

4. Forests and Climate Change

Climate change has multi-faceted implications and therefore, in order to address the related aspects a good scientific understanding of issues is required for maintaining the flow of goods and services from existing forests, both at the national as well as the global level. ICFRE is working on climate change related research and policy issues leading to international negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) and also various research projects at ICFRE institutes. A brief account of activities on forests and climate change has been given below.

Satellite based assessment of fire severity and its validation in Uttarakhand

Maps containing information on forest fire incidences in Uttarakhand state from 2001 to 2012 were prepared in GIS environment and data analyzed to get information on occurrence of forest fire at different forest administrative units i.e. state, forest circle, forest division, forest range and forest compartment on monthly and annual basis and also cumulative basis. The information on forest fire, in the form of maps and tables, was also compiled for different forest density classes, slope classes, aspects, altitudes and climatic zones. The study concluded in June 2013.



OTC's facility developed at FRI, Dehradun

Carbon, energy and water dynamics in Himalayan Chir pine forest

Six units of Open Top Chamber (OTCs) were installed at Forest Research Institute, Dehradun under ICFRE funded project "AICP on Elevated CO₂"

'Effect of elevated CO₂ on active principles of important medicinal plants'

Seedlings of *Andrographis paniculata*, *Adathoda vasica*, *Phyllanthus amarus* and *Gymnema sylvestre* were kept under different elevated CO₂ levels at nursery stage. Periodical data on growth, total plant fresh and dry weight, root shoot ratio, number of leaves, primary and secondary roots, etc, were taken. Observations on physiological parameters were recorded from different treatments. Medicinal plants parts were dried for alkaloids estimation. In all the medicinal plants, the elevated CO₂ levels, production of biomass, bio-chemicals (including total protein, tannin, etc.) were higher.

Assessment of soil organic carbon under different land uses in Tamil Nadu

Extensive survey was undertaken in Virudhunagar, Madurai, Tirunelveli and Tuticorin districts, covering the Southern agro-climatic zone of Tamil Nadu. Soil samples (180 nos.) belonging to Padarnthapuli, Nanguneri, Vayalagam and Mayamankurichi soil series were collected from various land uses viz., agriculture (sugarcane, maize, groundnut, cotton) agro-forestry (teak + coconut, teak + maize, ailanthus + maize, neem + sorghum, neem + fodder sorghum, teak + banana) and plantation (teak, *Casuarina*, neem, bamboo, eucalypts, *Melia*) for estimation of carbon stock. Soil samples were collected from three plots and at four depths viz., 0-30, 30-50, 50-80 and 80-100 cm. The per cent of coarse fragments (>2 mm size) was calculated for each layer based on visual observation of the area occupied by coarse fragments. The samples were

fractionated into three aggregate size classes viz., macroaggregates (250-2000 μ m), microaggregates (53-250 μ m) and silt and clay sized fractions (<53 μ m). The carbon was estimated in the soil samples.

Response of mycorrhizae and microbial symbionts to elevated CO₂ in commercially important tree species

Rhizosphere soils samples of selected tree species were collected, *Rhizobium*, *Azospirillum* AM fungi, Phosphobacteria isolates were multiplied and maintained in laboratory. VAM fungi, *Glomus geosporum*, *G. viscosa* and other microbial symbionts such as *Rhizobium* and *Frankia* were cultured and maintained in the laboratory. Nursery raised *Acacia auriculiformis*, *Melia dubia*, *Casuarina equisetifolia*, *C. junghuhniana*, *Eucalyptus camaldulensis* and *Neolamarkia cadamba* were inoculated with microbial symbionts such as AM fungi, *Rhizobium* and *Frankia* individually and in combinations. The seedlings were treated with 600ppm CO₂. After 15 days of incubation, it was found that the seedlings exhibit improved growth and stem girth as compared to those in uninoculated control ones during the same period. The rooted stem cuttings of *Acacia auriculiformis* inoculated with *Rhizobium* showed early nodulation at 600ppm CO₂. This is a new finding in the rooted stem cuttings of *A. auriculiformis*. The growth and biomass of *A. aruriculiformis* was also found improved. The seedlings placed in 600 ppm CO₂ chamber have shown improvement in growth and biomass, due to the inoculation of mycorrhizas and other microbial symbionts. The seedlings of *C. equisetifolia* and *C. junghuhniana* showed more number of nodules, inoculated with *Frankia* under 600 ppm of elevated CO₂. The seedlings of *Melia dubia* and *Neolamarkia cadamba*, inoculated with AM fungi showed increased height, stem girth and biomass as compared to the control seedlings under elevated CO₂. *Azospirillum* and *Bacillus* sp (PSB) found more effective in the seedlings of *Ailanthus excelsa*, *Neolamarkia cadamba* and *Gmelina arborea*. The growth and biomass was 2 times

higher than in the control seedlings. Higher photosynthetic rates were also obtained under 600 ppm conditions as compared to uninoculated controls.

Soil, Vegetation – atmosphere carbon fluxes measurement and modeling (SVF) project

ICFRE is collaborating with the Indian Institute of Remote Sensing (IIRS) for its National Carbon Project (NCP) under Geosphere Biosphere Programme (GBP) of the ISRO to estimate the carbon pools and fluxes in different terrestrial ecosystems of India. In Betul (teak forest), data from the flux tower site is being recorded by IIRS. Forest inventory and soil physico-chemical properties like soil moisture (%), soil carbon(%), EC, pH, N, P and K were analysed from the tower site by TFRI. Studies on litter production and its decomposition were also conducted. Phyto-sociological studies and forest floor biomass (herbs and shrubs) accomplished. Leaf Area Index (LAI) and phenology of 10 major species were recorded.



Collection of herb shrub biomass, litter collection and litter decomposition bag



Measurement of LAI using ceptometer LP-80

Utilization of Automatic Weather Station (AWS)/Agrometeorological station (AMS) data for agriculture, forestry and hydrological applications in Madhya Pradesh

This is a multi-institutional project coordinated by Space Application Centre of ISRO, Ahmedabad, with the objective to quantify energy and carbon exchange using field measurement and remote sensing data in different ecosystems of Madhya Pradesh.

In the 1st phase of the project, allometric regression equations were developed for quantification of carbon in *Shorea robusta*. Data collected on seasonal variation in grass biomass, soil moisture profile, Specific Leaf Area (SLA) and Leaf Area Index (LAI) from selected sites near AWS and AMS in Kanha, Bandhavgarh and Madhav National Parks of M.P.

In the 2nd phase, 11 quadrats of 0.1 ha size each were laid out in Pench, Panna and Satpuda Tiger Reserves of Madhya Pradesh on the basis of floral diversity and canopy density. Regularly collected tree growth data and observed seasonal variation in herbaceous and litter biomass and soil moisture profile. Average GBH of the trees in Panna Tiger Reserve was found to be 64.2 cm, whereas average height was 14.1 m. *Tectona grandis*, *Acacia catechu*, *Anogeissus pendula*, *Chloroxylon swietenia*, *Zizyphus xylopyrus* and *Boswellia serrata* were main tree species recorded. In Pench Tiger Reserve average GBH was found to be 66.8 cm, whereas average height was 17.3 m. *Tectona grandis*, *Pterocarpus marsupium*, *Buchanania lanzan*, *Syzygium cumini*, *Zizyphus xylopyrus* and *Chloroxylon swietenia* were the abundantly available tree species. In Satpuda Tiger Reserve, average GBH of trees was found to be 69.4 cm, whereas average height was to be 13.9 m. *Shorea robusta*, *Soymida febrifuga*, *Diospyros melanoxylon*, *Emblica officinalis*, *Hardwickia binata*, *Saccopetalum tomentosum*, *Chloroxylon swietenia* and *Gardenia latifolia* were the main trees species of Satpuda Tiger Reserve.



Collecting litter in Satpuda Tiger Reserve



Kardhai forest in Panna Tiger Reserve

Carbon sequestration through afforestation at Rourkela Steel Plant (RSP), Odisha

Study sites in and around Rourkela Steel Plant (RSP), Odisha were selected for vegetation survey and quantification of carbon in vegetation,



Conducting vegetation survey at Rourkela Steel Plant (Odisha)



Conducting soil profile study at Rourkela Steel Plant (Odisha)

litter and soil. Quantification of vegetation, regeneration status of trees and estimation of litter and dead wood and soil profile studies were conducted. Atmospheric concentration of CO₂ at 15 sampling locations in and around RSP was monitored in the first season of the first year.

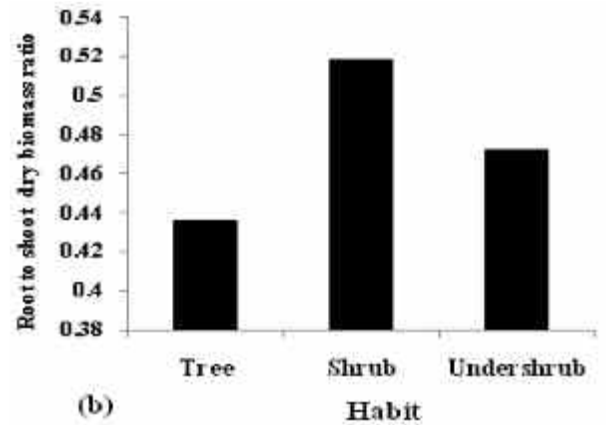
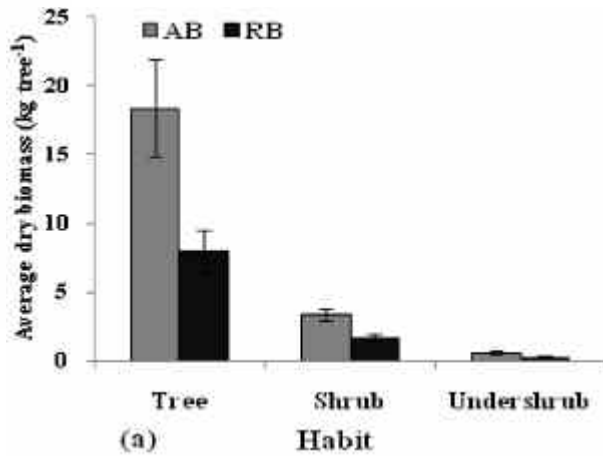
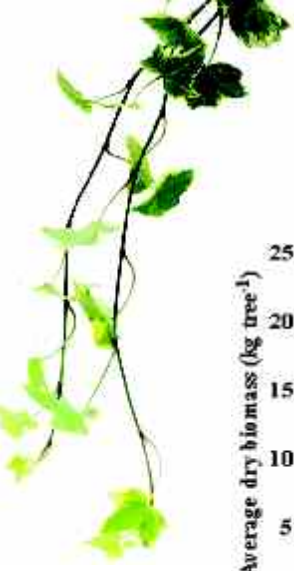
Studies on soil profile attributes under forest and Jhum land areas of some selected sites of Nagaland state

Soil profile attributes in three land use types i.e., jhum land, tea garden and forest areas of Nagaland state were studied. Under jhum land and tea garden, soil pH increases down the profile whereas under forest area soil pH decreases down the profile. Water soluble salt content in soil found decreasing down the profile from surface horizon under all the three types of land uses. Organic carbon content in soil showed increasing trend down the profile from surface horizon under all the three land uses. Available nitrogen content of soil found high in the surface soil and decreased down the profile under all the three types of land uses. Soils were sandy clay loam to clay loam in texture under forest land, jhum land and tea garden areas. Leaching of clay, due to the presence of clay films, down the profile was found in some profiles due to higher amount of clay content in sub-soil horizons. Soils were found heavy textured, bulk density in the range of 0.80 - 1.18 g/cc. Bulk density of soil increased down the profile under all three types of land uses.

Studies on carbon sequestration in different forest types of Rajasthan

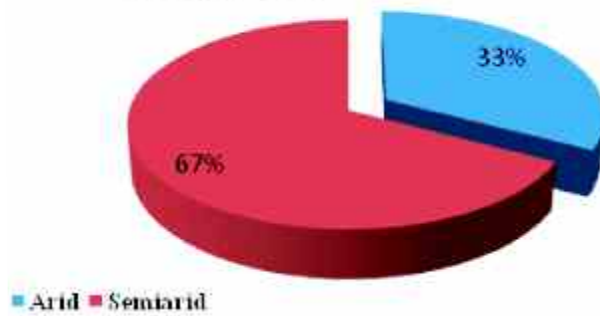
Project was started with objectives to estimate carbon stock in forest soils, forest litters, and in above ground and below ground biomass, with overall objective 'to provide an estimate of carbon stock in the forests of Rajasthan for its utilization in planning and execution of afforestation programmes. During the year 2013-14, data on dominant vegetation (trees/shrubs) in 903 forest blocks of all thirty three districts of Rajasthan were analysed and importance value index (IVI), diversity and carbon stock in soil (soil organic and soil inorganic carbon), dead material (litters and coarse woody debris), herbaceous biomass and live biomass (both above ground and belowground) of trees, shrubs, Euphorbias, bamboo and tree saplings estimated. There are 31 sub types of forests including plantation and types of *Prosopis juliflora* and *Mangifera indica* categorised in this study, though, some pure patches of *Madhuca indica*, *Diospyros melanoxylon* and *Anogeissus latifolia* have also been observed. Combined regression equations were developed to assess the standing dry biomasses (above ground and belowground) of shrubs, undershrubs, Euphorbias, trees and tree saplings and applied in biomass and carbon stock calculation. Overall ratios of average root biomass to above-ground dry biomasses are 0.518 for shrubs, 0.478 for under shrubs and 0.436 for trees.

Study also revealed that average carbon densities of soil organic and inorganic carbon were 35.61 tonnes ha⁻¹ and 43.26 tonnes ha⁻¹ respectively for top 100 cm soil depth in Rajasthan forest (after gravel correction). Total soil organic and inorganic carbon stored in top 100 cm soil layer were 121.61 million tonnes and 142.62 million tonnes, respectively. Total carbon stored in dead plant material was 1.24 million tonnes and that of herbaceous biomass was 0.77 million tonnes. Distribution of forest area, soil organic carbon, soil inorganic carbon and total carbon in top 1 m soil layer indicated greater forest area, organic carbon and total carbon stored in semi-arid region, whereas soil inorganic carbon storage is highest in arid region.

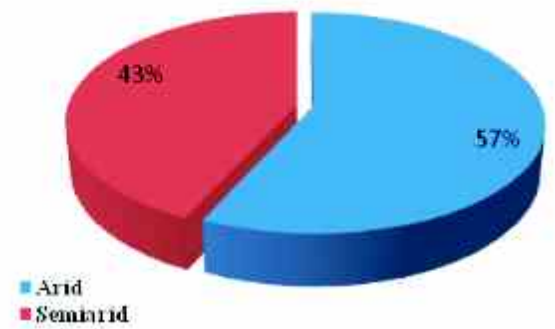


Average above ground (a) and root (b) dry biomasses of the harvested trees, shrubs and undershrubs (left) across the species, and RB to AB ratios under different plant habits (right).

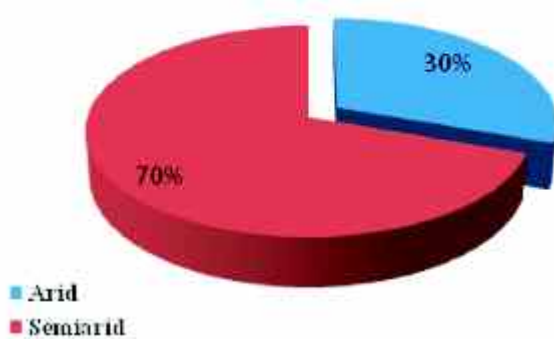
(b) Distribution of organic carbon in bioclimatic zone



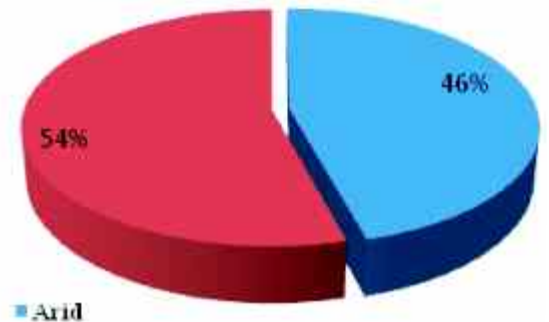
(c) Distribution of total inorganic carbon in bioclimatic zone



(a) Forest area (ha)



(d) Distribution of total soil carbon in bioclimatic zone



Distribution of organic (SOC) and inorganic carbon (SIC) stored in 100 cm soil layer in arid, semiarid and state as total depending in relation to forest area in the respective bioclimatic region

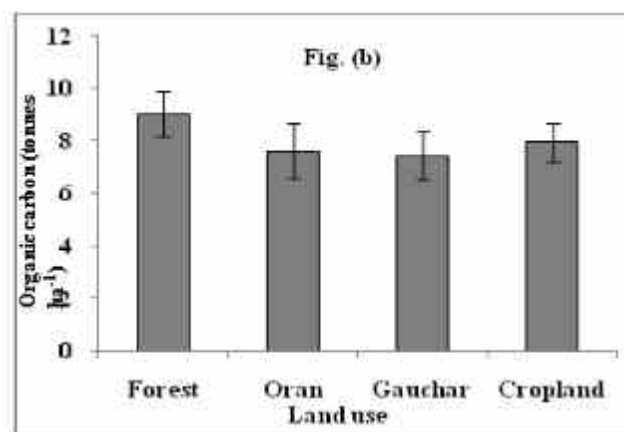
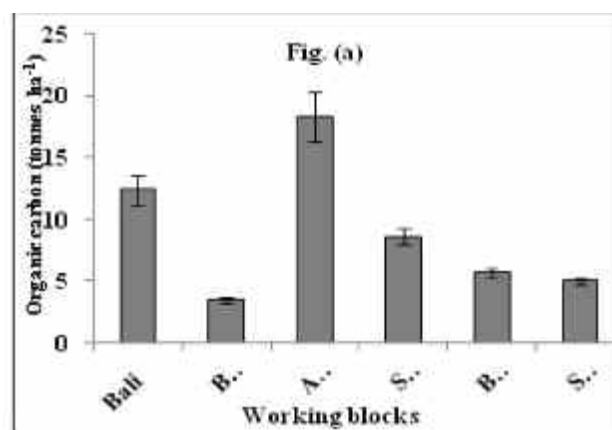
Carbon stock and soil classification mapping for Rajasthan forests

A GIS laboratory has already been established in the AFRI, Jodhpur equipped with Work Stations and facilities of like plotter and printer. Integrated GIS software was also procured having the capabilities of spatial analysis, image processing, RADAR analysis, hyper spectral analysis, photogrammetry, network analysis, GIS modeling, surface analysis, watershed modeling and atlas creation, publishing geo-referenced image/map in printable format and also in a format easily readable in the systems not having GIS software. Forest type maps of Rajasthan and Gujarat developed by the Forest Survey of India (FSI) were procured for base map. Data of soil physical and chemical parameters and site characteristics were compiled and entered for eight districts. District maps have been delineated for working on GIS.

Studies on the effects of MPOWER programme on mitigation and adaptation towards climate change in western Rajasthan

Mitigating poverty in Western Rajasthan (MPOWER) project is under implementation in six blocks, one each in Jaisalmer, Barmer, Jodhpur, Pali, Jalore and Sirohi districts of western Rajasthan for mitigating poverty of the target groups (households) through strengthened capacity, improved livelihood, sustainable enterprises, natural resources management and increased access to credit and markets. To monitor the impact of the project together with the changes in carbon stock (if any), adaptation strategies among the people in implementation area of this project was taken up. The basic objectives of the projects were (i) to identify best practice in terms of enhanced livelihood and adaptations among the villagers of the selected villages in western Rajasthan; (ii) to identify best practice supporting mitigation (i.e., carbon sequestration in soil) option of climate change in these villages and (iii) to document and suggest best practices of MPOWER in terms of climate change mitigation and adaptation for its further replication in large scale.

Field survey and data were collected from 102 selected villages. Questionnaire related to village profile data, socio-economic and people perception about climate change and adaptation were developed. Soil samples in 0-30 cm soil layer were collected for organic carbon, bulk density and gravel content estimation. Data analysis indicated that gravel content, soil carbon concentration and soil carbon density varied significantly ($P < 0.01$) between different working blocks. Variations in these soil variables did not differ among the land uses; Duncan Multiple Range test indicated that gravel content was significantly greater in forests and sacred grove area as compared to gauchar and agriculture lands. Soil carbon concentration was highest ($P < 0.05$) in forest lands (0.35%) and lowest in gauchar lands (0.21%). Soil carbon density was lowest (3.49 tonnes ha^{-1}) in Baitu (Barmer) and highest (18.32 tonnes ha^{-1}) in Abu-road area of Sirohi district.



Effects of site conditions and land use on soil organic carbon density

Assessment of carbon stock in forest types of Shimla Forest Circle, Himachal Pradesh

Studies continued in the already identified sites comprising of chir pine (*Pinus roxburghii*) forest, ban oak (*Quercus leucotrichophora*), deodar (*Cedrus deodara*), silver fir (*Abies pindrow*), spruce (*Picea smithiana*), kharsu oak (*Quercus semecarpifolia*) forest and alpine pasture in Shimla circle. Field studies were conducted for *Pinus roxburghii* forest at Dhama and Guma; for *Quercus leucotrichophora* forest at Taradevi and Koti; for *Cedrus deodara* forest at Koti; for *Abies pindrow*, *Picea smithiana*, *Quercus semecarpifolia* and *Betula utilis* forest at Larot (Rohru Forest Division). All the trees falling in the study plot (size 0.1 ha) were enumerated for height, diameter for biomass estimation.



Betula utilis



Rhododendron campanulatum

The biomass of under-storey (shrubs and herbs) was determined by destructive sampling by following standard methodology. Soil samples were collected from three depths for the estimation of organic carbon. The specific gravity of wood samples of chir pine, ban oak and deodar was 0.57-0.72, 0.70-0.90 and 0.77-0.84 respectively. The carbon content of plant samples of chir pine, ban oak and deodar varied from 52-56 per cent. The values for bulk density of soil



Fir & Spruce forest at Larot, Rohru Forest Division

collected from chir pine, ban oak and deodar varied from 0.92-1.28 g/cu cm. Soil organic carbon of chir pine, ban oak and deodar was 0.98-2.92, 1.22-3.90 and 1.90-2.78 per cent respectively. In chir pine forest, carbon stock in litter varied from 1.198 t/ha to 1.235 t/ha whereas, in ban oak forest it varied from 1.35 t/ha to 1.40 t/ha. Soil carbon pool in chir pine forest varied from 53.16 t/ha to 57.54 t/ha whereas, in ban oak forest it varied from 70.99 t/ha to 74.75 t/ha. Specific gravity of wood samples of spruce, betula, fir and kharsu oak was 0.92-0.95, 0.82-0.86, 0.88-0.94 and 0.89-0.96 respectively.

Study on the influence of climate on bionomics of *Pityogenes scitus* Blanford (Coleoptera: Scolytidae) in Himachal Pradesh

Biological information on the species from 3 selected sites was collected and the abundance of different stages (egg, larva, pupa and adult) of this insect under field conditions estimated. It was observed that the larva feed chiefly on the past layer and their galleries do not get deep into the

sap wood. Full grown larva eats out a depression at the end of their galleries in sap wood and pupates. 4-5 adult beetles / 20 cm² were recorded on infested kail tree. Kail forest seems to be more susceptible; however, this needs further validation by continuing study further for one more year. Data on biological information and meteorological observations is being analyzed for their co-relation and other interaction.

High altitude transition zone in Himachal Pradesh: Long-term study to assess the effect of global warming and trails to rehabilitate degraded site in this zone

On the basis of field survey and literature consultation, three potential and appropriate sites viz. Satluj Catchment (Kinnaur), Beas Catchment (Kullu) and Ravi Catchment (Chamba) were selected for the study. During the year, floristic composition was studied carefully in the selected plots in high altitude transition zones of the project area. Reconnaissance survey was also carried out for obtaining the information on broad floristic composition, especially with respect to the occurrence of keystone treeline species, occurrence of any red listed plant species

and their population status, incidence of biotic pressures and degradation status including recording of GPS coordinates for mapping purposes in the identified sites. Data loggers for recording ambient temperature and relative humidity at 2-hour intervals were installed at these sites i.e. Chakah, Ashiqui Park, Naradu (3 sites in Kinnaur) and Satrundi (Chamba)

Measurement of vegetation and biomass parameters under vegetation carbon pool assessment (VCP)

As part of the national programme, the assessment of the terrestrial vegetation carbon pool in Andhra Pradesh was undertaken to generate geospatial data of the terrestrial biomass and carbon. Studies were conducted in 54 forest sites in Nizamabad, Adilabad, Warangal, Karimnagar and Vishakhapattanam districts. Data on tree height, gbh, biomass collected as per standard research protocol approved by NRSC. The results of the study will help in assessing biomass and carbon sequestration, species composition and diversity over a time period, as these sites were already assessed during 2009-10.

