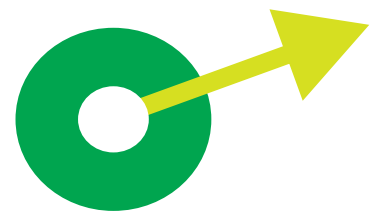**4**

FOREST AND CLIMATE CHANGE

Forest and Climate Change

Systematic and scientific studies in respect of forest ecology have become inescapable in the present times when climate change is impinging upon the dynamics of forest ecosystem. It is important to understand the behaviour of ecosystems in the wake of changing climatic patterns. Climate change has multi-faceted implications, accordingly, addressing the related issues in a scientific manner requires good scientific understanding in maintaining the flow of goods and services from existing forests both at national as well as at global level. The efforts and the provisions in the past under United Nation's Framework Convention on Climate Change in Kyoto-Protocol are mainly at broader levels and are inadequate to address the challenges and adaptive capacity of communities (human floral & faunal) at ground level especially in the developing countries. Even as per the prediction by Intergovernmental Panel on Climate Change (IPCC), the GDP of the country like India can decline up to 9 per cent due to shifting of growing seasons, which will have catastrophic impact on more than 400 million people, largely India's poor. The available studies have pointed out average increase in the temperature of 2° C in last over two decades, resulting in drying of rivers, vanishing of glaciers from the locations where forest dependent communities are habited and, thus, the food production is falling in such situations. Most vulnerable to such drastic changes in climatic factors are the poorest vulnerable population of forest dependent rural poor, apart from negative impact on downstream productivity. Accordingly, ICFRE has developed programmes including All India Coordinated Climate Change Forestry Research Programme (ALCFP- INDIA) to address the various challenges of this important sector. The initiatives of the Council have been presented in the following paras:

Satellite based assessment of fire severity and its validation in Uttarakhand

The maps containing information on forest fire incidences in Uttarakhand state for the period 2001 to 2012 were prepared in GIS environment. The data have been analysed to provide information on the occurrence of forest fire at different administrative units i.e. state, forest circle, forest division, range and compartment on monthly basis, annual basis and cumulative fire incidence basis. The information on forest fire, in the form of maps and tables, has also been developed for different densities of forest, slope classes, aspects, altitudes and climatic zones.

Climate Change and Forest Influence Division of FRI has launched an All India coordinated research programme "All India Coordinated Climate Change and Forestry Research Programme"; AICFP, involving all ICFRE institutes in their respective states of domain. Currently following research projects are going on:

(i) Process based carbon sequestration study.

(ii) Assessment of ecosystem services imparted by forests of Uttarakhand.

(iii) Carbon Footprint Mapping of Forest Research Institute, Dehradun.

(iv) Forest ecosystem studies in change environment conditions of elevated CO_2 and temperature by free air CO_2 enrichment (FACE) and Open Top Chamber (OTC).

4.1 Environmental Influence

Effect of elevated CO_2 on active principles of important medicinal plants

Seedlings of *Withania somnifara, Ocimum sanctum, Catharanthus roseus* and *Coleus forskohlii* kept under different elevated CO_2 levels in the nursery. Medicinal plants,when exposed to higher elevated CO_2 levels, they showed higher production of biomass, and bio-chemicals viz. the total protein, tannin, etc.

Response of mycorrhizae and microbial symbionts to elevated CO_2 in commercially important tree species

Rhizosphere soil samples of selected tree species were collected, and Arbuscular My-corrhizal (AM) fungi and plant growth-promoting rhizobacteria (PGPRs) isolated. Root colonization of AM fungi in Dalbergia *sissoo, Melia dubia, Gmelina arborea* and *Ailanthus excela* was

Formation of root nodules in rooted stem cuttings of *Acacia auriculiformis*

90-95 per cent. AM fungal root colonization in these trees was cultured and inoculated in *Casuarina junghuhniana* and *C. equisetifolia* cuttings and exposed to higher CO_2 supply in open top chambers. After 15 days of incubation, both the species showed nodule formation exposed in 600 ppm of CO_2/day. This study showed that the elevated CO_2 enhanced the growth of *Frankia* root nodules in both the species. The microbial biomass of beneficial microbes, such as, *Azospirillum* and *Bacillus* and *Pseudomonas* (Phosphate solubilizing bacteria) were increased from 2×10^5 to 5×10^5 due to increased supply of CO_2. The inoculation of cultured *Rhizobium* in the rooted stem cuttings of *Acacia auriculiformis* resulted in formation of root nodules within seven days after inoculation in 600 ppm CO_2/day.

Monitoring the impact of climate variables on plant diversity in Bhimashankar permanent preservation plot of Sub tropical hill forest of Maharashtra

Enumeration of vegetation was carried out in three permanent preservation plots. Enumeration of trees (number, height and girth), shrubs, herbs and

Some of the prominent flora found in preservation plot (A)- *Entada phaseoloides* (B)- *Lasiosiphon eriocephalus,* (C)- *Maytenus rothiana* and (D)- *Xantolis tomentosa*

grasses were done. 25 species of trees, 1 shrub, 4 climber, and 6 herb species were documented and identified from the preservation plots. Vegetation analysis is in progress.

Utilization of Automatic weather station/ Agrometeorological station data for agriculture, forestry and hydrological applications in Madhya Pradesh

Ten (10) study plots of 0.1 ha size each, were selected in three Tiger Reserves of Madhya Pradesh namely, Satpuda, Panna and Pench. Growth data (e.g., height, girth) of trees, litter biomass and herbaceous biomass recorded from quadrats. Soil samples were also collected from the selected quadrats and their physico-chemical properties analysed.

Tectona grandis, Acacia catechu, Anogeissus pendula, Chloroxylon swietenia, Zizyphus xylopyrus and *Boswellia serrata* are main tree species recorded from Panna Tiger Reserve. *Tectona grandis, Pterocarpus marsupium, Buchanania lanzan, Syzygium cumini, Zizyphus xylopyrus* and *Chloroxylon swietenia* tree species were abundantly found in Pench Tiger Reserve while *Shorea robusta, Soymida febrifuga,*

Laying out quadrate for data collection
on herbaceous biomass

Diospyros melanoxylon, Emblica officinalis, Hardwickia binata, Saccopetalum tomentosum, Chloroxylon swietenia and *Gardenia latifolia* were the main tree species recorded from Satpuda Tiger Reserve.

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

Pityogenes scitus completed three generations, starting from February and thereafter, by the end of October. Insect life-cycle was completed within the period varying from 56 to 75 days and entered into hibernation in pupal stage. It passes about 80 per cent of time during its life cycle (egg, larval and pupal stages) under the bark of the tree. Forest stand of selected tree species below 80 cm GBH was found to be highly susceptible to the attack of *P. scitus* as compared to the higher girth classes. Larval Growth Index was reported to be the maximum (4.0) in *Pinus wallichiana (Kail)* and a minimum of 1.6 in *Pinus gerardiana*. Maximum damage (65.3%) was reported in *P. wallichiana* in comparison to the other pine species with its minimum (1.0%) in *Cedrus deodara*. Insect lives in association with other bark and wood borer species i.e., *Polygraphus longifolia, Cryptorhynchus rufescens* and *Platypus biformis.*

High Altitude Transition Zones in Himachal Pradesh: Long-term studies to assess the effects of global warming and trials to rehabilitate degraded sites in this zone

The prime objective of the project is to study the floristic composition in carefully selected plots in high altitude transition zones and to monitor any changes in its composition over a period of time so as to arrive at any conclusion about the impact of climate change in the area. A reconnaissance survey of transition zones in the project area was
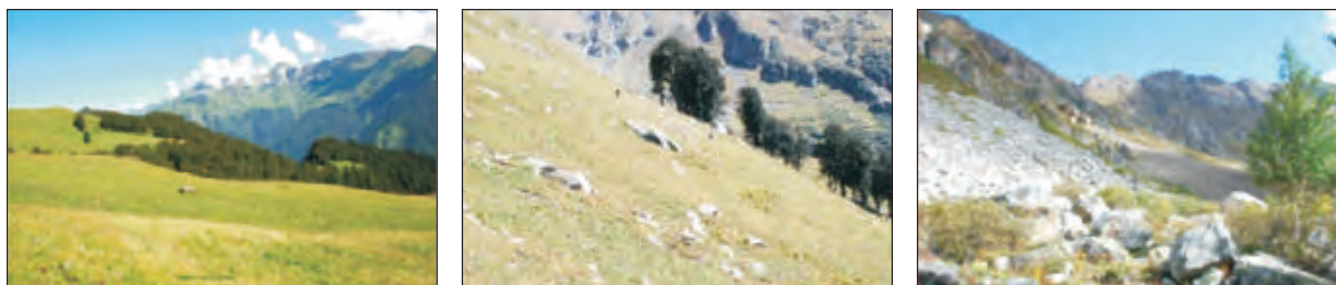
Glimpses of the survey and selection of sites under the project

undertaken. Five permanent plots with GPS coordinates (3 in the Satluj Basin and 1 each in Ravi and Beas Basins) were laid down for carrying out the detailed studies. During reconnaissance survey, broad floristic composition, especially with respect to the occurrence of keystone tree line species, occurrence of any red listed plant species and their population status, incidence of biotic pressures and degradation status recorded. Glimpses of the survey and selection of sites under the project are given above.

4.2 Carbon Sequestration

Studies on carbon sequestration in different forest types of Rajasthan

Study was started with an overall objective 'to provide an estimate of carbon stock in forests of

Rajasthan' for its utilization in planning and execution of afforestation/ reforestation programme, in particular, to estimate carbon stock in forest soils, and in above ground and below ground biomass. In the year 2012-13, data compilation on dominant vegetation (tree/shrubs) in 196 forest blocks of six districts (Alwar, Ajmer, Baran, Bikaner, Kota and Sirohi) indicated 26 dominant types of forest (including TOF). Out of the total, 36 forest blocks dominated by TOF, 32 forest blocks by *Prosopis juliflora*, 25 by *Anogeissus pendula* forests, 17 by *Butea monosperma*, 14 by Desert Dune scrub, 12 by *Acacia leucophloea* - *Z. nummularia* and 10 forest blocks by *Acacia senegal* trees. Other dominant types, covered less than 5 forest blocks.
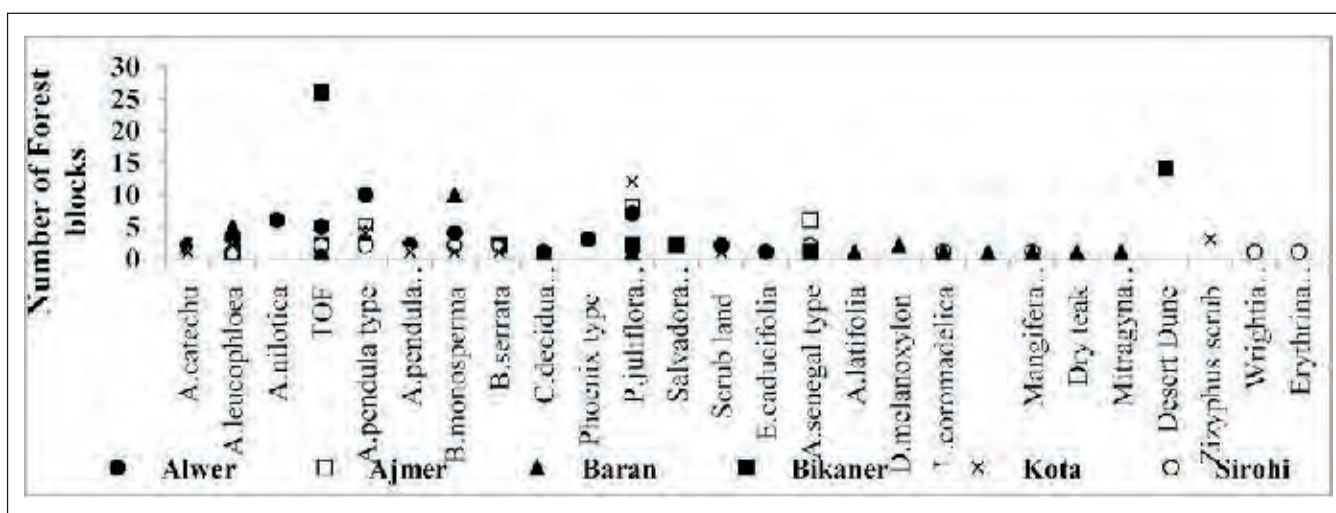
Number of forest blocks dominated by different tree/shrubs in the six districts of Rajasthan.
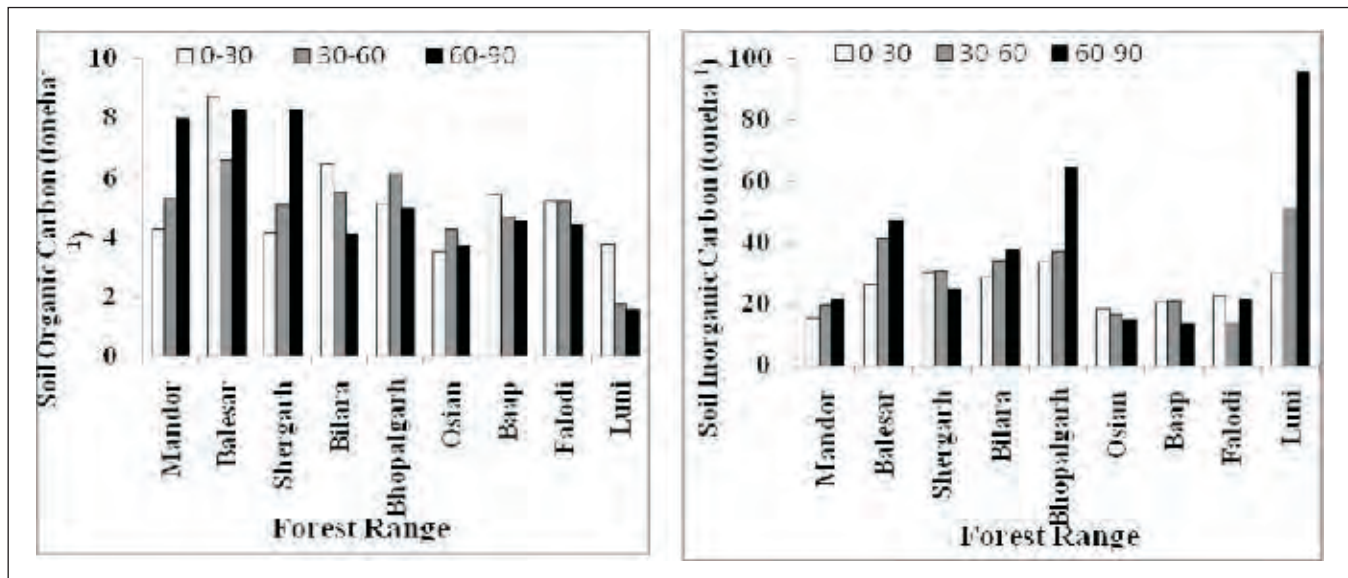
Distribution of soil organic carbon (left) and soil inorganic carbon (right) stock in the forests of Jodhpur district.

Carbon study in 1 m soil layer of 139 forest blocks in Jodhpur indicated that soil organic carbon stock ranges from 11.4 mg ha^{-1} (in Osian) to 26.2 mg ha^{-1} (in Balesar Range). Soil carbon stock was greater in 0-30 cm soil layer in Baleser, Bilara, Baap, Falodi and Luni ranges, in 30-60 cm soil layer in Bhopalgarh and Osian range and in 60-90 cm soil layer in Mandore and Shergarh ranges. Higher soil organic carbon stock in deeper soil layer is attributed to sand deposition on surface soil. Substantial amount of carbon is also available in inorganic form, which ranges from 50.6 mg ha^{-1} in Osian to 229.6 mg ha^{-1} in Luni Range. Soil inorganic carbon was greater in 0-30 cm soil layer in Osian and Falodi ranges, in 30-60 cm soil layer in Shergarh and Baap ranges and in 60-90 cm soil layer in rest of the ranges.

4.3 Forest Soils

Characterization and classification of forest soils of Rajasthan

Soil samples were analysed for physico-chemical propersties. Soils were analysed for soil texture, structure, consistency, colour, pH, electrical conductivity, organic carbon, inorganic carbon, NO_3 and NH_4, nitrogen and phosphorus. Data on species composition, regeneration status, forest floor litter, carbon stock in soils in different forest blocks were compiled and tabulated.

Analysis of 556 soil samples from different districts revealed that soil pH was ranging from 6 to 7 in Alwar, Baran and Pratapgarh., whereas, it was 7 to 8.58 in Hanumangarh, Sri Ganganager and Pali. In Bikaner soil pH was as high as 9.04 at Mehrasar block. Forest soils of Jalore district was in the range of 7 to 8.3. Electrical Conductivity (EC) of soils of Jalore varied from 0.06 to 1.75 dSm^{-1} indicating their non saline status. High EC was observed in
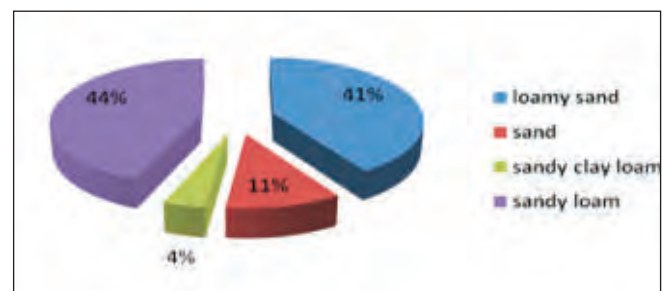
Relative abundance of different soil textural class

soils of Sri Ganganagar (0.26 to 1.31 dSm^{-1}). Soil organic carbon was low in Bikaner, Hanumangarh, Tonk and Sri Ganganagar, ranging between 0.02 and 0.3 per cent. It was higher in Alwar (0.04 to 1.06%), Baran (0.23 to 1.01%, Jaipur (0.02 to 2.21%), Pali (0.12 to 1.28%) and Pratapgarh (0.26 to 0.74%). High SOC was observed in soils of Kotputli in Jaipur. Soils are mostly sandy in nature (44% sandy loam, 41% loamy sand, 11% sand and 4% sandy clay loam).

Carbon stock and soil classification mapping for Rajasthan Forest

GIS laboratory has been established in AFRI with work stations and facilities like plotter and printer. Integrated GIS software has been procured having the capabilities of spatial analysis, image processing, RADAR analysis, hyper spectral analysis, photogrammetry, network analysis, GIS modelling, surface analysis, watershed modelling 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.

Measurement of Vegetation and biomass parameters under vegetation Carbon Pool Assessment (VCP)

An assessment of terrestrial vegetation biomass was carried out in 30 plots in the districts of Warangal, Karimnagar, Nizamabad and Adilabad. Soil samples were also collected, along with tree data, shrubs and herbs biomass samples.

Identification of soil-vegetation relations and indicator species for assessment and rehabilitation in lower Aravalli of Rajasthan

Study being carried out at five different locations with annual rainfall of 988, 961,950, 568 and 424 mm in Banaskantha (Trisulia), Motimori (Sabarkantha), Banaswara (Bara Nandra kho), Rajasmand (Sabalia) and Pali (Borvad forest block) respectively *to study* (i) physical properties and nutrient status of soil derived from different parent material, and (ii) vegetation structure and indicator species on dominant soil types. The sites were dominated by *Wrightia tinctoria*, *Tectona grandis*, *Lanea coromadelica* and *Anogeissus pendula* (trees) *Nyctanthes arbor-tristis*, *Lantana camara*, *Rhus mysorensis* and *Euphorbia caudicifloia* (shrubs). For herbaceous species, decrease in number of species, population, biomass and dominance was observed, whereas, species
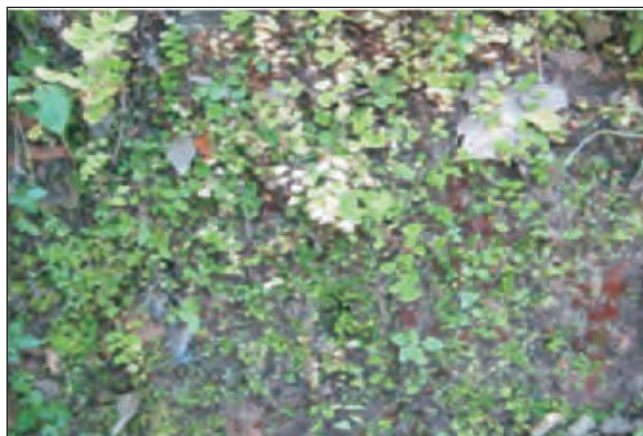
Adiantum lunulatum in Trisulia forests of Ambaji Palanpur, Gujarat

Tectona grandis and *Nyctanthes-arbor-tristis* dominated forest in Motimori in Sabarkantha

Vernonia scinerescence dominated at Borvad, Pali (Rajasthan)

Acacia catechu and *Dendrocalamus* strictus dominated at Sabalia, Rajasamand (Rajasthan)

richness, diversity (P>0.05) and species evenness (P<0.05) increased in 2012 as compared to 2011. Soil properties in 2012 showed a slight increase in soil pH, EC and SOC as compared to 2011.

Phyto-remediation of soil for productivity enhancement during land disposal of effluent (SFD Rajasthan)

Survey was conducted in (i) Luni river basin starting from Ajmer (near Govindgarh, Pushkar), Pali, Nagaur, Barmer, Jalor and up to its merging area *i.e.* Rann of Kutch, (ii) Jojri river in Jodhpur and (iii) Bandi river in Pali district. Water and soil

Alhagi maurorum

samples in effluent disposal area were collected and dominant plant species alongside the river bank were recorded. Most prominent plant species observed were *Acacia nilotica*, *Aerva persica*, *A. pseudotomentosa*, *Argemone mexicana Azardirachta indica*, *Alhagi maurorum*, *Haliotropium curassavicum*, *H. supinum*, *H. marifolium*, *Cassia angustifolia*, *C. italica*, *Crotalaria burhia*, *Cressa cretica*, *Echinops echinatus*, *Eclipta prostrata*, *Fagonia bruguierii*, *Glinus lotoides*, *Leptadenia pyrotechnica*, *Oligochaeta ramosa Prosopis juliflora*, *Pulicaria crispa*, *P. wightiana*, *Salvadora oleoides*, *S. persica*, *Solanum surattense*, *Sueada fruticosa*, *Tamrix aphylla*, *T. species*, *Tephrosia purpurea* and *Zizyphus nummularia*.

Cassia angustifolia

Effluent water samples were collected from Pali, Balotra and Jodhpur. Sample collected from CETP Pali was found alkaline (8.67). Highest Electrical conductivity (EC) was found in effluent sample collected from Punayta (Pali) which was 100.89 mS cm-1, whereas, lowest was found in water collected from Pali out skirts (0.83 mS cm-1).

Fagonia bruguierii

Highest Dissolved Oxygen (DO) was found in Pali outskirts sample (4.56 mg/l), whereas, lowest is found in sample collected from Salawas Steel Rolling mills i.e. 1.63 mg/l. Highest amount of TDS was recorded in sample collected from Jasol (17,500 mg/l), whereas, lowest (78 mg/l) was found in water sample collected from Pali outskirts.

Prosopis juliflora

Highest (204.8 mg/l) amount of SS was found in the effluent sample collected from CETP Balotra, whereas, lowest in water sample collected from Pali outskirts (12.4mg/l). Highest COD was recorded from Jhawarya village in Pali (310 mg/L), whereas, lowest was from Pali outskirts (22.6 mg/L).

Soil samples from Sindri showed highest pH (9.41) and EC (80.33 mS cm-1). Lowest pH was recorded from Jhawarya village Pali (5.24), whereas, Lowest EC (0.11 mS cm-1) was recorded from Guda malani (Barmer district) soil sample. Highest (22.4 ppm) phosphorus content was found

Tamarix sp.

Pulicaria crispa

in soil sample collected from Jhalamand (Jodhpur), whereas, lowest (3.15 ppm) in Laadpura sample. Highest (13.88 ppm) Ammonia content was recorded from Doli, whereas, lowest ammonia content (2.06 ppm) recorded from Kankani sample. Lowest (1.76 ppm) nitrate content was found in Pali outskirts sample, whereas, highest (29.51 ppm) in sample collected from Doli.

In a field experiment using Lysimeter (2m x 2m x 2m), seven forestry tree species *viz. Prosopis cineraria, Prosopis juliflora, Azadirachta indica, Eucalyptus camaldulensis, Tamarix aphylla, Salvadora persica and S. oleoides* with four irrigation levels and three control, implying Completely Randomized Design (CRD) were planted.

Assessment of Carbon Stock in Forest Types of Shimla Forest Circle, Himachal Pradesh

During first year of the project survey was undertaken to identify the sites representing different forests in Shimla Forest Circle. The major forest types identified were chir pine forest, ban oak, deodar, silver fir & spruce, kharsu oak and alpine pasture. The data collected from alpine pasture of Chansel, Kawar and Talra were analysed for biomass and soil carbon stock. Total biomass for Kawar, Chansel and Talra pasture was 3.80, 5.5 and 10.40 mg/ ha whereas, carbon stock for these pastures was 1.99, 2.75 and 5.40 mg C/ ha respectively. Total soil carbon stock for Kawar, Chansel and Talra pasture was 133.11, 160.00 and 132.16 mg C/ha respectively.
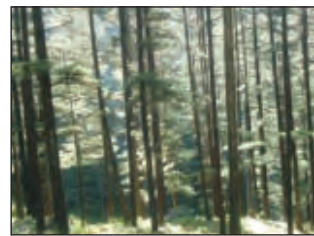
Assessment of soil quality indicators for different forest stands in Uttarkashi district through collection and analyses of soil samples
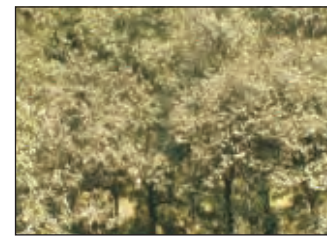

Chir pine forest, Dhami (Shimla Division)

Close View of Chirpine forest, Dhami

Deodar forest, Koti (Shimla Division)

Ban oak forest, Taradevi (Shimla Division)

from different forest stands viz. fir spruce , deodar, oak, chir, and miscellaneous forests from the sites in Naugaon, Shrukhet, Barkot, Radee Oonchaband, Jankichatti, siyanchatti and Hanuman Chatti (Upper Yamuna forest division), Uttarkashi.

Soil organic carbon store under different land uses in Haryana

- The Intergovernmental Panel on Climate Change, identified creation and strengthening of carbon sinks in the soil as a clear option for, increasing the removal of CO_2 from the atmosphere and has recognized soil organic carbon pool as one of the five major carbon pools for the land use and land use change in Forestry sector.

- This project was undertaken in Haryana to estimate SOC pool under different land uses *viz.* forests, block plantations, horticulture and agroforestry, as per the IPCC guidelines to

generate the authentic and scientific information.

- During the year, field works including site selection, soil sampling from 17 districts were carried out in Faridabad, Palwal, Rewari, Ambala, Panipat and Sonipat districts of Haryana.

- Assessment of soil microbial community and soil quality under poplar and eucalypts plantations in Haryana was carried out.

- Soil Quality Index (SQI) for different land uses of Tehri Garhwal district of Uttarakhand (Externally aided project of UCOST) is being carried out for different landuse to assess 'Soil Health'. So far the areas of Anand Chowk, Kodiyala, Tapovan, Narendranagar and Agrakhal of Tehri district of Uttarakhand have been surveyed and soil samples collected from these areas.

Study on beneficial microbial interaction with trees in heavy metal contaminated sites in Tamil Nadu

Heavy metal pollution of soil and water is a significant environmental problem. The present study deals with isolation, identification and characterization of heavy metal tolerant microbes from different polluted sites in Tamil Nadu. Surveys undertaken in different heavy metal contaminated sites (Textile dye; Paper industry; Tannery effluent) in Tamil Nadu and recorded the plant diversity status in contaminated and adjacent areas. Soil samples were analyzed and physico-chemical properties such as pH, E.C., macro and micro nutrients estimated.

Studies on the dynamics of litter decomposition in sal forest of Central India and its impact on the nutrient status of soil

Lophodermium shoreae, a dominant sal litter colonizer was recorded from the experimental sites of MP, CG and Odisha. Combination of *Trichoderma harzianum*, *Cladosporium* sp. and *Aspergillus niger,* accelerated decomposition of litter and also contributed nutritional substances to the soil. Fourteen documents of interesting fungi were prepared. Seasonal influence of micro fauna, during litter decomposition of sal was also evaluated.

Under the project 'Enhancement of Soil Carbon and Nitrogen Sequestration Potential of Different Land Use in Jharkhand, through Recommended Management Practices' the study on effect of green manuring on physical, chemical and biological properties of coalmine soil was done. The performance of jamun, sal and mahua in the reclaimed mine soils were studied. Biometric parameters viz. height, collar diameter, shoots and root biomass were recorded. Soil organic carbon and nitrogen content in the mine soil were

Some mycorrhizal fructifications of sal forest

Table 1. District wise list of dominant tree species, tribes and crops

	District	Dominant tree species	Dominant tribes	Major Crops
1	Pali	*Prosopis julliflora*	Rawat and Raika	Bajra
2	Sirohi	*Acacia pendula, Butea monosprema*	Ghrasiya and Meena	Maize, Wheat
3	Kota	*Acacia pendula, Acacia senegal*	Bheel and Meena	Wheat
4	Jaipur	*Acacia tortlis, T. undulata*	Meena, Keer and Gurjar	Jau, Mustard, Wheat and Bajra
5	Bundi	*A. pendula, B. monosprema*	Gurjar and Jhala	Maize and Wheat
6	Baran	*A. pendula, B. monosprema*	Ahir and Ghrasiya	Dhaniya and Wheat
7	Swaimadhopur	*A. leucophoea, A. pendula, B. monosprema*	Meena and Gurjar	Mustard
8	Dholpur	*A. pendula, S. cumini*	Gurjar	Wheat and Cicer
9	Chittorgarh	*A. pendula, A. catechu, Dyospyros melanoxylon*	Gurjar and Meena	Soybean and Wheat
10	Banswara	*A. latifolia, A. ferruginea*	Bhil, Damor and Meena	Maize, Rice and Cotton
11	Jhalawar	*A. pendula, M. parviflora*	Gurjar and Meena	Wheat and Mustard

estimated periodically. The changes in physical, chemical and biological properties of coal mine were studied and documented at specified time interval.

4.4 Fringe Forest, Urban Forestry

Identification of extent of forest land in forest fringe villages

Socio-economic survey and vegetation studies done in 11 districts of Rajasthan. The dominant tree species in forest fringe villages are given in Table 1 Among shrubs, undershrubs and grasses, *Capparis desidua, Zizyphus numularia, Lantana camara, Lasiurus sindicus, Leptadenia pyrotechnica, Saccharum munja* etc. are prevalently growing

there. Almost every village has primary school, electricity and sufficient irrigation facility. They grow peanuts, maize, soybean and pulses as cash crop.

Designing and Development of Urban Forestry Model For Indian Institute of Technology (IITJ), Jodhpur, Rajasthan

This project has been funded by Indian Institute of Technology, Jodhpur, (Rajasthan) for developing shelterbelt with aesthetic value on a very shallow calcareous soil of IIT(J) campus. The objectives were (i) to design a model shelterbelt plantation for urban forestry; (ii) to study the bio- remediation effect of shelterbelt plantation on soil properties; and (iii) to increase carbon stock of a land with low

productivity. Plantation of trees and flowering shrubs in a stretch of 5000 m along the roads and the institute boundary was carried out in September-October, 2012. Plantation was done after complete replacement of soil along with the calcium carbonate aggregates (murram layer) and refilling of pits with a mixture of sand, farmyard manure and pond silt. 4000 seedlings of different species were planted. The tree species planted are *Azadirachta indica*, *Tabebuia aurea*, *Terminalia catappa*, *Millingtonia hortensis*, *Peltophorum ferrugineum*, *Bauhinia racemos*a and *Butea monosperma*. The shrubs are *Ceasalpinea pulcherima*, *Bougainvillia glabra*, *Plumeria alba*, *Nyctanthes arbore-tristis*,

Plantation at IIT (J)

Tabernaemontana divaricata, Nerium oleander and *Tecoma stans.*