducted studies on changes in the nutrient composition of bamboo shoots during ageing and found that whereas the nutrient components of the shoots depleted with ageing, dietary fibre and moisture content increased. An increase in fiber content has also been reported in other bamboo species after shoot emergence from the ground (Hu et al. 1986). This indicates that the freshly/ newly emerging shoots are nutritionally superior to older shoots.

The cyanide content is lesser in the emerging shoots as also indicated by Haque and Bradbury (2002). Generally, plants which contain more than 20 mg cyanogens per 100g fresh plant material are considered potentially dangerous (Kingsbury, 1964) for consumption. EFSA (2004) have reported that the acute lethal concentration of hydrogen cyanide for human being is 0.5-3.5 mg/kg body weight. Thus, shoots should be harvested at right stage of maturity to avoid cyanide toxicity. On statistical analysis, by applying Duncan's Multiple Range Test, our results revealed that for *D. asper* 10-14 day old, for *D. strictus* 6-10 day old and for *B. tulda* 10-16 day old shoots are best to harvest.

Shoots harvested at right stage of maturity also posses higher antioxidant activity. Antioxidant capacity of bamboo leaves has been determined by Lu *et al.,* (2006) and is due to their high polyphenol content. Butanol extracts of the leaves of *Sasa borealis* exhibited significant antioxidant capacity against 1,1- diphenyl-2-picrylhydrazyl radical (Park *et al.,* 2007), ethanol extracts of *P. bambusoides* have nitrite scavenging ability (Lim *et al.,* 2004). Kim *et al.,* (2001) reported that extracts of bamboo leaves and stems of *Phyllostachys* spp. showed strong antibacterial activities. However, only a few studies have reported on the functional properties of bamboo shoots. Nirmala et al., (2011) reported the presence of eight phenolic compounds, protocatechuic acid, p-Hydroxybenzoic acid, catechin, caffeic acid, chlorogenic acid, syringic acid, p-Coumaric acid, and ferulic acid in bamboo shoots. Higher antioxidant activity is highly correlated with the total phenolic contents. Palav and Dmello (2006) and Vinson *et al*. (1995) also reported correlation of polyphenols with antioxidant activity.

CONCLUSION

A thriving economy revolves around bamboo resource. Inspite of the fact that, bamboo shoots has been an integral part of diet of the tribal community and their increasing demand over the world, no scientific validation were done to standardize their harvesting time. The present analysis on nutrient composition of bamboo shoots harvested on different days indicates that newly emerging shoots are nutritionally richer and contain lesser concentration of cyanides. Bamboo shoots hold the prospect of value added economic activity at industrial and society levels through cultivation, processing, packing and commercialization. Shoots harvested at right maturity will augment their marketability and utilization.

Table 2: **Nutritional composition of different aged shoots of *Dendrocalamus strictus***

Constituents / Days of harvest	2 day	4 day	6 day	8 day	10 day	12 day	14 day	16 day
Edible portion (g/100g)	16.24 ± 5.92 d	36.65 ± 5.96 c	57.63 ± 7.31 a,b	59.24 ± 7.20 a,b	59.60 ± 7.70 a,b	62.23 ± 6.59 a	59.28 ± 8.32 a,b	47.53 ± 9.39 b,c
Dietary fibres (g/100g)	0.52 ± 0.04 h	0.92 ± 0.04 g	1.59 ± 0.04 f	2.87 ± 0.03 e	3.36 ± 0.06 d	3.96 ± 0.05 c	4.68 ± 0.03 b	5.46 ± 0.04 a
Carbohydrates (g/100g)	1.42 ± 0.16 f	1.55 ± 0.18 e, f	1.83 ± 0.19 d, e	1.91 ± 0.18 c, d	2.12 ± 0.17 b, c, d	2.18 ± 0.23 a, b, c	2.27 ± 0.19 a, b	2.46 ± 0.12 a
Proteins (g/100g)	1.72 ± 0.15 a	1.6 ± 0.13 a	1.48 ± 0.19 a, b	1.34 ± 0.16 b, c	1.22 ± 0.25 c, d	1.01 ± 0.18 d, e	0.93 ± 0.15 e	0.8 ± 0.14 e
Total phenols (g/100g)	1.92 ± 0.21 a	2.4 ± 0.16 b	2.97 ± 0.19 c	2.04 ± 0.18 c, d	1.77 ± 0.19 d, e	1.65 ± 0.19 e	1.32 ± 0.17 f	1.04 ± 0.20 g
Cyanogens (g/100g)	0.01 ± 0.0 a	0.01 ± 0.001 a	0.015 ± 0.001 b	0.015 ± 0.0 b	0.015 ± 0.0 b	0.021 ± 0.001 c	0.03 ± 0.004 d	0.032 ± 0.003 d
Ascorbic acid (g/100g)	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a
Sodium (g/100g)	0.03 ± 0.01 c	0.03 ± 0.01 c	0.04 ± 0.01 a, b	0.04 ± 0.01 a	0.03 ± 0.01 c	0.03 ± 0.0 b, c	0.03 ± 0.0 b, c	0.03 ± 0.0 b, c
Potassium (g/100g)	0.52 ± 0.03 a	0.5 ± 0.02 a	0.5 ± 0.01 a	0.49 ± 0.0 a	0.45 ± 0.03 b	0.4 ± 0.0 c	0.39 ± 0.02 c, d	0.36 ± 0.0 d
Phosphorous (g/100g)	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a
Calcium (g/100g)	0.16 ± 0.01 a	0.16 ± 0.02 a	0.14 ± 0.02 a, b	0.15 ± 0.01 a, b	0.14 ± 0.01 b	0.14 ± 0.01 b	0.14 ± 0.02 b	0.12 ± 0.02 c

Magnesium (g/100g)	0.15 ± 0.01 a	0.15 ± 0.02 a	0.15 ± 0.01 a	0.15 ± 0.01 a	0.1 ± 0.01 a	0.15 ± 0.01 a	0.15 ± 0.02 a	0.12 ± 0.01 b
Gallic acid (mg/g)	0.040 ± 0.012 f	0.059 ± 0.015 e,f	0.072 ± 0.023 d,e,f	0.088 ± 0.026 c,d	0.102 ± 0.030 b,c	0.126 ± 0.014 a,b	0.144 ± 0.022 a	0.173 ± 0.020 a
Chlorogenic acid (mg/g)	0.092 ± 0.042 g	0.143 ± 0.032 f	0.306 ± 0.024 e	0.42 ± 0.020 d	0.99 ± 0.020 a	0.89 ± 0.030 b	0.631 ± 0.016 c	0.464 ± 0.018 d
Vanillic acid (mg/g)	0.273 ± 0.032 g	0.598 ± 0.024 f	0.805 ± 0.019 e	0.993 ± 0.022 d	2.01 ± 0.018 c	2.222 ± 0.018 b	2.436 ± 0.021a	2.563 ± 0.016 f
Caffeic acid (mg/g)	0.258 ± 0.022 g	0.466 ± 0.032 f	0.575 ± 0.035 e	0.613 ± 0.028 e	0.782 ± 0.017 d	0.974 ± 0.022 c	1.19 ± 0.018 b	1.317 ± 0.020 a

Data presented as mean ± SD (n=3). Values denoted by different letters differ significantly at p≤ 0.05

Table 3: **Nutritional analysis of different aged shoots of *Bambusa tulda***

Days of harvest / Constituents	4 day	6 day	8 day	10 day	12 day	14 day	16 day	18 day	20 day
Edible portion (g/100g)	24.53 ± 4.04 e	32.73 ± 6.43 d, e	38.97 ± 6.04 b,c,d	41.73 ± 3.51 b,c,d	45.04 ± 5.99 a,b,c	53.72 ± 4.68 a	49.91 ± 6.34 a,b	42.76 ± 4.39 b,c,d	35.14 ± 5.88 c,d
Dietary fibres (g/100g)	0.79 ± 0.05 i	1.22 ± 0.03 h	1.77 ± 0.03 g	2.18 ± 0.03 f	2.71 ± 0.05 e	3.22 ± 0.03 d	3.98 ± 0.04 c	4.57 ± 0.03 b	5.20 ± 0.03 a
Carbohydrates (g/100g)	1.91 ± 0.19 e	1.97 ± 0.19 e	2.16 ± 0.18 e	2.21 ± 0.24 d, e	2.51 ± 0.14 c, e	2.75 ± 0.14 e	3.31 ± 0.15 b	3.7 ± 0.17 a	3.89 ± 0.18 a
Proteins (g/100g)	0.51 ± 0.20 c	0.43 ± 0.18 c	0.95 ± 0.19 b	1.06 ± 0.21 a, b	1.13 ± 0.17 a, b	1.29 ± 0.14 a	1.15 ± 0.20 a, b	1.02 ± 0.21 a, b	0.89 ± 0.27 a
Total phenols (g/100g)	0.57 ± 0.21 f	0.62 ± 0.27 e, f	0.96 ± 0.25 d, e, f	1.15 ± 0.34 d	1.11 ± 0.38 d, e	1.33 ± 0.22 c, d	1.81 ± 0.27 b, c	2.51 ± 0.14 a	1.86 ± 0.36 b
Cyanogens (g/100g)	0.022 ± 0.01 a, b	0.02 ± 0.01 a	0.02 ± 0.0 a	0.021 ± 0.0 a	0.02 ± 0.01 a	0.02 ± 0.0 a	0.022 ± 0.01 a, b	0.025 ± 0.04 b, c	0.025 ± 0.04 c
Ascorbic acid (g/100g)	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a	0.006 ± 0.0 a
Sodium (g/100g)	0.02 ± 0.01 b	0.03 ± 0.01 a, b	0.03 ± 0.01 a, b	0.03 ± 0.0 a	0.03 ± 0.0 a	0.02 ± 0.01 b	0.02 ± 0.0 a, b	0.03 ± 0.02 a, b	0.02 ± 0.0.0. a, b
Potassium (g/100g)	0.33 ± 0.03 c	0.33 ± 0.0 c	0.41 ± 0.06 a	0.41 ± 0.05 a, b	0.3 ± 0.04 c, d	0.34 ± 0.06 b, c	0.34 ± 0.05 b, c	0.25 ± 0.01 d, e	0.21 ± 0.03 e
Phosphorous (g/100g)	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a	0.01 ± 0.0 a
Calcium (g/100g)	0.1 ± 0.02 f	0.12 ± 0.03 e, f	0.14 ± 0.0 d, e	0.14 ± 0.02 d, e	0.15 ± 0.01 c, d, e	0.16 ± 0.02 b, c, d	0.18 ± 0.03 a, b, c	0.18 ± 0.0 a, b	0.2 ± 0.0 a
Magnesium (g/100g)	0.12 ± 0.02 b	0.12 ± 0.0 b	0.15 ± 0.01 a	0.15 ± 0.03 a	0.15 ± 0.01 a	0.15 ± 0.03 a	0.14 ± 0.02 a	0.15 ± 0.0 a	0.15 ± 0.0 a
Gallic acid (mg/g)	0.041 ± 0.015 e	0.056 ± 0.019 d, e	0.076 ± 0.019 c,d	0.085 ± 0.030 c,d	0.105 ± 0.021 b,c	0.112 ± 0.017 b,c	0.25 ± 0.021 a	0.127 ± 0.016 b	0.129 ± 0.013 b
Chlorogenic acid (mg/g)	0.02 ± 0.013 h	0.112 ± 0.017 e,f	0.72 ± 0.013 b	1.6 ± 0.017 a	0.53 ± 0.015 c	0.36 ± 0.014 d	0.121 ± 0.012 e	0.091 ± 0.022 f	0.052 ± 0.019 g

Vanillic acid (mg/g)	4.483 ± 0.018 a	3.4 ± 0.017 b	3.05 ± 0.019 c	1.84 ± 0.015 d	1.67 ± 0.025 e	1.1 ± 0.020 f	0.925 ± 0.013 g	0.732 ± 0.016 h	0.61 ± 0.021 i
Caffeic acid (mg/g)	0.423 ± 0.015 i	0.55 ± 0.021 h	0.68 ± 0.026 g	0.82 ± 0.020 f	1.02 ± 0.015 e	1.183 ± 0.021 d	1.326 ± 0.015 c	1.41 ± 0.017 b	1.582 ± 0.018 a

Data presented as mean ± SD (n=3). Values denoted by different letters differ significantly at p≤ 0.05

Table 4: **Antioxidant activity of bamboo shoots harvested at optimum age**

Species	EC_{50} mg/ml
Dendrocalamus asper	40.64 ± 0.09 a
Dendrocalamus strictus	45.27 ± 0.12 a
Bambusa tulda	42.82 ± 0.11 a

Data presented as mean ± SD (n=3). Values denoted by different letters differ significantly at p≤ 0.05

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Influence of Growth Parameters on Wood Traits in Seed Raised Trees of *Dalbergia sissoo* Roxb.

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INTRODUCTION

Growth and wood properties are two important parameters which are to be assessed in the plantation grown timbers. These two important parameters are influenced each other. The properties of the wood are highly influenced by variation in anatomical characteristics (Dadswell, 1957; Burley and Palmer, 1979). Cell size, proportion and arrangements of different elements of secondary xylem and specific gravity are the features of interest in this connection. The general pattern of variation in wood element dimensions is not only within a species but also observed within a tree (Dinowoodie, 1961; Zobel, 1965; Rao and Rao, 1978; Pande *et al.* 1995).The variation of elements within a species is affected by climate and the system under which they are grown.

The relationship of growth rate to wood qualities is very important, it has been much studied, and it is confused, as is shown by the many contradictory results illustrated in the literature (Zobel and Tilbert, 1984). It is very complicated because of the many factors that affect both wood properties and tree growth. Anything that affects the physiology and growth of a tree can also influence the kind of wood that is formed (Larson, 1962). The literature in this area is voluminous for the temperate and exotic tree species. Only limited information is available on the relation of growth rate and wood in the tropical hardwoods (Howe, 1974).

Growth and wood-quality relationships are very complex in the hardwoods because of the various patterns of the distribution of vessels namely ring porous and diffuse porous (Zobel and Tilbert, 1984).

As *Dalbergia sissoo* is an important timber species for agroforestry and farm forestry plantations, it is important to analyse the impact of growth parameters like DBH, height, volume and productivity on wood traits.

MATERIALS AND METHODS

Experimental sites

The study was conducted in *Dalbergia sissoo* plantations at four sites located in three forest divisions of Punjab namely Amritsar, Hoshiarpur and Ferozepur, representing three agro-climatic zones of the State (Sehgal *et al.,* 1990). The annual rainfall and mean annual temperature in Hoshiarpur (latitude 30° 55' N, longitude 74° 40' E, altitude 260 masl) were 890.50 mm and 23.71 ^{0} C; in Amritsar (latitude 31° 37' N, longitude 74° 55' E, altitude, 234 masl) were 563.10 mm and 23.18 ^{0}C and in Ferozpur (latitude*:* 30° 55' 42" N. longitude*:* 75° 18' E, altitude, 198 masl) were 426.70 mm 24.38 ^{0} C. The study sites of the present study in all three agro-climatic zones of Punjab are depicted in Table 1.

Table 1: **Selected sites and respective agroclimatic zones* of Punjab**

Agro-climatic regions	Climate	Districts covered
Hot arid (2)	Western plains and Kutch peninsula	Ferozpur
Hot semi-arid (4)	Northern plains and central highlands	Amritsar
Hot sub-humid (9)	Northern plain	Hoshiarpur

**Number of agro climatic zone of Punjab is given in parenthesis.*

Biomass, productivity calculations

In the study the field data was collected using stratified tree technique method (Art and Marks, 1971) for harvesting the sample trees. Sample plots of different sizes (10 x 10m, 15x 15m, 20x 20m, 25x 25m) were laid out according to the size of the area in all the plantations *Dalbergia sissoo*. The DBH (diameter at breast height) of all the standing trees in the sample plots and height of 12 representative sample trees covering the entire diameter range of each plot were recorded.

The entire diameter range was then divided into different diameter classes (cm) from 10-15 to 41.1-45 cm. Though one-sample or more trees from each diameter class (close to the mean DBH of that class) was harvested and consider for biomass estimation yet the biomass and other growth parameters were considered for the sample tree only for the growth vs. wood traits studies.

All the tree components (leaves twigs, branches, bark, bole) including root were separated immediately after felling and their

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fresh weight recorded in the field. The representative samples of each tree component (100g each of leaves, twigs, branches bark, and fruit) were taken for oven dry weight estimation in the laboratory.

Growth data was collected as DBH, height, biomass and productivity of the selected trees. A total of 12 trees of different diameter classes of *Dalbergia sissoo* were felled from biomass estimation and wood traits.

The bole portion of the sample tree was cut into 2m long sections (billets) for convenience of weighing. Approximately 5-cm broad disc was removed from the base of each billet for estimation of fresh and dry weights of bark and wood (under bark) and also for the over bark). The average diameter of the two successive discs was taken to calculate the volume to get the volume of main bole (over bark and under bark).

The root systems of all the sample trees were completely excavated excluding their fine rootlets. All possible care was taken to remove the soil particles sticking to the roots and fresh weight taken immediately to prevent the weight loss. Representative root sample was also taken for its dry weight estimation and determining mineral contents.

The individual tree biomass was obtained by multiplying the dry weight of the sample tree of each diameter class. For calculating productivity the biomass values were divided by the age of each tree. Thus productivity each sample tree per year was obtained. To calculate NEP (net ecosystem productivity) bole biomass is divided by age.

Sampling for specific gravity and wood anatomical studies

Wood samples were collected from 12 trees of different diameters of *Dalbergia sissoo* plantations (Table 2). The sites were located at Kharkan, Hoshiarpur (Site-I), Dhirowal, Hosiyarpur (Site-II), Kamalpur, Amritsar (Site-III) and Dharmkot, Ferozpur (site-IV). In all 12 tress were considered for the study. Five transverse discs of 10 cm thickness were cut out from the trunk at 2 m, 4 m, 6 m, 8 m and 10 m heights from each of the tree. These discs were referred to as D_I, D_{II}, D_{III}, D_{IV} and D_V from the base. Each disc was divided into three directions of the periphery of the tree (North, South-East and South-West). Each direction was further divided into five radial parts from pith to periphery.

Laboratory methods

The material was macerated with 50% HNO_3 and a pinch of $KClO_3$. The macerated wood elements were thoroughly mixed and were spread on a glass slide, and observations were taken under compound microscope (Purkayastha *et al*,. 1980). Measurements for fiber length, fiber diameter, wall thickness, vessel element length and vessel element diameter were taken from the macerated wood. Twenty five unbroken cells were sampled for the measurement of each parameter (IAWA Committee, 1989). Basic density of core samples was determined by the ratio of oven dry weight and green volume. The green volume was determined by water displacement method. Specific gravity was the ratio of the density of the sample and density of water (Purkayastha *et al*. 1980).

Wood density = Oven dry weight of the sample/volume of the sample

RESULTS AND DISCUSSION

Tree characteristics of the selected trees of different diameters are given in Table 2.

Table 2: **Tree characteristics at different locations in Punjab.**

Site	Locality	Tree No	Age	Growth Rings considered	dbh (cm)	Height (m)
I	Kharkan, Hoshiarpur	1	33	27	13.10	11.7
		2	33	27	19	12.95
		3	33	27	20.5	15.55
II	Dhirowal Hosiyarpur	1	33	27	25.9	13.8
		2	33	27	34.8	17.55
		3	33	27	37.5	17.95
III	Kamalpur, Amritsar	1	29	27	28.10	18.90
		2	29	27	42.3	22.1
		3	29	27	43.19	18.7
IV	Dharmkot, Ferozpur	1	27	27	24.8	13.6
		2	27	27	36.4	18.33
		3	27	27	19.10	10.95

Intra and inter-tree variations

ANOVA showed that intra tree axial and radial and inter tree variations were significant for all the wood traits while variations due to peripheral directions were non-significant (Table 3). Significant inter-tree variations in wood traits were related to their differential growth and genetics. Generally, the tree-to-tree differences in wood properties within a species or within a provenance are large. For example, in *Pinus caribaea,* Lantican and Hughes (1973) found that all wood properties studied differed markedly from tree to tree, which is the usual pattern. Such variation occurs in both conifers and hardwoods and is of a magnitude that is often greater than that between species. For example, Harris (1961) stated that differences in specific gravity among radiata pine trees of the same age grown at any one site can amount to 60%. The density varied from 470 to 570 kg/m^3 between trees in *Eucalyptus* (Palmer and Dutta, 1982). For *Eucalyptus camaldulensis,* Chudnoff (1961) reported that usually there is more variability among trees on the same site that the average differences between sites. Tree to tree variation is so large that it commonly masks other causes of wood variability (Mc Kimmy, 1959).

Significant radial variations showed the impact of the increasing age on the wood traits. The same is also true for significant variations on the axial direction for wood traits in the present study. It showed that characters were not stabilized and showed variations. Significant differences in specific gravity

Table 3: **ANOVA for tree, disc, direction and locations**

Source of Variation	df	MSS (P –Value)					
		FL	FD	WT	VL	VD	SG
Tree	11	892086.27 (0.00)	97.62 (0.00)	9.59 (0.00)	12036.36 (0.00)	14740.18 (0.00)	0.27 (0.00)
Disc	4	20873.76 (.006)	18.76 (0.00)	1.76 (0.00)	3330.88 (0.00)	9194.73 (0.00)	1.63E-02 (0.00)
Direction	2	1597.10 (0.76)	6.695E-02 (0.97)	0.41 (0.12)	41.43 (0.87)	300.33 (0.56)	4.696E-03 (0.20)
Location	4	76953.45 (0.00)	32.42 (0.00)	0.27 (0.23)	1372.94 (0.001)	12235.53 (0.00)	7.936E-3 (0.03)
Error	878	5699.90	2.31	0.19	287.80	524.72	2.895E-03

Table 4: **Mean±SD of the dimensions of different wood element in all trees**

Tree No		FL	FD	WT	VL	VD	SG
1	Mean	996.1	20.4	4.7	170.5	167.7	0.591
	SD	77.4	1.4	0.5	13.5	25.9	0.039
2	Mean	950.8	19.2	4.2	153.3	156.5	0.724
	SD	154.5	2.9	0.7	31.0	29.9	0.100
3	Mean	980.2	18.93	4.25	152.25	154.69	0.72
	SD	124.90	2.02	0.53	25.22	25.89	0.06
4	Mean	925.5	20.9	5.4	177.4	176.2	0.625
	SD	63.1	1.5	0.7	12.2	24.9	0.040
5	Mean	1247.0	22.5	4.8	177.0	200.4	0.668
	SD	63.8	1.5	0.3	9.6	16.6	0.046
6	Mean	1072.2	20.4	4.4	157.3	168.1	0.674
	SD	72.3	1.9	0.5	16.8	26.5	0.059
7	Mean	1169.8	22.0	4.9	183.1	187.5	0.734
	SD	50.2	1.3	0.2	8.2	15.9	0.077
8	Mean	942.9	22.1	5.1	188.4	193.8	0.541
	SD	64.0	1.9	0.6	32.1	36.8	0.047
9	Mean	1181.3	19.7	4.3	152.3	176.5	0.643
	SD	58.1	1.0	0.3	8.1	21.2	0.043
10	Mean	1008.5	19.9	4.8	174.7	167.2	0.679
	SD	65.6	1.0	0.4	13.3	24.1	0.084
11	Mean	1144.3	21.5	5.0	177.3	187.9	0.612
	SD	59.7	1.2	0.2	6.1	20.0	0.046
12	Mean	1149.5	21.0	4.6	160.6	174.3	0.615
	SD	82.4	1.9	0.4	16.1	27.7	0.032

Fig. 1: **Relationship between growth parameters vs. fiber-length**

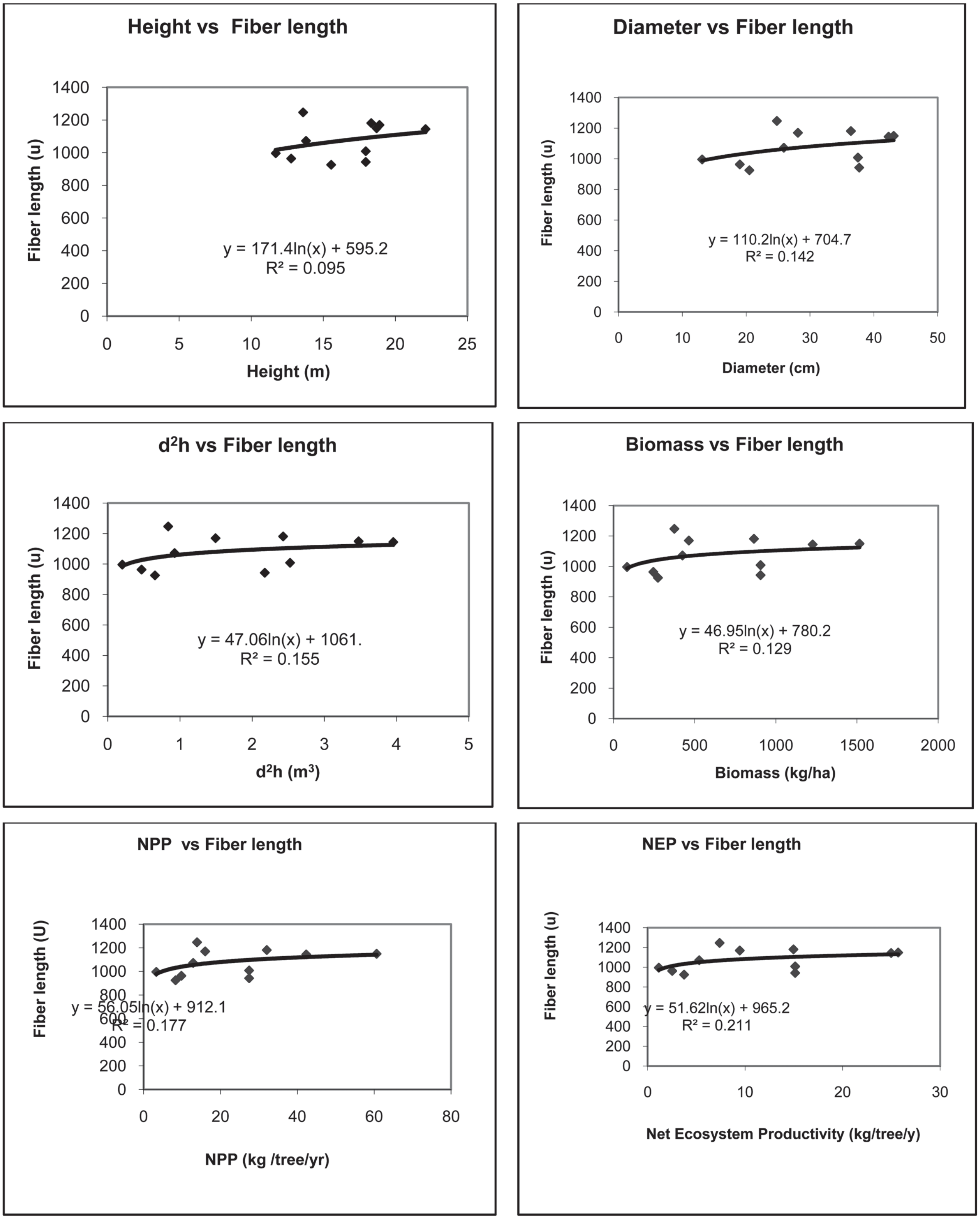


Fig. 2: **Relationship between growth parameters vs. fiber-diameter**

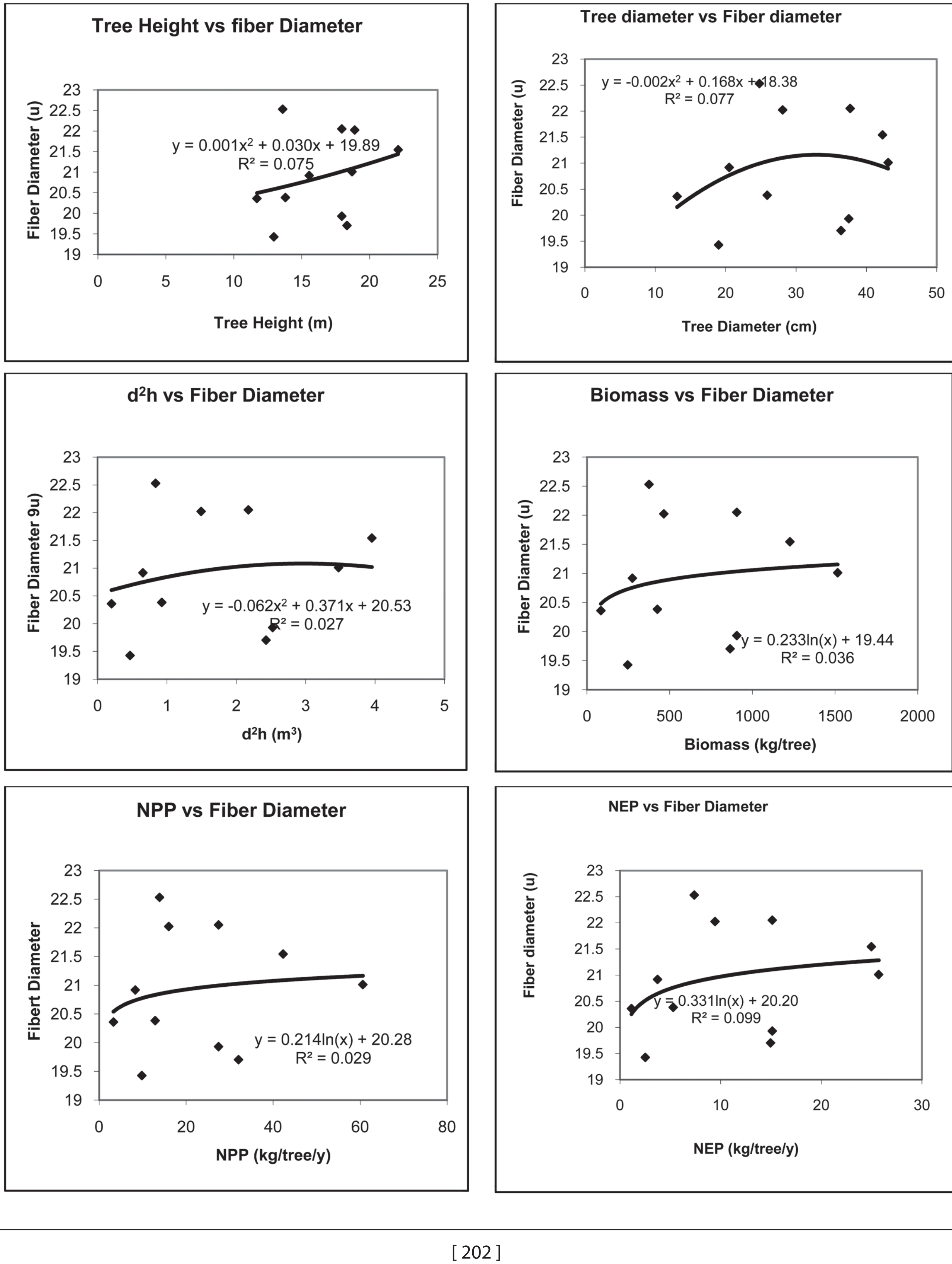


Fig. 3: **Relationship between growth parameters vs. fiber wall thickness**

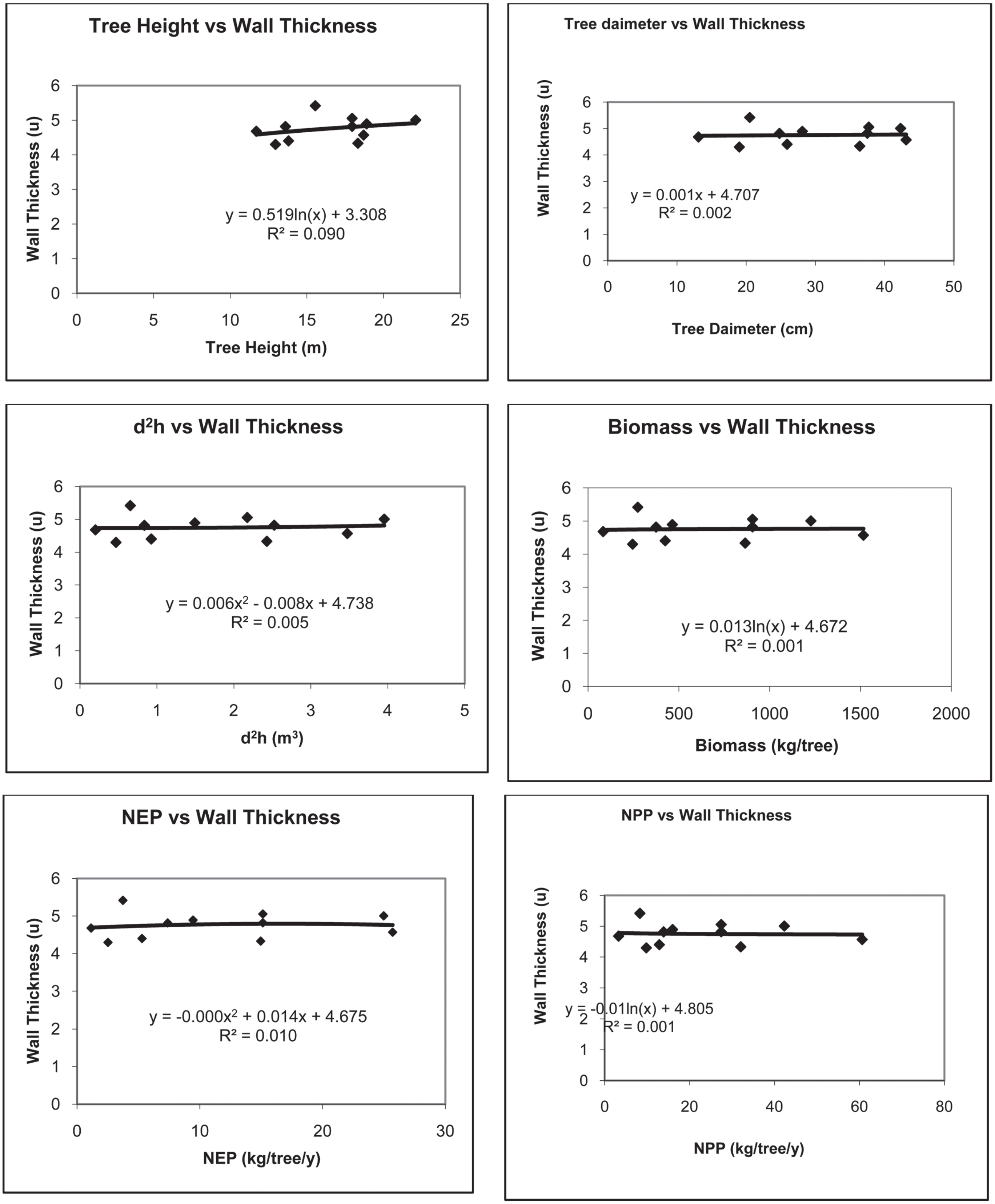


Fig. 4: **Relationship between growth parameters vs. vessel–element -length**

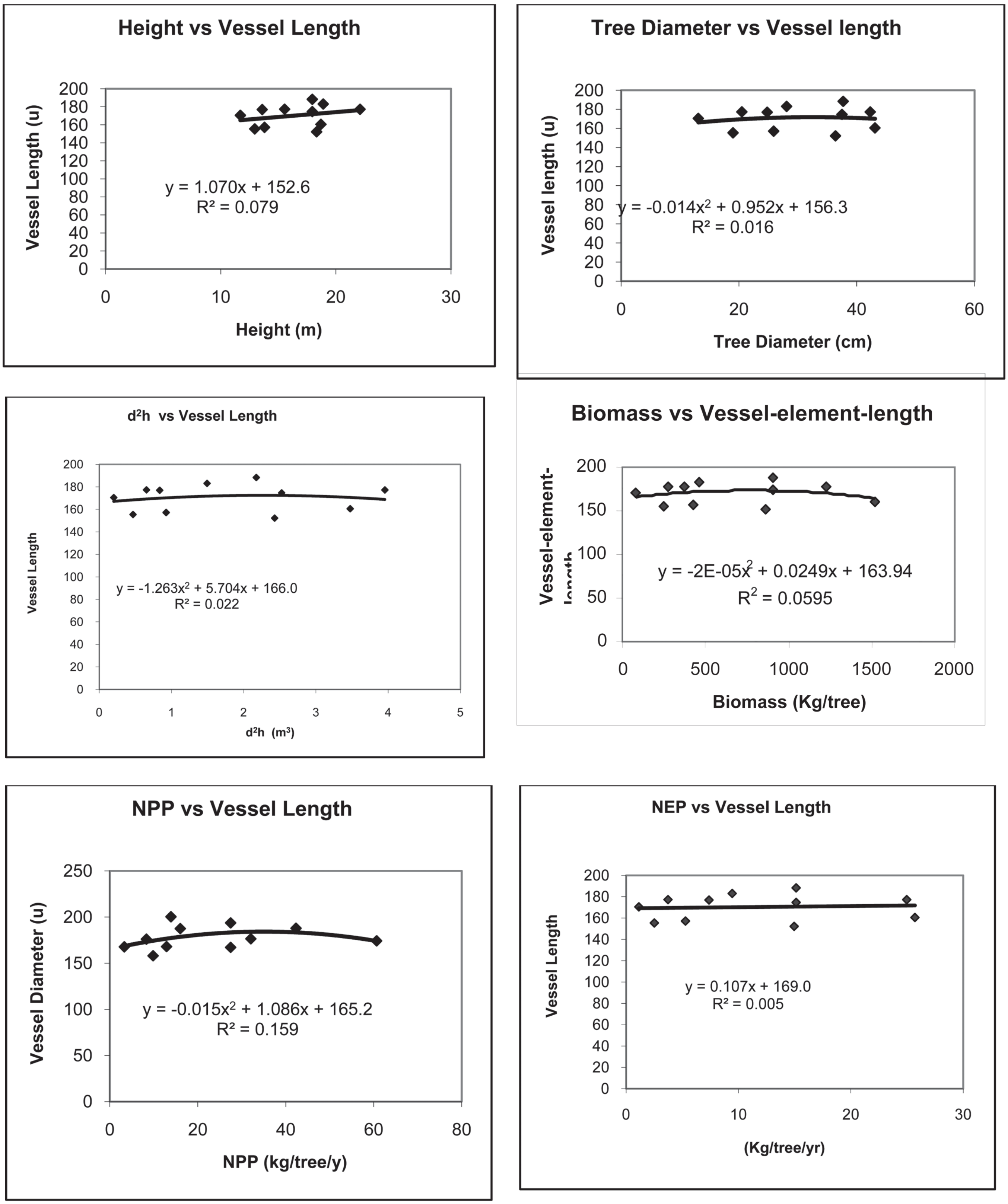
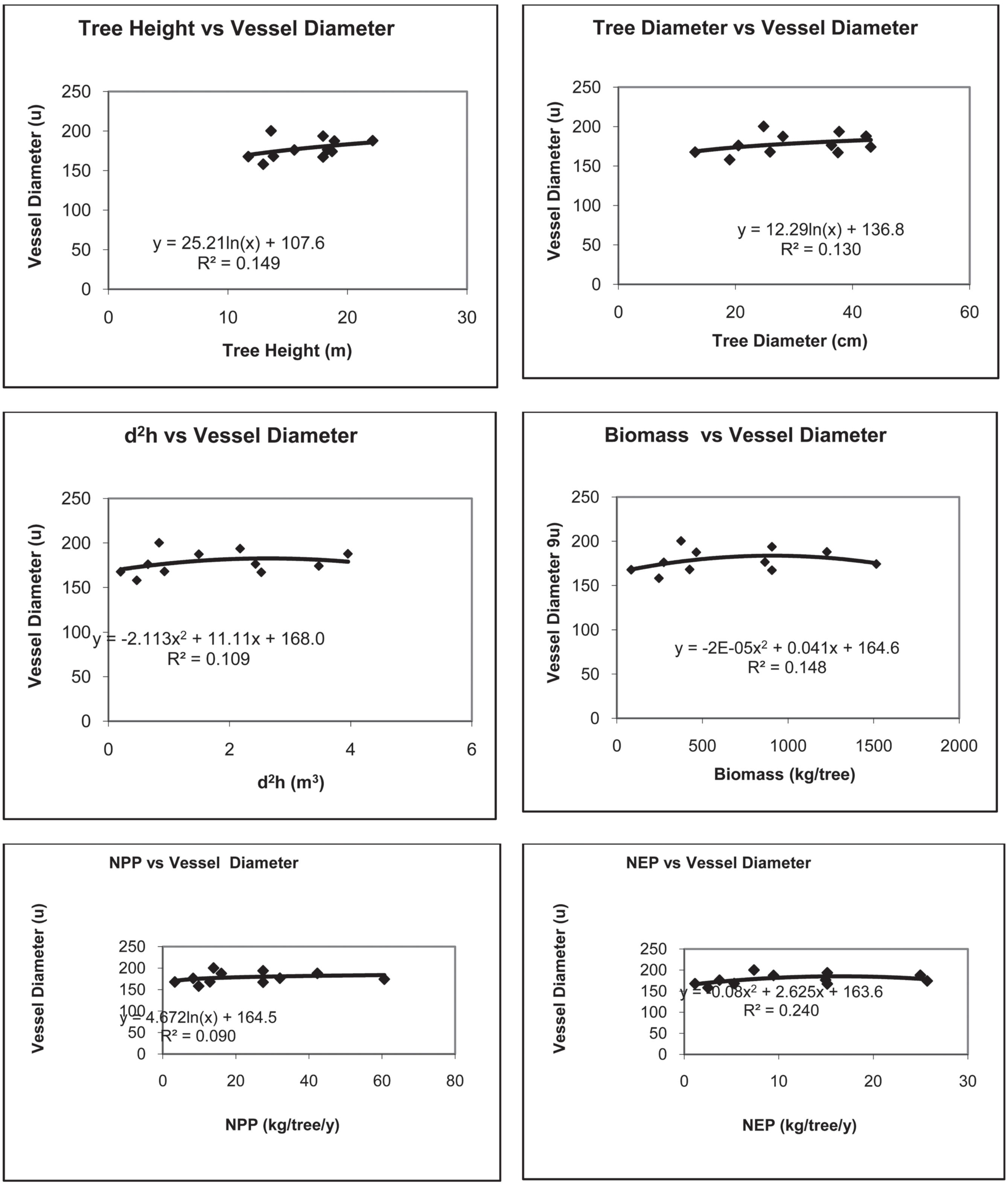


Fig. 5: **Relationship between growth parameters vs. vessel-element-diameter**



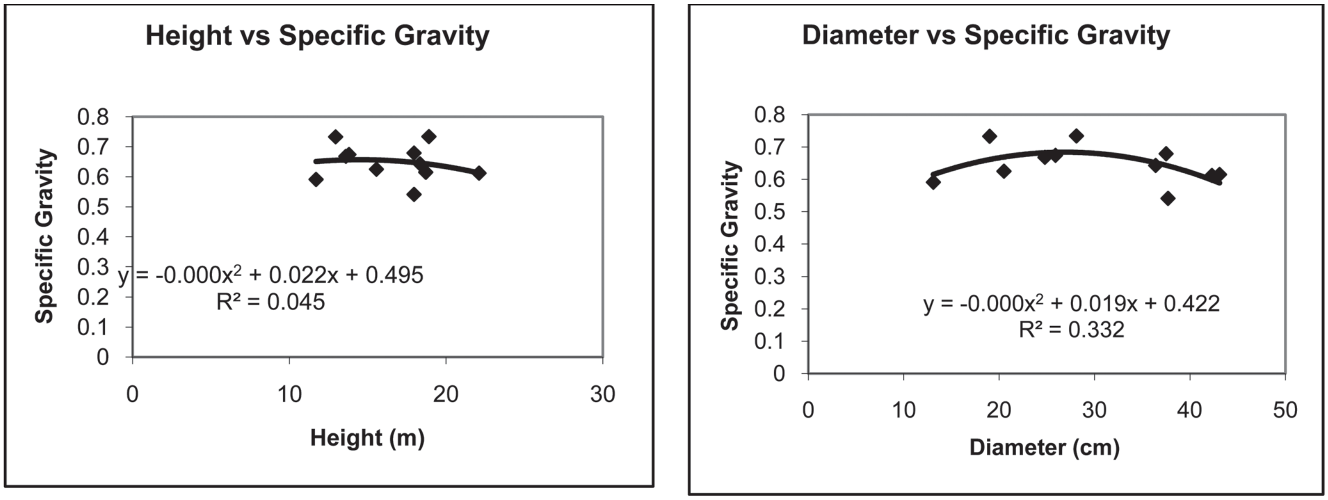


Fig. 6: **Relationship between growth parameters vs. specific gravity**

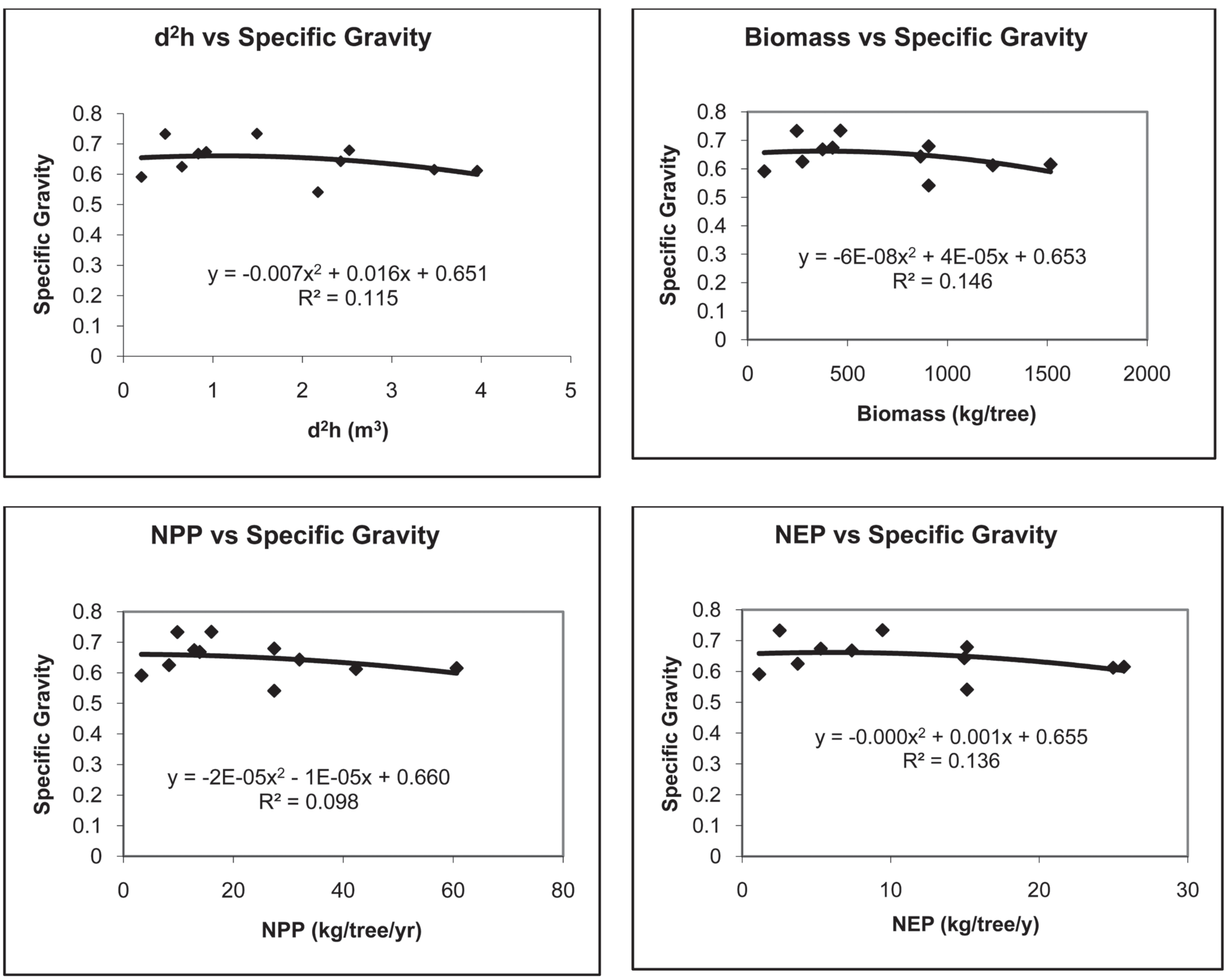
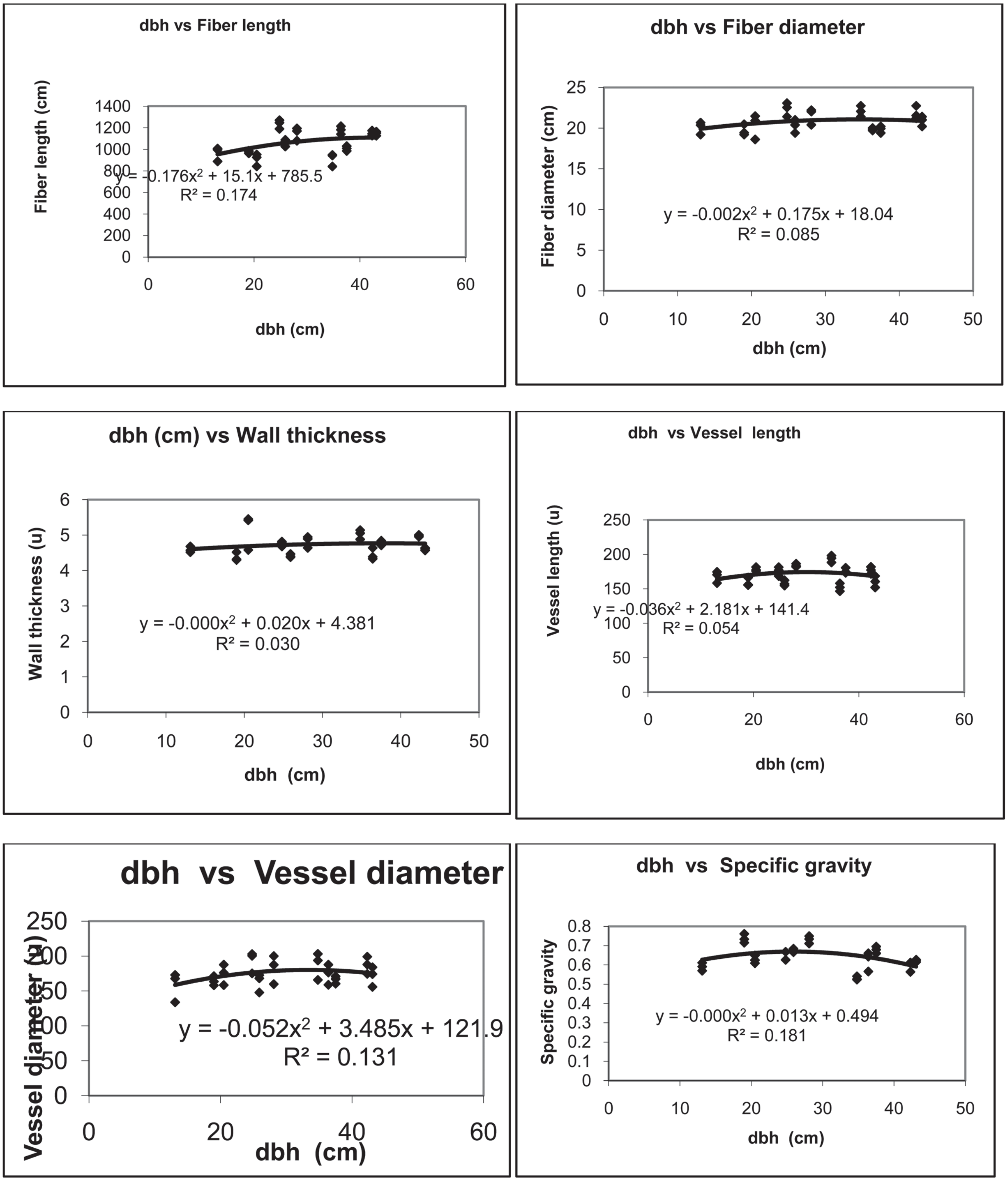


Fig. 7: **Relationship between dbh and dimensions of wood elements (values of central, mean of five blocks and outer most block)**



due to height within a ramet showed that height has impact on specific gravity due to differential sap and heartwood ratio (Pande *et al.,* 1995). Same as in teak the density increased towards the peripheral direction by 5-6 cm from the pith then stabilized at the age of 10-12 years (Okuyama *et al*., 2003). Non-significant variations at different heights and radial directions were reported in clone raised ramets of *D. sissoo* (Pande and Singh, 2005), which were related to the mature wood characteristics of ramets even during the early phase of the tree growth. Such types of results were also obtained by Chauhan *et al*., (2001) in *Populus deltoides* clone-raised tree. Bosman (1997) reported that wood properties parameters *viz*. percentage of fiber-wall, vessel, resin canal and specific gravity of six year old coppiced meranti trees corresponds closely to full grown trees. Bhat *et al*., (2001) also reported almost similar wood mechanical properties of juvenile and mature wood of plantation grown *Tectona grandis.* In the plantation grown teak as compared to natural teak, the extent of juvenile wood can be set about 7 cm radial distance from the pith and is about 12% of the total wood volume on the basis of natural durability variations (Richter *et al.,* 2003). They further reported non-significant differences in the variations in the density and related strength of the woods of plantation grown and natural teak.

Mean wood element dimensions of all the trees on the basis of whole tree mean data are given in Table 3. The range for fiber-length for 12 trees of different diameters was 925.5-1247.0 μm, was 19.7 -22.5 μm for fiber-diameter, 4.2 - 5.4 μm for wall thickness, 152.0 – 188.4 μm for vessel-element-length, 154.69 – 200.4 μm for vessel-element-diameter and for specific gravity the range was 0.54 –0.734. If we compare these values with the dimensions of 8 years old clonally plantation wood (Pande and Singh, 2005), it was observed that these values were lower for fiber-length and comparable for other wood element's dimensions. It seems that 8 years old clonally plantation wood has better wood anatomical properties than of the woods of 2 year-old seedling seed raised plantation wood of *Dalbergia sissoo.*

Growth parameters vs. wood element's dimensions

The relationships between different growth parameter *viz*. DBH, height, volume, biomass, NPP (Net Primary Productivity), NEP (Net Ecosystem Productivity) and wood elements dimensions *viz*. fiber-length, fiber-diameter, wall thickness, vessel-element-length, vessel-element-diameter and specific gravity are given in Fig. 1 to 7. In general growth parameters have shown positive relationship with fiber-length. R^2 values indicated that NEP, NPP, tree volume and diameter were the growth parameters, which affected more the fiber-length. Though, the relationship was poor in most of the cases, the trend was increasing. Tree height showed non significant relationship with fiber-length. Growth parameters showed poor relationship with fiber-diameter and wall thickness. NPP showed positive relationship with vessel-element-length while growth parameters showed polynomial relationship with vessel-element-diameter except for height vs. vessel-element-diameter and tree diameter vs. vessel-element-diameter, which showed positive correlations. Though, the relationship is poor in most of the case, the relationship was positive. Specific gravity showed negative relationship with growth parameters. In general, dimensions of wood anatomical parameters showed lower values till the DBH 25.9 cm thereafter characters were stabilized.

So the patterns of wood traits in relation to growth in hardwoods is directly opposite to the one frequently quoted for conifers; that is, the faster-growing trees have higher specific gravities than of the slow-growing trees. This may be true for some of the ring-porous hardwood such as ash *(Fraxinus)* and oak *(Quercus)* but is not general for the numerous species of diffuse-porous hardwoods (Zobel and Tilbert, 1984). It is because of that ring-porous trees produce equal volume of vessels each year regardless of the total growth during the year. As a result, the slow-growing ring porous trees will have a greater proportion of vessels per unit volume of the annual ring, compared to the denser fibers and tracheids, and will have a low-specific-gravity wood. Whereas, fast-growing ring porous tree continues to produce the denser fibers outside the band of vessels; therefore, the wood will have a higher specific gravity. In diffuse-porous hardwoods the number of vessels formed in an annual ring is closely related to the width of the ring, and growth rate has little direct effect on wood specific gravity. The same is true in case of *Dalbergia sissoo* in present study.

CONCLUSION

In general, growth parameters showed positive relationship with fiber-length. R^2 values indicated that NEP (Net Ecosystem Productivity), NPP (Net Primary Productivity), tree volume and diameter are the growth parameters, which affect more the fiber-length. Tree height showed non significant relationship with fiber-length. Growth parameters showed poor relationship with fiber-diameter and wall thickness. NPP showed positive relationship with vessel-element-length while growth parameters showed polynomial relationship with vessel-element-diameter except for height vs. vessel-element-diameter and tree diameter vs. vessel-element-diameter, which showed positive correlations. Specific gravity showed negative relationship with growth parameters. It showed that growth positively affect the length of fiber and negatively affect the specific gravity.

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Quality Assessment of *Dalbergia Sissoo* by Ultrasonic Technique

Y.M. Dubey and V. Kothiyal *

INTRODUCTION

Due to the porous structure and good strength, timber and timber products are known to be one of the main valuable building materials. But in the present scenario, scarcity and high cost of timber has drawn attention of the users to select a good quality timber for a specific application. It can be decided on the basis of different properties of timber and timber products. Therefore, in recent years, considerable interest has developed in determining the properties of timber through non-destructive techniques, as these are less time consuming and economical in comparison to destructive test methods. Among several NDT methods, ultrasonic technique is one of them and employed to evaluate the elastic properties and for assessment the quality of timber and timber products.

Vibration technique has been used by various researchers (Dolwin et al 1991, Stephen 1991, Ross and Pullerin 1988, Bucur 1987, etc.) for determination of different strength properties of timbers and timber products. Stephen (1991) reported a relationship of stress wave and static bending-determined properties of four northeastern hard woods. Dolwin et. al. (2003) used stress wave to measure fungal decay in small wood blocks and found a significant reduction in stress wave velocity of decayed wood blocks. Ross and Pullerin (1988) studied non–destructive evaluation of wood based composites with longitudinal stress wave and concluded that stress wave speed and attenuation characteristics are related to the same mechanisms that control the mechanical properties of wood based composite materials because they were strongly correlated to strength properties. Efransjah et. al. (1989) studied the impact of water storage on mechanical properties of spruce as detected by ultrasound. Sandoz (1989) found that modulus of elasticity and modulus of rupture in flexure for beams of commercial sized section can be estimated by observing the speed of propagation of a longitudinal wave applied to the longitudinal axis of the beam and graded construction timber (spruce) by ultrasound.

Only limited work has been reported in India to evaluate strength properties of timbers by vibration techniques. John and Lal (1964) and Sekhar et. al. (1969) determined dynamic modulus of elasticity (E_d) using vibration (resonance method) technique and static modulus of elasticity (E_s) by conventional static bending test of Indian timbers and found that on the average E_d is about 10% higher than Es. Sanyal and Gulati (1979) measured ultrasonic velocity of some timbers using ultrasonic pulse transmission technique and established a relationship between ultrasonic velocity and maximum crushing strength in air dry condition. Dubey and Gupta (1998) determined dynamic modulus of elasticity of timbers using Elasto-sonic equipment and established relationship of E_d with E_s and moisture content. In this paper, ultrasonic velocity(V_L) measured along longitudinal direction of *Dalbergia sissoo* and strength properties (modulus of elasticity (E_S) and modulus of rupture (MOR)) determined under static bending test as per procedure described (Anon. 1986). Ultrasonic velocity along multiple transverse directions of timber disc was also measured for defect (artificially made hollowness) detection at the centre of the timber disc and results are reported.

MATERIAL AND METHODS

Log of *Dalbergia sissoo* procured from Range office, Forest Research Institute, Dehradun was selected for the present study and converted into sticks of sizes 6 X 6 cm. cross section and into timber disc of 2.0 inch thickness. Test specimens of sizes 2 X 2 X30 cm. and 5 X5 X75 cm. of sizes for static bending test were prepared as per Bureau of Indian Standard BIS 1708- 1986 from these sticks. A test specimen was placed between the two transducers (one as a transmitter and other as a receiver) for ultrasonic velocity measurement along the longitudinal direction. A couplent (Vaseline) and slightly pressure was applied between transducers and specimens to make good contact between them. Transmission time taken by the ultrasonic pulse to travel from one end to other end of the specimen was measured within the accuracy of 1 μ sec. and ultrasonic velocity was evaluated based on the formula:

Ultrasonic velocity = (Length of the specimen/ Time) --- (1)

Subsequently strength properties (modulus of elasticity (MOE)), Fibre stress at elastic limit (FS at E.L.) and Modulus of rupture (MoR) of each specimen tested earlier determined as per specification IS: 1708 (1986) using hydraulic universal testing machine.

For defect detection in timber, disc of various diameters and

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2.0 inch in thickness prepared from the log of *Dalbergia sissoo* was taken for testing. Before testing, disc was divided into segments (blocks) and a particular number was given to the each block (Fig. 1 (a)-1 (c). Testing of disc for defect detection (8 points based) was carried out by placing transmitter (transducer) at the point '1' and receiver at point '2' using couplent to make good contact among them. Time (μ sec.) taken by the ultrasonic waves to travel from point '1' to '2' of the disc was noted. After that position of transmitter remained same at position '1'of the disc and position of receiver varied from 2 to 3, 4, 5, 6 ,7, 8 and for each position of receiver time was noted. There after the position of transmitter was kept at the point 2 of the disc and receiver was placed at the point 3, 4, 5, 6, 7, 8 and for each position of receiver, time was noted. The similar test procedure was followed for all point marked on the disc. Ultrasonic velocity for each position of transmitter and receiver was determined based on the formula described earlier equation (1). Thereafter, an artificial defect (circular hole of size 7 cm. diameter) was made at the centre of the disc and ultrasonic velocities again determined as per procedure described earlier. Drop (%) in ultrasonic velocity with respect to the referential value was worked out especially for the path that was passing through the centre of the disc that occurs due to defect present in the disc. Similar testing procedure was followed for measuring ultrasonic velocity along multiple transverse directions artificially made holes of sizes 14 and 21 cm diameters at the of the disc) for defect detection.

RESULTS AND DISCUSSION

Ultrasonic velocity measured along the longitudinal direction of *Dalbergia sissoo* and strength properties modulus of elasticity (MoE) and modulus of rupture (MoR) on same specimens in air dry condition (average moisture content 13.7%) determined under static bending test are presented graphically in Fig. 1 and Fig. 2. A regression equation has been established of ultrasonic velocity with modulus of elasticity (MOE) of the type:

$$(U.V.)^2 X\ 10^{-4} = A + B\ (MoE) \qquad (r = 0.81) \qquad \text{--- (2)}$$

and A linear type regression equation has also been established of ultrasonic velocity with modulus of rupture (MoR) in air-dry of the type:

$$(U.V.) = A + B\ (MoR) \qquad (r = 0.62) \qquad \text{--- (3)}$$

where A & B are constants.

The result reveals that relationship of ultrasonic velocity $(U.V.)^2$ X 10^{-4} with (MoE) was found statistically significant ($r = 0.81$) and ultrasonic velocity increases with increasing (MoE) and a similar trend was also found between ultrasonic velocity and modulus of rupture($r = 0.62$) but relationship between these was found poor in comparison to the between $(U.V.)^2$ X 10^{-4} with (MoE). Statistical analysis is presented in the Table 1.

Four referential values were determined for defect detection based on 8 points testing that is the average of ultrasonic velocity for a particular path like the points between 1-2, 2-3, 3-4, 4-5, 5-6, 6-7, 7-8 and 8-1 (first referential value), 1-3, 2-4, 3-5, 4-6, 5-7, 6-8, 7-1, and 8-2 (second referential value), 1-4, 2-5, 3-6, 4-7, 5-8, 6-1, 7-2, and 8-3 (third referential value), 1-5, 2-6, 3-7, 4-8 (forth referential value). These referential values compared with the values recorded for each holes size i.e. 7, 14, and 21cm diameter at the center of the disc for respective path. A relationship of defect size (average diameter) with the total size (average diameter) of the disc and drop in ultrasonic velocity (%) was established of the type:

$$d = D\ (A*Log_{10}(V)\text{-}C) \qquad \text{---- (4)}$$

Where:

d- diameter of the hole made at the centre of the disc
D- diameter of the disc taken for defect detection
A- constant
V- drop (%) in ultrasonic velocity due to presence of the defect with respect to the referential value
C- constant

The result indicates that ultrasonic velocity along multiple directions decreases in a particular path in timber due to the presence of defects. The recorded data analysed with the help of EXCEL programme and defected portion (hollowness) at the centre of timber disc was identified. The error found in the estimated holes for sizes 7, 14, and 21 cm. diameter was -9.5%, 2.5% and 0.29% respectively Fig. 3(a) –Fig. 3(c) and Table 1. Original photographs 1 (a)-1 (c) of timber disc are also presented.

Table - 1: **Statistical analysis**

Parameters	Count	Average	Minimum	Maximum	S.dev.	CV (%)
Density (gm/cm^3)	47	0.797	0.721	0.847	0.02	3.09
MoE	47	83.7	33.4	104.0	11.43	13.66
MoR	47	85.0	271	1235	201.30	23.68
(U.V.)	47	4510	3132	4988	276.11	6.14
$(U.V.)^2$	47	2042	981	2488	231.09	3.09

Table-2: **Estimated hole size of artificially made hole at the centre of the disc by ultrasonic technique**

S.N.	Species	Actual size of the hole diameter at the centre of the disc (cm.)	Estimated size of the hole diameter at the centre of the disc (cm.)	Error (%)
1	*Dalbergia sissoo*	7	6.32	-9.7
2		14	14.35	2.5
3		21	21.06	0.29

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Fig. 1: **Ultrasonic velocity as a function of modulus of elasticity**

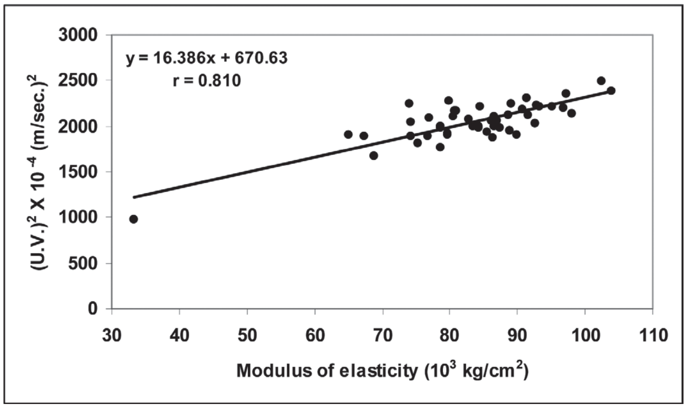
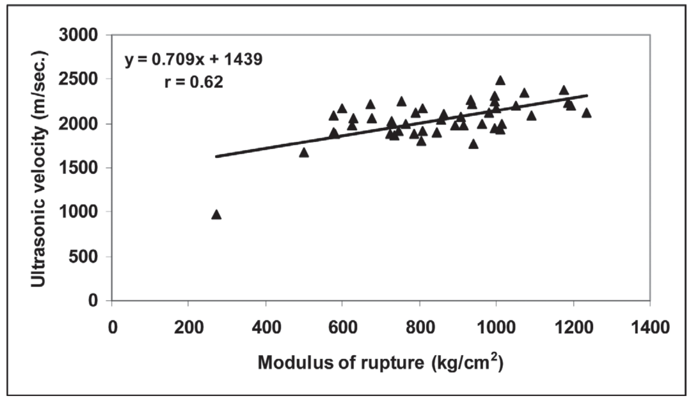
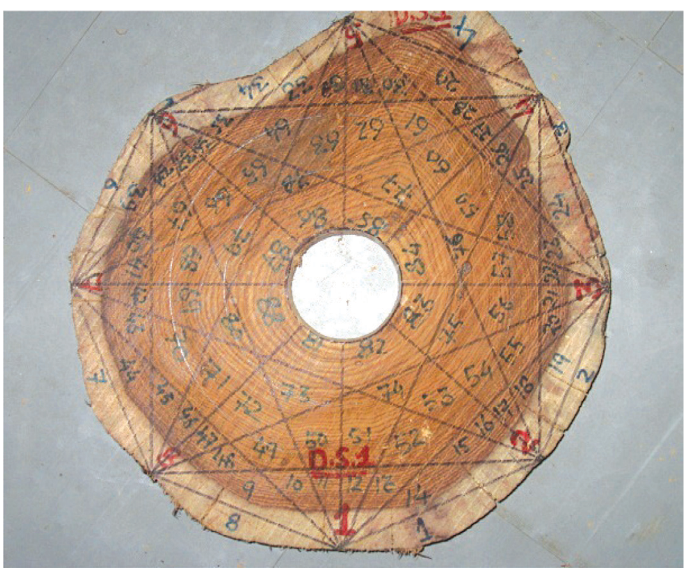


Fig. 2: **Ultrasonic velocity as a function of modulus of elasticity**





Photograph: 1 (a).

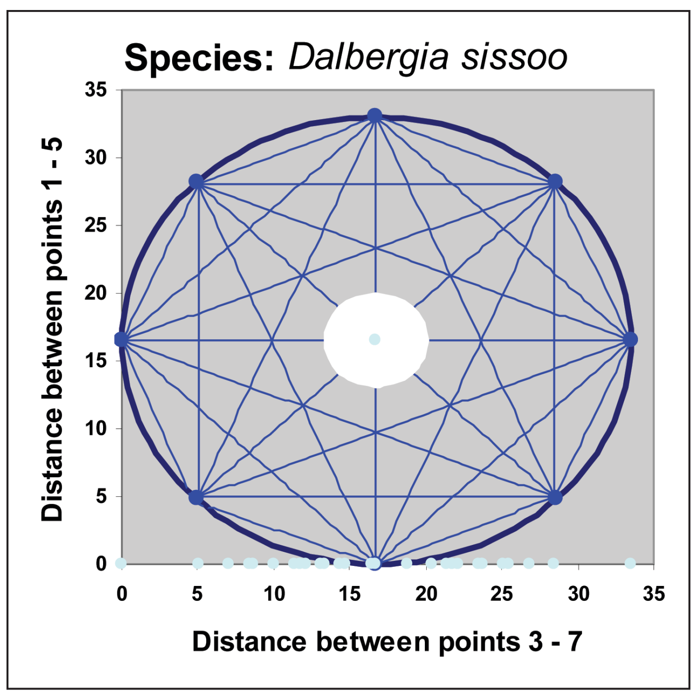
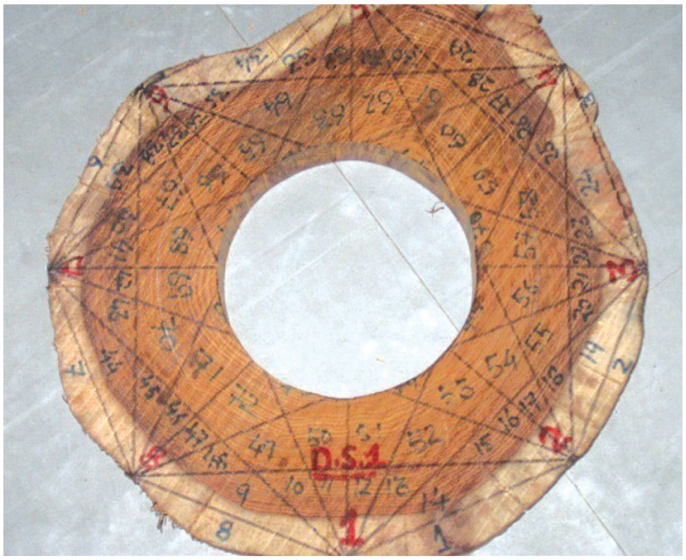


Fig.- 3 (a).



Photograph: 1 (b).

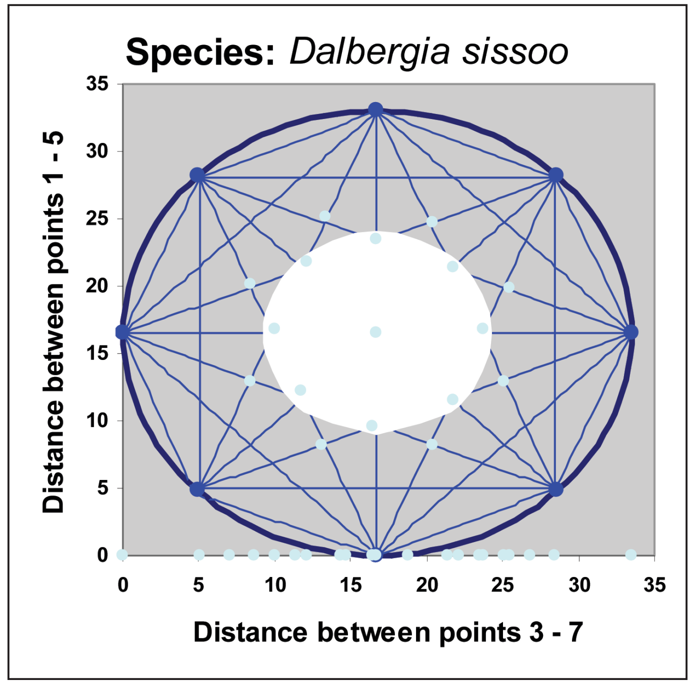
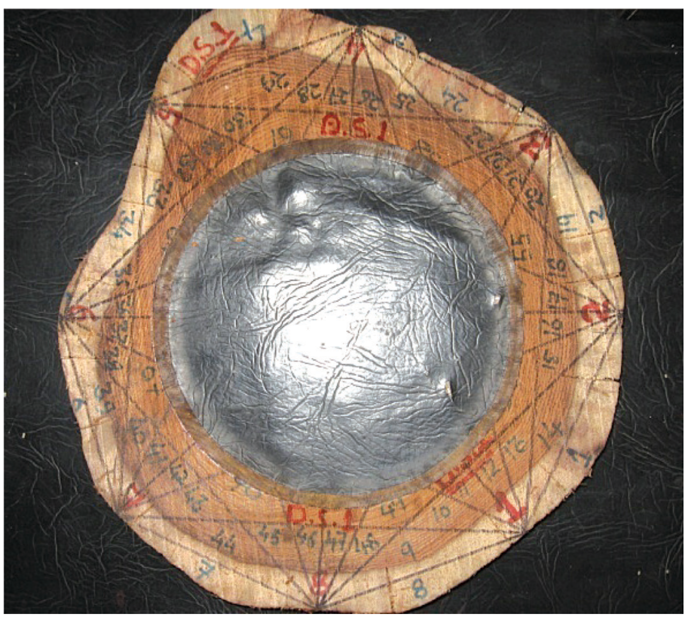


Fig.- 3 (b).



Photograph: 1 (c).

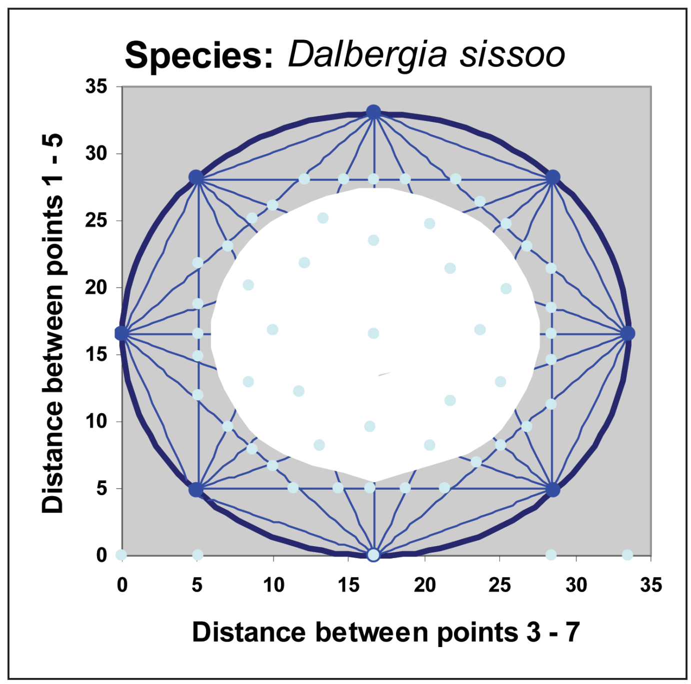


Fig.- 3 (c).

Photographs: 1(a) – 1(c). Actual photograph and Fig. 3(a)- 3(b) estimated hole of the disc of *Dalbergia sissoo*.

Improved Gum Production from *Acacia senegal*: Management for Livelihood

Moola Ram, J. C. Tewari, L. N. Harsh and A. K. Sharma *

INTRODUCTION

Acacia senegal is a deciduous shrub/tree, growing to 15 m tall and usually branched from the ground. Branches fork repeatedly and in mature trees commonly form a rounded, flat-topped crown. The trunk may vary in diameter up to about 30 cm. The bark is greyish-white, although in old trees growing in the open it may be dark, scaly and thin, showing the bright green cambium layer just below the surface if scratched with a nail. The slash is mottled red. Powerful hooked thorns, 3-5 mm long, with enlarged bases appear at the nodes of the branches, usually in 3s. They are sharp, with some pointing forwards and others backwards. Leaves bipinnate, 3-8 pinnae (glands between uppermost and lowermost pinnae); rachis up to 2.5 cm long; pinnacles are pairs of 8-15, green; 2 stipular spines strongly recurved with a 3rd pseudo-stipular between them. Flowers yellowish-white and fragrant, in cylindrical, axillary pedunculate spikes, 5-10 cm long; calyx of each flower has 5 deep lobes, 5 petals and a mass of short stamens; pistil inconspicuous. The pods are straight, thin, flat, shortly stipitate and oblong (7.5 x 2 cm), green and pubescent when young, maturing to shiny bronze, often with dark patches and bearing prominent veins; seeds 3-6, smooth, flat, rather small, shiny, dark brown. Varietal differences in *A. senegal* are based on variation in natural distribution as well as differences in morphological characteristics such as the presence or absence of hair on the axis of the flower spike, colour of the axis, shape of pod tips, number of pinnae pairs, occurrence of a distinct trunk and shape of the crown. Four different varieties of *Acacia senegal* are recognized: var. senegal, var. kerensis Schweinf, var. rostrata Brenan and var. leiorhachis Brenan. The generic name 'acacia' comes from the Greek word 'akis', meaning a point or a barb.

A. senegal has wide ecological amplitude and grows in countries like Maurtiana, Senegal, Zambia, Ivory Coast, Ghana, Nigeria, Mali, Burkina Faso, Niger, Central African Republic, Chad, Sudan, Ethiopia, Somalia, Uganda, Kenya, Tanzania, Rawanda, Zaire, Mozambique, Oman, Pakistan and India. The bulk of gum producing Acacia grow in an area known as "the gum belt" stretching from Ethiopian border through Central Sudan and across Chad into Senegal, where the gum producing trees were first identified by Linneaus in the 18th century. As it is commonly known for gum production, its uses in agro-forestry and silvipasture are also well known in some region.

In India, it grows on the dry rocky hills of Sind, the south east Punjab, the Aravali and other hills of north east part of Rajasthan, Gujarat, Madhya Pradesh, Punjab and Haryana. *Acacia senegal* is an important constituent of dry tropical thorn forest and found distributed throughout the arid western Rajasthan. In arid western Rajasthan, it grows abundantly in different habitat like rocky, semi-rocky, sandy plains and dunes of old formations in Jodhpur, Barmer, Jalore, Jhunjhunu, Churu, Fatehpur Sekhawati, Sikar, Bikaner and Ajmer district with a varying densities. It is also an important component of traditional agro-forestry systems. The density of the species varies enormously (30-2000 trees/ha) from location to location (Table 1).

Table 1: **Growth & tree density range of *A. senegal* in different districts of Rajasthan**

Districts	Height (cm)	DBH (cm)	Crown diameter (cm)	Density per ha
Fatehpur Shekhawati (Sheep & Wool Dept.)	400-650	24-28	460-500	1900-1925
Fatehpur Shekhawati (RAU)	500-550	40-45	700-750	45-60
Dhabla point – Churu (Forest Area)	300-600	60-70	900-950	250-280
Ratangarh – Churu	400-750	110-140	1000-1100	260-280
Bassi range (Forest Dept.), Jaipur	350-700	45-60	800-900	800-900
Puskar (Forest Dept, Ajmer)	400-600	35-45	600-625	1950-2000
Jhunjhunu	280-500	25-30	500-530	180-220
Ajmer	300-500	35-40	550-580	350-390
Barmer	300-700	40-60	500-520	35-55
Jodhpur	400-750	40-60	500-530	30-50

Acacia senegal is a multipurpose tree. The seeds are dried and preserved for human consumption as a vegetable. The dried

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seed is the main component of *panchkut*, a delicacy in Jodhpur, India, also containing fruits of *Capparis decidua*, *Cucumis sativa* and *Prosopis cinerearia*. Its leaves and pods are browsed by sheep, goats and camels. Crude protein values are 20% for leaves, 22% for green pods, and 20% for dry pods (expressed as a percentage of dry matter). Its wood is an excellent fuelwood, sometimes the only wood species to survive in dry areas. The calorific value is estimated at 3000 kcal/kg. The dense wood also yields charcoal. The heartwood is almost black and takes polish well. It is used for making carts and Persian wheels, sugar cane crushers, agricultural implements, horse girths and tool handles. Its long, flexible surface roots yield a strong fibre used for cordage, ropes and fishing nets.

Thus, *Acacia senegal* has multipurpose uses but it is main source of Gum Arabic. Gum Arabic exudes from the duct of the inner bark; it is tapped in the hot season (May-June) when the trees are stressed. Tapping begins when trees are 6-8 years old. It commences after leaf fall and ceases during the colder months of the dry season. Gum production is excellent on poor soils and higher in stressed trees. Gum nodules form in 3-8 weeks, exuding from the former broken abscission scars or traditionally farmers harvest gum Arabic from *A. senegal* trees by making injury at certain points on tree trunk and in the process they collect only 15-25 g gum/tree.

Current worldwide consumption of Gum Arabic is around 25,000 tonnes, of which about 20,000 tonnes comes from Sudan. The remaining 5,000 tonnes originates from other African nations, the majority of which, between 3000 and 4000 tonnes, comes from Nigeria. Nigeria currently produces about 20,000 MT of Gum Arabic annually ranking second in the world with Sudan as the leading producer and Chad after Nigeria as the third largest producer of the product whose world production has been estimated at 70,000 MT annually. Africa alone produces about 98% of the world requirement of Gum Arabic. The United States is the largest single market for Gum Arabic annual consumption, accounting for 25% of the world market. The European Community, Switzerland and Scandinavia collectively account for 40% of the world purchases of Gum Arabic. About 10% is channeled into Japanese markets. Some countries like USA, France, West Germany and United Kingdom are important entry ports and large quantities of gum are re-exported.

In India, the total annual output is only 800 million tonnes compared to world production and consumption of 60,000-70,000 million tonnes. The domestic production is insufficient even for domestic consumption and more of it is imported from Sudan and Nigeria to meet country's requirements. The import value of Gum Arabic has increased from US$33,32,125 in 2000 to US$1,28,22,492 in 2009 (Graph 1) (Source: http://data.un.org).

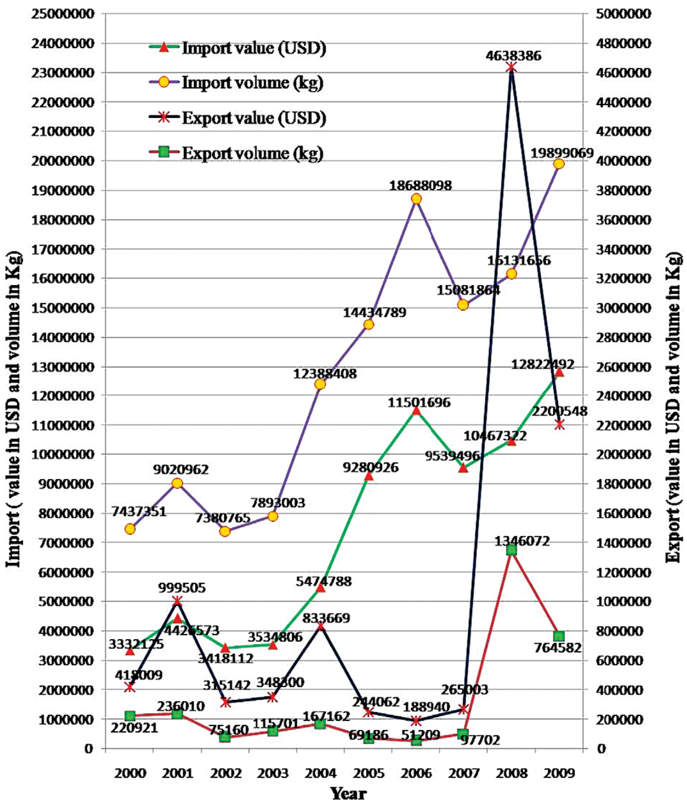
Gum Arabic produced in India has not been classified as forest product. In Indian market Gum Arabic is generally sold in the form of tears (often mixed with other gum). The gum yield from various acacia trees in their natural habitat in India is poor, particularly because many trees are very old and these are primarily being grown for timber, fire wood, seed and fodder, rather than for gum tapping. The regions producing Gum Arabic in India are the desert and arid region of Rajasthan and adjoining areas of MP, Gujarat, Haryana and Punjab. The region has enormous potential for Gum Arabic production and need of hour is to develop suitable technique to enhance the gum production. Under the network project on harvesting, processing and value addition of natural resins and gums, the CAZRI centre has developed a gum inducer and technique for improved production of gum from *Acacia senegal*.

CAZRI TECHNIQUE OF GUM EXUDATION (FIG. 1)

- The *Acacia senegal* trees of more than 8 years old having more than 6" diameter are selected for treatment. Generally trees growing on sand dunes, sandy plains and water courses are most suitable.
- A hole of about 1.5 to 2 cm diameter with 1 to 1.5" deep is made at one feet above the collar of the tree with the help of hand drill or mechanized drill.
- The tree is then injected with a 3.5 to 4.0 ml CAZRI gum inducer solution. The dose varies from species to species (2

Fig. 1: **CAZRI gum exudation technique**

Graph 1: **Gum Arabic trade in India (Export and Import)**



ml to 4 ml per tree).

- The tree hole is patched up with the help of bee wax or clay or pond silt.
- It is observed that the tree starts exuding gum tears after 8-10 days of the treatment.
- The best period of the treatment for *Acacia senegal* is March to May.

Gum yield with this technique is on an average 500g per tree which is 25 times higher than traditional method. The consistent and systematic efforts in India towards sustainable gum production can lead the country to tap the considerable chunk of the international gum exports. If all the trees producing gum are exploited in an organized manner, it can reduce the import bill of India to a considerable extent. The CAZRI gum inducer can be obtained from Silva section, Division-II of CAZRI during February to June @ Rs. 10/dose. For more detail, one can contact in CAZRI, Silva Section or visit the website www.npnrg-cazri.jimdo.com.

The technology of exudation of Gum Arabic through CAZRI gum inducer has been well established. It has spread far and wide in the Thar Desert. Stakeholders are earning good amount of money by way of sale of Gum Arabic in the local market. Since the inception of present network project the rate of adoption of the technology is increasing year by year. Data pertaining to adoption rate of the technology have been registered systematically (Graph 2).

The number of *Acacia senegal* trees treated with CAZRI gum inducer reached 22,600 during 2010-11, resulting in production of 6.7 t of Gum Arabic. In this way with average rate of Rs. 500 per kg gum, the farmers earned a total income of Rs. 38,00,000 by sale of Gum Arabic in local market. After network project on resins and gums came in operation since 2008-09 at CAZRI centre, the villagers have earned Rs. 117.9 lakhs in three years by the sale of 23.58 t of Gum Arabic in the local market and in turn CAZRI has generated a revenue of Rs. 5.55 lakhs by the sale of 55,558 doses of CAZRI gum inducer. This technology has national importance as it compliments very well in employment and income generation in drought prone areas. In drought like situations when crops fail and farmers have no other means to survive, *Acacia senegal* can provide a good value of income by way of gum production through improved technology. Thus, CAZRI technology of gum tapping has potential to change the scenario of income and service provided by gum yielding trees in arid land farming system.

ARABIC GUM USES

(1) As a non toxic food constituent

The major use of Gum Arabic is in food industry because it is non-toxic, odourless, colourless, tasteless, completely water-soluble and does not affect the flavour, odour, or colour of the food to which it is added. In India, it's usage ranges from domestic preparations to confectionery; and from glues to pharma-industries.

Confectionery

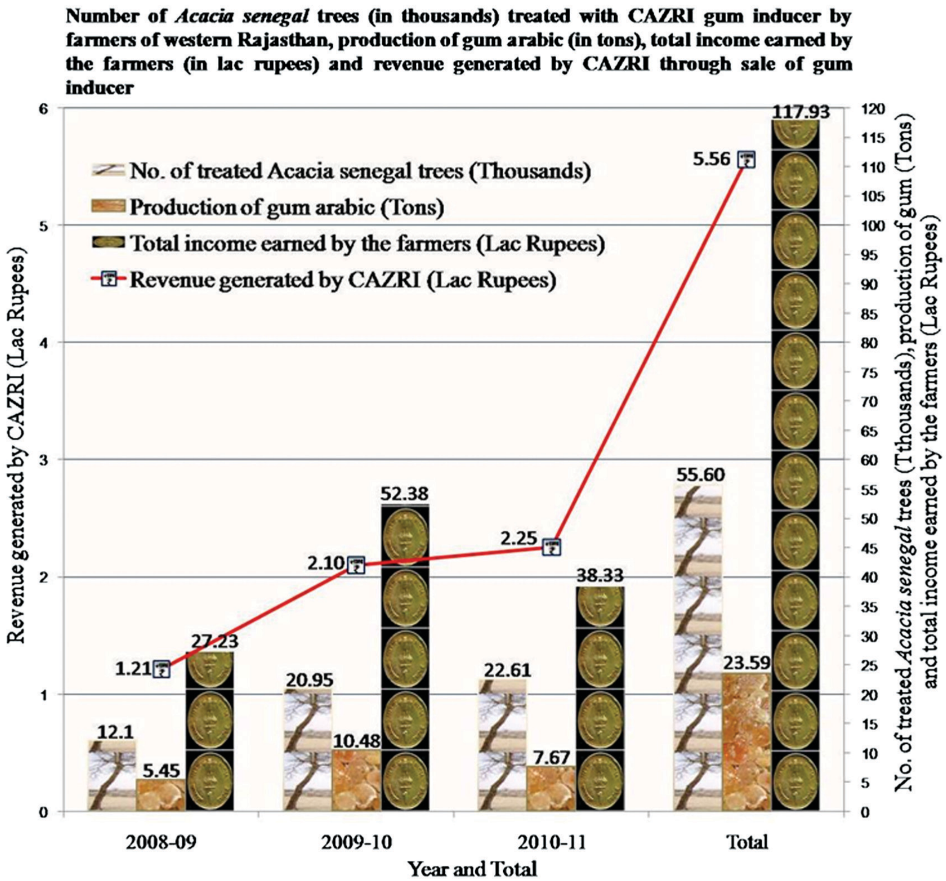
Gum Arabic is used extensively in the confectionary industry, primarily because of its ability to prevent cystallization of sugar and as a component of chewing gum, cough drops, and candy. It also acts as an emulsifier, keeping the fat uniformly distributed throughout the product so as to prevent it from moving to the surface and forming an easily oxidizable greasy film. In the preparation of jujubes, pastilles, or gum drops, Gum Arabic is dissolved in water and filtered solution is mixed with sugar and boiled. The desirable flavour is added with a minimum of stirring to prevent the formation of bubbles or opaque spots.

Dairy products

Gum Arabic has been used as a stabilizer in ice-cream, ices and sherbets, because of its water absorbing properties. The addition of Gum Arabic prevents the formation of ice crystals by combining with large quantities of water and holding it as water of hydration, thus producing a finer texture in the ice cream. It also uses in preparation of packageble milk or cream. The proper amount of milk or cream is mixed with gum-arabic; the mixture is heated mildly, poured into molds, cooled, and packaged. The product dissolves easily in hot beverages and keeps better under refrigeration than plain milk or cream. It acts as protective colloid in the preparation of processed baby food.

Bakery products

Gum Arabic is widely used in the baking industry for its viscosity and adhesive property. When used in bun glaze, gum Arabic imparts stability in conjunction with free-flowing and adhesive characteristics. The glaze is applied and adheres firmly to the bun upon cooling.



Graph 2: **No. of Acacia senegal trees (thousands) treated with CAZRI gum inducer, production of gum Arabic (tons), total income earned by the farmers (lac rupees) and revenue generated by CAZRI by sale of gum inducer (lac rupees)**

Flavour fixative

It is used as fixative and forms a thin film around the flavour particle, protecting it from oxidation, evaporation and absorption of moisture from the air. More recently, a new technique of microencapsulation has been developed and used for specialized flavour fixation. Gum Arabic is reacted with gelatin in a medium containing the flavour to form an insoluble, protective film surrounding or encapsulating the sphere of flavour.

Beverages

Gum Arabic is an effective foam stabilizer in beverages and is largely responsible for the lace curtain effect on the sides beer glasses. Eye-appealing opacity in beverages and beverage dry mixes are produced by spray-dried combinations of vegetable oil and gum Arabic sold commercially as a clouding agent.

(2) Pharmaceuticals

Probably up to 5% of the Gum Arabic import is used for pharmaceutical purposes. Its inherent emulsifying and stabilizing properties improve its demulcent and emollient characteristics have led to a number of applications ranging from the stabilization of emulsions to the preparation of tablets.

Emulsifying agent

Gum Arabic is superior to Gum Tragacanth for preparing cottonseed oil emulsions because the average diameter of the oil globules is much smaller. With both vegetable and mineral oils, Gum Arabic emulsions are stable over the pH range 2-10. Parafiin oil and water emulsions for use as laxatives have been prepared with Gum Arabic and Agar. Gum Arabic has also been recommended for use in oral laxatives and in laxative suppositories. One of the oldest applications of Gum Arabic has been in the preparation of cod liver oil emulsions. Used in conjunction with Gum Tragacanth, stable emulsions with excellent shelf-life can be made of cod liver oil, linseed oil, and mineral oil.

Antiseptic preparations

Antiseptic preparations have been made with a mixture of colloidal silver bromide and Gum Arabic. Silver arabate has antiseptic properties that make it suitable for use as a substitute for silver nitrate and organic silver compounds in the treatment of ophthalamic infection.

Component in medicienes

Gum Arabic has been used as an adhesive or binder for pharmaceutical tablets, such as aluminium subacetate tablets, and also as an excipient in the manufacture of pills and plasters. In additions, many types of coatings for pills employ Gum Arabic is their manufacture. Because of its emollient and demulcent properties, Gum Arabic is used in the production of cough drops and cough syrups. It produces a smooth viscous syrup and also prevents crystallization of sugar in both of these products. Gum

Fig. : **Gum Arabic production by farmers of western Rajasthan using CAZRI gum exudation technique**

Arabic itself has been used for the treatment of low blood pressure caused by hemorrhage or surgical shock. In plastic surgery, a 50% Gum Arabic adhesive has been used successfully in grafting destroyed peripheral nerves.

Cosmetics

In lotions and protective creams, Gum Arabic stabilizers emulsions, increases the viscosity, assists in imparting spreading properties, adds a smooth feel to the skin, and forms a protective coating. It is also a binding agent in the formulation of compact cakes and rouges, and as an adhesive in the preparation if facial masks. It is also used in preparation of face masks, hair creams and fixatives, face powder compact and protective cream.

(3) Industrial

Adhesives

Gum Arabic has been used widely in adhesives. Powdered Gum Arabic is considered to be a safe, simple for miscellaneous paper products and is commonly used by dissolving it in two to three times its weight of water. A 40% solution makes excellent mucilage for general office purposes. Gum Arabic glues are easy to prepare, light in colour, odourless, and very stable. In addition, the adhesive strength of the gum can be improved by the addition of certain metal salts, such as calcium nitrate and aluminium sulphate. Adhesives for envelops, labels, and stamps are commonly dextrins or starches, but Gum Arabic finds some usage, particularly in the manufacture of adhesive for postage stamps. A typical formula contains 100 parts of Gum Arabic, 2.5 parts of sodium chloride, 2.0 parts of glycerol, 2.0 parts of starch, and 130 parts of water. Wallpaper paste can be based on a mixture of gum Arabic, bentonite, and starch. In the preparation of laminated papers, Gum Arabic has found specialized applications.

Paints

The incorporation of protective colloids into a pigment-vehicle system, such as paint, is an old, established art. This is usually done to obtain improved particle size during precipitation of pigments, to control pigment aggregates and wetting qualities, and to control consistency and setting.

Inks

Gum Arabic is constituent of many special purpose inks because of its excellent protective colloid properties. It is used in the preparation of record ink, soluble ink, water-colour ink, quick drying ink, fabric and laundry marking ink, pigmented ink, emulsion or typographic ink, hectograph ink, gloss-finish ink, electrically conductive inks and wood grain ink. Besides use in ink preparations, it is important lithographic applications. Gum Arabic based transfer inks can be used for the preparation of good-grade carbon papers.

Textiles

Gums are widely used as sizing and finishing agents and in printing formulations for imparting designs or decorations to fabrics. Gum Arabic is an efficient sizing agent for cloth.

Status and Opportunities for Development of Wood Based Industries in India

C. N. Pandey *

INTRODUCTION

Wood-based industries, such as sawn wood, composite panel, pulp and paper, are key industrial contributors to income and employment generation, particularly in the rural and underdeveloped areas, but they continue to face challenges regarding the supply of forest-based raw materials. The total industrial demand for wood, in terms of Round wood equivalents (RWE), will rise from 74 million m^3 in 2005 to 153 million m^3 in 2020 (i.e., about 107% in 15 years). Wood-based industries can be divided into three groups: 1) sawn wood 2) composite panel and 3) pulp and paper. India is one of the major wood users in the Asia–Pacific region and recently had a fairly abundant supply of wood from several tropical hardwood species, including Teak (*Tectona grandis*), Sal (*Shorea robusta)* and Rosewood (*Dalbergia latifolia*).

TREES OUTSIDE FOREST SOURCES IN INDIA

Initiatives by the People and the Government

Trees Outside Forests (TOF) are commonly found as part of land use pattern in India and they have contributed in a big way to meet the various domestic needs and providing income, especially during scarcity to rural people. To meet such needs, trees have been planted on farm and marginal lands and on homesteads. (Pandey and Rangaraju, 2008). The resource of trees outside forests got a boost when the social forestry programmes were launched in the country in 1979-1980. About 35-40% of total plantation targets were achieved by distribution of seedlings, which were planted exclusively outside forest by individuals, private and other agencies. In addition many trees were planted by government departments on the common lands – land along roads, railway lines, canals, ponds and land owned by the village councils. It is estimated that the percentage of tree plantations outside forests is more than 70% of total plantations (Pande and Pandey, 2004). After the ending of the social forestry programmes, the Ministry of Environment and Forests of the Government of India has continued afforestation and reforestation programmes under different schemes since 1992. Some of the state governments' devised their own schemes to promote tree plantations on private land. This has helped government efforts to develop the trees outside forests resource.

Private sector initiative

There have been simultaneous efforts to improve the tree resource by the private sector. Some of the private wood based enterprises in the field of manufacture of Match stick, Pulp and paper like WIMCO Seedlings in Uttarakhand and ITC Bhadrachalam in Andhra Pradesh began raising quality seedlings and launched incentive schemes to attract farmers to plant trees during late 1980s. This approach became popular and has been subsequently replicated by many other private enterprises in the last decade. To mention a few: Harihar Polyfibres in Karnataka; West Coast Paper Mills in Karnataka; JK Corporation in Orissa; Andhra Pradesh Paper Mills; Century Paper Mills in Uttarkhand; Siv Industries in Tamil Nadu (Pande and Pandey, 2004). These companies are trying to practice a system where in, they are not only raising their own tree plantations (captive) to meet their raw material needs, but also have buy-back arrangements with farmers and land owners through banks or independently.

Policies and Legislation

There is no specific policy to promote and support plantation of trees on agricultural and other lands outside forests. Under the five-year development plans of the government, farmers have been encouraged to plant trees on agricultural land, especially since 1980. In the beginning, seedlings were provided by the forest departments cost-free and with technical guidance. Production, after care and treatment of the planted trees remained the responsibility of the farmers. The National Forest Policy 1988 of India (MoEF 1988) has emphasized that the raw material requirements of the forest based industries should be met by the industry itself through the establishment of a direct relationship with individuals who can grow raw material through agro-forestry without adversely affecting food production.

The legislation to harvest and market such trees varies from state to state. A number of states in the past have enacted tree preservation/protection acts with the specific aim of restricting uncontrolled felling of trees on private land. Transportation of timber in most of the states is governed by the transit pass rules

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under which specific permission is required from the local forest officer before the timber/wood is transported. Strict regulations on the felling of trees on private land have been found adversely affected the tempo of tree planting on private land in the past. In addition, land revenue rules and regulations of the state governments have indirectly put restrictions on tree planting activities, as change of land use is not permissible under the law (Hegde, 1991).

The mechanism to market the forest products generated by farmers at a remunerative price has not been developed in many parts of the country. In Northwest India, the farmers who planted eucalyptus on a massive scale in 1980s were disappointed when they did not get a favourable price from paper mills. Because of saturation in the paper market the produce was sold as fuel wood (Saxena 1991). This combined with the legal hurdles in felling and transportation of the forest products has resulted in exploitation of the farmers, causing a great disincentive to plant trees. There is no market information system to provide the prevailing price of wood on a day-to-day basis, nor is there any support price fixed by the government as has been the case in agricultural products.

India's market for wood and wood products is predominantly domestic in nature. The export of wood – logs, timber, stumps, roots, barks, chips, powder, flakes, dust, pulp and charcoal – has been totally banned and the export of wood products has been restricted. On the other hand, import of wood and wood products has been liberalized since 1992. The tariff charges on the import of logs or rough wood (round logs and sawn timber) have been drastically reduced over the last decade. This has resulted in a gradual increase in imports. Because of raw material shortages and low production volumes, domestically produced pulp is more expensive than imported pulp. The logs and other wood also face competition on account of the relatively cheap availability of imported wood compared to the price of locally produced wood, and this causes disincentives in terms of growing trees outside forests. Trees outside forests play multifunctional roles by providing a wide range of goods and services, particularly to rural India and to wood-based industries.

The recorded production of round wood from India's forests was of the order of 12-14 million m^3 annually during the 1970s (National Commission of Agriculture 1976), but at present this has gradually declined to about 2.5-3 million m^3. This has happened mainly because of the increasing emphasis on the conservation of forests and serves restriction on felling of trees from natural forests. About 2.5 million m^3 of timber is being imported to fill the gap. Though consumption and sources of round wood supply have not been studied reliably at the national level, it has been roughly estimated that, of total timber production in India, about 80% is being produced from non-forest areas under private ownership (Rai and Chakrabarty, 1996). In addition trees from outside forests include non-forest species like rubber, coconut and oil palm, whose main economic role is to provide rubber latex, nut and palm oil, respectively. These species are utilized for production of industrial wood, fibre and fuel wood on harvest.

Growth Pattern in Demand for Wood

Tables 1 & 2 depict the demand and supply scenario of wood in India. The average annual rate of growth of demand of timber in RWE from 2000 to 2005 was found to be 5.52%; this is likely to increase until 2015, then showed a decreasing trend between 2015 and 2020 (Ahamed, 2005). This slight decline in the growth rate will be due to a decreased rate of growth in requirements, as wood is replaced by substitutes.

Table 1: **Demand and Supply Scenario of Wood (Million M^3)**

No	Description	1985	1996	2001	2006	2010	2020
1	Wood demand for Domestic/Industrial uses	50	64	73	82	95	153
2	Output from forests	24	12	12	12	3	3
3	Output from plantation and social & farm forestry	-	41	47	53	58.5	88.7
4	Deficit	26	11	14	17	33.5	61.3

Source: Ganapathy (1997); Parag Dubey (2009)

The total growing stock of wood reported in the year 2007 was 6098 million m^3 which includes 4782 million m^3 inside the forests area and 1632 million m^3 outside the forest. The average stock volume percentage within the recorded forest area is 61.72 m^3/ha. Per capita forest and tree cover in the country is 0.08 ha/person and the country has the lowest per capita forest area among the major wood and wood products producers in the world. However, only 40% is considered as commercial. Furthermore, the current system of collection of wood production data does not distinguish between wood supply sources; hence, long-term assessment of supply is difficult. In terms of meeting the gap between demand and supply, timber from plantation/agro/social/farm forestry or tree from outside forests (TOF) has played a significant role in the recent past, and the import of timber has also increased simultaneously.

Table 2: **Growth pattern of future demand of wood**

Year	Demand (million m^3)	Percentage increase (Av. per annum)
2000	58.00	-
2005	74.00	5.52
2010	95.00	5.68
2015	123.00	5.89
2020	153.00	4.88

Source: Ahamed P. 2005

TIMBER IMPORT TREND

Most imports into India are in an unprocessed form, mainly as logs. Relatively small but sizeable quantities of sawn wood are also imported, while the import of veneers and plywood is almost negligible and limited to certain categories (Adkoli, 2005). The import of timber and timber products has increased substantially from 3.6 million m^3 in 2005 to 6.98 million m^3 in 2010. The import data is given in Table 3.

Table 3: **Summary of Import of Wood Logs and Wood Products in Rupees for the Years 2005-06 to 2009-10**

	2005 - 06	2006 - 07	2007 -08	2008 - 09	2009 - 10
1. Wood Logs	3681.74	4113.98	4712.43	5126.42	6980.59
2. Sawn Timber	92.4	103.29	102.47	144.95	220.5
3. Veneer	49.24	64.25	74.32	92.46	93.09
4. Particleboard	117.86	148.6	187.22	178.312	184.62
5. MDF/ Hardboard	123.78	159.87	229.27	220.09	225.14
6. Plywood	36.61	56.69	114.48	161.36	189.18
7. Wooden Furniture	136.86	235.77	278.52	296.48	234.47
Grand Total = Rs.	**4238.49**	**4882.45**	**5698.71**	**6220.07**	**8127.59**

Source: Director General of Commerce Intelligence & Statistics, Kolkata

In a major policy initiative, the Government of India permitted wood imports by classifying wood under open general licence in 1996 to ease the wood shortage and reduce pressure on natural forests. However, the tariff structure is biased in favour of log imports, and a conscious attempt has been made to stop imports of processed wood and products to protect domestic wood-processing industries. India has imposed a complete export ban on logs but not on wood-based panel products and secondary processed wood products (e.g., furniture, builders joinery, table and kitchenware and inlaid work). The decreasing trend in panel products appears to coincide with changes in the structure of the Indian plywood industry as practically all large and medium-scale industries have been closed and many plywood manufacturing units in the small-scale sector have been opened based primarily on plantation grown timber including Poplar and Eucalyptus in northern India and Rubber wood (*Hevea brasiliensis)* and Silver Oak (*Grevillea robusta)* in southern India.

WOOD-BASED INDUSTRY

Wood-based industry in India is an age-old industry and produces a range of processed wood and non-wood products including sawn wood, composite panel products and pulp and paper. The industry can be broadly divided into three groups: 1) sawn wood, 2) composite wood panels and 3) pulp wood–based.

Sawn Wood Industry

Sawn wood Industry is the largest single category. According to current estimates, consumption is about 29 million m^3. Because of the import liberalization policy, there was 3298702 m^3 of logs imported in round and other forms in 2005: a considerable increase (Government of India 1998). Logs import data for last ten years is shown in Table 4. About 70% of sawn timber is used in the construction sector. The rest is used, for example, in commercial packing, furniture making, vehicle building, etc.

Table 4: **Summary of Import of Wood Logs for Last Ten Years 1999-2000 to 2008-09-Code No: 4403**

Year	Quantity in M^3	Value In Rupees (Crores)
1999-2000	1,950,132	1860.00
2000-2001	2,097,851	2092.00
2001-2002	2,055,841	2431.00
2002-2003	1,399,132	1603.39
2003-2004	2,992,303	3068.14
2004-2005	3,329,953	3737.10
2005-2006	3,298,702	3681.74
2006-2007	3,491,872	4113.98
2007-2008	3,931,372	4712.43
2008-2009	3,875,317	5126.42

Source: Director General of Commerce Intelligence & Statistics, Kolkata

Sawn wood end uses include: construction mainly housing, (62%), sleepers (8%), packing (6%), furniture (7%), vehicle industry (7%), ship building (4%), mining (2%) and other miscellaneous uses like pencils, sports goods and toys, textile industries, textile accessories, handles, shoe laces, battery separators, etc. Since India's Independence, the country's saw milling capacity has undergone considerable expansion, but without changing orientation. Much primary sawing is still done at the felling sites by hand, especially in the coniferous hill and mountainous forests. However, hand sawing has completely disappeared from reconversion industries in large cities.

About 80% of wood converted into sawn wood comes from various hard wood species and 20% from coniferous species. It is processed in over 60,000 small saw-milling units catering to local needs, most of them without technological backup. The product comes to the saw mills either in log form or (around 40%) as slabs in non-standard sizes, pre-sawn by hand in the forests and then transported to the mills.

The industry is also unable to modernize because of the daily struggle for raw material. The utilisation of sawn wood is strongly influenced by local resources, customs and utilisation. Moreover, there is no integrated all-India market for sawn timber, partly because of the structure of the industry. Most of the saw mills do piece-work, with the bigger plants acquiring and stocking wood in log or slab form for re-sawing to customer requirements. The Indian timber markets showed that teak, sal, laurel (*Terminalia alata*), mango (*Mangifera spp*.) and benteak (*Lagerstroemia lanceolata*) are by far the most common broad-leaved species in use, while deodar (*Cedrus deodara*), kail (*Pinus wallichiana*) and chir (*Pinus roxburghii*) are the leading coniferous species. The Association of Timber Merchant estimates that these main species account for 85–90% of the total quantity of round wood sawn from coniferous and about 65–70% from broad-leaved species. The end use sector itself needs to be estimated if end-use demand projections are to be made. Thus, demand projection for RWE for different industries has been calculated and the industries/ end-use segments identified as using sawn wood are: housing and construction, packaging, furniture, automobiles, handicrafts, catamaran building and miscellaneous industries. Demand projections for all these industries have been calculated and the demand for sawn wood is shown in Table 5 (Government of India 1998).

Table 5: **Projected demand for Sawn Wood (million m³)**

Year	Housing	Packaging	Furniture	Auto-mobile	Handi-craft	Other misc. Industry	TOTAL
1998	13.6	4.36	2.25	0.17	0.40	5.14	25.92
1999	14.6	4.49	2.38	0.18	0.42	5.40	27.47
2000	15.9	4.62	2.52	0.19	0.45	5.70	29.38
2005	19.4	5.54	3.36	0.28	0.54	6.70	35.82
2010	22.1	6.40	4.62	0.41	0.65	9.40	43.59
2015	26.3	7.55	5.90	0.60	0.78	11.20	52.33
2020	28.5	9.00	7.53	0.87	0.95	15.15	62.00

1 m^3 of sawn wood = 1.67 m^3 of raw wood. Source: Government of India 1998.

Composite Panel Industry

The history of composite panel industry in India goes back to over 100 years when the first plywood industry for tea-chest making was set up in Bengal (World Bank 2006). From Bengal, factories spread out over the northeast during the second half of the 20th century. In 1996, however, a Supreme Court order put a stop to all cutting and processing of timber throughout the northeast forested states, which adversely affected the planning and growth of plywood industries. Under those conditions, entrepreneurs were constantly toying with establishing plywood manufacturing units in the northern states with a view to:

a) Arrest the trend of indiscriminate tree felling;
b) Reduce transportation costs involved in importing plywood from the northeast; and
c) Ensure timely supplies.

As the climate and soil conditions were found to be most conducive for timber farming in the northern and central part of India, plywood manufacturing units started being established there, resulting in a gradual shift away from the northeast. The availability of farm timber in the north and central states also boosted entrepreneurial efforts. Attempts by the industry to install new capacity and upgrade existing capacity to meet greater market demand for quality products also came to a grinding halt because of "policy drift" in the Ministry of Environment and Forests and a recent Supreme Court decision to restrict felling. Most of the industries are virtually closed until the states can prepare a working plan for sustainable harvesting.

The shift from small to medium- and large-scale operations has become of vital importance because of the erosion of import tariff barriers and consequent supply pressures from abroad. Raw material shortages have also hindered industries' growth. A major challenge has been to overcome the shortage of high-quality raw materials which may constrain the long-term growth of the Indian composite panel industry. After cement and steel, the plywood & panel and wood-processing industries are the third most important contributors to the housing sector. According to the Federation of Indian Plywood and Panel Industries (FIPPI), there are about 62 large and medium-size plywood mills and over 2,500 small-scale industry (SSI) units, of which more than 1,000 are located in Haryana, Punjab, Uttaranchal and western Uttar Pradesh. These industries use plantation wood like Poplar and Eucalyptus grown by the farmers under the agro-forestry system. With the R&D backup from the Indian Plywood Industries Research and Training Institute (IPIRTI) and other institutes, wood-based industries are now in a position to produce speciality value-added panel products such as shuttering, marine plywood, pre-laminated particle board and medium-density fibre board (MDF), laminated veneer lumber, moulded skin doors, bamboo composites, finger-jointed and edge-laminated timber in addition to general-purpose plywood, block board and flush doors to national and international standards. Development of technology to overcome the processing problems related to these new sources of raw materials is required, and there is also a need for timely information to the industry. A stable plywood market would be more attractive to consumers and thus help plywood producers to better resist the continuing pressure from other wood-based panel. The panel industries are using wood to manufacture plywood, veneer, particle board, MDF board etc. The demand projections for these products are summarised in Table 6.

Table 6: **Projected demands for Panel Wood Products (million m³)**

Year	Plywood	Veneer	Particle Board	MDF Board	Total
1998	10.10	0.25	0.13	0.13	10.61
1999	10.50	0.26	0.13	0.14	11.03
2000	11.00	0.27	0.14	0.14	11.55
2005	14.00	0.34	0.18	0.17	14.69
2010	17.96	0.43	0.22	0.21	18.82
2015	22.90	0.54	0.28	0.24	23.96
2020	29.20	0.70	0.35	0.28	30.53

Source: Government of India 1998.

The production of particle board may likely to increase in the coming years (Pandey *et al* 2006).

The present share of particle board is 6% and MDF 4% of the INR 200 000 million (US$5 billion) and 90% is dominated by plywood in Indian market. The panel-producing industry is growing at a rate of 35% per annum in India. Table 7 gives the corresponding market share of plywood, particle board and MDF in India, China and the world.

Table 7: **Corresponding market share (%) of Plywood, Particle board and MDF in India, China and the World**

Product	India	China	World Average
Plywood	90	10	30
Particle Board	06	30	55
MDF	04	60	25
Total	**100**	**100**	**100**

(Source: Plyworld 2007)

The government policy of liberalising log imports is neither considered a long-term viable alternative for the growth of the industry nor a basis for long-term investment decisions. The current tax structure in India continues to favour small-scale, agro- and recycled fibre–based products against medium and large-scale mills using conventional raw sizes that are bonded together with a binder under pressure; medium-density fibreboard is manufactured by drying the wood fibres before they are formed into a mat and bonded with a binder under high pressure. This has resulted in various jute composites (medium and low-density jute boards) coming into the market as substitutes. In view of its robust growth demand, large regional variation, and the strong substitution pressure, composite panels will be one of the most rapidly evolving businesses in today's forest industry. The speedy growth and changing supply and demand patterns will provide attractive opportunities for companies that stay abreast of critical developments as long as the raw material situation is resolved appropriately.

Pulp and Paper Industry

Pulp and paper industry is the most important cellulose fibre-based industry in India with a turnover exceeding INR 100 000 million (or US$2.5 billion). This industry provides direct employment to more than 0.2 million people, indirectly supports one million people and contributes more than INR 200,000 million (US$5 million) annually to the Exchequer. There are more than 380 mills with an installed capacity of nearly 0.5 million tonnes. Historically, the industry has grown at 5% per annum, but during the 1990s the growth rate was around 8%. Most mills are very small compared to international standards; 315 mills or 83% have less than 10,000 tonnes' per annum capacity. Only four have installed capacity over 0.01 million tonnes per year. Per capita consumption of paper in India is very low—around 5 kg compared to world average of around 50 kg (40 kg for the Asia–Pacific region).

The major issue confronting the industry is shortage of good quality fibrous raw material. The pulp and paper industry is considered to be one of the high consumers of forest-based raw materials; however, on an average, the industry in India uses only 3.5% of the total wood from forests. Nearly 90% of the wood from forest is used as fuel. The industries consuming pulpwood are primarily paper and paper board, newsprint and rayon grade pulp. The demand projections for pulp wood-based industries are given in Table 8.

Table 8: **Projected demand of RWE for pulpwood -based industries (million m³)**

Year	Paper and Paper board	News-Print	Rayon Grade Pulp	Total
2000	4.48	1.78	2.50	8.76
2005	8.96	2.56	2.80	14.32
2010	15.40	3.42	3.10	21.92
2015	26.64	4.63	3.40	34.67
2020	35.84	6.22	3.80	45.86

Source: Kulkarni A.G. 2006

Each tonne of paper production requires approximately four tonnes of freshly harvested pulpwood. Current forest resources cannot even meet the fibre demand of existing pulp mills. There is tremendous scope for the farm forestry sector to increase production and bridge the growing gap between demand and availability of pulp wood. The demand for wood by the Indian paper industry is likely to increase to 13.2 million tonnes by 2020. It is estimated that about 0.6 million ha. of land will be required for plantations to sustain the raw material supply through captive plantations to meet the paper industry's wood demand by 2010 and about 0.8 million ha. by 2020 (Kulkarni, 2006).

According to the Indian Paper Industry there will be a massive increase in demand for pulp and paper products in the coming years. It is reported that by 2012 demand for pulp and paper products will increase to 10 million tonnes as against 8 million tonnes in 2010. There will be further heavy increases in demand in the coming years. In case of newsprint, the same demand growth pattern is predicted. In both subsectors, a high shortfall is predicted, unless long-term planning for installation of green field mills and raw material begins immediately.

Raw material scenario in Indian paper industry

The Indian paper industry uses a variety of raw material (i.e., wood, bamboo, non-wood and waste paper). Over the years, the industry's raw material consumption scenario has undergone tremendous change. While still depleting the forest resource, the wood-based segment of the paper industry has shrunk from 84% in 1970 to 39% in 2000. By 2010, it is envisaged that the paper mills will be supplied from captive plantations, thereby increasing the use of plantation-based raw materials to about 42%. The industry must make concentrated efforts to obtain quality wood by aggressively promoting plantations. There has been a drastic increase in pulp wood prices from INR 1000 to INR 1800 (US$ 25–45) per tonne in the span of 6–7 years. Because of stiff competition, the wood is transported from distant places, thereby considerably increasing transport costs. To avoid this, core area development is now being seriously embraced by the industry.

By 2005, nearly 0.0343 million ha. of farm forestry plantations were promoted by the paper industries. It is estimated that this land mass can produce approximately 2 million tonnes of wood at 60 tonnes/ha. yield (Kulkarni, 2006). To meet the demand for pulp wood on a continuous and sustainable basis, plantations of eucalyptus, subabul *(Leucaena leucocephala)*, casuarina *(Casuarina equisetifolia)* and acacia *(Acacia Spp.)* have been promoted during the last five years by the industry under farm forestry, and are mostly seed route-based.

The actual requirement for pulp wood is around 0.55 million tonnes per annum. Recently, 0.1 million tonne paper and board capacity expansion was proposed by the industry with an investment of INR 726.4 million (US$ 180 million). Hence, the total pulpwood requirement will be around 0.85 million tonnes (say 100 000 tonnes) per annum. The projected demand for paper and board by 2011–2012 is 11 million tonnes, leading to a shortfall of 5.5 million tonnes, for which additional raw material required is projected to be 20 million tonnes.

CONCLUSION AND RECOMMENDATIONS

Wood is the most preferred material for various end uses ranging from fuel wood to composite woods. Thus wood can be replaced by wood itself. The emphasis is shifting from natural forests to plantation timbers as the major wood source. The choice of species for different end uses is also changing from durable primary conventional timber species to short-rotation, fast-growing plantation species with certain limitations. Amongst the several options available to bridge the gap are: importing of timber, which is purely a short-term measure, and generating tree resources within the country which could be a better idea as a long-term measure in sustainability terms, as well as a source of carbon stocking which is important from the ecological and environmental viewpoints. The third option of rational utilisation of timber, which has also resulted in the development of wood composites, will be more important as this will take over the future demand of wood industry.

The National Development Council, the highest planning body in India, has decided that the forest cover in the country should be increased to 33% of the geographic area by 2012 against approximately 23% that exists at present. To achieve this target, adequate funds are required, as is an appropriate policy frame work, innovative and people-centred policies and schemes, efficient delivery mechanisms and effective monitoring at the field and national levels. Further close collaboration with agriculture rural development, public works, irrigation and *panchayat* departments is needed to achieve the targeted coverage.

Despite the high population density, sufficient land is available to expand tree plantations both for ecological restoration and for the production of industrial and non-industrial wood. To promote the growth of trees outside forests resource, the private sector has to play the most important role. Opportunities have not been fully realized because of limited funds. Increasing investments in plantations through the involvement of the private sector requires innovative policies, as well as support through appropriate financial policy instruments.

There are certain issues related to policy as well as implementation which deserve attention, keeping in mind the future scenario, such as:

- ♣ Although the information available and generated on the status of consumption and production is voluminous, most of the data lack reliability and consistency. In the absence of such data it would be difficult to forecast or make projections. There is a need for reliable information on this issue so that policies can be formulated to bridge the gap.
- ♣ Plantation programmes have been an ongoing activity for quite some time. Now, there is a need for systematic monitoring and evaluation of various plantation programmes carried out by forestry departments. So that any shortcomings can be overcome. Studies on socio-economic parameter associated with generating tree resources/plantations are also essential as the ultimate objective is to meet end-user demand.
- ♣ There is a need for intervention through policy changes at state level to relax transit rules for species raised under various plantation programmes outside forest areas, including private plantations.
- ♣ Multi-location trials in different agro-climatic zones are necessary to identify and evaluate the performance of suitable species, including native species that have potential for high productivity.
- ♣ There is a need for a central agency to certify the quality of planting material such as seeds or vegetative propagates.
- ♣ The import tariff is biased in favour of imported roundwood and logs. Policies to encourage plantation programmes by private entrepreneurs to generate tree resources by way of incentives, financial assistance, and subsidies could be considered.
- ♣ The land ceiling laws need to be relaxed (much those for tea, coffee and rubber), particularly in dry areas that cannot support agriculture, so that wood-based industries can establish large-scale and economically viable plantations. Companies should be allowed to enter into long-term lease agreements with farmers, free of land ceiling restrictions, to raise commercial tree plantations. To ensure that prime agricultural land, which forms India's grain bank, is not diverted to tree growing, exemptions should be provided only for rain-fed areas.
- ♣ Proper regulations should be developed to control the quality of planting materials supplied to farmers through public or private agencies to ensure high productivity and disease-free planting materials. Only certified producers should be allowed to market seedlings. Raising high quality planting materials and the establishment of centralized hi-tech nurseries and a network of satellite nurseries throughout the country are integral parts of the "Green India" initiative.
- ♣ Private companies starting in-house research should be encouraged and supported to develop high yielding, disease resistant planting stock and improved management practices. One possible approach would be tax exemptions on investments made in research.
- ♣ Laws and procedures related to cutting, transporting and selling of privately owned trees should be simplified. Where government forests are absent or minimal and the risks of

timber theft from public forests are negligible, restrictions on cutting, transportation and selling of privately owned trees should be abolished.

- ♣ Import duties on wood and wood products should be raised to increase the competitiveness of domestic production.
- ♣ Market mechanisms and linkages between production system and user group should be developed to ensure reasonable prices to private wood producers.
- ♣ Effective extension mechanisms should be developed through the establishment of model plantations, frequent technology-promotion camps, distribution of attractive extension literature and extensive media publicity to support farmers and other landholders interested in growing trees.

Thus to promote the production of wood raw material with a view to making the country self-reliant in the field, action would be required on part of all major stakeholders. The following recommendations are considered important in order to effectively and fruitfully involve the government, private sector and other institutions:

- ✓ Promotion of public-private partnership in agro-forestry, farm forestry or Trees Outside Forests (TOF).
- ✓ Setting aside part of the forest area for commercial high jurisdiction forestry.
- ✓ Nationalisation of felling and transit permit regime.
- ✓ Establishment of a regulated timber market.
- ✓ Legislation on certification of seeds and planting materials for forestry plantation species.
- ✓ Tax incentives for capital investment in farm forestry.
- ✓ Afforestation credits for direct relief for farmers and creation of National Afforestation Trust.
- ✓ Levying cess on forest and tree products.

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Wood Based Industry in India: Past, Present and Future Prospects

Vimal Kothiyal *

INTRODUCTION

India is one of the most populous countries of the world and one of the various challenges posed by the large population is that of providing proper shelter to the millions. India's forest based industries diversity is synonymous with its cultural diversity encompassing micro level (artisans) and macro level (pulp and panel based) cardinal points. It is an important wheel of large scale employment. Timber stands at the pinnacle of all forest based industries overstretching all the ages of human civilization with regard to utilization. Fragmented knowledge acquired through experience and practice in the country incubated into systematic scientific knowledge with the setting up of premier Forest Research Institute (FRI). Generations of scientific knowledge propelled the growth of wood based industry in the country. Over last hundred years 'Forest Products Research' has witnessed a huge change and FRI's history is a testimony to this. Continuous harvest of timber from natural forests in the past has resulted in reduction of forest cover and depletion of resources. The profile of available raw material changed over the years and challenges to R and D organizations and industries manifested with every change. Global challenges of open economy have infested timber and timber product industries also which is traditionally slow in adopting new developments. Wood science, which used to be simplistic in definition having carpenter and artisan as iconic figure, is now defined as an amalgamation of chemical, material, bio and forest sciences and engineering. Its utilization involves processing and instrumentation for various wood, wood products and their chemical uses. Latest addition to this group is nanotechnology, carbon sequestration and smart products. Products developed out of wood waste, agro waste and other lignocellulosic resources have added a new dimension to it. All these together constitute "Wood sciences and technology".

The field is experiencing rapid changes. Consumer choices are shifting towards design, quality, trendiness and smart products. Fusion of traditional richness and modernity is providing opportunity unlimited. Enlargement of product attributes by diversification in products and innovation catering to environment is a challenge for the scientists and technologists together. Predominantly, a solid wood user society depended on quality timber, the art of which was perfected through ages and centuries is sluggish in change. Importers and foreign collaborators are taking advantages of the opportunities available. Domestic development in this field is lagging behind. Developments in the field have not reached the target groups due to societal and educational bottlenecks. Utilisation of timber and other forest products still continues to be generally unscientific and with little value addition. This is so, even, when some of the best technologies have originated from the country and are available for use. Barring few success stories, we still produce low value products with substantial degrade from high value raw material. This is resulting in great drainage of resources. This article dwells in the past developments in brief, sails through the present, analyses success and not so success stories, and stumbles upon opportunities and challenges of the future.

RENDEZVOUS WITH THE PAST

Traditionally Indian wood based industries remained in the unorganized sector. With the state control on forest and forest land, timber trade was dominated by government departments. Skill and development achieved through experience and practice were passed and perfected through 'guru-sishya (driver-cleaner syndrome) parampara'. Scientific developments in wood science primarily started at Forest Research Institute (FRI), Dehradun with its inception in 1906. Initial foot prints dates back to Economic Branch of FRI followed by Utilisation Branch. Forest Products research was later organized into Directorate of Forest Products Research (DFPR) headed by a Director. It acquired the pioneering status in systematic research on wood based Forest Products. Initial throttle to 'Wood Science' growth in the country was provided by German collaborators (Troop, Traver, Pearson etc.). The legacy was carried forward by many Indian stalwarts at FRI. Subsequently new Institute like IWST (Institute of Wood Science and Technology) and IPIRTI (Indian Plywood Industries and Training Institute) were set up. With setting up of new Institutes and reorganization of forestry research, the status of DFPR was reduced to a Division. The research output of DFPR is available in the form of more than 2200 publications/ Indian forest records/ bulletins etc (Kishan and Kothiyal 2011). Contribution in building up national standards is significant. More than 300 BIS specifications on wood and wood products are based on the work of FRI.

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Initial R&D at DFPR were aimed for defence, railways, ship-boat building and other government and public sector units. Unintended benefits of some of the developments passed on to private sector and small unorganized entrepreneurs. Utilization of forests available in the form of varieties (species) of natural timber was the prime objective. This resulted in generation of voluminous data on number of timber and bamboo species (Rajput et al 1991; Shukla and Negi 1994; Anon 2006; Kishan and Kothiyal 2011) which formed the basis of many national standards on utilisation and grading (BIS hand book). Data on specific gravity (Rajput et al 1991; Shukla and Negi 1994) on more than 500 species spreading over seven hundred records (generated over a hundred year period) is now used by one and all for estimation of carbon in wood by various researchers. Physical and strength properties data on about 500 species helped in recommendation of various unknown species for different end uses. Researchers in the past have worked out an algorithm to predict various strength properties on the basis of specific gravity of small samples (Rajput and Shukla 1989). Standardization, grading and quality control of products was one of the major activities. Period until 1970 was marked by timber from natural forests. Subsequently plantation timber species started dominating the minds of researchers.

The field of preservation and treatment also dominated through development of world class preservatives and evaluating natural durability of more than 300 species (Kumar and Dev 1993; Kumar 1995; Gairola and Aggarwal 2005). Bigger consumers of timber like railways, cooling towers and defence took full advantage of the world class developments. However, small units, though large in number could not harness the benefit themselves from world class scientific achievements. With shifting of material base of the large consumers, the utilisation of the development in this field declined over the years in India. Although an important field of research having world class notable achievements and which can save large volumes of timber, developments in this field are underutilized. Another area in which significant development has taken place is timber seasoning (Pandey and Jain 1992). Drying schedules of a number of timbers (250 species) and kilns to dry them were developed. These kilns carried the name of FRI solar and steam heated kilns and were popular among wood based industries. Utilization of research in this field also remained under utilized, although understanding and absorption was better compared to preservation. Seasoning kilns development reduced the down time and lock up period of financial resources. It was a major step forward but energy costs involved in the process and absence of hand holding mechanism for addressing the societal needs hampered the adoption of technology. Further development in the field also remained stagnated as far on reducing the energy cost is concerned.

Panel products, commonly called as composite wood products are reconstituted products which can be utilized as a supplement of timber in many applications. Properties of the original raw materials are modified / manipulated to the extent that it matches with solid wood for various applications. The raw material base for such products is large and utilizes non-conventional sources like plantations, lops and tops, wood residues and lignocellulosic residues from agricultural origin. Panel products which comprise mainly of plywood, block boards and flush doors are common in India. The first plywood factory in India was setup in 1906, almost a hundred years after the first veneering machine was developed in Europe. Development and production of other composited / reconstituted wood products started subsequently (Shukla and Singh 1994). The sector however had skewed development for many decades and therefore full utilization of raw material available could not be made. For ease of describing developments in India, the composite wood sector is divided into four parts in this article. The first sector consists of maintaining some original form of timber (e.g. veneer, wood panels consisting of veneers and small solid wood, flush door etc.). Second consists of products in particle board class utilizing small particles (size 20-40 mesh size) from wood and other sources. Third consists of even smaller particle size i.e. fibers and classified under Medium Density Fiberboards (MDF). There is another (fourth sector) one consisting of other products such as oriented strand boards (OSB), extruded and other materials. The first sector is more or less well developed in India where sufficient R&D inputs are also available. Scale of operation of industries is however small hindering cost efficiency and quality, up scaling. Skill level and knowledge of manpower managing this sector is however low like the other wood based sectors. Second sector of particle boards is also fairly developed with some level of R&D inputs available. It is the 3rd and 4th sector where development is negligible and R&D inputs are almost nil, although some industries were established with foreign collaboration. On OSB no work has been done at industrial level and no factory exits in India.

Wooden handicraft in India evolved through tradition and though generates large scale employment, is the most unorganized. Due to economic and societal problems benefits of R&D has not reached the grass root levels. With the change in traditional raw material base and emergence of plantation timber, this sector is at the cross road as adaptation to new material is full of struggles in the absence of ability to harness scientific and technical knowledge. Traditional knowledge acquired through ages is not applicable to new material base. Forest and Forest Products Certification aimed at sustainable development has potential impact on the sector. The discipline of Wood Working and Finishing set up at FRI under Forest Products Division to cater to this field had limited impact due to interrupted research and inability to penetrate this unorganized sector. Common facility centre set up by governmental organizations have hardly yielded results.

Raw material availability has been the major factor in retarding the growth of Wood based industries. Scales of operations have been low, impacting quality of products, innovations, cost and energy efficiency. Efforts of plantation had some positive impact in pulp and paper sector. Some success is also there in veneering sector. This success has lead to developing of improved varieties by R&D organizations, but the success is far behind what green revolution has done to agriculture. In agriculture, we are moving towards second generation reforms with main focus on processing, storage and food viability for longer period. In forestry sector, we have not even completed the first round. Tree improvement and variety generation falls under current research programmes. R&D efforts by industries and research organizations therefore lacked synergy leading to slow or dismal adoption of wood based technologies.

In the absence of proper support for R&D, the developments have been much below international standards. Many of world class technologies are dying in laboratories due to lack of upscaling and absence of takers for research. Incubation facilities / support for technology upgradation is lacking in this field. Private funding in plantation and R&D is inadequate due to small scale of operations. Vital role which Indian Wood based industry is playing in Indian economy is hardly recognized and therefore does not receive due attention and privileges. Low volume of operations is impacting technology utilization and development. Even with all this the forest products industry is set to grow at 5-6% with share of panel industry in the range of 17-20%.

WAY AHEAD

In the rapid changing global economy, human resource, technology development, its adaptation and preparedness for new challenges and emerging issues have become keys to success. With India marching forward to play a leading role in world economy, it is important to focus on all these issues and plug the gaps. Wood science research in the country had made significant progress but the information flow from the R&D organization to end users has not been very effective. Progression of absorption of wood technologies had been very slow in the country and therefore their importance in tree diversity conservation, enhancement of carbon sink has never been fully recognized. Importance of human resource development in the field of wood science has never been understood. Some efforts have now been made to develop human resource, but a lot is required to be done. Wood science research base needs to be enhanced and introduction of more courses of diverse nature in wood science technology with help of engineering and R&D institutions are required to be introduced. In service training for professionals should be a continuous process. Basic level education programme for students should be introduced by involving school boards.

Technology is changing very fast and new areas are emerging. To provide a backup support to industries, our R&D institutes are required to be well equipped both in terms of manpower and facilities to ensure the acceleration in growth and prosperity of wood and wood based panel industries in future. Sustained raw material supply by utilizing genetic gains and timely intervention by wood science tools at early stages of selection has become immensely important. Reduction in manufacturing and energy cost through technology intervention should be a continuous process. Interlinking of Institutes at global and regional level followed by exchange of scientists and technical manpower for exchange of information is to be addressed.

Environmental issues are important today and promotion of new environmental technologies and products will help in ensuring their long term viability. Formulation standards at par with international standards, enhancement of service life of products through technological intervention are some of the priority research areas that need to be investigated. Use of non-wood renewable fibers from agro residues and bamboo are another important research area which needs to be looked into. Forest Products is an industry which provides large scale employment and therefore should be aptly utilized to foster growth. Globally, a vast lignocellulosic resource (biomass) is available for industrial use, but everyone needs to recognize that it must be used in a systematic and sustainable manner. This may be achieved by diverse approaches linking development to livelihood sustainability with environment and climate change as central theme. More attention to market, social and policy research is needed.

Two seminars were held in 2010-11 (One at FRI, Dehradun and other at IWST, Bangalore) to deliberate upon need of wood based sector. Fruitful deliberations were held and important issues were flagged off in the form of recommendations. Some key areas emerging can form the part of the future strategies:

National Wood Use Policy

Need to set up a special commission / task force for wood science and technology at Government of India level in a two tier system. One may be for discussing and formulating the "National wood use policy" and the other on technical aspects for setting up goals for technological development. It should be on the line of Agricultural commission. Perspective planning of 20-30 years on forestry and wood Use issues on the lines of European and American communities needs to be set up.

Non-availability of raw material

Only few industries like pulp and paper manufacturers have made their own arrangements for raw material and have good rapport with the farmers because of which they are having enough material. It is the mechanical wood processing, plywood and panel industries sectors which are facing shortage of raw material. Majority of the wood based industries are in the unorganized or small/ medium scale sector where scale of production is low and unless and until it becomes economically viable they are unable to take up captive plantations. Tree outside forest cannot support the requirement of industry. Real estate prices are very high and growing trees on costly land is uneconomical. It is not only the raw material availability that is important but also the cost of raw material itself to make the wood based industry to survive. Today the timber is being imported from countries like Africa, Uruguay, Germany and the landing cost makes it uneconomical. India talks about 33% forest cover for quite some time. Countries like Germany and New Zealand have taken a conscious decision of having the separate areas under permanent protection/ conversation forestry and production forestry. India should also devise a policy on similar lines. Cross sectoral policy and institutional frame works that support agro-forestry at national and State levels needs to be devised. Also bamboo resources need to be efficiently utilized. The flow of raw material i.e. bamboo is major problem. Therefore government should work towards freeing the bamboo resources from excessive and unproductive regulation.

Indigenous trees domestication and development of their improved varieties should be taken up instead of relying so heavily on exotic species. Integration of wood science and technology in tree improvement and breeding programmes to be scaled up for producing high yielding material of desired characters. Tree improvement research in USA is funded by consortium of Industries which take up large scale tree improvement programme. Similar mechanism needs to be evolved in India also. Wood substitutions through utilisation of agro residues and bamboo needs to be promoted. Strategy to develop the technology for total bio-resource utilization for value addition and reduction in pollution is required.

Slow absorption of the technologies by the processing industries

R&D initiatives in lab are not widely adopted by the industry because it is not going through up scaling process which requires lot of funding. There is hardly any grant-in-aid or funding in the field of wood science. Industries also hesitate to come to R&D organizations. At present there is no effective mechanism for transferring any research findings from lab to end users. So there is a need to evolve a new mechanism to market technological developments made by wood science research organizations to the industry. Creation of intermediary marketing organization/ mechanism to transfer technology as a complete and holistic package having inbuilt scaling up mechanism with substantial funding grant is the need of the hour. The present and past practice of extending the technology with the onus lying on researcher has not yielded the desired results and therefore demands a change in approach. R&D technology needs to be developed as a complete package consisting of raw material, machinery, process and training of manpower. For this, R&D organizations should have complete and state of the art infrastructure in terms of machinery/ pilot plants / testing facilities well supported by matching manpower. With the present set up, only piece meal information can be generated which is not attracting the industries unlike foreign countries. Strengthening of present wood science institutes is of prime urgency looking at the global competition and scenario.

Another reason for slow absorption of technology is that the need for the technology is seldom spelt out by industries. Wood based industries associations in India should devote sufficient time in prospective planning for the future 20-30 years with well targeted goals and objectives. These goals and objectives are to be flagged off to wood based institutes in India for inclusion in their future R&D and training programmes. Industries are approaching foreign organizations for technology instead of Indian Wood Science Institutes. Transfer of scientific know-how to the artisans who are at the bottom of the ladder of stake holders has to be strengthened.

Improving/development of risk assessment methodologies/ modelling in wood based products, processes and related aspects are also rarely addressed in India. Interactions between the government agencies and wood based industries to be strengthened, the linkages between the research oriented units and wood based industries should be established.

Shortage of technical manpower in R&D organizations and industry

Shortage of manpower in R&D organizations has clearly emerged as a major problem. Condition of technical manpower in industries is also similar. Hardly 5-10% of the manpower in the industry is trained. The training imparted by FRI, IPIRTI is grossly insufficient. There is a need to expand training and education courses in wood science and technology. Shortage of manpower is not only in the technical area but also in managing these industries. Properly trained people with skills in Wood Science Technology and Management who can manage at top and middle levels are also required.

Training of trainers is also vital in wood based science and technology. Being a multidisciplinary field involving knowledge of physics, chemistry, engineering and social science, it is difficult to find readily available manpower unlike other fields of forestry. Specialized training to trainers is a must at all levels.

A large proportion of 'wood use' in our country is guided by building engineers, architects, and carpenters and other such skilled personnel. Proper and adequate sensitization of such professionals is very much necessary, and requires carefully drawn strategy and continuous efforts.

On the lines of Krishi Darshan, Forestry and Wood use should also be a regular programme on national TV and radio channels.

Development of consumer friendly "product standards"

Enhancing consumer awareness aiming at preference for wood products with longer service life. Development of standards to the level of ISO standards to market the products: India needs to develop adhesives which complies with higher emission norms i.e., E2 to E1 and strive to achieve E0 status. Development of formaldehyde and volatile organic compounds emission free binder for panel products, bio adhesive and fire resistant panel products should be taken up. Today there is a need for the industry to develop better products and adopt processes which are environmentally friendly also.

Creating scientific evidence through LCA studies on carbon-sequestering potential of wood products

Contribution to efforts in "ameliorating climate" and "Greening India", and establishing a national database covering entire range of "wood and processed wood products' for the benefit of all stakeholders. Enough focus may be on developing accounting system for carbon sequestration potential in wood products. India will not be able to export its handicraft and wood based products after 2012 if steps are not taken for forest certification and chain of custody (Forest Products Certification). Life cycle analysis studies of wood and wood products are required. Enhancement of service life of wooden products using eco-friendly preservatives may be promoted.

Some areas for future research

- **Energy and Cost efficiency**

Energy and cost efficiency in wood and wood product processing processes such as seasoning, saw milling, waste reduction and adhesives technology. Vacuum drying with microwave is fast but costly, so vacuum with convectional heating can be used because as it is more environmental friendly and shows less energy consumption

- **Improved and New products**

Improved products through modification for dimensional stability/aesthetic appearance and durability by applying physical, chemical and thermal means.

Development of Glulam, Parallam, OSB, wood/lingo-cellulosic polymer composite and wood lingo-cellulosic reinforced composites. Use of lingo cellulosic based material from wood and non-wood sources including agro-waste and weeds. Economic utilization of smaller pieces of wood through Finger jointing to be promoted in semi structural uses.

- **Nanotechnology**

Research in this field holds the potential to stimulate the next industrial revolution. Application of nano-particles in developing smart material/product (sensor based bio-composites), wood protection (through nano- biocide), wood coating (nano coating systems) and many other applications.

- **Green Building**

Green building is a concept of using green and energy efficient material. It is a systematic effort to create, sustain, and accelerate changes in practice, technology, and behaviour to reduce building-related environmental impacts while creating places that are healthier and more satisfying for people.

- **Improvement in raw material quality**

Biotechnological intervention to produce wood of desired quality / traits. Efforts to exploit the natural variation through selection for improving timber quality having desired characters.

- **Preservative development**

Development of environmental friendly preservatives and finishes. Bio-molecular methods to detect wood-destroying fungi in commercial buildings and monuments and their preservative treatments *in- situ*. Methods for in-service wood preservative test to be developed. Potential utilization of plant and fungal extracts for wood protection, their identification through modern tools. Biological Control of Wood Stain Fungi. Keeping in mind the sanitary and phyto-sanitary agreement, more work is needed in the field of fumigation of logs which are exported and imported. Work on corrosion avoidance with new wood preservatives may be taken up to make new preservative systems more suitable with metal fasteners

- Conversion of lingo-cellulosic based material into bio fuels using digesting enzymes produced from organisms, e.g. Marine borer.

Infrastructure and manpower support for meeting future challenges

To meet the above objectives new pilot plant facilities to be created for MDF, particle board, OSB and radio frequency curing. Scientific manpower base in wood science to be drastically increased in the country at least four times. Wood quality/product quality assessment by development and utilization of advance testing and characterization techniques like spectroscopic (NIR), microscopic (SEM, AFM), gravemetric (TGA, DSC, DMA), X-densitometry and Silviscan.

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Non-Timber Forest Products and Rural Livelihoods with special reference to the Policies & Markets in Orissa

Tapas Kumar Sarangi *

INTRODUCTION

Rural poverty in India is generally considered to be linked to a lack of access to cultivable land, or to its low productivity. Changes in the collection of gathered items from common property resources such as forests go largely unnoticed, and are not even accounted for in the national accounts and Gross National Product (GNP). However, about 100 million people living in and around forests in India[1] derive their livelihood support from the collection and marketing of non-timber forest products (NTFPs). These NTFPs provide subsistence and farm inputs, such as fuel, food, medicines, fruits, manure, and fodder. The collection of NTFPs is a source of cash income, especially during the lean seasons, because of their increasing commercial importance. Thus the issue of rights and access to NTFPs and incomes from NTFPs is basic to sustenance and livelihood for the forest dwellers.

SOCIO-ECONOMIC PROFILE OF THE STATE

The state of Orissa is located in the East of India, having a total geographical area of 15.57 million ha. The population of the state is 36.71 million (3.6% of the population of India), of which, 85% are rural and 15% are urban population (Population Census, 2001). The average population density is 236 persons per sq km. The tribal population constitutes 22.2% of the total population. The livestock population is 22.7 million constituting 4.8% of country's livestock population. The state ranks 4th among the states in terms of area under forest cover. The present day state of Orissa has a complex historical tradition because it has been formed over time by taking areas from other states with different administrative and institutional arrangements including forest institutions. The present state of Orissa is an amalgamation of different parts coming from Bengal, Bihar, Madras Presidency and Central Province.

The state can be divided into four distinct physiographic regions. These are North Plateau, Eastern Ghats, Central Tableland and Coastal Plains. Forest is mainly found in first three regions of the state, as the tribal population is high within the region. The economy and livelihood of the state and its people is predominantly agriculturally based, involving an estimated 75% of the working population. However, 47.1% of population in the state is below the poverty line as per 61st round of National Sample Survey 2004-05. Of the total poor, 90% live in rural areas, and the intensity of poverty is particularly high among the tribal population located in forest-fringe villages. In view of this there is a need to understand the forest and forest related issues in order to understand the livelihood of people dependent on forest.

The structure of the paper is as follows: besides the *introductory* section; the *second* section discusses the extent of dependence of rural poor on forest and forest based resources. The *third* section analyse the management of NTFPs and the market mechanism for its sale. The *fourth* section provides the problems in NTFPs trades in Orissa and the policy reform. *Last* section ends with a conclusion.

DEPENDENCE ON FOREST

In the absence of adequate resource endowment such as land and access to service sector the majority of poor households rely on forest and on labour market. Forests play a crucial role in the livelihood strategies of many rural households in Orissa (Sarap and Sarangi 2009). Beyond subsistence, fuelwood and fodder collection, there are a wide range of forest products which poor households depend on, particularly for consumption and generation of income in the lean season. The dependence on income from NTFPs has been shown to be inversely related to the size of landholdings in Orissa as well as in India (Fernandes and Menon 1987, Sarap 2007). It is labour-intensive, but the returns from this are quite low. Sarap's (2007) study has found that the percentage of household's total income coming from forest related activities varied from 40% to 50% in the case of poor households. But, absolute income from the forest is low and below the poverty line income for these groups. Similarly a study conducted by the Indian Institute of Forest Management in 1996 (see MoEF 1998) found that the contribution of forests to the economy, for tribals was very high. The average tribal family drew about half of its annual income from forests and 13% from cattle (see also Sing 1997)[2].

Women play an important role in the collection of NTFP (see Khare and Rao 1993, Mallik 2000, Sarap 2007). Total women

1 India's population in 2001 was about one billion.

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2 See also Singh (1997) for similar findings for forest fringe villages located in the district of Sambalpur, Mayurbhanj and Ganjam in Orissa.

labour engaged in the collection of forest produce in Orissa is as high as 300 million woman days per year. Throughout India, collection of kendu leaf generates part time employment for 7.5 million people - a majority of them tribal women (Arnold 1995) while in Orissa, 1.8 million women are involved in this, collecting 45 thousands tones (Rs. 450 million) of leaves per annum. Despite higher participation of women in the collection of NTFPs the price realised from selling the product is very low.

IMPORTANCE OF NTFPS FOR THE LIVELIHOOD OF FOREST DWELLERS

Non-timber forest products (NTFPs) have been the lifeblood of the forest dwellers especially the tribal living nearby the forest. These products provide food and cash income to the poor tribal during the lean seasons. Yet policy makers have overlooked the potential of NTFPs in combating rural poverty and food insecurity, and state policy on NTFPs has mostly favoured private business interests: private leaseholders, traders, moneylenders as well as its own interest. The private business houses were the monopoly traders of major NTFPs till 2000. As a result the primary collectors were worse off because of the low payments received by them when they exchanged their products with the traders. Even the low income derived from the sale was irregular due to erratic procurement of these products by the buyers.

DEFINITION OF NTFPS

The state differentiates between Non Timber Forest Products (NTFPs) and Minor Forest Products (MFPs). This is because the Constitution of India stipulates that ownership over the MFP has to be transferred to *Panchayats*. The state has identified 85 items as NTFPs. Out of these, 68 items have been transferred to *Panchayats*. The rest have been divided into nationalised NTFP (bamboo, *sal* seed and *kendu* leave) and 'lease barred' items. The products under the lease barred items are mostly gums, barks and leaves that are either banned or allowed selective extraction by primary collectors.

This classification came up only after the provision of Panchayat Extension to Scheduled Area (PESA) act came into being in 1996. In response to PESA the state has come out with legislation whereby *Gram Sabhas* have been given ownership rights over NTFP in their area of jurisdiction. In operational terms, it means that traders who want to operate in any area have to become registered with the respective *Panchayat* and pay a fee. The traders are supposed to pay the prices fixed by a district level committee.

After the promulgation of Orissa *Gram Panchayats* (Minor Forest Produce Administration) Rules in November 2002, the responsibility of fixing the minimum procurement price (MPP) has been vested with the *Panchayat Samiti*. The MPP so fixed by *Panchayat Samiti* is to be rectified by *Gram Sabha* and the *Gram Panchayat* has been empowered to modify the MPP if needed. According to the new rules, any person who is interested to deal in forest produce can deposit a required amount of money and register himself as a dealer. The *panchayat* has the power to cancel his registration if it finds that the dealer buys forest products at less than the fixed price approved by it. Further, each dealer has to give a statement about the amount of products bought by him in the *panchayat* areas to the *panchayat* office and the Range Office of the Forest Department. But in practice traders do not follow this. It is noteworthy that there is no restriction on movement of produce inside the state. Overall it is clear that the *panchayats* have been provided with the responsibility and authority of managing non-nationalised NTFPs, but lacks the capacity to exercise these powers, and in many cases they are not aware of their power.

NATIONALISED NTFPS

Sal seeds, *kendu* leaf and bamboo are the nationalised NTFP items in the state. *Kendu* leave trade was nationalised in 1973 and Sal seed during 1983, with a view ostensibly to ensuring a fair price to the gatherers, and also to enhancing government revenue. The contradiction between these objectives have largely been resolved in favour of the later: the policy environment relating to NTFP trade was characterised by revenue maximisation by the state. Furthermore, apart from the above three nationalised forest products, trading rights for several marketable NTFPs were given to private houses as monopoly leases up to 2000. In such a situation the fate of forest products and livelihood of people dependent on these products, were in the hands of private parties and industries.

The price fixation of the NTFPs is mainly based on minimum wages. For instance, as per the relevant Acts [OFP (CT) Act 1981, and OKL (CT) Act, 1962] the price fixed for the NTFPs are mainly based on consideration of minimum wages. The Orissa Forest Products (control of trade) Act, 1981, section (7) states that while fixing the price of specified forest products, regards may be paid to among other things, "general level of wages for unskilled labour prevalent in the units and the provisions of the minimum wage Act, 11 of 1948". However the prices fixed by state have little relevance in the absence of mechanisms to ensure that these prices are paid. The monopoly leaseholders depend on the local sub-agents/ traders in varying degrees for procurement of NTFPs. Because of low bargaining power of the primary collectors vis-à-vis these traders, the former rarely get the state administered prices.

The overall impact of the polices and laws were depression of prices received by the primary collectors for NTFPs especially due to monopoly leases and high royalty fixed by the Forest Department, with a resultant deprivation of their livelihood. On the other hand the state generates significant revenue from its trade (*kendu* leave and sal seed) that is based on the hard work of the primary collectors. It is desirable that the primary collectors should get a share in the profit from the operations of NTFPs. The state has a provision for channelising of profits from *kendu* leaf operations to the primary collectors, but the system of distribution is faulty. For instance, a provision exists that at least 50% of the profit earned from Kendu Leaf (KL) operations has to be distributed to *panchayat* bodies in the KL growing subdivisions. But so far only *ad-hoc* grants have been given. Further, instead of sharing the profit within the *kendu* leave growing/ collecting areas the profit is distributed widely, even to non-*kendu* leaf areas. Further the funds given to the *panchayats* under the KL grants are utilised for a variety of purposes including payment of salaries to the staff. As a result the primary collectors hardly get much benefit from the transfer of profit to *panchayats*. Moreover, the percentage share of revenue passed on to the primary collectors of KL as wages is the lowest in the case of Orissa at around 20% (see Vasundhara, 1997). Clearly, although NTFPs form an integral part of the livelihood of the forest dependent communities, state policies related to these items have been generally pro-rich and trader- oriented until 2000. As a result the livelihood conditions of the poor, dependent on these produce, have been very precarious. Likewise the post 2000 changes in the policies of NTFPs have not much improved the livelihood condition of the forest dwellers.

NTFPS MANAGEMENT VIS-A-VIS MARKET MECHANISM

In the process of commercialisation of NTFPs, a number of agents, namely: middlemen, businessmen and traders, government agencies, etc., enter in to the market network. Also, the very characteristics of NTFPs influence the market behaviour, mode of exchange and prices differently in different situations.

In Orissa, while non-traditional NTFPs such as; barks, lac, medicinal plants, resins, oilseeds are exchanged for salt, tobacco and dry fish in remote tribal regions NTFPs of greater exchange value are bartered for cloth, umbrella and other luxury goods. Lac, resin and honey are by and large bartered to peddlers. Oil seeds, barks, resin, gum, leaves, fibers, canes and other similar products are sold in large quantities to generate cash income to tribal households.

Nationalised and commercially significant NTFPs, such as; *kendu* leaves, *sal* seeds, bamboos restrict trade, and also limit number of legal buyers. It chokes free flow of goods, and delays payment to gatherers. Thus, it reduces the income that the forest dwellers might get and impoverishes them. It creates inherently exploitative alternative markets, such as: State monopolies, Private monopolies and illegal trade channels.

The structures of marketing channels vary depending upon number of agencies involved and nature of products.

Primary gatherer → village merchant (either an agent or sub-agent) → wholesaler → processor consumer. Under such an arrangement, the primary gatherer ends up receiving a small share in what the final consumer pays.

Marketing of NTFPs exhibits a wide range of variations in terms of market structure, marketing channels, price and scope for processing. Most of the NTFPs markets are essentially local, and exhibit seasonal behavioural pattern - such as, honey market in autumn, *kusum* seed market in pre-monsoon season, tamarind market in summer, and broom stick market in early spring.

Better quality products attract higher demand, and better prices in any market. But, the quality of primary NTFPs is influenced by post-harvest handling, processing and storage conditions. Admittedly, consumer markets need sustainable and continues product availability, reliable and predictable supply, and stable quality products.

A study (Mallik and Panigrahi 1998) suggests that while many vendors sell NTFPs for making extra income, others are supported by a network of merchants and several levels of buyers and sellers. Local traders and merchants are the main intermediaries. They buy NTFPs cheaply from the primary gatherers, and sell them to exporters/processors or their agents at exorbitant prices.

Lack of timely dissemination of information about the support prices, market avenues, processing units for value addition etc indeed increase vulnerability of primary gatherers owing to "distress sales". In the absence of appropriate link between input sector and post-production sector, the gatherers, the cultivators and resource owners of NTFPs fail to secure a fair share of processing and value addition (Chandrasekaran 1998).

NTFP trade and markets are highly disorganised. Government agencies, private middlemen stand between the primary collectors and the manufacturing units/whole sellers/outside dealers as intermediaries. But, the primary collectors in the disposal process are in close contact with the direct consumers in the local weekly markets as well as village '*haats*'[3]. The major buyers of their collections are private businessmen, traders, government agencies and consumers. The trader very often does not pay in cash, and insist on barter,

Markets for NTFPs are by and large informal and unstructured. As a result, the primary gatherers and NTFPs dependent population suffer from various exploitative practices in the hierarchical structure of market network in the tribal areas. Their exploitation is manifested in low price, credit-liked trade and by way of cheating in the measurement.

The price variation in the bordering states as well as within the districts is a matter of great concern. Evidently, the monopoly buyers within the state pay a lower price to NTFPs as compared to the alternative markets and also their counterparts in bordering states. This transaction is supposedly illegal, but operates in everybody's knowledge.

TERMS OF TRADE AND MODES OF EXPLOITATION

Various modes of exploitation and deprivation arise owing to situations, where exchange takes place between illiterate, poverty-stricken, ignorant, impoverished and unorganised tribal forest dwellers and a group of organised vested interests, traders/ business men. In the absence of an effective, vibrant and procurer-friendly institutions a number of non-tribal intermediaries namely; middlemen, businessmen, traders seem to have infiltrated in to tribal hinterland in guise of traders, shopkeepers and medicine men to take the advantage of the poverty, ignorance, spendthriftness of the tribal people.

The mode of NTFP trade exhibits great variation by type, region, season etc. Barter is a common mode. Traders also make advance payments to primary collectors, and later buy goods at very low rates and sell them in cities for huge profits. These modes have set up exploitative elements due to non-payment of prices fixed for NTFPs. Traders also function as money lenders, and buy NTFPs towards repayment of debt or interest. While private traders and middlemen buy NTFPs through agents and sub-agents at the primary level, the government agencies procure specified items; such as; Tamarind, Hill broom, *Mahua* flower, *Sal* seed, *Kendu* leaves, etc., directly from the primary collectors at the local collection centres.

Among the modes of exploitation in trading activities, differential prices, grading of the products, limited processing, creation of situations towards more indebtedness, means of distress sales, metric system of weight and measure etc are very

3 'Haat' is a local term refers to village market.

important. In situations, where weaker sections are prone to sell as much they can to meet their pressing consumption needs, the exploitative elements become more active, to exploit the situation.

Though market is the most powerful channel of communication particularly in the tribal region, the NTFPs indeed face "buyers' market". In such a situation, the middlemen indeed largely benefit from the commercialisation process in terms of appropriating a greater share of value. Thus, relationship between primary collectors and middlemen (in a sense) is symbolic.

Much of the miseries of tribal and other forest-dependent communities are primarily due to lack of access to forests to collect NTFPs. Even if collection is not prohibited from the revenue and protected forests, the right to process some NTFPs and sell the products freely in the markets has not been granted. Market intermediaries including private traders form a dominant link between the primary gatherer and the final consumer.

The intermediaries are capable of maintaining a stronghold in the marketing network due to their ability to meet immediate needs of the primary gatherers. They offer quick and timely credit, make quick payment and also have a good network of procurement at the door step of the producers.

Poor communication and transportation facilities, highly segregated markets and unequal bargaining powers between buyers and sellers make the field more profitable for middlemen (FAO 1995). Thus, middlemen can and often get involved in unfair activities and exploit the producers' weak bargaining power due to latter's ignorance of the market factors, and thereby retain a disproportionate share of producers' earnings.

PROBLEMS WITH NTFP TRADE IN ORISSA

Given the collection of forest produce, the income of the forest dwelling communities would depend on value addition to the products and their selling at reasonable prices. But, the marketing structure for sale of NTFPs is exploitative to the tribals. The nature and structure of marketing in the tribal dominated area is quite different from other areas because the sellers, who are mostly illiterate and resource poor, have to deal with powerful buyers, who are mostly traders/money lenders. NTFPs have also low demand in local areas. In such situation they have to sell these products at low price (Sarap 2005).

Various reasons could be attributed for realising low prices by the sellers. Interlocking of credit and output market force the gatherers to sell their produce to the money lenders, only at predetermined prices. Further, the limited surplus erodes their bargaining capacity and makes them more vulnerable to exploitation. Another reason for low prices for produce is lack of value addition at the village level. Even price realised by selling of nationalised forest products is very low and the sellers don't receive the price in time. The state policy on NTFPs has mostly favoured private business interests till 2000.

NTFPS UNDER PUBLIC SECTOR MONOPOLY

The state government nationalised the trade of *Kendu* leaf and Bamboo during the year 1973 and *Sal* seed in the year 1983. In most of the cases, the Tribal Development Cooperatives Corporation (TDCC) or the Orissa Forest Development Corporation (OFDC) appointed agents formally or informally (Government of India 1988) to purchase NTFPs from village traders. This puts the forest produce gatherers at the mercy of two different sets of people, the agent as well as the government department officials. Whatever payment that gatherers received had to be routed through both of them. In a study by Fernandes et al, 1987, it was found that government agencies had not managed to eliminate middlemen in majority of the villages in the purchase of NTFP. On the other hand, the same middlemen, who until recently exploited the tribals as moneylenders and merchants, continued their work in the garb of agents of government bodies (Das 1998).

The state institutions (OFDC, TDCC) are unable to serve the primary gatherers of forest products because they are sick and no adequate funds to buy the products from the sellers. Faced with this situation, they wish to pursue a completely risk-free policy. In the few commodities that the TDCC traded (e.g. hill brooms), purchase transactions were first finalised; these selling prices were, down-marked to fix the procurement prices for the gatherers. Because of the middlemen involvement on the actual prices received by the gatherers could be lower still. More generally, the state institutions opted to limit their role by becoming rentiers (Saxena 2003).

Monopolies reduce the number of legal buyers, chokes the free-flow of goods, and delays payment to gatherers, as government agencies find it difficult to make prompt payments. This results in contractors entering from the back door, but they must now operate with higher margins required to cover uncertain and delayed payments by government agencies, as well as to make the police and other authorities ignore their illegal activities. This all reduces gatherers' collections and incomes (ibid).

PRIVATE MONOPOLIES

The public sector's disappointing performance also led the state to take monopoly powers away from them in favour of private parties. Thus from 1985 onwards, government of Orissa encouraged private parties to acquire monopoly rights over forest produce. The largest beneficiary was Utkal Forest Products Ltd (UFP), which was given long-term lease for 29 items for ten years in 1989 (ibid). Its control was even extended to the designated forest products growing on private lands and non-forest government lands. This was, despite emphasis in law as laid down in the Orissa Forest Code and Orissa Forest Produce (Control of Trade) Act, 1983, to encourage the Tribal/Labour Cooperative/ *Gram Panchayats* as procurement agents for NTFPs. However, up to March 2000, there was no involvement of grassroots-level *Gram Panchayat* in NTFP trade.

CASE OF KENDU LEAF AND SAL SEED

In Orissa, the share of NTFP revenue (particularly revenue from *kendu* leaf) in total forest revenue has increased from 43% in 1985-86 to 89.3% (share of *kendu* leaf is 85.1%) in 2001-02. About a million pluckers are engaged during the season to pluck *kendu* leaves, which last about 45 days in summer, at a rate fixed by the government. However, the wages paid to *kendu* leaf pluckers is much lower in comparison to the profits earned by the state. For every rupee paid to the pluckers, the State earns three rupees (in one year i.e. 1989-90 it went up to more than Rs.10). The wages paid to the pluckers are abysmally low and not in keeping with the amount of labour put by them in procuring the leaves (Saxena 2003).

Sal seed is another important NTFP in Orissa whose trade, like *kendu* leaf, is often controlled by the State. The price paid to the primary gatherer has been around Rs 3 per kg and as daily collection is not more than 6–8 kg per day, a person can earn only about 20–25 rupees per day, which is just 40–50% of the minimum prescribed wage (ibid). Although NTFPs form an integral part of the livelihood of the forest dependent communities, state policies related to these items have been generally pro-rich and trader-oriented up to 2000 (see Vasundhara 1998).

POLICY REFORM FOR NTFP MARKETING

Due to concerted efforts by civil society, the state NTFP policy was changed in March 2000. The new policy seeks to give primacy to welfare of forest dependant poor over revenue objectives of the state. It also seeks to deregulate NTFP trade and encourages competition for NTFP procurement by conferring rights over 68 NTFP items to *gram panchayat* as opposed to the earlier policies of monopoly leasing.

However in operational terms, it means that traders who want to operate in any area have to register with the respective *panchayat* and pay a fee fixed by a *panchayat samiti* level. In many cases the district level committees generally declare the price well after the procurement time. As a result, the collectors of the major NTFP items have to sell their produce to the traders at prices lower than that fixed by the public agencies. This is because the latter do not have direct market access and are not involved in processing of the products for end use (Sarap and Sarangi 2010).

Overall the *panchayats* have been provided with the responsibility and authority of managing non-nationalised NTFP, but lack the capacity to exercise these powers, and in many cases they are not aware of their powers. Clearly the recent changes in the policies of NTFPs have not improved the livelihood condition much (see Sarap 2005).

CONCLUSION

The overall impact of the polices and laws were depression of prices received by the primary collectors for NTFPs especially due to monopoly leases and high royalty fixed by the Forest Department, with a resultant deprivation of their livelihood. On the other hand the state generates significant revenue from its trade (*kendu* leave and *sal* seed) that is based on the hard work of the primary collectors.

Clearly, although NTFPs form an integral part of the livelihood of the forest dependent communities, state policies related to these items have been generally pro-rich and trader-oriented until 2000. As a result the livelihood conditions of the poor, dependent on these produce, have been very precarious. Likewise the post 2000 changes in the policies of NTFPs have not much improved the livelihood condition of the forest dwellers.

The NTFP Policy has given many responsibilities to GPs in terms of monitoring and regulating the NTFP trade. This is a newfound role of the *Panchayat*s. Given their earlier experiences they have little knowledge of NTFP market and trade. Thus measures should be taken urgently to enhance their capacity to regulate and monitor the trade so that they can discharge their responsibilities and the primary gatherers benefit. Their involvement in the price fixating system can be a first step towards this. Similarly, proper coordination and cooperation between the *Gram Panchayat*, Forest Department and other concerned departments involved in the process need to be stressed.

Processing is another area that needs to be looked into. If markets can be provided for simple processed items which can be done in households, then subsidies for effective training for processing can help gatherers value add and improve income. For example, broom grass can be bound into broomsticks with simple training by women and men in their own houses. The same can be said for products like tamarind, which can be processed and packed as a household/cottage industry. The market is quite extensive for these items, and household producers can have the choice of either selling in the open market, or through government outlets, depending on the pricing.

This is also true in the case of bamboo. The art of bamboo processing is a fast dying art in the tribal regions of Orissa, due to the wrong policies of the Government, which has denied access to the local artisans. However, a sizeable demand for bamboo products still exists, as the tribal economy and livelihood has a variety of uses for it. A two-pronged effort needs to be made here to regenerate bamboo forests, along with support for once again reviving the art of bamboo weaving. This would help several tribal communities to have a better income.

Rather than be a monopoly buyer of NTFPs or try to regulate price through administrative mechanisms, government should adopt market-friendly policies, facilitate private trade, and act as a watchdog rather than eliminate the trade. It should encourage local bulking, storage and processing, and bring large buyers in touch with gatherers, so as to reduce the number of layers of intermediaries. Government should encourage the formation of self-help groups (SHGs) among the forest dwellers so that such groups are able to bargain better with the trade. Finally, a more effective implementation of credit-oriented and poverty alleviation programmes will help the poor in recovering from debt bondage, which is the single most important factor for their dependence on traders and depresses the price that forest dwellers are able to negotiate with them.

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Forest Certification: Opportunity and Challenges

A.M Singh *

FOREST CERTIFICATION

Forest Certification is a process in which an approved independent organization issues a certificate confirming that, based on the findings of an audit; a forest holding is being managed in accordance with an agreed standard. It has emerged as a market based mechanism in support of sustainable forest management (SFM). Certification initiatives rely on consumers exercising purchasing choice in favour of products labelled as originating from certified sustainably managed forests. Initially it was designed as a means of identifying forest products as sourced from a forest or forestry operation that follows minimum standard of good practices, including responsible processing of wood harvested from a sustainably managed forest resource. The main objective was to create an alternative to the failure of public policies and government action to control illegal logging and in turn check rates of deforestation and forest degradation. In other words, the process of certification ensures that a particular forest produce has been extracted without harming the forests.

In order to achieve this, three things are needed. **The Standard:** firstly, any forest certification scheme needs a standard which lays out the level of management which must be implemented by the forest enterprise. **Certification Process:** secondly, there must be a defined method to be followed by the certification body for assessing whether or not a particular enterprise meets the standard. **Accreditation:** thirdly, there must be a process in place to assess each certification body which wishes to issue certificates for a particular standard to ensure that they are competent and credible. This process must include the power to prevent incompetent operators from issuing certificates.

Basically, for a credible third party certification, there must be a set of standards against which organizations are assessed, a defined certification process, and an accreditation process to assess certification bodies.

GENESIS OF FOREST CERTIFICATION

During 1980s the media and environmental NGOs raised public concerns worldwide about rapid deforestation, particularly the loss of Rain Forest of Amazon and the illegal logging of tropical hard woods. Certification has been developed or rather emerged as a response and an alternative to timber boycott campaigns. The initial focus of certification was on tropical forest which rapidly shifted to all forest types. After more than a decade from the first certification schemes, most of the forest (more than 90%) that have been certified are located in Europe and North America, only 9% of the certified forest are located in developing countries and 5% of the insufficient certified forest are located in tropics (Fig. 1).

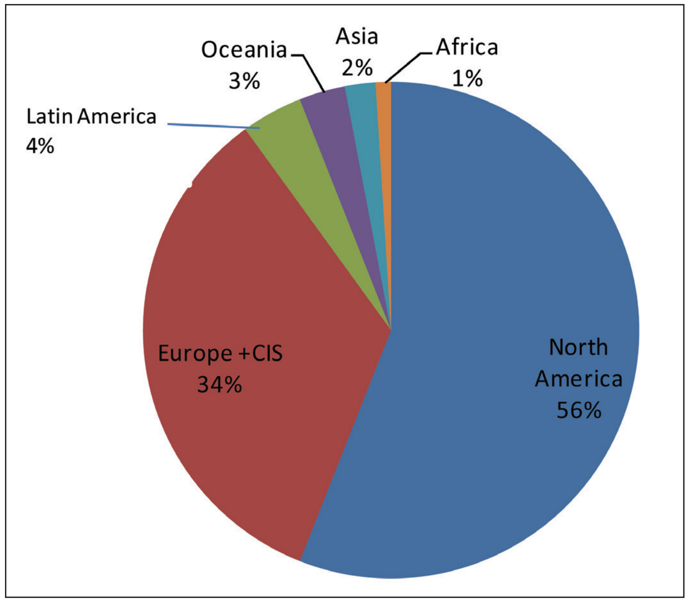

Figure 1: **Status of Forest Certification**

The reasons for less progress of certification in developing countries are, less/no market demand for certified products, wide gaps between existing managements standards and certification requirements, policies and programme, insufficient capacity to implement verification standards at the FMU level, constraints in developing indigenous standards and developing mechanism due to various regions/site specific factors, weak forest governance and high cost of obtaining certification. Despite these challenges and constraints, many developing countries have understood the intricacies of the mechanism of certification, both at National and International level, and they remain interested in pursuing certification and making decent progress in achieving the goal.

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Forest Certification is increasingly recognised by consumers and governments as an important tool for identifying responsible forest management. It has emerged out also as a tool to identify forests that is well managed towards a goal of sustainability addressing concerns of environmental, ecological, economic and social aspects. The whole forest certification system is a procedure in which a third independent party validates in writing that forest of a given area complies with the standard of good or sustainable forest management. Basically it consists of two major aspects:-

- **Forest Management Unit (FMU) Certification – Certification of the Source:-**
    - o FMU is an independent assessment of the forest management operation with respect to an evaluation of the ecological health of the forest, ecological sustainability and the social impact of the forest management activities.

- **Chain of Custody (CoC) Certification – Certification of the processes:-**
    - o Another aspect called CoC inspection, involves verifying the flow of forest products from the stump in the forest through milling and manufacturing to the final finished product.

At present both the aspects, FMU and CoC are being carried out by both non profit and profit organizations all around the world and being characterized as an independent objective and a third party process. Forest Stewardship Council (FSC) and Programmes for Endorsement of Forest Certification (PFEC) are the two major internationally recognised schemes covering most of the forest for Forest Certification (Fig. 2 and 3).

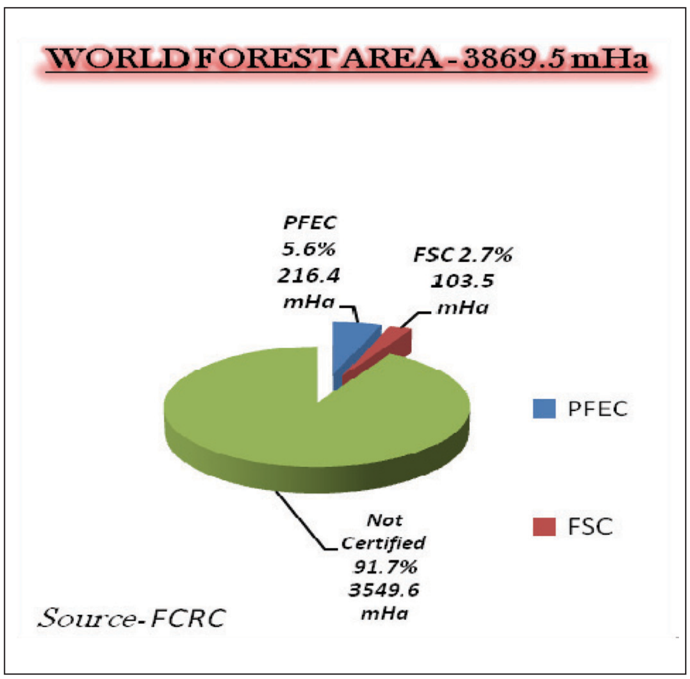

Figure 2: **Global Certified Forest Area**

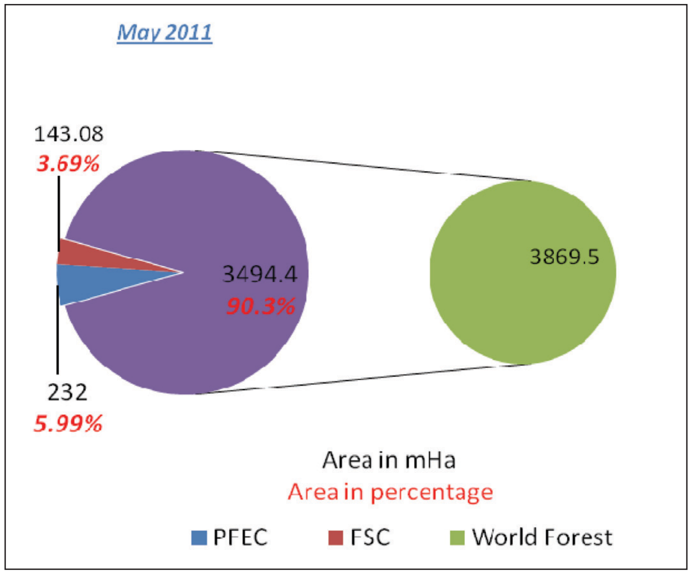

Figure 3: **Certified Forest Area by FSC**

NEED AND SCOPE FOR FOREST CERTIFICATION

Forest Certification was conceived as a market-based system that identifies products coming from responsibly managed forests. However, certification has evolved beyond this market-based tool and has been identified as a means for measuring good forest management and for identifying legal production, prompting some countries to incorporate certification into their national requirements for forest management. For example, in Bolivia, the government now accepts third-party forest certification as an equivalent to government audits, enabling certified forest concessions to forego statutory inspections for compliance with national management standards. In Guatemala, certification is a requirement for the retention of forest management concessions in the Mayan biosphere reserve and in Mexico, the national government offers subsidies for certification evaluations.

Forest certification was developed initially as a mechanism for identifying forests where good forest management was practised and involve the labelling of the products that came from these forests. The label, as well as providing proof of the source of product, was designed to permit customers to identify and purchase their products in preference to products from other sources. Forest certification was not an end in itself but an instrument by which the market could be used to influence the suppliers of timbers and act as a stimulus to improve the standards of forest practises. Thus, forest certification is not only a mechanism that confers market advantages but it is also designed to act as a means of promoting and facilitating responsible forest management.

However, while certification has been adopted rapidly in some regions, it is more difficult to obtain formal recognition for the stewardship in the form of forest certification particularly for small-scale and low intensity forest operations including some community forestry or NTFP initiatives. The cost of certification per hectare, and the challenges of interpreting forest management standards to their reality, has created barriers for some forest managers and communities.

NEED FOR FOREST CERTIFICATION IN INDIA

As far as India is concerned in the present scenario, there is not much domestic demand and market for certified timber products. Some of the real estate businesses/entrepreneurs are putting one of the conditions in their building plan to use certified timbers in their projects in the name of green building. However there are requests from timber based products exporters like wood based handicrafts and paper mill industries for certified raw material. Also, India has potential for exports of certified value added products made up of bamboo and rattans and also for medicinal and aromatic plants used for herbal and cosmetics industry.

The impact of demand on forest based industries and growers particularly of small and medium scale enterprises like handicrafts in India will be severe unless they secure forest certification. Currently, the demand for certified timber is being fulfilled through imported timber and Indian importers are receiving CoCs for exporting certified timber products. Consumer awareness is gradually increasing for environment friendly products, green building ratings and doing so the demand for certified timber will further increase. Since India is the net importer of timber and would continue to import timber in near future, there is a definite case for having a national forest certification scheme of its own on primarily two counts : Firstly, the forest certification scheme of its own will push for the demand for certified timber. Secondly, having its own forest certification scheme will help in increasing competition for accredited certification entities and thus there will be reduced cost of certification for its users, which currently are exorbitant.

In India, most of the forests are under the State control through the Forest Department under the Indian Forest Act and State Forest Acts. Community forests and private forests also exist in small proportion. Currently in India there are no certified forests. Consequently it is impossible for manufacturers to use locally produced timber to meet this demand and supply certified products. However there is an elaborate framework of policy, law and regulations to ensure that forest are conserved and managed under sustained field regime forest management expertise and experience also resides primarily in the forest departments.

INITIATIVES TAKEN BY MINISTRY OF ENVIRONMENT AND FORESTS, GOVERNMENT OF INDIA

- As SFM is being emphasised at every National and International forum, the SFM and Forest Certification also have rightly been focused for the last one decade in India**.** The criteria and indicators for SFM have been developed considering the forest policy imperatives and the current forestry situation prefixed with specific adjectives that indicate direction of intended changes. Their applications at field management unit level involving the community are in the process for standardization.
- Realising the need for Forest Certification, as a proactive measure, the Ministry of Environment and Forest, Government of India had taken initiatives to develop Forest Certification in the country. As per the initiatives from Ministry of Commerce and Textiles in 2004, a task force was setup under the chair of DGF&SS in the Ministry. Three technical committees were setup for developing standards for Forest Certification, accreditation and certification processes on the basis of the concept paper developed by IIFM Bhopal. However, on the recommendations of these committees in a series of meeting in October, 2007, it was decided to merge three committees into one known as National Forest Certification Committee (NFCC) headed by Mr. Maharaja Mutthoo, President, Roman Forum, Rome with other 46 members from various fields.
- After a series of NFCC meeting, the committee has finally submitted its report to the Ministry in September, 2010. The main recommendations of the report are as follows:-
  - o Setting up of an Indian Forest Certification Council, as a non state multi-stakeholder independent entity.
  - o The Government of India may consider providing corpus core funding which could be around Rs. 10 crores.
  - o Meanwhile
    - a) A suitable organization may be assigned to host the Secretariat of the proposed IFCC at the earliest and intimate work for setting up of the National Forest Certification Scheme.
    - b) The NFCC Core Group, duly re-nominated, based on its expertise may continue to facilitate the process of setting up IFCC and NFCS related work.

ISSUES ADDRESSED SO FAR

In the process of developing mechanism/framework for Forest Certification by Government of India (Ministry of Environment and Forests) various crucial issues were identified and addressed in the process of developing certification activities both for Natural Forests and Plantations outside the notified forest area along with NTFPs. Some of the issues addressed so far are as follows:-

- Developing appropriate national regulatory, fiscal and institutional structures that are essential for certification system to operate and the mechanisms to implement the certification schemes.
- Participation of stakeholders in setting of national and regional standards and in the implementation of the certification processes including smaller growers/farmers and communities.
- Role of such a Nodal /National Autonomous Agency for forest certification in India
- Ensuring credible and feasible certification schemes encompassing the elements of quality of assessment of forest management and acceptability to all key stakeholders.
- Cost effectiveness and commercial viability of the certification process.
- Ensuring comparability and equivalence in standards with the other international certification initiative in consistent with the provisions of WTO.
- Role of Government of India and State Governments in developing policy and legal framework for certification

activities and also in developing the certification process.

- Establishing accreditation or licensing standards for 3rd party certifiers and recommending mechanisms for registration, monitoring the work of certifiers.
- Raising awareness about forest certification amongst cross section of state or national stakeholders.
- Clearly defining the objectives, area and responsibility to bear large expenses of forest certification.
- Developing certification capacity in civil society and imparting of training and technical assistance etc.

During multi stakeholders discussion by the National Forest Certification Committee and also by the Core Committee of Ministry of Environment and Forest, most of the issues mentioned above have been taken care of and a conscious decision to establish a Forest Certification Council at the National Level has been taken and in the last meeting held in June 2011, the task for finalising the framework of the Indian Forest Certification Council has been initiated by the Ministry.

CONSTRAINTS

As mentioned earlier, most of the certified forests are located in Europe & North America and very less forest have been certified in developing countries. In India, certification of natural/ planted forests (RFs) at FMU level is yet to take off. It requires an in depth analysis keeping socio-economic, land tenure rights, administrative, legal and regulatory factors in mind. Just to analyse the principle cause of the disparity in distribution in certified areas between developed and developing countries the important factor is that many developed countries have a longer track record of supporting and enforcing regulation that support SFM. The reasons for slow uptake of certification in many developed countries can be attributed to following main constraints:-

1. Insufficient demand of certified products in global market

North America and Europe offer the only markets for certified wood products. There is little or no local demand in developing producer countries at present, nor in the major importing countries of Asia. The demand for certified products is coming from businesses and government agencies wanting to pursue an appropriate environment policy towards sustainability. There is very little recognition or demand from private end consumers who are generally unwilling to pay more for certified products.

2. Wide gap between existing management standards and certification requirements

Although there is a gap which is exacerbated by the fact that there are often insufficient financial and human resources to effectively raise standards, the shortages of high quality trained forest managers are particularly acute in many developing countries. Another problem faced by these countries is that the basic standards required for certification are often more difficult to achieve in these regions (tropics) than in the regions where temperate forests exist.

3. Weak implementation of policies and programme in developing countries

There are many constraints which attribute to weak implementation and badly hampering the progress of Forest Certification process in developing countries such as ineffective implementation of National Forest legislation and policies, weak governance, inadequate forest law and enforcement, conflicting socio economic and extra sectoral policies and uncertain and disputed land tenure which collaborate the ineffective implementation.

4. Insufficient capacity to implement verification standards at the FMU level

There are various problems in developing standards and its implementation due to its composition, complexity, types of forests and issues related to the local people dependant on forests for their livelihood and daily needs. Actually the composition of forests and problems are totally different in North America and Europe where most of the forests are certified. It has been quite a success in Temperate and Boreal forests where mainly forests are not natural but planted. To develop the standards keeping these issues in mind and to implement them effectively is a very difficult task in which all the stakeholders are having the responsibility to make it much more effective. In most of the countries due to non-availability of standards, they are forced to rely on the generic international standards in order to become certified which increases cost and not always relevant to the local situation.

5. Inflexibility of Standards

One of the reasons that tropical forests have been certified to very limited extent, over more than a decade is the inflexibility of standards of performance. Tropical forest, where efforts to implement SFM have started only a few years back and far from definitive, are disadvantaged because certification standards tend to focus on the end results of SFM practices.

6. Lack of recognition of local land use issues

Certification primarily focuses on FMUs in terms of management practices, procedures and welfare of the manpower involved and often fails to take into account other land use issues-such as the development of agriculture- which can have a significant impact on forest. For example, comprehensive land-use planning at the landscape or regional level may include delineating permanent forests and designating forested areas where the development of agriculture will be allowed. In such a case, only permanent forest would be concerned by certification, which would not recognize efforts to sustain land use practices on a larger scale.

7. Conflicts between legal settings and certification standards

In most of the developing countries, there are conflicts between national laws and forest certification standards, such as the ownership of land, usufruct rights of forest products and services, and the sharing of responsibilities between the government and the local people. Furthermore, the forest rights and concessions may be locally defined in a way which does not correspond to the requirements of voluntary certification. What may be considered "illegal" based on public law or unacceptable for voluntary certification standards may still be part of customary law and the traditional rights of local people living in and around forests. Still there is no harmony between customary law and traditional rights of local people living near forest fringe areas and national laws/ acts dealing with forests and land use.

8. High cost of certification

There are no clear cut norms available for the cost of certification per hectare. It varies widely and will continue to be a substantial inhibiting factor for many developing countries. Cost can be direct or indirect. The direct cost includes activities such as preparation for audits, actual forest management audits, CoC audits, etc. These costs are higher in developing countries because most certifiers are from abroad mainly from Europe and North America and demand very high fees wages. The indirect cost includes the cost incurred to improve forest management and wood processing systems levels that are certifiable. Fixed cost (especially roads) per unit of output tends to increase with increasing area. The only way to keep total cost down is to reduce the variable cost per unit of output. This means improving productivity. The level of output at which this trade-off lies will vary from forest to forest. The inference of this cost analysis is something like certification of small FMUs shall be proportionately more expensive than for large FMUs.

Inference from the graph above:

- Typically certification requires an increase in ratio between fixed and variable cost.
- Increased fixed cost requires a reduction in unit variable cost in order to contain the total cost.
- Q_L = level of output where total cost with certification equals total cost without certification. At lower level of output the total cost per unit of production the total cost is higher with certification. At higher levels of production the total cost per unit of production is lower with certification.

It is widely acknowledged that the cost of managing tropical forest sustainably are generally higher than other forest types due to the greater complexity and heterogenic, difficult accesses and unfavourable climatic conditions. The size of the forest management system, when considering the cost certification is also important. The smaller the management units, the greater are the cost of certification on a per unit basis.

CHALLENGES

Although certification is well established in other agencies such as food, health, hygiene, organic products, agriculture products etc. in India but forest certification has not achieved the progress so far achieved by other agencies. Some of the challenges which can also be taken as an opportunity to fast forward the process of forest certification in India are as follows:

➢ **Involvement of different stake holders:** To take the forest certification in a right way, development of forest management standards are very important although developing these standards at national level is very complex and contentious. Stake holders have strong views and resist dilution of Forest Certification principles of their priority concerns. Certification will not carry credibility unless supported by organizations trusted by the public so it is vital to involve all the stake holders in the

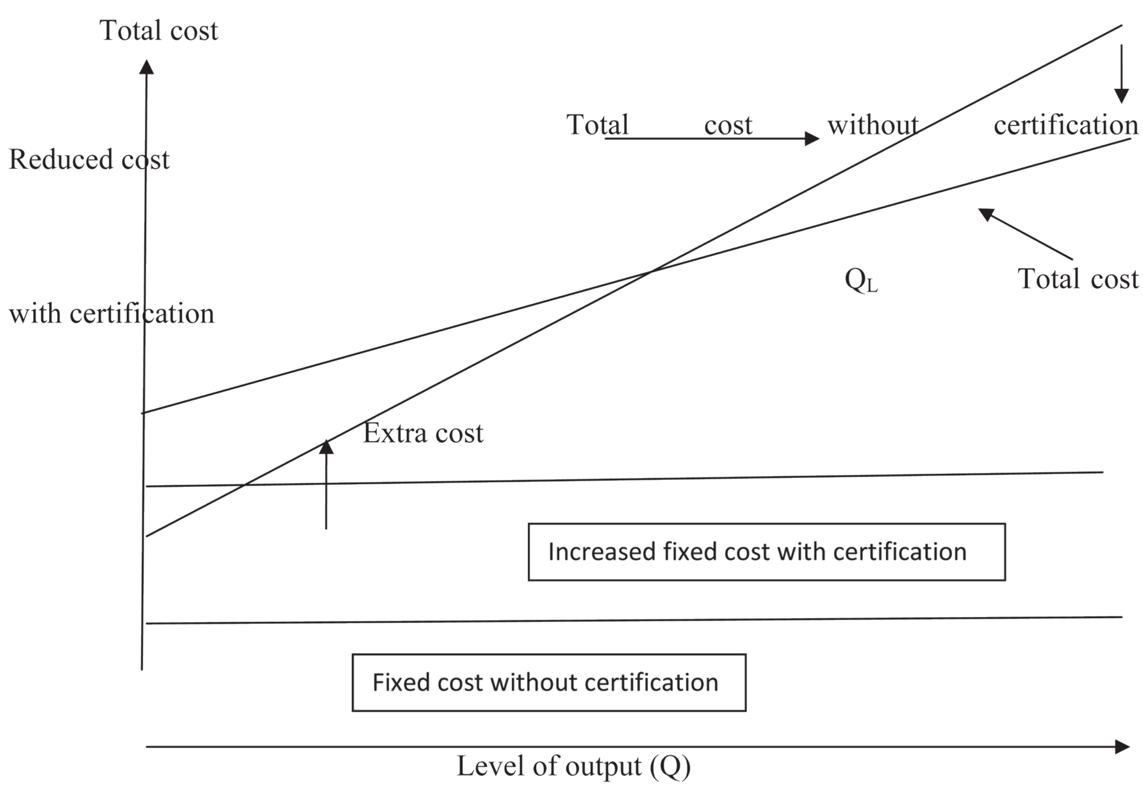

Figure 4: **Changing relationship between fixed and variable cost in an FMU**

development and testing of standards. There are various conflicts of interests among them such as Local community versus Trader versus Consumers interest, Big versus Small operators, North versus South and Global versus National and Regional Certification Systems. The biggest challenge is of unity in diversity.

➢ **Site specific/region specific/country specific Forest Certification:** Certification in the south is often perceived as non tariff barrier. Forest especially in tropical region are very rich in bio-diversity including flora and fauna that rarely exists elsewhere. If SFM is treated as a tool for Forest Certification as one of the objectives its imperatives have to be understood and accepted.

➢ **Mandatory Rules (National/International)**: Mandatory Rules, regulations and conventions set the legal framework of Forest Certification. Forest inspections by independent third party accredited organizations assess compliance with a set of Principles, Criteria and Indicators (PC&I) including adherence to legal framework. This practice ensures that timber from certified forest is not only legal but also sustainably produced according to the certifier's criteria. Although certification cannot substitute an appropriate forest policy, a strong legislative framework and capable forest managers but it can have an impact in the absence of these. Harmonization of the set of rules/regulations with the PC&I is very much required.

➢ **Certification and logo:** Certification schemes for customers and traders need to maintain consistency, credibility and transparency of standards and auditing. It should also have the capacity to be responsive to different scenario and requirements, at the same time. The certification and labelling requirement should be feasible, realistic and cost effective. Certification will lose its credibility if it is too undemanding, business as usual, certifying the lowest common denominator. Trust and faith of all the stakeholders are also very important to keep its credibility intact on a longer run.

➢ **Cost and benefits:** The costs and benefits of using certified wood products is a problem. The profitability can be viewed taking several parameters into account such as the market share certified wood products; the market growth rate the increased cost of certified wood; the small price premium for certified wood products; and the lower profit margin for certified wood products relative to non-certified wood products. The profitability of certified wood products will influence short-term and long-term marketing strategies of companies supplying certified wood products linking with branding and marketing. All major certification programmes are now in the process of attaching their labels to wood products, hoping for higher financial return, green accounting and consumer credence to compensate certification costs.

➢ **Cross cutting issues:** There are many cross cutting issues which need to be resolved while dealing Forest Certification mechanism in India. The important challenge is how and if certification can address the cross cutting issues of poverty among forest dependent communities. How the forest dependent communities remain motivated for concomitant environmental services which is a pre requisite for forest certification. Forest Certification should dovetail its systems accordingly and inter-alia get involved in payment of ecosystems services (PES) to concerned countries and communities, more so in the context of climate change mitigation and carbon sequestration.

➢ **Consistency and Decentralisation:** Another important challenge facing Forest Certification programmes is to construct the structure of Forest Certification and systems that can claim to be globally consistent and at the same time respond to the local circumstances in very diverse places. Due to difference in composition of the forests and land tenure rights, Forest Management Unit (FMU) level certification without national FSC standards is more prone to inconsistent assessment and less supportive for social benefits, due to differences in interpretation of generic standards by certifiers and the arguably lower accountability of certifiers hired by FMUs seeking certification.

➢ **Expanding beyond timber:** The development of market and payment for multiple products such as NTFP and products from less know species alongwith environmental services is vital to the future of natural tropical SFM and timber certification. Payment for environmental services (PES) automatically demand higher forest management standards. In the future, certification could become a major tool for justifying and attracting PES, for example in the context of landscape scale, forest certification is more focusing for the industrial forest sector than for Community forestry sector. National Certification standards can be over detailed, inflexible, incompatible with local and customary standards and ultimately costly for local people even with Group Certification.

➢ **Certification for the people:** For any process of certification, sustainability remains a key aspect. Another important factor is the social aspect, which calls for the "concern for the people". The forests should not be seen in isolation. People, especially those inhabiting the forests, must have their fair share in the benefits accruing from the certification process and thereby be integrated into the mainstream society. Therefore, there is an urgent need for maintaining a balance between the forests and the needs of the people. The willingness and acknowledgement of a policy by the Government will encourage sustainable management of forest, a policy of non-destructive harvest and a policy for developing multi-tier forests.

➢ **Willingness to pay premium:** Another challenge which is in front of us is how to create awareness among the consumers to use the certified products. One setback in Forest Certification is that the demand for certification comes from developed countries; it offers benefits only for forest product destined for export from developed countries. Mere certification process will not lead to arrest deforestation because in any case forests in their countries are managed to meet local demands. Further more than 2/3rd of the marketed wood and wood products are consumed locally in India, where willingness to pay for a premium price for certified products is almost nil or absent. There are other reasons also

- Lack of information

- Socio economic conditions
- Insufficient government support
- Rigidity of standards
- Complexities between laws, human rights and certification standards.

Certification also faces a serious dilemma between expanding the supply of certified products to meet the emerging demand and maintaining a credible standard that takes into account all aspects of Forest Management. This challenge is made more difficult by the fact that domestic market has little demand for certified products.

Despite such daunting challenges and the slow uptake of certification in most developing countries, there is sufficient interest in Forest Certification. Recently in a study on a scale of one to five, market access and image were the two most important motivating factors for the producer seeking certification. The price premium ranked the last of the five parameters suggesting that the producers have accepted the reality that price premium are unlikely to be realized in most cases. Many developing countries are motivated to develop National Forest Council Schemes out of concern for national sovereignty issues. Most of the countries are quiet apprehensive being told by outsiders how to manage their own forest. This is one of the main reasons why most of the countries have developed their own certification standards/ scheme. The advantage of National Forest Scheme is that it can be developed by local stake holders to recognize and address the specific and socio economic condition of the country. However in order to gain international market acceptance of their scheme, most National scheme need official recognition from an International Certification Scheme.

OPPORTUNITIES TO MOVE AHEAD

Despite the slow progress of Forest Certification, there are several promising opportunities for moving ahead:

1. Simplifying the certification procedures at National Level
2. Phased approach to Certification
3. Creating awareness in Forest Certification and use of certified wood and forest products
4. Group Certification

Group Certification is one of the mechanisms developed at unit cost and makes the certification of small forest ownership and management unit financially attractive. It enables small forest owners to join together to benefit reduced unit cost while maintain management control of their individual forest. There are many guidelines, issued by certification agencies to address the problem of cost to small forest. Some of them have streamlined/ simplified the procedures. Lok Vaniki Act, 2001 and Lok Vaniki Adhiniyam, 2002 of Madhya Pradesh are also an attempt to address the problem of small forest growers/plantation owners in the State which can be replicated by means of either enacting an act of similar nature at National Level or formulating guidelines/ regulations to other states for addressing the issues of small growers/forest owners.

Certification of non-wood forest produce shall enhance the well being of both the forests as well as the people. Today, there is a worldwide interest and demand for natural, herbal and organically grown products. This should be seen as an opportunity to alleviate the poverty of our people by ensuring better market and marketability of the produce collected and processed by the people. It is of paramount importance to put enabling policies and people friendly framework in place, which would lead to **'man with forests'** rather than **'man versus forests'.** Forest Certification can offer opportunities for the communities to have more control over the marketing and use of their forest resources. Forest certification can provide access to market outside local communities and potential higher/prices and revenues may create incentives to manage natural resources sustainably.

CONCLUSION

It may be too early to be sure of the impacts of forest certification as the concept is still evolving and will take some time to take a final shape and stabilise but some of the positive outcome of the last 20 years cannot be ignored. Forest Certification has led to an increase in demand for timber products from well managed sources from retailers and consumers. It has slightly improved forest management practices mainly in the North and working conditions mainly in the South. Although it has not solved the land rights problems but the problem has been highlighted effectively. Another positive outcome is that it has increased understanding of what constitutes good forest management that needs to be developed jointly by economic, social and environmental interests groups.

The challenges have been enormous given the greater complexity of forest management especially in the face of such serious problem as weak governance, poorly defined tenure rights, and corruption at Institution level. The major economic problem has been that while the demand for sustainably harvested timber exceeds supply, the market has largely not willing to pay the higher cost of certified management. Even there is not much pressure from the stakeholders directly affected with certification and Government is not taking any proactive measures although having more than 95% stakes as owner of the forests. Even the whole issue has limited the political will to develop credible standards and criteria as national initiatives and put pressures on producers to seek easier standards of sustainability that allow them to remain in the higher value markets.

Of late the focus has been on establishing standards for forest managers and developing a critical mass of certifiable timber. But the focus should be to strengthen National Institutions, policies and legislation to reduce the gap between current level of forest management and certification requirement, reducing the cost of certification, better access to the markets and incentives for trade in certified forest products, combating illicit felling and illegal trade, promoting PES, linking the issues of REDD and carbon trading change in forest certification and increasing the effectiveness of marketing among consumers.

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Forest Certification: Opportunities and Challenges for India

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INTRODUCTION

Public concern for the environment has grown remarkably during the last few decades, both in developed and developing countries and, as a result, environmental issues are beginning to take more of a center stage in global economic and trade policies. The emergence of "eco-labelling"; a process that attempts to provide an indicator of how well a product is environmentally adapted, is a contemporary example of how consumer interests have driven information processes aimed at differentiating the environmental appropriateness of goods and services. The basic concept of eco-label is derived from the word *eco,* which means natural environment, and *label,* which means a sign on a product that differs from other products (Museum et al., 2008). Labelling wood products with a mark of quality can be traced back in Europe to a French royal decree of 1637, which stipulated that members of the guild of cabinet makers had to mark the furniture they made (Pradere, 1989). Relying on this market driven mechanism, the world's first eco-labelling programme "*German Blue Eco Angel*" was created in 1978 (Rametsteiner, 2000).

Eco-labels belong to the "second generation" of environmental policy, which supplemented and partially substituted the previously established environmental policy instruments. These older approaches were developed in the 1970s when the regulation of environmental media became dominant. Eco-labels, by contrast, aim directly at changing the behaviour of consumers ("sustainable consumption") who are enabled to assess the impacts of a product throughout its entire life-cycle. Environmental labelling programmes can provide consumers with an immediately available, objective, and accurate evaluation of a product's environmental impact. They also provide an incentive to manufacturers to meet the Environmental standards (Sitarz, 1998). The enhanced social awareness on the values attributed to the forests, forced global consensus and regional understandings on developing a management paradigm of forest management that ensures its sustainability. Various international and regional initiatives developed principles, criteria and indicators to assess and monitor the progress towards sustainable forest management. The International Tropical Timber Organization (ITTO) was the first to develop the Criteria and Indicators (C&I) approach for the purpose of assessing sustainability of tropical forests. More than 160 countries actively participated in one or more of 9 internationally recognized processes for sustainable forest management (SFM) in the development of C&I for SFM (Castaneda, 2000).

In 1992 the United Nations Conference on Environment and Development (UNED), the global participants adopted the first global policy on Sustainable Forest Management (SFM) known as '*Forest Principles*', that states: 'forest resources and lands should be managed sustainably to meet the social, economic, ecological, cultural and spiritual functions and for the maintenance and enhancement of biological diversity' (UNCED, 2000).

THE EVOLUTION OF FOREST CERTIFICATION

While the formal processes of developing criteria for sustainable forest management were in progress, forest certification started to take shape through a non-governmental organization (NGO) channel. This innovative idea was developed during the parallel NGO Rio meetings. The concept was to develop a system for certifying and l forests and forest products. As a result, a voluntary non-profit organization called the Forest Stewardship Council (FSC) was launched in 1993 with the coalition of Worldwide Fund for Nature (WWF) and other leading environmental organizations. The scope of forest certification was originally focused on tropical forests, but has now broadened to include temperate and boreal forests (Perera and Vlosky, 2006).

Certification is the process of independent third party verification that forest management has reached the level required by a given standard. In some cases, when combined with a chain-of-custody certificate, certification allows products from a particular certified forest area to carry an eco-label. Basically, the verification process is conducted through an audit system directed by an external and internal forest management team. Internal auditing is carried out to obtain assurance that the forest management unit fulfills the minimum requirement, which is assessed by an independent third-party external auditor (ITTO, 2004b)

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EMERGENCE OF FOREST CERTIFICATION SCHEMES

As on date, there are a handful of international forest certification schemes and many regional and national certification schemes setting up standards for measuring better practices towards sustainable management of forests. There is a growing competition among these certification programmes to become the global leader which have global operations and coverage. These are **Forest Stewardship Council** (FSC) and the **Programme for Endorsement of Forest Certification Schemes** (PEFC). The remaining certification schemes are working at national level and thus only catering to the needs of the country specific clients. Many of these certification schemes are mutually recognized by PEFC.

American Tree Farm System (ATFS) has undergone many changes since its beginnings in 1941 and is now recognized internationally as a credible forest certification system started in 2002 through the Independently Managed Group (IMG). ATFS certifies landowners to the American Forest Foundation's Standards of Sustainability for Forest Certification. It is to ensure market acceptance by undergoing third-party certification audits by independent, ANSI-ASQ National Accreditation Board (ANAB) accredited certification bodies. It has been endorsed by the PEFC in 2008. ATFS focuses on certifying the forestry practices of non-industrial private landowners in the U.S. who own between 10 and 20,000 contiguous acres of forestland not associated with a forest products manufacturing facility (www.treefarmsystem.org).

The **Canadian Standards Association** (CSA) is a non-profit voluntary association established in 1919 with a core focus on the development of a range of standards and product certification. In 1994, the CSA was asked by federal and provincial governments and a coalition of forestry associations to establish a multi-stakeholder technical committee to develop a Sustainable Forest Management (SFM) standard for Canada. The CSA and the standards it develops are designed to conform to the requirements of the International Organization for Standardization. Certified operations are monitored annually to review progress toward achieving SFM targets. The CSA has been mutually recognized by the PEFC since 2005 (http://www.pefccanada.org/default.htm).

The **Forest Stewardship Council** (FSC) is an international non-profit organization that offers forest certification. It was founded in 1993 by representatives from environmental groups, the timber industry, the forestry professionals, indigenous peoples' organizations, community forestry groups and forest product certification organizations from 25 countries. The FSC is an organization with nearly 600 members from more than 70 countries representing social, economic and environmental interests. The FSC has developed a set of global Principles and Criteria for forest management. There are 10 Principles and 57 Criteria that address legal aspects, indigenous rights, labor rights, multiple benefits and environmental impacts surrounding forest management. Although the Principles and Criteria are applicable to all forest ecological types throughout the world, FSC encourages national working groups to adapt these Principles and Criteria to local ecological, economic and social conditions to create regional or national standards. In addition to standards development, the national groups are also responsible for providing public information, offering a national dispute resolution mechanism, and monitoring certification organizations to ensure compliance with FSC requirements. The FSC certification process involves a pre-interview between the auditor and forest manager, a review of documentation and a field assessment to determine conformance to the FSC standard. Certified entities are subject to annual field audits to ensure they continue to comply with the Principles and Criteria and must undergo a full evaluation to renew their certificates every five years (www.fsc.org).

The American Forest and Paper Association (AF&PA) developed the **Sustainable Forestry Initiative** (SFI) programme to document the commitment of member companies in the United States to sustainable forestry. The In 2000, the Sustainable Forestry Board (SFB) was established to oversee the SFI standards (SFIS) development and certification processes. The SFIS contains 13 objectives covering sustainable forest management, procurement of wood and fiber, public reporting, continuous improvement and mitigating illegal logging. Verification of conformance with SFI programme requirements may be first, second or third party audited. The SFI has been mutually recognized by the PEFC since 2005 (http://www.sfiprogram.org/sfi-standard/forest-certification-endorsement.php). The Programme for **Endorsement of Forest Certification Schemes** (PEFC) is a membership-based global umbrella organization that provides a mutual recognition framework for national forest certification systems developed in a multi-stakeholder process. Mutual recognition is a process whereby an entity states that multiple certification systems meet its definition for sustainable forest management. The organization was founded in 1999 for the purpose of promoting national forest certification systems, particularly in Europe. It has expanded to recognize systems throughout the world. The different national systems are mutually recognized as guaranteeing a level of sustainable forest management and certification procedures conforming to PEFC requirements. The PEFC recognizes national certification systems with standards based on intergovernmental processes for sustainable forest management. Examples include the Pan European Forest Process and the Montreal Process. Recognized systems must also be compatible with Pan-European Operational Level Guidelines (PEOLG) or an equivalent framework. National standards are developed by forming a body of interested parties such as forest owners, processors, environmental groups and retailers. The standards are subject to public review and consultation. Once a standard has received national approval it is submitted to the PEFC for its review and mutual recognition process. Each of national standards goes through a public consultation and independent assessment process to decide whether it is to be mutually recognized. Certified entities are subject to annual surveillance audits and are subject to recertification every five years (www.pefc.org).

The **Malaysian Timber Certification Council** (MTCC) was established in 1999 as an independent organization to develop a voluntary national timber certification system in order to provide independent assessment of forest management practices as well as to meet the demand for certified timber products. The Malaysian Timber Certification Scheme (MTCS) is the first certification scheme in Asia, and the second in the South after the Gabonese Forest certification Scheme, which was endorsed by the PEFC in 2009. Thus companies having MTCC certification can use PEFC logo on their products as well as for advertising (www.mtcc.com.my).

The **China Forest Certification Council** (CFCC) was set up to develop standards for forest certification and an appropriate forest certification scheme) in 2002. The China Forest Certification Standards issued by SFA comprises of 9 Principles; 45 Criteria; and 112 Indicators (http://pulp-paperworld.com/asian-news/item/1318-pefc).

FOREST PRODUCT CERTIFICATION AND MARKET ACCEPTANCE

Timber certification is a process which results in a written statement (a certificate) attesting to the origin of wood raw material and its status and/or qualifications, often following validation by an independent third party. Certification is designed to allow participants to measure their forest management practices against standards and to demonstrate compliance with those standards. Timber certification may also be used to validate any type of environmental claim made by a producer, or to provide objectively stated facts about the timber products and their forest of origin that are not normally disclosed by the producer or manufacturer. Timber certification typically includes two main components: certification of sustainability of forest management; and product certification. Certification of forest management covers forest inventory, management planning, silviculture; harvesting, road construction and other related activities, as well as the environmental, economic and social impacts of forest activities. In product certification, roundwood and processed timber products are traced through the successive phases of the supply chain. Certification of forest management thus takes place in the country of origin; product certification covers the supply chain of domestic and export markets (Baharuddin, 1998).

Independent forest product certification may also be a means through which producers can achieve public credibility and recognition of their forest management practices (Kiekens et al., 1995). Thus, the objective of certification is to link the consumer who wishes to favour environmentally and/or socially responsible products with the producers of these products and the raw materials from which they are made. This involves several assumptions, including:

- Consumer purchasing patterns can be influenced by differentiating similar products according to environmental and/or social attributes.
- Producer behaviour can be influenced by market signals based on environmental and/or social concerns.
- The premium generated through differentiation will provide sufficient economic incentive for producers to adopt improved management practices.
- Efficiency and competitiveness will increase by internalizing environmental and social concerns.

However the market acceptance of certified timber is not very high. According to a survey conducted in Ghana to determine the current status of chain of custody certification indicate that the keenness to adopt chain of custody certification among the sector is low. The primary reasons deterring the sector from adopting certification is the lack of stakeholders' awareness and price premium. Therefore, it enlightens that an increasing adoption of chain of custody certification among the forest sector can be realized with good stakeholder consultations and resource rights. The use of premium in promoting certification could quicken the rate of growth of chain-of-custody certification in the tropical timber countries in general (Attah, et al., 2011).

In general, the market impact of certification has been far greater in Europe. PEFC certification is a standard of choice for public timber procurement policies in e.g. the United Kingdom, Germany, and Japan, in addition to numerous private timber procurement policies. Strong growth in demand for PEFC has been seen in several countries, including the United Kingdom, where more than half of all wood imported in 2008 was PEFC-certified (PEFC, 2011). According to FSC International, the market share of certified timber and timber products in the Europe is approximately 6-7%. Although this percentage varies significantly among the different EU countries and also depends on the product group, the market share is growing in all EU member states. The "UK Timber Industry Certification" report published in 2009 reveals the volume of FSC certified timber and panel products supplied from UK production and importation rose to 52% in 2008, from 48% in 2005. Importantly, this increase was made against a background reduction in the total volume produced and imported.

GLOBAL STATUS OF FOREST CERTIFICATION

At the global level, there are two competing certification schemes with different operating modalities. The Forest Stewardship Council (FSC) provides all the necessary elements of certification through centralized decision-making on standards and accreditation. The Programme for the Endorsement of Forest Certification (PEFC), on the other hand, operates as a system for mutual recognition between national certification systems. Almost two-thirds of the world's certified forests carry a PEFC certificate, while the FSC's share is 28%; the remaining forests are certified solely under national certification systems. Most of the certified forests in the tropics are FSC-certified. As of 15 July 2011, FSC has certified 140 million ha forest area and issued 21077 CoC certificates. The region-wise details of FSC certified forest area given in Table 1. Whereas, about 239 million hectares of forest area are managed in compliance with PEFC's internationally accepted Sustainability Benchmark. As of July 2011, 8470 Chain of custody (CoC) certificates are issued by the PEFC. The country-wise details of forest area certified by PEFC are given in the Table 2. Over 1,79,000 hectares of forest in China have received Forest Stewardship Council (FSC) certification up to June 2011 giving a major boost to China as the leading FSC player in Asia.

STATUS OF FOREST CERTIFICATION IN INDIA

A few forest certification projects have been undertaken in India including two FM certificates issued in 2002 one each in UP and West Bengal for small private plantations using FSC standards. The first certification issued in India was a FSC CoC certification which was issued in January 2001 to a Toys manufacturer in

Saharanpur UP for Babul (*Acacia nilotica*) and Shisham (*Dalbergia sissoo*) wood species. However there was no FM certification for this CoC. The second certification in India was for both FM & CoC certification issued by FSC in 2002 for Kadam (*Ailanthus grandis*) plantations on 432 acres in West Bengal. However both these certificates were discontinued within one year of issuances for unknown reasons.

The third and fourth CoC certifications were also issued in 2002 for Silver Beech (*Nortofagus menziesii*) wood species from France imported by hand tool manufacturers in Jalandhar, Punjab. The hand tools are exported to the European countries. Both these certificates are continuing even today and thus are the oldest CoC certifications in India. IIFM has done a pioneer work in undertaking Forest Certification for bamboo resource in Northeast region in the country i.e. Tripura, Arunachal Pradesh Nagaland and Madhya Pradesh. The initiative undertaken in the state of Tripura where farmers cultivate bamboo using traditional system of sustainable practices was audited by one of the recognized certification body FSC and the certification almost reached the final stage in the year 2003 itself.

However there is only one FSC Forest Management Certificate in India issued to a private rubber plantation in the State of Tamil Nadu on 676 ha area. Of late there has been a sudden increase in FSC CoC certifications since 2006 and as of September 14, 2011, there are 225 FSC CoC certifications and seven PEFC CoC certifications issued to divergent types of businesses in India. The majority of these certifications holders are mainly small and medium companies to meet export obligations. But the situation is changing in favour of big firms opting for certifications due to the increasing demand for forest certification in the global market and the high growth rate of Indian economy.

The first corporate initiated FM certification is likely to be finalized shortly. It relates to farm forestry project for eucalyptus plantations in Khammam district of Andhra Pradesh for supply to a nearby paper mill. There are some other community owned/ managed forests which are at various stages of FM certification assessment under FSC standard. These are in the states of Karnataka and Orissa. Preliminary analysis of Chain of Custody certifications (COC) issued for Indian business organizations indicates that majority of the COC certifications are owned by small and medium forest based enterprises. These enterprises represent the pulp and paper mills, wood craft and hand-tool enterprises, printers and publication houses, plywood, paper and board industries, timber traders and exporters. Among the prominent business houses which have received COC certifications include ITC Ltd. (Triveni, Bollaram and Bhadrachalam units), J.K. Paper Ltd., BILT Graphic Paper Products Ltd. (Kamlapuram and SEWA units), A.P. Paper Mills, West Coast Paper Mills, Archies India and Durian Industries etc.

FOREST CERTIFICATION: CHALLENGES AND OPPORTUNITIES FOR INDIA

Forest certification has emerged as a marketing tool for linking the good forest management (SFM) practices with the environmentally conscious consumers. The forest certification involves two aspects; one is an independent assessment of the forest management operations, according to specific ecological, social and economic norms (standards). The forest assessment typically includes an evaluation of ecological health of the forest; economic viability of the operations; and, social impact of the forest management activities. Whereas, the second aspect known as chain-of-custody (CoC) involves verifying the flow of forest products from the stump in the forest, through milling and manufacturing processes, to the finished product. Together, these two processes constitute forest product certification, also known as timber certification, forest product labelling, and forest management auditing. This process of assessment for issuing certification is undertaken by both non-profit and for-profit organizations in a number of countries and is characterized as being an independent, objective, and third-party process. Forest certifications has led to greater recognition of the importance of environmentally and socially sound wood products practices and has engaged producers, consumers and retailers in a positive effort to help clean up the timber industry. It has also strengthened a global debate on the future of forestry. Forest management, including intensive commercial management, can be a critical and cost-effective conservation tool within larger-scale conservation strategies. Well-managed commercial or community forests can for example provide vital buffers for and links between protected areas. Forest management should therefore seek to maintain forest quality and not degrade either the timber resource or the range of associated goods and services (non-timber forest products, environmental services, biodiversity, spiritual values, recreational uses etc) (GFTN, 2010).

Though forest certification is a voluntary and market driven mechanism, however, the recent regulations in the United States, i.e. the Lacey Act requires a compulsory certificate of source of origin of any wood and wood product entering the US market. Similarly, the European Commission has also finalized the EU Illegal Timber Regulation (ITR) which will be effective from March 2013 and is intended to prohibit import of illegally sourced timber and products from the foreign countries. Thus, there is need for the wood and wood based industry players to improve the timber supply chain operations with the objective of making the supply chain more transparent as well as to provide for documentation on the local source of origin of the wood materials. This would enable the wood based industries including pulp and paper industries and the plywood and panel industries to comply with the requirements of the US and European markets. It is in this context that the forest certification (both FM - Forest Management certification and the Chain of Custody certification) can not only help in making the timber supply chain more transparent as well as will ensure the market access to developed countries.

The major challenges of forest certification in India will be because of the unorganized nature of the timber trade with associated problems of documentation and thus evidence of the source of origin of the raw material. The other problem of FM certification in India is because of the absence of large scale plantations based on a formal management plan, which is a pre-requisite of forest certification audit. Another challenge to forest certification in India is the absence of a national initiative or standard for forest certification. This is primarily because of the diversity of the forest types in the country and small scale plantations by the individual farmers who are neither part of any formal legal structure/entity, nor can afford the cost of forest certification audit undertaken by a foreign certification body.

There are already market requirements for forest certification for the business organizations which are currently the suppliers to big firms and retail chains in the US and the EU markets. These Indian suppliers are procuring the certified timber through imports from forests certified in those countries and is thus supplying finished products to foreign buyers using the imported materials. This has been the primary reason for more than 230 COC certifications obtained by these Indian wood-based businesses; some of the examples are discussed above. However such a requirement would become more intense with increasing consumer awareness and regulations particularly in the developed markets.

INDIA'S TIMBER PRODUCTION, CONSUMPTION AND TRADE

As per Government of India report 2007, an estimated 270 million metric tonnes of fuelwood, 280 metric tonnes of fodder, over 12 million m^3 of timber and numerous NTFPs are removed from the forests annually in India. Part of the requirement is also supplemented by the non-forest areas i.e. farm forests, revenue forests, etc., that account for approximately 98 million tonnes (GoI, 2007). Owing partly to a simplistic analysis of a complex issue and partly to the wish for a quick solution, it is envisaged that the timber harvest should be below the incremental yield and efforts should be made to raise plantations of desired forest tree species (Baharuddin, 1998). According to ITTO India timber market study projections (table 3), India's total timber consumption is expected to stand at 117 million cubic meter by 2013 (ITTO 2004a). But as per the other studies the demand for industrial round wood was estimated at around 95 million m^3 for the year 2010 where as supply was just about 62 million m^3 from the forests, plantations and social & farm forestry, leaving a huge gap in the demand and supply. This gap will continue to grow owing to India's average annual GDP growth of 7-8% during the next decade (Table 4). The increasing gap between demand and supply, which is being fulfilled mostly from tree outside forests and partly from imports may be also through illegal logging from the forests. In the absence of adequate supply from domestic sources, the nation has to depend heavily on imports to meet its demand for timber (WWF India, 2009). Thus India is likely to face severe shortage of supply of timber to meet its requirement from both domestic and international front. India is currently the second largest importer of timber and is poised to become largest timber importer in next few years, leaving China behind (ITTO, 2009).

FOREST MANAGEMENT IN INDIA: HISTORICAL PERSPECTIVE

India has a long history and rich traditional practices for management of forests. The productive as well as protective aspects of forest vegetation were emphasized during the Vedic period (4500 and 1800 BC.). In particular, religious texts such as Aranyakas ("forest" works), Upanishadas, and Smritis contain many descriptions on the uses and management of forests, and highlight sustainability as an implicit theme. During the late Vedic period (500 BC) with the emergence of agriculture as the dominant economic activity, the concept of cultural landscapes such as sacred forests and groves, sacred corridors, and a variety of ethno-forestry practices evolved, which continued into the post-Vedic period (1000 to 200 BC) (Kumar, 2008).

A very systematic forest management approach was prevalent even from the Mauryan era (320 BC) when forests were classified into four main categories i.e. reserved forest for King, reserved forest for State, forests donated to eminent Brahmins and forests for general public. Also the communities living in and around forests managed the forests as commons. The general principle for the management of forests remained almost the same during the period of Gupta and even subsequently, but due to fragmentation of various states and continual fights between the princely states led to destruction of large forest areas in the later centuries. By the 16th century, when the Mughals had established their rule in India, the country was again unified as almost one nation. However the historical details indicate that Mughal rulers were not very much found of forests. Rather forests were cleared for agriculture purposes in order to obtain higher taxes. The forests were regarded as hunting grounds for Kings, Nawabs and Jagirdars. There was no comprehensive approach towards forest management, conservation and protection (Kumar, 2008). The earlier conservation ethos of ancient Indian people received a major setback during the second millennium period. In pre-British India; forests were managed by native villagers or forest dwellers. The scientific management of forests started with establishment of the Forest Department in 1864.

FOREST CERTIFICATION REQUIREMENT FOR INDIA

The Forest Policy 1988 has categorically made it clear that wood-based industries have to progressively shift their dependence for raw material from the natural forests to the farm forestry. As a result the industry has undertaken the dual strategy of expanding the raw material base in the domestic market as well as sourcing through imports. The pulp and paper industry now depends for almost 50% of their raw material requirements through imports. Similarly there has been tremendous growth in imports of wood and wood products for meeting the demand of other wood-based industries including the plywood and panel industries. Though the exports of wood products have also grown but the imports have surpassed the exports and the country has become a net importer of wood and wood products in the last decade as evident from Table 5. The existing supply chain of wood Industry in India involve from three types of sources – from the government owned and managed forests; tree outside forests including farm/agro forestry at small farmer level; and imports from other countries. India does not have certified forests as of now and hence certified timber is just now available in the country. Thus the only source of certified timber is through imports and it is because of this reason that as of today there is only one FM certification (676 hectare private rubber plantation in Tamil Nadu) and more than 230 COC certifications which are again mostly for controlled and some for certified wood from other countries.

However there are some efforts by the Indian wood industry to undertake FM certifications for social/farm forestry projects in the absence of government owned forests not going for forest certification. This is logically right trend as most of the wood requirement is met from these sources.

MANAGEMENT OF GOVERNMENT OWNED FORESTS

For the legally sourced wood material there is well established supply chain and documentation up to the point of sales from the forest department depot. The 1988 national forest policy embodies most elements of SFM. It focuses on the maintenance of environmental stability and the restoration of ecological balance; the conservation of the country's natural heritage and biological diversity; improved soil and water conservation; increasing forest cover (to the target, set in 1952, of 33% of the country's total land area) through massive afforestation and social forestry programmes; providing the basic needs of the rural and tribal populations; increasing forest productivity; improving the efficiency of forest product utilization; and minimizing pressure on existing forests. The policy stipulates that requirements for industrial wood should be met increasingly from trees outside forests. It is noteworthy, however, that the reiterated target of 33% forest cover is backed neither by an in-depth assessment of the need for this level of forest cover or the type or location of the forest to be established, nor by the institutions and resources needed to achieve the target (ITTO 2006b). As a result there is continuous loss of forest area as well as deteriorating quality of existing forest area. There is loss of forest area to the extent of 30000-40000 hectare per year for diversion of forest area for other land uses.

India follows a system of preparation and periodical revision of working plans or management plans for established forest divisions or FMUs. Working plans are tactical documents but lack a strategic framework; and they do not seem to include model-based yield calculations and predictions. An estimated 75% of notified forests were under working plan prescriptions in 2005, but it is unclear what area of forest was involved (ibid.). According to FAO (2010), 30.6 million hectares of forest nationwide are subject to management plans. The management of government forest land is the direct responsibility of state forest departments. In some cases, industrial units are allowed to extract trees marked under a selection system. There are no long-term timber concessions of the kind practiced in Southeast Asian countries.

In recent years, logging in natural forests has been discouraged and, in several cases, locally banned. The resulting wood scarcity has provided impetus for the development of farm forestry, homestead forestry and agro-forestry. Some states, such as Andhra Pradesh, are developing joint management schemes in closed-canopy areas of natural forest. The silvicultural harvesting of teak, sal and other natural forests is allowed in states such as Chhattisgarh, Gujarat, Madhya Pradesh, Maharashtra and Orissa on the basis of working plan prescriptions. In others, only salvage felling of dead, damaged and diseased trees are allowed. Harvesting operations are mostly done using simple hand tools such as axes and crosscut saws, which are associated with high wastage of valuable butt logs. There seems to be no application of reduced impact logging. Trees tend to be bucked into much shorter lengths than in other tropical countries

ITTO (2006a) estimated that 9.72 million ha. of the production PFE (all India) were being managed under regular working plans, of which at least 4.8 million ha. were considered to be sustainably managed. This area comprises forest reserves that have been managed according to working plans for more than 30 years. These forests, if put to any forest certification audit, in my opinion have high degree of probability of receiving certification. If that happens, the wood industry sourcing wood from these areas can go for COC certification and thus meet the requirement forest certification and labelling up to the retailer end.

A set of Criteria and Indicators (C&I) for the sustainable management of the dry-zone forests of India was developed under the Bhopal-India Process initiated by the Indian Institute of Forest Management in 1998, and the same have been refined for tropical forests under an ITTO project. In 2008 the Conference of Forest Secretaries endorsed eight criteria and 37 indicators as the national set of C&I and have been further tested in different forest types in the country. An SFM 'cell' was created in the Ministry of Environment and Forests, and similar cells have been created in many state forest departments. The national government has created committees for the inclusion of the C&I in the National Working Code; in the future, working plans will therefore involve the use of C&I as the basis for monitoring the sustainability of forests. Once the SFM approach to forest management is put in place and with the setting up of a national forest certification system can help the wood based industry to source certified wood from within the country itself.

NON-WOOD FOREST PRODUCTS (NWFPS) AND FOREST CERTIFICATION CHALLENGES

India is home to an amazing diversity of plants, with over 46,000 plant species recorded to occur there. Many of these species are used for medicinal purposes, with approximately 760 known to be harvested from the wild for use by India's large herbal medicine industry. 90% of the raw material for herbal and traditional medicinal industry is sourced from the wild. There is concern, however, that collection methods for many if not most of these species are destructive and wild populations are declining as a result. While the market for herbal products is expanding both within the country and globally, there is decreasing trend of availability of NTFPs including medicinal and aromatic plants from the wild because of degradation of forests in the country. At the same time there is increasing global concern about the harvesting practices and the source of origin of the NTFP resources from the forests. Thus there is a need to develop some mechanisms to ensure appropriate harvesting and transparent flow of these resources from the point of harvesting to the point of trade in the domestic as well as international market.

As per FAO the global trade value of NTFPs increased from US$9 billion in 1996 to US$14 Billion in 2005 (based on UN Comtrade data accessed as on 30 September 2011 at http://www.iifm.ac.in/ntfp/index.html). The overall herbal market in India was estimated to be about US$1.75 billion in 2008, with exports accounting for about US$900 million, and these numbers were expected to more than double by 2012 (Sharma, 2008). Certification, will improve the market prospects of non-wood forest products including medicinal, aromatic and dye plants in the country as well as open avenues for improvement in the international trade as there will be a transparent traceable supply chain and also an improvement in the quality of the produces available in the market. At present, forest certification systems are available only for the wood products but there has been little effort so far on certification of non-wood forest produce. For product certification, source of origin must be known and the product should meet specified quality standards.

NTFP availability, utilization, commercialization, exploitation, management practices, policies and tenure system in different parts of India has high diversity and variability, which imposes greater challenge for development of any generic standards for certification of NTFPs. Forest certification mechanism is utilized for forest monitoring, tracing and labelling non-timber forest products, where the quality of management from legal, environmental, social, and economic perspectives is judged against a series of agreed standards. Various plant parts are being used as Non-Timber Forest Products. In order to develop the generic set for standards for certification of NTFPs based on the plant part used.

The Rainforest Alliance came out for the first time with a set of guidelines for NTFP certification with ten principles (same as FSC certification) and 54 criteria (Rainforest Alliance, 2008). An IIFM study identified four principles and 16 criteria viz. Legal and policy framework; Wild area conservation and management; Responsible collection and use practices; and Economic development and benefit sharing for development of standards for certification of NTFPs (Bhattacharya, 2009). Another IIFM study recommended similar four principles *viz.* Policy, legal and institutional framework for sustainable NTFP management; NTFP management plan, strategy and operations for Sustainable Availability; NTFP Value chain and market network; and Socio-cultural and spiritual benefits and 17 Criteria and 55 Indicators for two natural forest sites in central India (Yadav, 2011)

MANAGEMENT OF TREES OUTSIDE-FORESTS AND ITS SUPPLY CHAIN

The other source of wood, which is a major source, is Tree s Outside Forest. But this source is highly un-organized and fragmented; making it difficult to trace the source of origin of the wood. Secondly the silvicultural and management practices followed are not uniform and are based on oral communication either between the farmers or from wood sourcing companies to the farmers. In order to bring this source into a possible certification regime would require two things. One, organizing these individual farmers into a group which can be uniformly brought under scientific and sustainable plantation management practices so that these can be assessed for a potential Forest Management certification.

Second, linking these farmer groups to the wood user industries through a formal network so that there is visible movement of raw material with proper records and documentation. This will help in designing a transparent supply chain for ensuring traceability and hence chain-of-custody (CoC) certification. Both the above efforts can facilitate in achieving FM certification as well as COC certification for wood raw material in the country. We have some success stories of this type of farm-forestry models in India; particularly for the pulp and paper industries. One such example is the ITC Paper Division initiative in the states of Andhra Pradesh and Orissa, where the company has provided the farmers with high yielding saplings of fast growing tree species and know-how to managing the plantations. In order to meet the requirements of a certification standard (FSC in ITC case) the firm has also developed a management plan to be uniformly implemented by all the member farmers and these farmers have been grouped through a legal organization (society).

Similar efforts can be made by other wood based industries – pulp & paper, plywood and panel, and furniture industries. However there are problems of putting these efforts together and then meeting the requirements of the international certification standards in the absence of an Indian Forest Certification Scheme/ standard. Recognizing this problem and future trade implications the government of India has initiated the process of establishing a national forest certification system in the country.

PROPOSED INDIAN SYSTEM OF FOREST CERTIFICATION

Recognizing the importance of forest certification and its potential implications particularly in foreign markets, the Ministry of Environment & Forests, Government of India has been working towards the objective of initiating a national forest certification scheme of its own. The taskforce on initiating forest certification in India with inputs from various stakeholders including institutions, industry and non-government organizations has prepared a broad outline for the national forest certification initiative in India and it is hoped that the initiative will be finalized shortly for the benefit of the wood based industry in the country. The broad framework of Indian Forest Certification Council (IFCC) proposed by the Indian Institute of Forest Management, Bhopal is depicted in the Fig. 1.

The National Set of Criteria and Indicators (C&I) for Sustainable Forest Management (SFM) in India are being evolved at the Indian Institute of Forest Management under the Bhopal-India process. This process has support from Government of India, Ministry of Environment & Forests, many state forest departments, International funding agencies and the local communities. Once finalized, these national set of Criteria and Indicators (C&I) for Sustainable Forest Management can form the basis for developing forest certification standards specific to the Indian forest conditions. The forests can be assessed against these standards for seeking forest certification for better market access for timber harvested from these certified areas (Yadav, 2009). Plantations also have potential opportunity to benefit from such a national forest certification initiative. The forest certification could assure consumers that their purchases of forest products do not contribute to the destruction and degradation of the forests.

CARBON EMISSION REDUCTION, REDD+ AND FOREST CERTIFICATION

Deforestation is a major environmental issue, while demand for timber products increases rapidly in the developing world. One can thus wonder whether forest harvesting is sustainable worldwide. The countries where timber harvesting is more important tend to experience larger deforestation rates than others, giving the intuition that forest harvesting is generally not sustainable. Thus, timber certification seems to be a good indicator of harvesting sustainability and minimizing deforestation (Damette et al., 2011).

To support this target, WWF addressed the critical role that forest companies play in providing solutions to climate change through responsible management of forests and plantations by showcasing its leading, innovative solutions – GFTN and New Generation Plantations Project – at a special event that attracted over 255 attendees. The discourse demonstrated how the global marketplace can be harnessed as a key force to conserve the world's valuable and threatened forests, while providing economic and social benefits for the businesses and people that depend on them (WWF, 2009). Plantations are an attractive investment, not only for reforestation initiatives, but also for drawing benefits from emerging issues such as reducing emissions from deforestation and degradation (REDD). Management practices that lead towards sustainability are only likely to be adopted where there is good governance backed by financial incentives for effective enforcement of management regulations. Policy interventions designed to lower net greenhouse gas emissions by decreasing rates of forest degradation and increasing carbon stock recovery in logged-over or otherwise degraded forests. Implementation of REDD+ could provide critical compensation to forest users for improved management practices in the absence of, or in combination with other economic incentives (Nasi et al., 2011). Voluntary forest certification systems may be applied to enhance forest management to meet even stricter standards than those required by legislation. Voluntary certification provides useful practical experience that should feed into the design of the international REDD+ regime (Merger, *et al*., 2011).

India envisages increasing its forest cover from the current 24% to 33%. Improvements in around 9% of degraded forests to a medium or high density canopy can also capture large amount of CO_2. If these plans are implemented, India can save 550 million tonnes of carbon dioxide emissions per year by exploring all these alternatives.

CONCLUSIONS

Sustainable forest management as a philosophy has been part of its economic, socio-cultural and natural heritage and thus is not new to Indian forest management system. But the comprehensiveness of the Criteria and Indicators approach to SFM which requires multi-disciplinary competence in managing, monitoring and reporting progress is something new to Indian forest management practices. The world community recognized the importance of managing forest resources sustainably during the decades of 1980s and 1990s. The acceptance of Agenda 21 at the Rio Earth Summit is a watershed in emphasizing importance of sustainable forest resource management and the required actions by the member states. Globally nine processes have emerged for implementation of SFM through Criteria & Indicators approach. Based on one of these approaches called – Regional Initiative for Dry Forests in Asia, a country specific initiative was started in India named as Bhopal-India process since 1998. After a thorough field testing and consultative process the final draft set of national set of criteria and indicators (8 and 37) has been recommended to the MoEF in November 2010 by IIFM.

Recognizing the change in mindset at the international level, the businesses, particularly those in timber, pulp & paper, furniture and other forest based industries along with social and institutional stakeholders came together to put in place a system of tracking and verification of good timber management, harvesting and trading practices for the benefit of all. This system of credible tracking of sustainable forest/ plantation management, timber procurement and use in trade is called as Forest Certification and Labelling and thus helps in communicating with the various stakeholders including the customers that the products they buy having such labels are environmental-friendly. The system of verifying sustainability of forest management is called as Forest Management (FM) certification and the tracking of supply chain of timber from such forests to the customers is called as Chain-of-Custody (CoC) certification. Both the certifications together are part of product certification. Apart from two internationally recognized systems and labels of forest certification, namely FSC and PEFC, there are a number of country specific certification programmes in operation.

Recognizing the increasing acceptance and demand for forest certification, the Government of India, Ministry of Environment & Forests has also initiated the process for establishing an Indian Forest Certification Scheme of its own with the support from institutions like IIFM. The format, structure and other modalities for the same are being worked out by the Ministry of Environment & Forests in consultation with the expert group. It is envisaged that with the setting up of an Indian Forest Certification Scheme the pace of certification will increase and more areas will come under sustainable management and globally recognized certification regimes. The institution of IFCC will also be a great help in monitoring and verification in REDD+ mechanism of UNFCCC once it is agreed upon by the parties and is put in operation in the country.

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Table 1: **Global FSC certified* forest area by region (as of July 15, 2011).**

Region	Total area (ha)	No.
Europe	59057416	431
Latin America & Caribbean	12004316	227
North America	55254176	197
Asia		
China	2569340	40
India	676	1
Indonesia	567294	8
Japan	386355	33
Korea	728	14
Laos	81704	2
Malaysia	742849	7
Nepal	14145	1
Sri Lanka	38854	6
Thailand	7208	4
Vietnam	15641	3
Oceania	2072764	29
Africa	7448796	46
Total	**1402622262**	**1049**

**FSC certified area includes forest management as well as forest management & Chain of custody (FM/CoC) certificates. Source: http://www.fsc.org/facts-figures.html (accessed on August 30, 2011)*

Table 2: **Global PEFC certified forest area by country (as of July 31, 2011).**

Country	Certified forest area (ha)	Number of C-O-C certificates*	Number of PEFC logo users
Argentina	0	2	2
Australia	10115877	2006	156
Austria	2517245	354	232
Belarus	7787600	0	3
Belgium	286475	225	292
Brazil	1260164	28	17
Canada - CSA	63086187	0	9
Canada - SFI	53193487	0	5
Canada (PEFC Total)	116268747	192	66
Chile	1913521	49	44
China	0	130	50
Colombia	0	2	2
Czech Republic	1883149	186	159
Denmark	244995	53	73
Egypt	0	2	1
Estonia	868834	14	19
Finland	20786936	153	168
France	5067026	1918	29021
Germany	7391155	1242	8662
Hungary	0	4	4
India	0	6	1
Indonesia	0	14	8
Ireland	0	25	22
Italy	754821	423	648
Japan	0	206	142
Latvia	400519	7	7
Lebanon	0	1	2
Lithuania	0	2	3
Luxemburg	27869	18	56
Malaysia	4646068	168	71
Mexico	0	1	1
Monaco	0	3	3
Morocco	0	1	1
Netherlands	0	352	308
New Zealand	0	17	17
Norway	9115902	32	54
PEFC Council	0	0	40
Peru	0	3	3
Philippines	0	2	2
Poland	499307	34	17
Portugal	206830	29	57
Romania	0	11	4
Russia	177396	2	3
Saudi Arabia	0	1	1

Singapore	0	17	6
Slovak Republic	1253708	38	62
South Africa	0	1	1
South Korea	0	3	1
Spain	1454817	414	601
Sweden	7905170	127	99
Switzerland	215239	50	241
Taiwan	0	7	1
Thailand	0	2	1
Tunisia	0	2	2
Turkey	0	5	4
UK	1298047	1321	1064
United Arab Emirates	0	6	4
Uruguay	0	2	1
USA - ATFS	10799449	0	2
USA - SFI	23493103	0	3
USA (PEFC total)	34292552	354	104
Vietnam	0	3	2
Total	**238650900**	**8470**	**42659**

** This no. does not include the companies participating in group CoC certification but only gives individual and group certification. Source: http://register.pefc.cz/statistics.asp (accessed on August 30, 2011)*

Table 3: **Timber consumption prospects (million m3).**

Particulars	2002-03	2005-06	2007-08	2012-13
Log Consumption				
Urban India	12.58	14.17	15.44	17.64
Rural India	37.74	42.52	46.31	52.92
India	50.32	56.69	61.74	70.56
Sawn wood consumption				
Urban India	7.92	8.29	8.63	9.45
Rural India	23.76	24.88	25.89	28.34
India	31.68	33.18	34.52	37.79
Total veneers & plywood				
Urban India	2.60	2.88	3.09	4.89
Total builders' joinery				
Urban India	3.35	3.44	3.55	3.88
Construction end-use				
Urban India	3.85	4.07	4.34	4.80
Rural India	11.56	12.22	13.02	14.40
India	15.41	16.30	17.36	19.20

Source: ITTO, 2004a

Table 4: **Demand and Supply Scenario of Wood in India (million m³).**

S.N.	Description	1985	1996	2001	2006	2010	2020
1	Wood demand for Domestic/ Industrial uses	50	64	73	82	95	153
2	Output from forests	24	12	12	12	3	3
3	Output from plantation and social & farm forestry	-	41	47	53	58.5	88.7
4	Deficit	26	11	14	17	33.5	61.3
5	Imports	-	0.9	2.7	3.7	5.3	-

Source: Ganapathy, 1997; Dubey, 2009; and ITTO stat

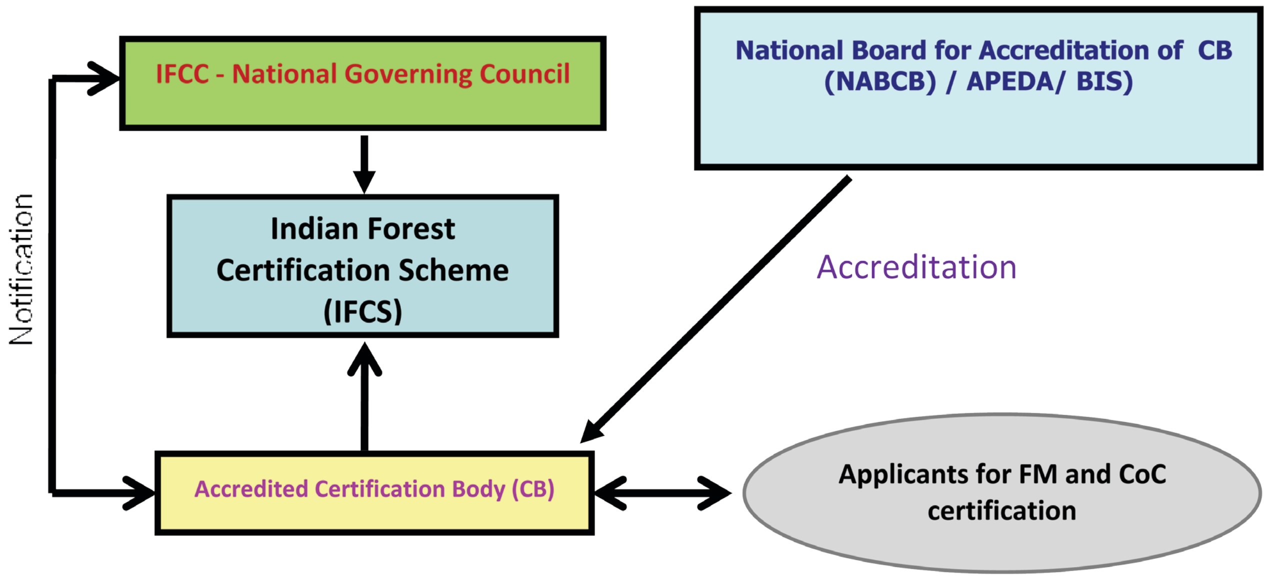
Table 5: **India's Wood and Wood Product Imports ('000 m³).**

Year	Logs	Sawnwood	Plywood	Veneer	Total
1991	853	9.1	3.6	0.8	867
1996	869	9.7	23.6	5.1	907
1997	1362	6.6	24.5	10.2	1404
2001	2623	60	24.9	3.7	2712
2003	3482	98	24.2	7.3	3612
3005	3749	75	12	14	3850
2006	3608	60	25.8	15.8	3710
2007	4654	57	36.6	17	4765
2008	4792	83	57.1	24.9	4957
2009	5972	153	91.8	26.1	6243
2010	5062	136	91.7	26.8	5316

Source: computed from ITTO stat.

Figure 1: **Proposed Framework for Indian Forest Certification Council**

IFCC – Indian Forest Certification Council



Investigation on Efficacy of Different Types of Planting Materials of *Bambusa vulgaris*

N. BHOl * and A.K. Srivastava **

INTRODUCTION

Bamboo is one of the most ubiquitous, multi-use plant species in the tropical, sub-tropical and mild temperate regions of the world. According to Ohrnberger (1999), there are 1575 species of bamboo under 111 genera all over the world. They are abundant in the southern and south-eastern boundaries of Asia from India through China and Japan to Korea. Bamboos also grow in Africa, Australia and Madagascar. In the Western hemisphere bamboos extend from eastern United States to Chile and Argentina. South America is also rich in bamboos (Soderstrom and Calderon, 1979). India is the second largest diversity centre for bamboos with 18 genera and 128 species (Seethalakshmi and Kumar, 1998). Including exotics, 135 species of bamboo are grown in India. India is one of the leading countries of the world in bamboo production, second only to China producing 32.3 million tonnes per year (Pathak, 1989). India and China account for more than 50% of the total bamboo reserves in the world (Vatsala, 2003) and possess one of the largest bamboo resources in the world (Sharma, 1987).

There are some bamboo species which are cultivated by people because of their good economics, livelihood support nature and environment protection ability. One such species is *Bambusa vulgaris* Shrad. known as Common bamboo which is one of the extensively cultivated bamboo species of the world. In India, it is grown in north eastern states, Orissa, West Bengal and many other parts of the country. In coastal areas which are more fragile to climate change, this species plays an important role in livelihood support of people. For establishing large scale plantations, it is required to know the relative efficacy of different planting materials by which this species is propagated. This species does not produce viable seed (Banik, 1995; John and Nadgauda, 1997; Koshi and Pushpangadan, 1997; Bhol, 2006 and Bhol and Nayak, 2010) and is propagated vegetatively by different types of planting materials. The merits and demerits of different methods of propagating *B. vulgaris* are given in Table A (Bhol and Nayak, 2008).

To recommend suitable type of planting material, investigation has been carried out on relative efficacy of different types of planting materials such as offset, rhizome, rooted culm cutting, directly planted culm cutting and rooted culm-branch cutting. It has been carried out at Orissa University of Agriculture & Technology, Bhubaneswar under the technical guidance of Silviculture Division, FRI, Dehradun.

MATERIALS AND METHODS

The investigation was carried out at Bhubaneswar inside the Central Research Station of Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, India. Geographically the Central Research Station of OUAT, Bhubaneswar is located are 20^0 15' N latitude and 85^0 52' E longitude with an altitude of 25.9 m from above the mean sea level. The Research Station is 60 km away (by road) from Bay of Bengal (Indian Ocean).The climate is warm and humid with short mild winter. The normal rainfall is about 1500 mm with 113 rainy days in a year. The rainfall is received from south-west monsoon and 85% is received between June and September. The experimental site was a marginal upland lying fallow before taking up experimental plantations. This is a typical representative site which is generally put under tree plantation like bamboo by the people in Orissa. The land is predominantly red lateritic having loamy sand texture. The levels of available nitrogen, phosphorus and potassium are low.

The relative performance of five types of planting materials such as rhizome, offset, rooted culm cutting, directly planted culm cutting and rooted culm-branch cutting of *B. vulgaris* were investigated. The clumps were raised at 5m x 5m spacing in the main field and the experiment was laid out in Randomized Block Design.

The planting materials were collected/prepared from vigorous clumps. Rhizomes having active eyes were collected from underground parts of 1½ year old culms. Offsets with 4-internodes were collected from the base of 1½ year old culms. The rooted culm cuttings and cuttings which were directly planted were prepared from 1½ year old culms. The rooted culm- branch cuttings were prepared from the primary branches of 1½ year old culms.

The bare rhizomes were collected on 31 March 2003. Immediately after collection, these were soaked in water for 24 hours, and then treated in 0.15% Bavistin solution for 20 minutes. The rhizomes were then planted in nursery bed at 30 cm apart. The nursery bed was 10-15 cm deep consisting of soil and sand in the ratio 3:1 (Banik, 1995). Straw mulch and shade were provided

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Table A

S.N.	Method of propagation	Merits	Demerits
1.	Culm cutting	a) Easy to propagate b) Growth of plants fast c) Success rate maximum d) Only 4 culms required for one acre plantation e) Generates market for the bamboo grower f) Feasible method for commercial cultivation	a) Materials are bulky
2.	Culm-branch cutting	a) Materials available easily b) Less bulky	a) Success rate less b) Requires one year more in comparison to plants propagated by culm cutting method
3.	Offset	a) Growth rate more in initial years in comparison to other materials	a) Availability of materials is very less b) Extraction of offset from clump damages adjacent rhizomes c) Extraction is difficult, time taking and labour consuming. d) Success rate less in comparison to culm cutting materials e) Materials are bulky
4.	Rhizome	a) Less bulky in comparison to culm cutting method	a) Availability is limited b) Extraction from clump is difficult and time consuming c) More extraction hampers productivity of clumps d) Success rate less
5.	Tissue culture/ micro-propagation	a) Large scale production is easy b) In small area, more plants can be produced	a) Comparatively costlier b) Requires more care c) Initial growth rate is less in comparison to culm cutting method d) Can not be produced by all farmers

with regular watering. The plants developed were transplanted in the experimental field on 30 June 2003. The pit size was 45 cm × 30 cm × 30 cm.

The offsets were collected from clumps carefully keeping the eyes of rhizome portion as well as culm portion well protected. Immediately after collection on 29.06.2003 they were soaked in water for 24 hours followed by treating in 0.15% Bavistin solution for 20 minutes. Then the offsets were transplanted in the experimental field. The pit size was 30 cm × 30 cm × 60 cm. The root and rhizome portions were put inside the soil as they were in the parent clumps.

The rooted culm cuttings were raised in the nursery first. For this 1½ year old culms were collected on 31 March 2003 and culm-branches were pruned leaving 5 cm basal portion attached to the node. Two noded cuttings were prepared from the lower 2/3rd portion of the culm. In each cutting at the middle position of the internode, a hole of 2 cm length and 1 cm width was made to open the culm cavity. The hole was made in such a way that both nodal branches of the cutting were parallel to the ground. The cuttings were soaked in normal water for 24 hours. Then cuttings were placed horizontally keeping the hole upward in nursery beds prepared earlier having a depth of 15 cm. The distance between two adjacent cuttings was 30 cm. The culm cavity was filled with normal water through the hole. The holes were covered with ordinary polythene strips (size about 12 cm long × 8 cm wide). The cuttings were then entirely covered with 2-3 cm layer of top soil. Regular watering was done upto last week of June 2003 during which cuttings were developed into rooted plants. On 30.06.2003, they were uprooted from the beds carefully without damaging roots. The binodal rooted cuttings were divided from the middle into one nodal and planted in the field along with the culm segment. The pit size was 45 cm × 30 cm × 30 cm.

The culm cuttings planted directly were collected from 1½ year old culms on 29 June 2003. The culm branches were pruned leaving 5 cm attached at the base of node. Single noded culm cuttings were prepared from the lower 2/3rd portion of the culm. The cuttings were soaked in water for 24 hours and then planted horizontally in the field on 30 June 2003. While planting, the entire cutting was covered with 2-3 cm layer of top soil. The pit size was 45 cm × 30 cm × 30 cm.

The rooted culm-branch cuttings were first raised in nursery. For this, cuttings were collected from primary branches of 1½ year old culms on 31 March 2003. Two nodal cuttings were prepared and soaked in water for 24 hours. Then the cuttings were planted horizontally in nursery bed at a distance of 30 cm from one another. The cuttings were covered with a soil layer of 1-2 cm. Watering was done regularly up to last week of June 2003 during which cuttings developed into rooted plants. They were removed carefully from the bed on 30.06.2003, made into single nodal rooted plants and transplanted in the experimental field along with branch segment. The pit size was 45 cm × 30 cm × 30 cm.

The planting of all five types of planting materials was done on 30 June 2003. While planting, in each pit 5 kg FYM, 25 gram P (156 gram single super phosphate) and 20 gram phorate granules were added and mixed with pit soil.

During the period of study i.e. 1 July 2003 to 31 December 2006, the experimental plantation was properly managed. Weeding-culm-soil working, watering, and fertilizer application were carried out timely. Weeding-cum-soil working was done thrice during the first year, thrice during the second year, twice in the third year and once in the fourth year of the plantation. Watering was done by spot irrigation making 10 cm deep crowbar holes around the clumps during summer months such as February, March, April, May and June. The quantity of water provided to each clump on alternate days was approximately 4 litres in first summer, 8 litres in second summer and 12 litres in third summer excepting on rainy and cool days. NPK fertilizer was applied @ 50:25:25 gram in first year, 100:50:50 gram in second year, 150:75:75 gram in third year and 250:125:125 gram in fourth year per clump. The N was applied in the form of urea, P in the form of single super phosphate and K in the form of muriate of potash. The nitrogen fertilizer was applied in two splits. The total P, K and 50% N were applied at the beginning of monsoon and rest 50% N after one month of that. However, in first year total P was applied as basal at the time of planting, total K and 50% N in the first week of August and rest 50% N in the first week of September.

The performance of plants under different treatments was evaluated at the end of growth season in 1st, 2nd, 3rd and 4th year of the crop. In Orissa generally growth of bamboo plants in the year is ceased towards end of the December. Hence, observations were recorded in the last week of December. Observations were recorded on number of new culms recruited per clump, height of culm, DBH of culm and number of internodes of culm. The height, diameter and number of internodes were recorded for the three dominating culms of each clump and averaged.

RESULTS AND DISCUSSION

The relative efficacy of different types of planting materials of *B. vulgaris* such as rhizome, offset, rooted culm cutting, directly planted culm cutting and rooted culm-branch cutting in terms of growth performance of plants are depicted in Table 1-4.

NUMBER OF NEW CULMS RECRUITED

The number of new culms recruited varied significantly in 1st, 2nd, 3rd as well as in 4th year of the plantation under different types of planting materials (Table 1). In all the year, maximum number of new culms recruited was noticed in clumps raised by the offset whereas minimum by the rooted culm – branch cutting. The rooted culm cutting closely followed the offset. The maximum number of culms recruited during

Table 1: **Effect of type of planting materials of *B. vulgaris* on recruitment of new culms**

Type of planting materials	Number of new culms recruited per clump			
	1st year	2nd year	3rd year	4th year
Rhizome (T_1)	1.28	2.58	5.16	6.56
Offset (T_2)	1.75	3.55	7.10	8.08
Rooted culm cutting (T_3)	1.44	2.92	5.84	7.00
Directly planted culm cutting (T_4)	1.02	2.04	4.04	5.44
Rooted culm-branch cutting (T_5)	0.50	1.00	2.04	4.10
SE(m)±	0.05	0.08	0.18	0.35
$CD_{(0.05)}$	0.15	0.24	0.55	1.08

1st, 2nd, 3rd and 4th year were 1.75, 3.55, 7.10 and 8.08, respectively whereas the minimum number of culms recruited during that period were 0.50, 1.00 and 2.04, and 4.10, respectively. The performance of different types of planting materials with regard to new culm recruitment over the period of study was observed to be in the order of : $T_2 > T_3 > T_1 > T_4 > T_5$. However, towards 4th year the performance of offset and rooted culm cutting was statistically at par with each other.

HEIGHT OF CULM

A considerable variation was observed in height growth of culms under different types of planting materials (Table 2) from 1st year to 4th year of the plantation. In all years, offset put maximum height growth (3.62m, 5.42m, 7.28m and 9.11m in 1st, 2nd, 3rd and 4th year, respectively) whereas rooted culm-branch cutting put the minimum height growth. Every year the height growth under rhizome and directly planted culm cutting was statistically

Table 2. Effect of type of planting materials of *B. vulgaris* on height growth of culm

Type of planting materials	Height of culm (m)			
	1st year	2nd year	3rd year	4th year
Rhizome (T_1)	1.62	3.62	5.78	7.98
Offset (T_2)	3.62	5.42	7.28	9.11
Rooted culm cutting (T_3)	2.15	4.33	6.52	8.63
Directly planted culm cutting (T_4)	1.65	3.77	6.02	8.14
Rooted culm-branch cutting (T_5)	0.63	1.02	3.70	6.18
SE(m)±	0.06	0.12	0.20	0.25
$CD_{(0.05)}$	0.19	0.36	0.61	0.77

at par. Rooted culm cutting occupied the second position in height growth from 1st to 4th year. With increase in age the height under rooted culm cutting got closed to offset and in 4th year they were similar. In 3rd year and 4th year the height under T_4 was at par with T_3.

DBH OF CULM

The five types of planting materials exerted differential growth with regard to DBH of culm (Table 3) in all four years. However, the culms developed from rhizome and directly planted culm cuttings showed parity in all years. The highest collar diameter was

Table 3: **Effect of type of planting materials of *B. vulgaris* on DBH growth of culm.**

Type of planting materials	DBH of culm (cm)			
	1st year	2nd year	3rd year	4th year
Rhizome (T_1)	0.48	1.87	3.12	4.30
Offset (T_2)	2.44	3.30	4.20	5.12
Rooted culm cutting (T_3)	0.77	2.20	3.46	4.70
Directly planted culm cutting (T_4)	0.50	1.98	3.30	4.46
Rooted culm-branch cutting (T_5)	0.00	0.00	1.64	3.48
SE(m)±	0.03	0.07	0.11	0.14
$CD_{(0.05)}$	0.10	0.21	0.33	0.42

resulted from offset followed by rooted culm cutting and the lowest was obtained from rooted culm-branch cutting. Towards 4th year the DBH values of offset and rooted culm cutting were similar. The performance of T_4 was at par with T_3 in 3rd and 4th year. The highest DBH values recorded were 2.44, 3.30, 4.20 and 5.12 cm in 1st, 2nd, 3rd and 4th year of the crop, respectively.

NUMBER OF INTERNODES IN CULM

The data in Table 4 demonstrate an appreciable variation among different types of planting materials with regard to number of internodes in culm from 1st year to 4th year. Every year, the numbers of internodes were found to be maximum under offset (21.52, 29.00, 36.66 and 44.50 in 1st, 2nd, 3rd and 4th year, respectively) while it was found minimum in culms developed from rooted culm-branch cutting. However, parity was observed

Table 4: **Effect of type of planting materials of *B. vulgaris* on number of internodes of culm**

Type of planting materials	Number of internodes in culm			
	1st year	2nd year	3rd year	4th year
Rhizome (T_1)	12.00	20.02	28.86	38.92
Offset (T_2)	21.52	29.00	36.66	44.50
Rooted culm cutting (T_3)	16.32	23.97	32.56	42.13
Directly planted culm cutting (T_4)	12.50	20.88	30.06	39.72
Rooted culm-branch cutting (T_5)	5.20	7.60	20.08	32.87
SE(m)±	0.39	0.74	0.84	1.05
$CD_{(0.05)}$	1.20	2.28	2.58	3.23

between T_1 and T_4 in all years, between T_3 and T_4 in 3rd and 4th year and between T_2 and T_3 in 4th year. The rooted culm cutting followed closely to offset towards higher age of the clump and exhibited statistically similar number of internodes (42.13) in 4th year.

The perusal of the date in Table 1 – 4 reflect that the overall performance of different types of planting materials of *B.vulgaris* during the four years study period was in the order of : offset > rooted culm cutting > rhizomes > directly planted culm cutting > rooted culm-branch cutting. However, towards 4th year, the recruitment of new culms, height, diameter and number of internodes under offset and rooted culm cutting were statistically at par. The relative performance of different types of planting materials indicated significant differences among the treatments during all the years of investigation. Rooted branch-culm cutting performance was lowest in comparison to other treatments irrespective of year of investigation with regard to all growth and yield parameters. The performance of offsets was significantly higher over rest other treatments for all the years followed by rooted culm cutting, rhizome and directly planted culm cutting. However, the performance of rooted culm cutting was as par with offset during 4th year. The performance of plants raised by offset was carried out by Banik (1988), Azmi (2000) and Tewari (1992) in different species of bamboo. Enhanced growth and yield as observed in the present investigation is in agreement with the findings of Banik (1988) in *Bambusa vulgaris*. Rooted culm cutting was next to offset with regard to growth and yield parameters up to 3rd year beyond which both the rooted culm cutting and offset behaved similarly. Better performance of plants raised by culm cutting, either rooted or directly planted, has been reported by Seethalakshmi *et al*. (1988), Dong and Dong (2000) and Barnes *et al*. (1999). However, in the present investigation rooted culm cutting was found better than the directly planted culm cutting. Banik (1995) and Othman (1991) reported relative performance of branch cuttings and culm cuttings in different species of bamboo. The performance of rooted branch cutting as reported by above workers in the initial years is similar to the present investigation. Jagadamba (1948) has reported superiority of rhizome planting over transplanting of seedlings or direct sowing of seeds in *Dendrocalamus strictus*. In the present investigation rhizome was found better over directly planted culm cutting and rooted culm-branch cutting. Therefore, for large scale commercial cultivation of *B. vulgaris* rooted culm cuttings are more preferable in comparison to offsets and rhizomes because of easy availability, less cumbersome process, reduced cost and high success rate.

CONCLUSION

From the results of this investigation it is recommended that for large scale commercial cultivation of *Bambusa vulgaris,* rooted culm cutting should be preferred over offset, rhizome, directly planted culm cutting and rooted culm-branch cutting as the planting material.

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Forest Products: Management for Livelihood in India's Context

S.S. Negi *

INTRODUCTION

In India, forestry is the second largest land-use after agriculture covering about 641,130 square kilometers, or 22% of the total geographical area. Roughly 27% of the total population of India depends on forests for at least part of their subsistence and cash livelihoods, which they earn from fuel wood, fodder, poles, and a range of NTFP, such as fruits, flowers, and medicinal plants. About 50% of the 89 million tribal population of India, the most disadvantaged section of society, live in forest fringe areas, and they tend to have close cultural and economic links with the forest. The demand on forests by the India's teeming millions is becoming more diverse and is rising faster than the capacity of forests to meet the requirements on a sustainable basis. In addition to the demand for timber and non-timber forest products, India's forests are also providing environmental goods and services, ecological and food security. In India, about 100 million people are estimated to be forest dwellers and another 275 million live in the vicinity of the forests and derive their livelihood from the forest products. People living in and around forest areas are extremely poor and management of forest products for their livelihoods is thus vital.

Forest products play a vital role of eradicating poverty and hunger by improving food security and nutrition. Forests provide a wide range of the non–timber forest products for subsistence and also for sale in local markets. Collection and value addition of NTFPs generates employment leading to increased livelihoods. Development of small scale forest enterprises utilizing NTFPs have been an important component of rural development. The newly enacted Scheduled Tribes and Traditional Forest Dwellers Act, 2006 assigning ownership of NTFPs to the local communities for enhancing their livelihood opportunities and raise their income calls for effective management of timber NTFP management in forest areas.

DRIVERS OF CHANGE

Many different factors have an impact on forest products management for livelihood in India's context.

Population Pressure: The rising population is set to put additional pressure on agricultural and forest products. Societal needs are bound to grow. The growth of agricultural products will be limited and may reach a plateau in the near future. Forest being the second largest land use will have to play dual role – environment protection and provider of products for livelihood support.

Poverty: Forests, forestry and forest product management has a major role to play in providing not only in subsistence but have to provide the poor with long term income sources on a sustained basis. There are potentials to link forest products with livelihoods. Poverty alleviation would thus be a major factor affecting forest product management for livelihoods.

Development: Marginal poor people are the victims of development. Any development in the areas which provides forest products based livelihood support to poorest of the poor marginalizes them further by eroding the basis of income generation. These drivers of development may be big dams, mining operations, degradation of forests and setting up of industries. Protection of the livelihood of the poor, from the social and environmental consequences of an industry that operates largely outside the regulatory system is a must

LIVELIHOOD SUPPORT SYSTEMS AND OPPORTUNITIES

The forest product based livelihood support systems and the opportunities available have been discussed in the following text.

Timber from Forest: Forest products industry in India is growing at 5-6% with contribution of 17-20% from panel industry (Pandey et al. 2011). Growth in this construction sector is at any all time high. There is every possibility of increasing direct and indirect livelihood through forest products management. India's import of wood logs and wood products in rupees terms have increased from 4238.49 crores in 2005-06 to Rs. 8127.59 crores in 2009-10 (Muthoo 2006). The present requirement of wood in India is about 29 million cubic meters, where as the estimated production is about 16 million cubic meter only. A study conducted by Zhang et al (1997) indicates that present industrial round word consumption in India at 28m^3per 1000 persons is much below the world average of 290m^3per 1000 persons. As the economy grows, the need for timber would grow, thus increasing the livelihood options directly or indirectly.

Trees outside Forest: At present, about 80% of timber production for the forest based industry comes from trees outside forests (including imported timber). Growing of trees outside

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forest needs to be developed on scientific lines to generate additional incomes for the farmers and other stakeholders. For the pulp and paper industry liaison between industries and farmers to be encouraged in such a manner that all their demands are met from trees outside forest. For meeting the growing needs of saw milling, plywood and other industries government degraded forests need to be regenerated and planted with participation of local communities and support for the industry.

Agro and forest based residues: According to one estimate the availability of agro and forest residues (rice, straw, wheat straw, rice husk, coconut husk, cotton husk, bagasse, pine needles, non-edible grasses) stand at 332.1 million tonnes/annum (Pandey et al., 2011). Additionally weeds like lantana and others which are affecting forest growth are available for exploitation. Proper policy frame work to convert these opportunities into sustained income generation activity will be of immense help. Full utilisation of this sustained resource into panel products, paper and other value added products will always be economical and income generating activities

Bamboo for generation of livelihoods: There is huge potential to increase bamboo production from plantations as bamboos support the livelihood of millions of people.

Value of NTFPs from Forests: It was estimated (Chopra and Dasgupta 1993) that in a Tropical deciduous forest in India, the total present value of NTFPs and services available from one hectare area varied from US$4034 to US$6662 and of it, the NTFP use value was about 45%. People living in and around the forest traditionally collect these NTFPs. Therefore, careful management of NTFPs by studying the availability, seasonality traditional use, method of collection, harvesting and post harvesting techniques and marketing are important.

Processing and Value Additions: Production and collection of raw material is not enough for enhancing livelihoods from NTFPs. Efforts need to be made to retain the benefits of downstream processing and value addition (Ball et al. 2005) for the benefits of the poor. Skill upgradation and facilities for downstream processing of the raw material to harness 100% benefits is required. Technology development for low volume operations fetching competitive prices compared to high volume operations is needed.

Market Information System: Informed market choices to maximize returns have to be incorporated in village and forest fringe areas development programmes. JFM and other such activities need to diversify to maximize their income. A market information system based on a national network needs to be developed for increasing returns to the poor.

APPROACHES

Assessment of livelihood opportunities from Forest and forest products based operations: There is few studies available on livelihood opportunities from forestry based operations. For example logging is regular operation in forests but it is difficult to say how many man-hours will be created in harvesting one cubic meter of timber leaving apart transportation and marketing. The forestry sector like agricultural sector should have complete data on its operations.

Kothiyal and Kumar (2006) attempted to estimate the jobs opportunities created by downstream processing of round wood timber logs once they reach the saw mill. The study included only solid wood operations such as sawing, seasoning, preservation and wood working and plywood manufacture. They estimated that a total of 12.5 lakh jobs for 292 days in a year are available if proper planning is done. This estimate did not include logging and transportation to the saw mill. It also excluded jobs created by painting and finishing and owners of saw mills and other units. It was assumed that only 50% of the material will require preservation treatment. The other assumption made was that all processing units are integrated and transportation between different processing units is limited. Jobs created in marketing of the products are also excluded. The figure of the job opportunities would have been higher considering that 25% jobs have already been lost to plastics. Seasoning and preservation is not actively followed and therefore of the 12.5 lakh jobs, 18700 jobs are lost annually. Considering that seasoning and preservation are important for carbon sequestration in wood products (Gundimeda 2001) for longer time, the losses in environmental terms are much more. Assuming that supply of timber meets the demand, the jobs available will be much more not only in solid wood processing but also in plantation program to sustain the demand. Modified chain saw method (Anon. 2006) can be adopted in villages where volume of timber is low.

This is one such example where forest based industry can provide additional livelihood opportunities. The need is to make an assessment and quantify the opportunities available. There are number of operation which can be shifted to village and fringe areas

Value addition and processing of NTFPs: Value addition and processing of most of the Non-Nationalized NTFPs is nearly absent and therefore, the quality and value cannot be enhanced. For example, the ideal time for processing sal seeds is within 72 hours to maintain a low free fatty acid level; however, normally the process of procurement and processing take much longer time. To save time and in a hurry to earn for livelihood, forest products like sal seeds after collection are dried on the ground and then set on fire to burn down the seed wings. This method leads to deterioration of seed quality but a collector friendly de-winging facility is yet to reach them. Most of the NTFPs are sold raw, prompting the traders to exploit the collectors by fixing purchase price arbitrarily. This all happens in the light of NTFPs which give much greater revenue to the state than timber.

NTFPs are perishable items and require immediate value addition and treatment. In India , village level infrastructure for storage facility and value addition of NTFPs is still very poor or even nonexistent, moreover, the skill for value addition among the collators is lacking which results in inferior quality of products and lower price to collectors (Bhattacharya & Hayat 2004). Addressing such needs will improve their livelihoods and income.

Marketing and collection of NTFPs: NTFP management in the present times is not well developed in India. Collectors of NTFPs are mostly unorganized thus, weakening their bargaining power in the market. Income accrued from NTFP collection is often non-remunerative at times even not enough to realize their minimum daily wage. A study by Regional Centre for Development Co-operation, Bhubaneswar reports that one person in an 8 hour working day could collect around 8-10 kg of sal (*Shorea robusta*) seeds selling of which fetches them only about 50 rupees a day. This meager amount could have been made profitable by value adding the seeds, but such technologies must first reach the collectors.

The primary collectors are forced to take up unsustainable exploitation to enhance their income. Further, due to the poverty, the collectors may have to obtain advance money before the collection season to meet their family and subsistence needs, which during the season had to be paid in terms of NTFPs at a price much lower than the prevailing market price. Intervention which will remove such trends is required at the grass-root levels.

Micro financing: Micro financing is an important approach for NWFP management in rural areas. There is need to provide financial support during the lean income season to those whose livelihood depends on NTFPs. This will prevent distress selling and help in subsistence requirements of the forest dependent communities. Micro credit can be made more effective through Self Help Groups (SHGs). These SHGs may be trained on simple value addition techniques starting from harvesting, cleaning, grading and drying and also in marketing strategies.

Local forest-based enterprises: The development of local forest-based enterprises represents an opportunity for strengthening the livelihoods of the poor and forest-dependent communities and also providing them with an economic incentive to conserve forests through sustainable management. Governmental efforts should provide the right policy environment so that raw material production and its processing become a viable alternative. Storage, drying and processing facilities for NTFPs can provide higher returns. Solar seasoning kiln developed by FRI for drying of timber was also set up (Pandey et al. 1986) at two places (Anjul (Orissa) and Jabalpur) in the country for drying of bedi and tendu leaves. A unit has also been set up in Uttarakhand for drying of NTFPs, especially medicinal plants.

A study was conducted by Uma Nanduri and Jha (2006) in Orissa Athamallik Forest Division and found mahua flowers being used as a barter. A tin full of flowers weighing about 8-9 kgs were bartered for 2 kgs of salt and 1 kg of rice or potatoes. The value of mahua flowers with this bartering is about 3 rupees per kg only. In this way, the primary collectors are exploited in the absence of processing facilities at the local level. Making available the drying facilities in the remote villages will therefore increase the income levels of the collectors.

There are a number of NTFPs in the villages where solar drying will be effective. Most of the houses in the villages and fringe areas are made of thatch and bamboo. This requires frequent replacement costing money to marginalised people. Treatment with chemicals by simple process is easily adoptable in villages which can increase the service life to 25-30 years.

Efforts to shift some of the operations to village and fringe areas: There are many operations which can be shifted and integrated with village communities for cost and livelihood benefits. A process for skill upgradation and technology development is required. JFM, CAMPA and programmes like NREGA can provide hand holding mechanisms to the poorest of the poor. Timely skill upgradation will also help in improving the product quality.

EXAMPLES OF SOME FOREST PRODUCTS BASED LIVELIHOOD OPPORTUNITIES

Fiber in and around villages: Huge quantities of different types of fibers are available in and around villages. Among fibers, sisal, rhemi and nettles available in the forest areas have great commercial value. Making use of the traditional knowledge blended with the modern technology for fiber extraction and value addition and making it into exportable products have great potential for livelihood support, and raising the living standard of the rural people. The traditional method of retting the plants in the running water is not sustainable and therefore, scientific retting in stored water needs to be developed and passed on to the traditional fiber stakeholders. Long, flexible and strong fibers are used for making textiles, fabrics, cordages, ropes and netting. Coarse fibers are also for straw hats, mats, baskets, chair seats, etc. Over 80 species of fiber yielding and more than 10 floss yielding plants are available for development and commercialization.

Natural dyes: Natural dyes making from forest plants and agro-forest waste are some examples. Over 110 plants in the country yield natural organic colouring materials. There is considerable demand for organic colouring materials in dyeing industry. Natural dyes are utilized in textile industry, colouring paints, varnishes, leather, inks, papers, wool, medicine and also foods. Natural dye bearing plants like *Bixa orellana* which yield 'annatto' dye have great commercial value in colouring butter, cheese, margarine and other food stuffs.

Agarbatti making technique: Simple agarbatti making techniques are available. Maida lakri (*Litsaea glutinosa*) is exploited extensively in the forest areas for its bark. The bark is used mainly as a binder component in agarbatti making. The demand is huge in the country and therefore, the resource dwindles over the years. The trees have good coppicing ability and therefore, continue to grow but production diminishes in the absence of sustainable harvesting. Such knowledge need to be imparted for adoption by the collectors.

Hill brooms: Hill brooms (*Thysanolaena maxima*) are a household item of most families. The demand for it is constant and will further increase with the rise in population. Children and women have a major role in broom processing. During January month, the tender inflorescences are collected and value added. The plant is able to grow even in shallow and less fertile rocky areas can be effectively planted and harvested to benefit the forest dependants for their livelihood and income.

Basket and mat making: Basket making and mat weaving is common practice for village folks. Few attempts have been made to upgrade the product. Slivers of bamboo used for basket (Singh et al. 2005) and mat making can be treated with using stains from natural sources and improving the product quality. Cluster processing in bamboo (Singh et al. 2005) can also help in reducing drying degrades. All over the country bamboo artisans collect green bamboos almost the entire year. A case study at Athamallik Forest Division of Orissa was conducted among Ghasi, Betra and Dama castes. The villagers collect bamboos and are value added in the form of baskets, hand fans, hats, changudi, etc. The monthly income of an artisan family on an average was about Rs. 2000 and they get their livelihood support from bamboo works for almost 6 months in a year. Bamboo artisans require green bamboos throughout the year. The existing working plans which prescribe bamboo collection or harvesting on maturity of the culms. However, since the local artisans need green bamboos suitable amendments need to be made.

Medicinal and aromatic oils: Medicinal and aromatic oils have a wide potential for providing livelihood and income. Collectors' friendly oil extractors are available. The linaloe yielding forest plant *Bursera penicillata* for example, has a great future in perfume industry. It can be successfully cultivated in low rainfall and even in denuded and eroded areas. The oils of the perennial grasses *Cymbopogons* continue to be imported though we can grow extensively in the country. *Eucalyptus citrodora*, *Junipers* etc. too have good market demand. *Pinus roxburghii* yielding turpentine, *Santalum album* yielding sandalwood oil, *Aquillaria agallocha* yielding agar wood oil are of forest origin which brings much gains to the collectors as well as the states where they grow. About 60 important plant species yielding aromatic oils are recorded in the country.

Gums: Forest Research Institute has developed technology for value adding gums. Gums are used in many ways. In confectionary sweet-meat syrup, in whitewashing walls, water colours, medicine, face, powder, in soaps, hair curling powders lubricants, etc. There are over 40 important gum yielding plants available for plantations in suitable areas.

Resins and oleoresins: They are used in medicines, varnishes, paints, sizing paper and polishes, etc. Resin tapping methods have been perfected which need to be disseminated to the uneducated primary collectors. There are over 30 resins and oleoresin bearing plants suitable for enriching forest areas for tapping to support livelihood and income.

Utilization of lantana: Utilization of lantana for panel board making (Singh et al. 2001) and using it to produce high value furniture is also an alternative for enhancing livelihood support and income.

Charcoal and briquettes making are other examples of providing livelihood through forest products. Technology for converting pine needle into fuel briquette is available and there is no dearth of pine needles in the Himalayan region for such activity.

Handmade paper and paper industry: Handmade paper is one other activity which can be easily shifted to villages. Over 70 important plant species which can be used for paper and pulp are available in the country.

According to some forecasts, India's consumption of paper and board would increase to 20 million tonnes in 2030. Presently the paper industry consumes about eight millions tones of wood and by 2010 requirement would be of 9 million tonnes. The forecasted percentage of annual growth rate of paper consumption during decade (2010-2020) would be around 8% probably the highest in the world (Gopalratnam, 2007). The main challenges of the industry have been the availability of raw materials, energy, water and environment. Globally planted forests contribute almost 50% of total wood production. Of the planted forests in India, 56% are for productive purposes and the rest for protective purpose. China and India occupy the top positions in the world with largest area of planted forest for fulfilling the demand and increasing livelihood opportunities. Even planted forests raised under JFM could meet the requirements of the paper and pulp industry. There are about 660 pulp and paper mills in the country of which only 26 mills are wood and bamboo based and the rest are recycled-fibre-based (Toland, 2006).

Livelihood opportunities from timber and agro based residues: There are about 128 large industries registered with Director General of Technical Development (DGTD) in 35 different types of wood (http://www.worldpanelindustry.com) and agro based panel products out of a total of 40. This figure is much less compared to China (472 in 39 types of panel products out of 40) and USA (448 in 32 types of panel products out of 40)

Most of the timber based industries in India are in small and medium scale sector. The country has about 23,000 sawmills, more than 450 plywood units at Yamnanagar. Likewise barring few (paper, newsprint, railways, particle board, MDF board) industries most of them (paper and paper board, construction, furniture, packing, agricultural implements, sports goods, handicrafts, veneer, match box, and mining) are in the small and medium scale sector. Although large in number, their scale of operation is not allowing them to develop and enlarge. Many of them are not operating to their full capacity due to power and raw material shortages. Due to scale of operations skill upgradation and technological adoption is not taking place resulting low value products from high value raw material. This is also not making it possible to fully exploit the livelihood opportunities these can generate.

DAIPER technology developed by FRI using waste pieces of different timber species having different colours can be used to develop table top having substantial potential for market acceptability. The technology can be easily adopted at village level with small training. Rajput (2005) lists number of items like furniture, door and window, tool handles, agricultural implements, packing cases, match splints, turnery, carving and variety of handicraft items that can be produced with plantation timbers. Udya et al (2005) illustrates how finger jointed timber can be produced from plantation species using indigenous machines

ISSUES REQUIRED TO ADDRESSED

- Recognition of the fact that forest, forestry and forest products has to play a major role in livelihood generation. Forest products industry growth therefore needs to be sustained. Forest policy to be framed with societal inclusion in view and aiming at increasing the forest cover to $1/3^{rd}$ and providing livelihood support to 27% poor in India.
- Realizing the fact that forestry is the second largest land-use after agriculture.
- Policy for regeneration of degraded forest areas with livelihood opportunities
- Assessment of livelihood opportunities from Forest and forest products based operations
- For the development of wood based industry timber from forest and Trees Outside Forest to be sustained
- Agro and forest based residues to be recognized as potential raw material resource
- Bamboo for generation of livelihood
- Value of NTFP in forests of India to be assessed and policy for its growth in forest area to be framed
- Processing and value additions to be the key areas to be

addressed through JFM, CAMPA and NREGS programmes. Efforts to shift some of the operations to village and fringe areas to increase employment opportunities.

- Market Information System to be developed for better return from the products. Marketing and collection of NTFP to be organized.
- Social inclusion for livelihood and good health of forest
- Development of local forest-based enterprises
- India forest based industries are large in number although volume of operations is small. Recognizing this as strength and for livelihood opportunities.

CONCLUSION

Though the resources are plenty, without extensive extension of the available knowledge to the rural stakeholders, the situation will remain the same or even go worse. Without replenishment and enrichment in forest areas, the NTFP bearing plants will be depleted in due course of *time.* The fate of an important plant like *Rauvolfia serpentina* used to treat hypertension was overexploited in the past since the market demand was met only from natural resources without replenishing the forest areas where it is grown. Therefore due to its depletion there is shortages of this drug bearing plant necessitating import from other countries.

The degraded forest must be enriched with the local NWFP bearing species. Forest division must be the basic unit for such planning. Every range must be surveyed and NTFP availability bearing plants must be planted in all the available gap areas as gap planting. Each range must have a specialized forest product unit, equipped with available technology, value addition and marketing facilities.

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