2.2 Forest Productivity

Overview

The productivity of our forests is one of the lowest in the world standing at 0.7 m^3 /ha/year as compared to the global average of 2.1 m^3 /ha/year. The forest plantations in India, constitute 17% of global population but their productivity is as low as 1.0 m^3 /ha/year. At the same time, output of the, plantations under farm forestry and agroforestry is also not as high as to match the productivity figures of other countries–major reason for it being the non-availability of quality planting material. Proper scientific management of land and forest resources, especially in the hills, is quite important for achieving the long term conservation and production needs of the particular forests.

Increase in the population and over-exploitation especially of the forest resources for meeting the requirements of the growing populace, the demand for fuelwood, fodder etc., can no longer be met with from the existing resources. Accordingly, practice of agroforestry in its true sense needs to be popularized. No doubt, such practices in India have been known and recognized since time immemorial and are being followed traditionally in different manners all across the country but need to be documented and understood with reference to its ecological, bio-physical and socio-economic aspects.

Even the survival of manmade plantations is quite poor, key factor for this is related issues impinging directly upon the quality of the planting stock selected during establishment of plantations those are normally driven by the targets. For achieving plantation targets, the quality of planting stock is invariably compromised ignoring the fact that the success behind any of the plantation programme is the quality of nursery stock. Though, there are some morphological parameters fixed in case of important tree species for selecting the stock for out planting, yet are not adhered to for want of the number of plants required for achieving the targets. In fact, culling is rarely practiced in the forest nurseries in the country which, otherwise, is the most important component for getting higher survival percent and better establishment of plantations for enhanced productivity. Therefore, the outcome of the trails carried out in the nursery for standardization of parameters in the nursery stage can help in fixing the minimum standards of seedling quality.

Forests may reproduce more successfully when special efforts are made to encourage regeneration. Either artificial regeneration that involves planting seeds or seedlings, or natural regeneration that relies on existing seedlings or seed may be used.

The effective planning and implementation of afforestation programmes depend on the availability, at all times of sufficient quantities of seeds with right physiological and genetical characteristics. In the first place, the seed must be collected from a genetically proven superior source. Secondly, there must be a continuous checking by testing the physical and physiological characteristics of the seeds. Finally, it is important that seed is stored until required without losing its germinative capacity and viability. Gujarat state Forest Department has selected plus seed stands, established several seed production areas, seedling seed orchards, CSOs under planting stock improvement programme.

Seed though take up only a minor proportion of the overall cost of plantation, establishment and their management yet their insufficient supply is often seen as a major bottleneck for carrying out various improvements in the production of planting stocks.

Keeping all these aspects in view, the ICFRE is making all out efforts through some research projects so as to suggest specific strategy to the stakeholders.

Seed database is being created on economically important forestry species of Jharkhand for the use of forest seed certification agency. Seed germination studies were conducted on seeds collected from Rajasthan and of *D.sissoo* and *A. catechu* collected from various seed sources of Gujarat.

The germination data of the trials laid out to find the optimum time of seed collection in *Juniperus polycarpus* revealed that second fortnight of November is the best time for seed collection. However, in case of *Fraxinus xanthoxyloides*, optimum time of seed collection is the second fortnight of October.

The moisture content of berries of the *Juniperus polycarpus* is 26.69%, whereas, in case of seed it comes out to be 9.20%. In case of *Fraxinus xanthoxyloides* the moisture content of the samara is 8.28% and that of seed it is 8.22%.

The seeds of *Juniperus polycarpus* stratified in cowdung and placed in open pits for 60 days duration during winter recorded maximum 70% germination, whereas, control (untreated) seeds recorded 40% germination. However, in case of *Fraxinus xanthoxyloides*, the best treatment for overcoming seed dormancy was gibberellic acid (1500ppm).

Air tight moisture-proof polysac containers under low temperature (<5^{0}C) in refrigerated condition were found to be the best storage container and storage environment for storing seeds of *Juniperus polycarpus* for maintaining seed longevity. The seed stored under such condition retained more than 70% viability after one year of storage and 55% viability after two and half years of storage, whereas, other storage containers/storage environment showed decreasing trend in seed viability. Similarly, best storage container and storage environment for storing seeds of *Fraxinus xanthoxyloides* for maintaining seed longevity was also air tight moisture-proof polysac containers, under low temperature (<5^{0}C) in refrigerated condition. The seeds stored under such condition retains > 80% viability after one year of storage and >70% viability after two and half years of storage period whereas, other storage containers/storage environment showed decreasing trend in seed viability.

Physical and physiological parameters including seed purity, seed morphology (length, width, aspect ratio, colour etc.), germination and storage behavior of 20 species were studied to create seed database on economically important forestry species of Jharkhand aiming at functioning of forestry seed certification agency.

Information on natural populations and plantations of kadamb and semul in Jharkhand, Bihar and West Bengal was collected and 70 Candidate Plus Trees were identified. Clonal propagation procedures for both the species have also been evolved.

Soil carbon and nitrogen sequestration potential of mined/overburden soils in Jharkhand is being enhanced through management practices. Soil samples were collected and analysed for understanding their nutrient status and the medicinal plants viz. *Asparagus racemosus*, *Decalepis hamiltonii*, *Hemidesmus* and *indicus* were planted in Tamil Nadu. These plants were also planted as intercrop along with the tree species. Soils of Western Rajasthan districts found deficient in nitrogen and phosphorus. Overall

46% soils were sandy loam, 29% - loamy sand, 20% - sandy, 3% - sandy clay loam and 0.5% - clay loam.

The soil samples were collected from the coal mine overburden and analysed. Pot trial experiment with four tree species in the overburden soil, reclaimed by vermicompost and green manuring, are being undertaken. Performance of species with respect to germination and growth is being recorded at Ranchi.

Casuarina equisetifolia, Casuarina junghuhniana and *Eucalyptus camaldulensis* have been planted at four locations namely Cuddalore, Jeyamkondam, Sembanoor and Sendurai in Tamil Nadu.

Two study sites as an OSR experimental area of Tropical Forest Research Institute, Jabalpur, and as an OFR in farmer's field, Neemkheda village, Jabalpur district were selected to establish the multitier cropping system by raising Aonla intercropped with Arhar and Adrak.

The project, to develop agroforestry models with *Wrightia tinctoria* R.Br. and *Gmelina arborea* Roxb. as tree species is being implemented.

Quality and yield improvement in agroforestry based food product under integrated nutrient management for bio-fortification was analyzed on the basis of pH value and organic carbon content in agricultural soil to establish correlation with Iodine.

The assessment of litter production by important agroforestry species indicated that *Grewia optiva, Morus alba, Celtis australis, Bauhinia variegata, Toona ciliata* and *Albizia chinensis* contributed significant amount of litter-fall annually through various litter fractions.

Integrated strategy is being developed for evaluation of indigenous fast growing multipurpose trees of eastern India for plantation forestry.

Two species of bamboos viz. *Bambusa nutans* and *Dendrocalamus strictus* were selected to establish the bamboo based agroforestry system at experimental area of Tropical Forest Research Institute, Jabalpur and to create the awareness among the farmers of different villages of M.P. and Chhattisgarh state for the adoption of bamboo in their field.

The experiments are being conducted to develop packages of practices for high yield plantations for bamboo. The data on survival rate and growth performance in terms of number of tillers and average height is being collected in the field trials. Training on Bamboo macro-proliferation and vegetative propagation was provided to officials of Goa Forest Department (GFD), Andhra Pradesh Forest Development Corporation (APFDC) and Karnataka Forest Department (KFD) during February, September 2010 and January 2011 respectively as a part of objective i.e. validation of packages of practices for high yield plantations for bamboo.

The studies are being carried out to extend shoot production period and enhance edible shoot production of selected bamboo species through cultural practices.

BPS of *B. nutans, D. asper* and *D. strictus* are being raised through Tissue Culture and clonal culm propagation at Ranchi, Lalgutwa and Forest Rangers College, Mandar. The plantation has also been raised in half an hectare of land.

The nature and degree of degradation and the limiting factors for tree growth in the degraded soils of Chhotanagpur plateau areas of Jharkhand sites were investigated. The species suitable for the area were screened and the strategy for reclamation of these soils were developed.

Application of rain water harvesting, afforestation and protection helped restoration of degraded hills by enhancing soil water, nutrients, number of herbacious species and biomass. In addition, there was increase in carbon stock and water, fodder and fuel wood availability.

Low cost enriched vermicompost has been developed for commercial production. A permanent low cost vermicomposting unit has been established at FRC, Mandar where vermicompost enriched with neem cakes, karanj cakes, phosho-bacteria, cow urine, and poultry manure is being produced.

Initiatives such as establishing field trials with preferred trees and crops along with suitable geometrical arrangements have been taken for productivity enhancement in abandoned jhum land through agroforestry management and value addition in Mizoram and Meghalaya.

Bambusa balcooa was identified as potential bamboo species for rehabilitation of jhum land with reference to carbon sequestration and livelihood development.

Productivity related parameters have been assessed under different land use practices including Jhum in three different watersheds of Arunachal Pradesh.

Five forest blocks studied for identification of indicator species revealed that *Tectona grandis, Lanea coromadelica, Anogeissus pendula, Wrightia tinctoria* and *T. grandis* are the dominant species at the sites in Banswara, Rajsamand, Pali, Palanpur and Sabarkantha districts, respectively.

Ficus bengalensis is the most common species of ficus retained by farmers in cropping systems and mostly grown for fodder for livestock and for small timber. Around 200 individual farmers and 16 villages were surveyed in 7 talukas in Mandya district to capture the ecological, economic and socio-cultural evaluation of a traditional Ficus based agroforestry system in Mandya district, Karnataka.

Sixty thousand seedlings of RET species (*Gmelina arborea, Pterocarpus santalinus* and *Santalum album*) were raised for distribution to farmers and stakeholders.

Studies on sustainable management of medicinal plants in JFM areas in two agroclimatic zone of Madhya Pradesh were conducted. Germination percentage was improved by pretreatments on *Schleichera trijuga, Terminalia arjuna, Sapindus laurifolia, Terminalia chebula, Ablomoscus moscatus, Rauvolfia serpentina, Emblica officinalis* and *Mxvimusops elengi*, out of 12 target species.

On the basis of survey, conducted in Kanhan region of Western Coal Fields Limited, Shivpuri area and Junnardeo and Pench area of Western Coal Fields Limited, for selection of coal mine overburden site for laying out experiment, the Shivpuri open cast mine-1 was selected for laying out the experiment.

Experimental plantations of deodar and ban oak are being maintained intensively in the field and the relevant data recorded regularly by Himalayan Research Institute, Shimla. The plantation success through wildling is still a critical issue since, the results are not encouraging and the fact is being investigated. Less snowfall and rains followed by severe drought subsequently during the years 2008-2009 and 2009-2010 might have added to the large scale mortality in the field conditions of the tall plants.

The experimental sites established for assessing the various morphological parameters of the nursery stock of deodar and ban oak in Shimla and Solan districts of Himachal Pradesh (HP) could not perform well because of the less snow fall/rains during 2008 and 2009 followed by continuous drought like conditions during summer, which resulted in large scale mortality in experimental plantations of deodar and ban oak – indicating moisture as the triggering factor for mortality.

Preliminary growth data indicated that the G*melina arborea* is performing well on all the study sites and have attained an average height of about 250 cms within three years of its establishment. Though very early to predict, yet, it

can be a potential species for carrying out future plantations in the lower hills.

Experiments on foliar spray of chemical fertilizers were conducted in Morga to observe the effect of different doses of fertilizers, either individually or in combination, on increment in size of tendu leaves in M.P.

Projects under the Theme

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During the Year
Plan	18	40	25
Externally Aided	9	9	9
Total	**27**	**49**	**34**

2.2.2 Silviculture

Impact of Ban on Green Felling in Deodar, Kail, Fir and Spruce Forests of Uttarakhand

The Govt. of Uttar Pradesh (then Uttarakhand was part of UP) imposed ban on green felling, above 1000 m altitude in the Himalayas, in early eighties. Before 1980, the coniferous forests of the Himalayas were felled under prescribed silvicultural techniques of working plans**.** These forests are being managed by the forest department on salvage felling to meet the timber rights of the villagers. To observe the impact of ban on green felling in *Cedrus deodara*, *Pinus wallichiana*, *Picea smithiana* and *Abies pindrow* forests**,** twelve sites were selected in Uttarakhand in the coupes which were prescribed for felling but felling was not carried out and in those coupes where felling was actually done. Nanda Devi (Old Badrinath division), Uttarkashi and Chakrata forest divisions were selected for data collection based on the presence of species and records of compartment's histories, with the help of Uttarakhand forest department. Data were collected on phyto-diversity, growth of trees, regeneration status, socio-economic conditions of the people near forests and soil organic carbon, soil moisture and soil nutrients from felled and un-felled coupes.

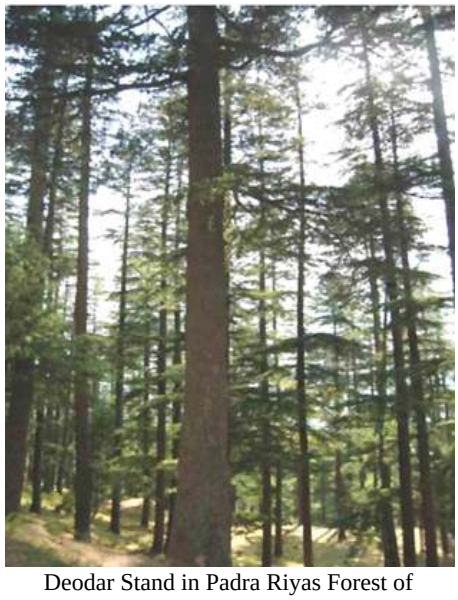
It was observed that plant diversity of shrubs and herbs was high in un-felled coupes in comparison to felled coupes although tree diversity was observed more in felled coupes owing to presence of advance regeneration crops due to opening of canopy during felling. In felled coupes, monoculture species was observed but in un-felled coupes, some broadleaved species like oaks, maples, bhojpatra and burance etc. were also associated with coniferous species probably due to favourable micro-climatic conditions.

The growing stock and productivity of all the four conifer species did not differ significantly in felled and un-felled coupes. The normal regeneration trend was found in all age groups in felled coupes. A very sparse regeneration was found in un-felled coupes. The regeneration was affected due to slow decomposition rate of soil litters in un-felled coupes. The values of soil organic carbon and soil organic matter were found high in un-felled coupes. It may be due to slow decomposition rate of soil organic matters in un-felled coupes. Soil moisture did not show significant differences between felled and un-felled coupes.

The villagers, whose employment was based on felling operations, have migrated from the fringed areas in search of other employment. A few settled households were in favour of green felling but majority of fringed villagers were not in favour of felling owing to the fact that coniferous forests are protecting their houses and agricultural fields from natural disasters.

Study on Impact of Ban on Green Felling in Deodar, Kail, Fir and Spruce Forests of Uttarakhand and Himachal Pradesh. (A collaborative project of HFRI Shimla with FRI Dehradun)

Basic information pertaining to study sites from the offices of respective Divisional Officers was collected and the forests in Chamba, Shimla and Kullu districts were identified for the detailed investigations. Preliminary survey has been



Deodar Stand in Padra Riyas Forest of Naggar Range, Kullu Valley

undertaken in Chamba, Chopal and Kullu Forest Divisions of the identified districts and the basic information/ details of the forests was collected from compartment history files from the respective ranges. Accordingly, sites for carrying out the studies were selected in Naggar Range of Kullu Forest Division, Upper Chamba Range in Chamba Forest Division and Chopal Range of Chopal Forest Division.

During the year under report, Padra Riyas Forest area having Silver, Fir and Spruce forests and Nashala block supporting bluepine and deodar forest were investigated for detailed studies. However, on the information of the Chairperson of RAG, that the Forest Department (FD) is already working on a project with Indian Institute of Forest Management (IIFM), Bhopal, Madhya Pradesh, with the similar objectives, the institute has terminated the project.

Development of Techniques for Raising Deodar (*Cedrus deodara)* Plantations through Tall Plants

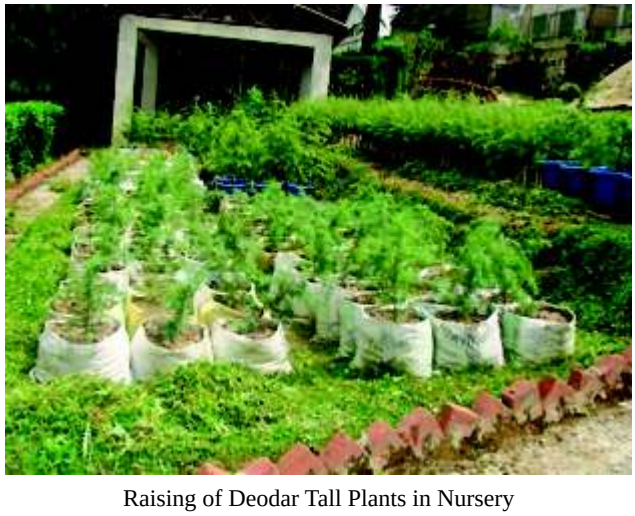
One site, adjacent to Field Research Station of this institute located at Shillaru, District Shimla, was selected for establishing pilot scale experiment by using deodar wildlings. In addition, areas for extracting wildling for experimental purposes were surveyed and identified. The experimental plantations of Deodar was carried out, using tall wildlings of the species, during August 2008 and February 2009 and the same was repeated during August 2009 and August 2010. Wildlings were planted on the basis of height and root collar diameter classes. Experiments were also carried out as per Root Exposure Time and Root Desiccation Protecting Substances while extracting and planting wildling directly in the field.

Nursery studies were initiated during March, 2009 as per the availability of deodar plants in nursery beds. Deodar seeds were also sown in nursery during December 2009 and maintained properly for further research in the nursery. Nursery bed raised seedlings after attaining height of more than two feet were transplanted to gunny bags or plastic buckets for further growth, development and stabilization in the nursery conditions. Experiments are also being conducted on pruning, root exposure time during transplanting and root desiccation protecting substances similarly as being done in case of direct planting of wildlings.

Experimental plantations are being maintained intensively in the field and the relevant data are recorded regularly. The plantation success through wildling is still a critical issue since, the results are not encouraging and the cause is being investigated. Less snowfall and rains followed by severe drought subsequently during the years 2008-2009 and 2009-2010 might have added to the large scale mortality in the field conditions. However, the experiments have been repeated during August 2010 and the wildlings exhibited initial success. The findings, however, can be confirmed only after one summer.

Raising tall plants in the nursery in big containers such as gunny bags, plastic containers etc are in progress. Initiated works on tall planting

experiments in gunny bags with Gel Grow treatment in the nursery. For the benefit of end users particularly field functionaries of the Himachal Pradesh State Forest Department (HPSFD) a Training-cum- Interaction programme on "Production of Tall Plants in Nursery: Issues and Concerns" was conducted on 15th February 2011 at Forest Training Institute, Chail, district Solan, Himachal Pradesh.



Raising of Deodar Tall Plants in Nursery

Training on Production of Tall Plants in Nursery

Determination of Morphological and Physiological Quality Parameters of Nursery Stock of Deodar (*Cedrus deodara)* and Ban Oak (*Quercus leucotrichophora*)

Raised and maintained nursery stock of deodar (5,000) and ban oak (20,000) at Model nursery Shimla and Shilly nursery Solan respectively. Visited 35 nurseries of State Forest Department of Himachal Pradesh and collected information from field functionaries regarding nursery raising and quality parameters adopted in deodar and ban oak nursery stock. Sites were selected for carrying out experimental plantations in Shimla and Solan Forest Divisions. Experimental plantations carried out as per morphological parameters of these species during August 2008 & 2009 at six sites, three for each species. In order to develop interim minimum standards of quality of deodar and ban oak nursery stock, extensive survey in various deodar and ban oak nurseries of State Forest Department (H.P.) was carried out. The survey was done through structured interview and a questionnaire was developed for that purpose. It was found that only one physical parameter was adopted in the nurseries of State Forest Department (SFD) for measuring the quality of deodar and ban oak nursery stock i.e. height (shoot length) of the nursery stock. According to that the stock is considered fit for planting or marked as quality stock if the height is 9 inch or more. The root collar diameter, type of production system (polybag or bare root), age, site conditions of plantation area etc. are important for selecting quality stock for planting but not being considered presently. On the basis of field discussions, interim minimum standards for nursery stock of deodar and ban oak have been proposed for further discussions and finalization.

For achieving second objective of the project, out planting has been carried out during 2008 and 2009 rains based on morphological grading of nursery stock of ban oak and deodar. The experimental sites which are located in Shimla and Solan districts of Himachal Pradesh (HP) received very less snow fall/rains during 2008 and 2009 followed by continuous drought like conditions during summer which resulted in large scale mortality in experimental plantations of deodar and ban oak. Therefore, during the rainy season of 2010, the out planting experiments based on morphological grading of deodar and

Out Planting of Deodar and Ban Oak in Gunny Bags

ban oak nursery stock in gunny bags were repeated following Randomized Block Design (RBD) with 10 plants per replication. Initiated the studies for judging quality of deodar and ban oak nursery stock based on Root Growth Potential (RGP), were conducted during the year 2010.

Influences in Regeneration of Silver Fir (*Abies pindrow*) and Spruce (*Picea smithiana*) Forests-Effect of Natural Leachates on Seedling Growth in Nursery

Sites were selected for experimentation at Deoban, Chakrata Forest Division. Litter, humus and soil samples have been collected on monthly basis and soil samples have been analyzed for Total Nitrogen, Available N and Organic Carbon. Leachates of soil and humus were prepared. Seed of fir and spruce, collected from Chakrata, were sown in Deoban forest nursery for further experiments.

Enhancement of Seed Longevity of *Diploknema butyracea*

Seeds of *Diploknema butyracea* were collected from four locations in Pithoragarh FD (Uttarakhand). The seed parameters, initial germination, viability, vigour, studies on desiccation sensitivity of seeds were studied. For storage studies, seeds were desiccated to four moisture levels i.e. 30%, 25%, 20 % and 15 % and desiccated seeds were stored at four temperature viz. ambient room temperature, 15^0C, 10^0C and 5^0C. Seed longevity could be enhanced to 30 days. Better growth (height, collar diameter, vigour index) was observed in seedlings in polybags. Potting media of soil: sand in 2:1 was found to be best for the growth of the seedlings. Morphological and biochemical studies during fruit/seed development was also done.

Variability Studies on Seed Quality Parameters and Seed Mycoflora of *Bauhinia purpurea, Bauhinia semla* and *Bauhinia variegata* for their ex-situ Conservation

Seeds of *Bauhinia variegata , B. purpurea* and *B. retusa* were collected from 15 sources in Dehradun, Tehri, Uttarkashi, Muzaffarnagar, Saharanpur and Kanpur. Variability in seed morphological parameters such as total sample weight, seed length, seed width, seed thickness, seed colour, 100 seed weight, purity %, moisture content, number of seeds in a single fruit, number of seeds in 100g seeds were recorded. The seeds were subjected to moisture content and germination tests. Seeds from all the sources had high initial viability (85-90%). Seeds of all the sources stored well and maintained high viability (75 -85%) after one year in storage. Status of fungi associated with seeds of *B. variegata* and *B. purpurea* collected from FRI was studied. Out of seven sources of *B. retusa*, seeds of Kaichidham and Kandikhal had highest infection (21 colonies) followed by Retighat and Rambar source (20 colonies).

Enhancement of Seed Germination in *Anogeissus latifolia* Through Various Seed Technological Inputs

Seed Maturity indices of *Anogeissus latifolia* have been quantified and seed handling protocol developed. Germination and storage protocol has also been developed but needs to be confirmed with sound seed. More than 90% emptiness was observed in the seeds of species. Sucking of sap by insect from fruits during developing stage seems to be one of the causes of the emptiness for which studies are continuing and also planned for identification and control of the insect in collaboration with Entomology Division of FRI.

Seed Physiology of the Tropical Forest Species with Special Reference to their Maturity and Storage

Out of 12 target species germination percentage was found improved after pretreatments of seeds of *Schleichera trijuga, Terminalia arjuna, Sapindus laurifolia, Terminalia chebula, Ablomoscus moscatus, Rauvolfia serpentina, Emblica officinalis* and *Mimusops elengi,* . Other species did not needed any seed pretreatment. Studies on desiccation tolerance and seed storage behaviour had been done on *Schleichera trijuga, Terminalia arjuna, Hardwickia binnata, Moringa oleifera, Holoptelea integrifolia, Sapindus laurifolia, Terminalia chebula Ablomoscus moscatus, Rauvolfia serpentina, Emblica officinalis, Bassia latifolia* and *Mimusops elengi. Mimusops elengi* was found as intermediate and *Bassia latifolia* as recalcitrant. Other species were observed orthodox type and can be programmed for long term storage. Seeds of *Terminalia arjuna, Hardwickia binnata, Moringa oleifera, Holoptelea integrifolia, Sapindus laurifolia, Terminalia chebula, Rauvolfia serpentina, Emblica officinalis, Bassia latifolia* and *Mimusops elengi* were adjusted to three to five moisture contents and stored at four different temperatures for evaluation of storage potential for estimation of viability at regular intervals. Viability constants were estimated for four orthodox species: *Hardwickia binnata, Moringa oleifera, Holoptelea integrifolia*, and *Sapindus laurifolia*. Best storage conditions were determined for other species.

Studies on seed maturation for determination of seed collection time had been done and maturity indicators were determined on *Schleichera trijuga, Hardwickia binnata, Moringa oleifera, Holoptelea integrifolia, Sapindus laurifolia, Ablomoscus moscatus, Bassia latifolia* and *Mimusops elengi.* Seeds of *Rauvolfia serpentine* and *Emblica officinalis* should be collected after full maturity and seeds of these species need after-ripening for better germination. Biochemical characterization of three categories of seed. Total fatty oil and carbohydrate composition was compared between different categories of seeds. It was concluded that there was no significant difference among the three categories of seeds. As all these three species are oil-rich seed (fatty oil composition: *Schleichera trijuga*- 45%, *Bassia latifolia*- 51%, *Mimusops elengi*- 31 %.) As only one out of 12 species was identified as recalcitrant and another as intermediate, no conclusion could be made in this aspect.

Germination Ecophysiology of Two Important Tropical Forest Tree Species: *Schleichera oleosa* and *Pterocarpus marsupium*

A study on germination phenology and physical dormancy was done on *Schleichera oleosa* seeds. Immature and mature Seeds of *Pterocarpus marsupium* were collected from Jabalpur and Mandla District. Effect of seed maturation on germinability was done on *Pterocarpus marsupium.*

Studies on the Effect of Different Level of Seed Collection on Natural Regeneration of Sal (*Shorea robusta*) in Chhattisgarh

Studies on the effect of different levels of seed collection on natural regeneration of Sal (*Shorea robusta*) was conducted in three agroclimatic zones i.e. Bilaspur, Raipur and Bastar in Chhattisgarh. Sample plots were laid out in Marwahi, Dhamtari and Bastar Forest Division as per statistical design.

Phyto-sociological studies including regeneration survey of newly recruited seedlings of seed and of coppice origin were recorded. Flowered trees were enumerated. Hoeing, cleaning and fire treatments were applied to see its effect on regeneration of sal.

Sal seeds were collected and their weighing / counting were done. The seeds were

broadcasted under the sal trees as per the experimental design. After rains, again regeneration survey of newly grown seedlings of seed and coppice origin were done to see the impact of different treatments.

Studies on Seed Traits of Seeds Collected from Seed Stands / SPAs / SSOs / CSOs of Important Species of Gujarat State

Seeds of 11 species were collected during the year 2010-11, amongst them five species (from 61 seed sources viz. 9 stands of *Acacia catechu*, 04 CPTs of *Dalbergia sissoo*, 32 source of *Tectona grandis*, 09 source of *Anogeissus pendula* and 07 source of *A. latifolia*) were tested for germination. 100 seed weight of *A. catechu* varied from 4.50±0.13g in seed-lot of Khakharia, Rajpipla seed stand to 5.66±0.19g in Mandav, Godhara seed stand. Seed germination varied from 64±3.74% in Mandav, Godhara seed stand, to 84±1.83% in Keliya Godhara seed stand.

100 pod weights of *D. sissoo* varied from 2.11±0.08g in seed lot collected from Fulwadi, Rajpipla CSO tree no. 5 to 2.51±0.04g in Tree no. 10 of the same CSO. Percent seed germination, varied from 35% in tree no. 2 to 41% in tree 10 of same CSO.

Amongst all the CSO of teak, the length varied from 8.20 mm in Manch, Rajpipla to 11.17 mm in Fulwadi Rajpipla and the width varied from 8.94 mm in Manch, Rajpipla to 11.38 mm in Manch, Rajpipla. The un-weathered stones ranged between 35.33 g in Fulwadi, Rajpipla and 51.38 g in Manch, Rajpipla. While from weathered stones the length, width and 100 stone weights ranged from 8.31 mm in Fulwadi Rajpipla to 9.75 mm in Fulwadi, Rajpipla, 7.77 mm in Fulwadi, Rajpipla to 9.94 mm in Manch, Rajpipla and 26.80 g in Fulwadi, Rajpipla to 39.24 g in Manch, Rajpipla, respectively. Locule/stone and seeds/stone varied from 3.56 in Manch, Rajpipla to 3.96 in Manch, Rajpipla to 1.08 in Manch, Rajpipla.

Seeds of *A. pendula* were collected from 09 sources from Ranakpur region of Rajasthan. Seed from all the sources were subjected to seed testing parameters. Number of seeds per gram ranged from 154.50±05.20 in Parasram mahadev to 254.75±18.06 in near Ranakpur temple. Germination percentage and vigour index ranged from 0.80% and 1.446 (near Ranakpur temple) to 3.48% and 7.274 (Ranakpur/Highway), respectively.

In *A. latifolia* number of seeds per gram ranged from 146.50±16.54 in Ranakpur to 241.50±05.00 in Jeatran, Rajsamand. Minimum value of germination percent and vigour index observed were 0.175% and 0.293, respectively in Jeatran. Whereas, maximum value of germination percent and vigour index were noticed 0.917% and 1.333, respectively in Jeatran.

Standardization of Methodology for Seed Collection, Seed Handling, Storage and Breaking Seed Dormancy in *Juniperus polycarpos* C. Koch and *Fraxinus xanthoxyloides* (Wall. ex G. Don) DC.

The germination data of the trials laid out to find the optimum time of seed collection in *Juniperus polycarpus* revealed that second fortnight of November was the best time for seed collection and the seed collected during this period recorded maximum of 40.00% germination as compared to other collection dates which recorded less germination percent. Similarly, germination data of the trials laid out to find the optimum time of seed collection in *Fraxinus xanthoxyloides* revealed that second fortnight of October was the best time for seed collection and the seed collected during this period recorded maximum 26.66% germination as compared to other collection dates which recorded less germination percent. The moisture content of berries and seeds of *J. polycarpus* and samaras and seeds of *F. xanthoxyloides* under different

collection dates were taken after complete drying in the laboratory. The moisture content of berries of the *J. polycarpus* is 26.69% and the seed is 9.20% respectively. The moisture content of the samara of *F. xanthoxyloides* is 8.28% and the seed is 8.22% respectively. The best treatment for overcoming seed dormancy in *J. polycarpus* seeds is cold moist stratification in cowdung. The seeds of *J. polycarpus* stratified in cowdung and placed in open pits for 60 days duration during winter recorded maximum 70% germination where as control (untreated) seeds recorded 40% germination. The best treatment for overcoming seed dormancy in *F. xanthoxyloides* is gibberellic acid1500ppm. The seeds of *F. xanthoxyloides* treated with different concentration of gibberellic acid ranging from 500ppm to 3000ppm recorded maximum 74% germination in seeds treated with gibberellic acid 1500ppm where as control (untreated) seeds recorded only 19% germination within a month's period.

The air tight moisture-proof polysac containers under low temperature (<5^{0}C) in refrigerated condition produced best storage container and storage environment for storing seeds of *J. polycarpus* for maintaining seed longevity. The seeds stored under such condition retains more than 70% viability after one year of storage and 55% viability after two and half years of storage whereas other storage containers/storage environment showed decreasing trend in seed viability. Similarly, best storage container and storage environment for storing seeds of *F. xanthoxyloides* for maintaining seed longevity is also air tight moisture-proof polysac containers under low temperature (<5^{0}C) in refrigerated condition. The seeds stored under such condition retains > 80% viability after one year of storage and >70% viability after two and half years of storage period whereas other storage containers/storage environment showed decreasing trend in seed viability.

Creation of Seed Database on Economically Important Forestry Species of Jharkhand Aiming at Functioning of Forestry Seed Certification Agency.

The study envisaged generation of base line information on physical and physiological characteristics of 20 important forestry species of Jharkhand. Identification of 16 important seed sources in 12 districts, recording of seed characteristics of 20 species on physical and physiological parameters including seed purity, seed morphology (length, width, aspect ratio, colour etc.), germination behaviour and storage behaviour in different types of containers and storage temperatures was carried out. A technical bulletin for dissemination of findings is in process of publication.

The study was important in the context that the seeds being employed in the ongoing plantation programmes were generally of poor quality having low germination percentage, poor emergence, poor survival and poor adaptability to site and susceptibility to disease despite continual advocating on use of high quality seeds from identified superior seed sources. That result in wastage of efforts, time and other inputs involved in the forestry endeavour. The most probable reason for use of inferior seeds resulting in such failures was due to lack of regional forestry seed database pertaining to variation in germination and other attributes due to seed sources. The Institute of Forest Productivity, Ranchi has built up the required infrastructural facilities to act as seed testing and certification agency under the project which will be beneficial for forestry operation in the region. The following are the achievements under the project :

Identification of 16 important seed sources in 12 districts, recording of seed characteristics of 20 species on physical and physiological parameters including seed purity, seed morphology (length, width, aspect ratio, colour etc.), germination

behavior, storage behaviour studied through recording viability under storage in different types of containers and storage temperatures. A technical bulletin for dissemination of findings is alsoin process of publication.

Developing Seed Technology and Propagation Techniques for Germplasm Conservation of *Buxus wallichiana*

Seeds of *B. wallichiana* were collected from Matkangra block (Chakrata FD) at different stages of maturity and also Mandal forest in Kedarnath WLS. Almost 55-60% of the seeds were found empty. Fresh seeds yielded 15-20% germination and that too was very slow. Seeds were subjected to stratification, Gibberellic acid, KNO_3 and Cytokinin pretreatments for enhancing the germination. Seeds responded best to 45 days stratification yielding 63% germination, while it was 85% in GA_3 (0.02% for 24 hours) soaked seeds.

Cuttings of *B. wallichiana* collected from Chakrata FD were treated with various combinations of rooting hormones (IBA & NAA) and kept for rooting in the mist chamber. Air layering experiments were done on trees in Chakrata.

Establishing Germplasm Garden of Some Rare and Endangered Plants

Locations of five species viz. *Catamixis baccharoides, Ulmus wallichiana, Rauvolfia serpentine, Berberis aristata* and *Mahonia jaunsarensis* were identified and collection of propagation material (seeds/ cuttings/wildlings) was done from Chakrata, Haridwar and Dehradun area for their multiplication and conservation. Wildings of *Catamixis baccharoides* have been successfully established in germplasm garden. Germplasm of *Mahonia jaunsarensis* and *Berberis aristata* have been propagated through cuttings. Germplasm of *Ulmus wallichiana* has been collected from Chakrata and Kashmir and plants have been produced successfully through cuttings.

Characterization of Eucalyptus clones for Physiological and Nutritional Parameters

For characterization of Eucalyptus clones for physiological and nutritional parameters, field trials have been established in four locations viz., Pudukottai, Tirunelveli, Sivagangai and Coimbatore. For the short-listed 30 Eucalyptus clones, parameters like chlorophyll A. B and total chlorophyll, total leaf area were worked out. Observations on physiological parameters and growth parameters are being recorded in four locations. Biomass sampling has been completed in four locations and biomass components like leaf, twig, branch, stem, etc. were collected for nutrient analysis. Soil samples were collected from two depths (0-15 and 15-30 cm) on monthly basis for recording the moisture status with reference to productivity of clones.

Nursery project on Rare Endangered and Threatened Species - *Gmelina arborea, Pterocarpus santalinus* and *Santalum album*

Sixty thousand seedlings of *Gmelina arborea, Pterocarpus santalinus* and *Santalum album* have been raised for distribution to farmers and other stakeholders. Nursery infrastructure like shade house and irrigation system have been developed.

Silviculture Studies of *Hippophae salicifolia* –A Wonder Lesser Known Plant of Uttarakhand

Three districts of Uttarakhand where natural populations of *Hippophae salicifolia* are found were surveyed i.e Uttarkashi, Chamoli and Pithoragarh. The geographic range of seed sources in Uttarakhand varied from 30° 03´ to 31° 34´ N latitude, 74° 30´ to 80° 13´ E longitude and the altitudinal range varied from 1949 to 3212 m above msl. The study suggested Chamoli district to be superior to the other two provenances. Hanumanchatti in Chamoli district could be recommended as a seed source for large scale plant production of the species for afforestation programme and for further breeding work as Hanumanchatti is superior to rest of the eleven

seed source with respect to various growth parameters studied.

Temperature of 25±1°C was considered optimum temperature for seed germination of *H. salicifolia* under laboratory conditions. The results revealed that 15^{0}C, 20^{0}C and 25^{0}C temperature have positive influence on seed germination but 30^{0}C temperature showed negative influence on seed germination. The maximum germination percentage was observed under red light followed by yellow light and minimum germination was observed in green light.

IBA 1000 ppm is most suitable hormones for initiation of rooting in the cuttings of *H.salicifolia*. IBA treated cuttings showed better results than IAA. In *H. salicifolia* phytohormones does not play much role but effect of season is important. Late March and April is the best season to plants its cuttings without any hormones. Vegetative propagated plants are better for field planting as comparison to seeds. Plants from seeds are very delicate and need protection till 2½ yrs of age and only those plants which are branchy/woody can be outplated. Like conifers *H. salicifolia* also need to be kept in nursery for longer duration**.** Weeding in polybags/root trainer is harmful for young seedlings of *H.salicifolia*.

Sustainable management of medicinal plants in JFM areas in different agro-climatic zones of Madhya Pradesh

Studies on sustainable management of medicinal plants in JFM areas in two agro-climatic zone of Madhya Pradesh was conducted. Sample plots, for the study of sustainable harvesting of *Andorgraphis paniculata* (Kalmegh), were laid out in Satnur, Naunichhapar, Delakhadi and Umaranala Forest area, Chhindwara Forest Division. Sample plots for the study of sustainable harvesting of *Buchanania lanzan* (Chironjii) were laid out in Sitadongri, Delakhadi, Khumbhadeo, Batkakhapa and Ojhaldhana Forest Area, Chhindwara Forest Division. Sample plots were also laid out as per statistical design in Umariya Forest Area, Katni Forest Division for the study of sustainable harvesting of *Asparagus recemosus* (Satawar) and *Chlorphytum borivillium* (Safed Musli).

Data on sustainable harvesting collected from the field was statistically analysed and interpreted. On the basis of three year's observation, it was concluded that regeneration of *A. paniculata* is sustainable at all harvesting level (20-80%) and thus, 80% entire plant of *A. paniculata* can be harvested for maximum productivity and without loss in regeneration. Regeneration of *B. lanzan is* sustainable at all harvesting level (60-90%) and thus, upto 90% fruits of *B. lanzan* can be harvested for maximum productivity and without loss in regeneration. Regeneration of *A. racemosus* and *C. borivillium* is sustainable at 20-60% harvesting level and thus, for maximum productivity and without loss in regeneration, 60% *A. racemosus* and *C. borivillium* plants with roots can be harvested.

Standardization of Pruning Practices and Optimum doses of Organic and Inorganic Fertilizers to Increase Leaf Surface Area of Tendu.

Sites were selected in Morga, Kotadol, Litipara and Lohattar in Chhattisgarh. Experiments on foliar spray of chemical fertilizers were conducted in Morga to observe the effect of different doses of fertilizers, either individually or

Foliar Spray of Chemical Fertilizers on Tendu Leaves in Morga (Chhattisgarh

in combination, on increment in size of Tendu leaves using RBD statistical design. Surface and sub-surface soil samples were collected from the selected site and analysed in laboratory for their physico-chemical characteristics.

Integrated Strategy for Evaluation of Indigenous Fast-growing Multipurpose Trees of Eastern India for Plantation Forestry

The information on natural populations and plantations of kadamb and semul was collected. Seventy Candidate Plus Trees were identified in Jharkhand, Bihar and West Bengal and relative analyses of CPTs was carried out on physiological parameters. The experiments were designed for evolving clonal propagation procedures and the Hedge garden/VMG of *Anthocephalus chinensis* and *Bombax ceiba* has been established.

Edible Shoot Production of Selected Bamboo Species and Extension of Shoot Production period Through Cultural Practice

Thirty five villages and 25 markets were surveyed in Jharkhand and information on quantity of edible shoot consumed by villagers, species used, persons engaged in collection, self bamboo utilization, quantity marketed, persons involved in shoot trade, average quantity sold and earnings etc. have been collected. The field trials on shoot production period and yield of the species by improving soil health through soil working, mulching, irrigation and organic and inorganic amendments and also through clump management were conducted.

Effect of shoot removal at different intensities have also been studied on quality and quantity of edible shoot production and on the general health of the clumps of the said species so as to standardize shoot extraction method.

2.2.3 Social Forestry, Agroforestry/ Farm Forestry

Effect of *Populus deltoides* on Medicinal Plants

The findings of the project indicates that Chitrak (*Plumbago zeylanica*) and Satavar (*Asparagus recemosus*) are suitable species of medicinal plants under poplar based agroforestry systems in Shiwalik foot hills of Uttarakhand. The farming of these medicinal plants can be started in three years old plantation and minimum two crops may be taken in a rotation of 6 years of *P. deltoides*. Poplar – Chitrak and Poplar – Satavar agroforestry models are economically viable and may be beneficial to farmers provided availability of market. The study has a vital utility for different category of stakeholders like farmers, plywood industries, pharmaceutical and State Forest Departments. The study also reveals that a proper guidance to farmers to adopt Poplar – Medicinal plants based agroforestry practices through different extension tools can also be helpful to raise the medicinal plants on their farmlands under agroforestry practices.

Tree- Crop Interaction: Effect of *Melia* spp. on Crops

Keeping in view of this a project on *Melia composita* was started under which experimental plots were established at Handesra in district Mohali and Hukran in district of Hoshiarpur. Focus was kept on interaction of *Melia composita* with agriculture crops like maize and wheat. Three plots having the spacing of 4X5m, 5X5m, 4X6m respectively were established at both places. Overall observations showed that the *Melia composita* attains about 14m height with a girth of about 65cm. Under proper canopy management the plants also give good amount of fuelwood in its rotation of 8 years. Yield of two crops i.e. wheat and maize was also recorded unto 4 years plantations of *Melia composita* under different spacing and it was found that there was no remarkable difference in the yield of both crops in comparison of open area crops. Property of the soil was also studied during the experimentation in all plots and it was found that there was no adverse effect on the fertility of the soil in *Melia composita* plantation. The fertility of the soil was found improved in plantation.

To Study the Timber Markets of Important Agroforestry Species in Eastern Uttar Pradesh

In the present scenario, agroforestry is aviable option for increasing tree cover in Eastern U. P. The unorganized and poor availability of wood based markets as well as timber industries depressed farmers for promoting agroforestry. But the market linkages are very poor in the Eastern U.P. as farmers and traders are not well aware about raw material as well as the trading sources of timber and Bamboos. Thus, with a view to strengthening market linkages between growers and traders, this study has been proposed in the region of Eastern U.P. Consultation of literature under the project regarding baseline data, identification of species , selection of districts, identification of market places , village list in respective districts .Under the study, important species of the area for agroforestry had been identified. The selected species are shisham, sagaun sam, neem, jamun, kathal, bamboo, mahua, popular, babool and *Eucalyptus*. The study area has been identified in consultation with UPSFD in six districts covering all the three agro-climatic zones lying under Eastern U.P. The selected districts are Allahabad, Raebareli, Barabanki , Bahraich , Gorakhpur and Sonbhadra. The questionnaire for collecting growers and traders information had also been prepared for market places, farmers, village information, industries, contractors, furniture/wood markets. The data collection has been done in two districts-Raebareilly and Allahabad for farmer/grower information having marketable timber under agro forestry. One representative village had also been selected from each block for collection of general information of villages, demand supply gap status of selected species and constraints in marketing of timber species. Likewise market details had also been collected from saw mills, industries and other market places. The data compilation is under progress for preparation of database of traders/growers.

Development of Site Specific Medicinal Plant based Agroforestry Models for Existing Plantations in Eastern Uttar Pradesh and Establishment of Demonstration Model

Surveyed the area for site selection for on-farm agroforestry participatory research and questionaire has been prepared for identification of suitable farmers for the participatory research. Site has been selected for experimental trials of medicinal plants in Allahabad district with the tree crops of mango, aonla, mahua, bamboo and *Eucalyptus* sp. Procured the propagules of sarpgandha, pachauli and satawar and kalmegh from CIMAP Lucknow and nursery for Propagation of medicinal plants and experiments laid out.

Establishment of Bamboo Model Plantations in Different Agro-climatic Zones of Tamil Nadu

Established bamboo plantations in 100 ha in different agroclimatic zones of Tamil Nadu using quality planting stock to demonstrate the growth performance of introduced species (*Bambusa balcooa, B. tulda, B. nutans, B. vulgaris and Dendrocalamus stocksii)* and native species (*Dendrocalamus strictus* and *Bambusa bamboos*) and also to demonstrate the growth performance of micro-propagated, macro-propagated and seedling raised planting materials. The species recommended for different zones in order of preference based on number of culms are:

Western zone: *Dendrocalamus strictus, Bambusa vulgaris, Bambusa tulda, Bambusa nutans, Bambusa bambos, Bambusa balcooa* and *Dendrocalamus stocksii.*

North-eastern zone: *Bambusa vulgaris, Bambusa tulda, Bambusa nutans, Dendrocalamus strictus, Dendrocalamus stocksii, Bambusa bambos* and *Bambusa balcooa.*

North-western zone: *Bambusa vulgaris, Dendrocalamus strictus, Bambusa nutans,*

Bambusa tulda, Bambusa bamboos and *Bambusa balcooa*.

Cauvery delta zone: *Bambusa vulgaris, Bambusa tulda, Dendrocalamus strictus, Dendrocalamus stocksii Bambusa bamboos, Bambusa nutans* and *Bambusa balcooa.*

Southern zone: *Bambusa vulgaris, Dendrocalamus strictus, Bambusa nutans, Bambusa bamboos, Dendrocalamus stocksii, Bambusa tulda* and *Bambusa balcooa*.

Among the different selected phenotypes studied for the 7 different species, BB5 and BB6 of *Bambusa balcooa,* BA1, BA12 and BA8 of *Bambusa bambos,* BN6 of *Bambusa nutans,* BT1 of *Bambusa tulda,* BV2 and BV6 of *Bambusa vulgaris,* DSI2 of *Dendrocalamus stocksii* and DS4 of *Dendrocalamus strictus* were found to be most adopted phenotypes which can be grown across different regions of Tamil Nadu.

The planting of seedlings, branch cuttings and rhizomes should be done prior to North-East Monsoon season preferably before October. Watering of plants should be done frequently to enable them grow vigorously before the rainy season. Bamboo needs water but cannot stand water-logging. Watering is needed in the dry season to keep the moisture balance inside the bamboo which is essential for survival of newly planted Bamboo and rhizome expansion. The clay soils and soils with low moisture retention capacity should be avoided. The bamboo should be grown in fields where irrigation is available since all the species other than the native ones have original distribution in wet conditions.The silica content in *Bambusa vulgaris* is low as compared to other species, hence paper and pulp industries particularly TNPL is promoting the same under contract farming. There is an assured market for the species in the present situation in Tamil Nadu. Hence farmers are encouraged to grow the species, provided they enter into contract with the paper mill.

Spacing for bamboo should be increased from 5X5m to either 7X5 or 7X6m since there is early congestion in plantations of 3 years age. Further, wide spacing will be useful for intercropping as well as future working of the clumps.Bamboo can be grown with agroforestry models and species like Tapioca, Turmeric, Groundnut, Banana and vegetables atleast in the initial years upto two years. Pruning of branches need to be done in the third year to decongest the clump which will also ensure clump hygiene. Branch nodal cuttings are the effective way for mass propagation of bamboos. From one branch a minimum of five to seven cuttings can be made. From each culm three to four branches can be obtained. The knowledge gained from the project has been used in the training programmes organised for Horticulture officers of Tamil Nadu, Farmers of Tamil Nadu and officials of NABARD, Tamil Nadu Forest Department and Puducherry Forest Department. A brochure on cultivable bamboos in Tamil Nadu was published for the benefit of farming communities.

Improving Productivity of Bamboo Cultivation in Farmlands of Tamil Nadu

Traditional bamboo planting is restricted to raising of few clumps of *Bambusa bamboos* along the bunds of agriculture fields as is prevalent in the Cauvery Delta region of Tamil Nadu. Under the project funded by the National Bamboo Mission, Department of Agriculture and Cooperation (Horticulture Division), Ministry of Agriculture, Government of India, block plantations of non-thorny bamboos viz., *B. balcooa, B. vulgaris, B. tulda, B. nutans* and *Oxytenanthera parvifolia* have been raised in farmers fields. Farmers were invited, through newspaper advertisements, to offer their land for raising non thorny bamboo block plantations from three agro-climatic zones of Tamil Nadu viz., Southern zone, Cauvery Delta zone and North-Western zone. Farmlands offered were inspected

and based on availability of irrigation and protection facilities, sites were shortlisted. In each location, 1.5 acre (0.6 ha.) of block plantation of each species has been laid out, in 2 replications, which is subjected to different levels of fertilizer treatment including control. In each location, 7.5 acre (3 ha) of field trials covering 5 species is laid out. In each agro-climatic zone, 3 such trials have been laid out totaling 9 trials spread over 27 ha. of on-farm trials. Data on survival are being recorded periodically.

In order to establish a bamboo germplasm and multiplication garden, 10 ha. area has been prepared within the IFGTB Field Station at Kuruchi, Coimbatore. Eighty one accessions of 34 bamboo species to be assembled in bamboo germplasm bank have been collected from across the country. Fourty accessions of 5 species have been assembled and are being maintained in the Model Nursery, Coimbatore.

Development of Elite Planting Material and Model Plantation

For raising 50 ha of model plantations of Neem and Pungam, 15,000 Neem seedlings were raised in the Institute's nursery at Coimbatore while 12,500 Pungam seedlings were procured from a private agency. Utilizing the seedlings, 2 ha. each of Neem and Pungam plantations has been established at the recently established field station at Salem in the form of block plantations and line planting. Similarly Neem (5 ha) and Pungam (1ha) plantations were raised within BSF Campus, Kittampalayam, Coimbatore by adopting line planting model. Tamil Nadu Magnesite Limited (TANMAG), Salem has granted in principle approval for raising Neem and Pungam trees within their campus over 40 ha area in forthcoming monsoon season.

A Value Chain on Industrial Agroforestry in Tamil Nadu

The best Clones / Seedlots of *Eucalyptus* and *Casuariana* identified as superior by IFGTB are transferred to the Industry under a Material Transfer Agreement. This material in turn is supplied by the Industry to the farmer, with whom it has Buy-back management. It is a tri-partite arrangement between a Forestry Research Institute, Wood-based Industry and tree farmers. Two districts of Tamil Nadu are covered under this project (Agroforestry) by contract forming. The experimental sites or farmers field are selected in consultation with the Industry. About 30 ha plantation were completed in the farmers field under tri-partite system.

Casuarina: Two hybrid clonal trials were established in Coimbatore (Bharathiar university campus), Cuddalore and five clonal trials were established in the following five places Coimbatore, Erode, Karur, Namakkal and cuddalore.

Eucalyptus: One clonal-cum-progeny trial established for selection of clones/ families in high sodic soil at Athipalayam and 15 farmers field trials are established in Karur District like Athipalayam puthur, Uppilipalayam, Kanagapiliyur and 2 fields near NH 7 Dindugal main road. One hybrid trial established at Coimbatore.

The tri-partite arrangement is effective in transferring the results of research to the farmer's field. Genetically improved material is made available for planting by tree farmers and there is an assured market value for the produce due to the Buy-Back arrangement.

Development of Agroforestry Systems with Economically Important Medicinal Plants under Industrial Tree Species of Casuarina and Eucalyptus

Agroforestry is gaining importance as land use practice in different parts of the country. In farmlands, farmers intercrop tree species with many agricultural crops like cotton, soyabean maize, ground nut and many other food plants. While agroforestry models have been developed for these agricultural crops by many researchers,

no adequate research has been done to develop agroforestry system with medicinal plants. In the context of growing interest among the farmers for cultivating tree species in farmlands, particularly Casuarina and Eucalyptus and existing potential market for medicinal plants, the present study has been carried out to develop suitable agroforestry systems with medicinal plants. Under this study, industrially important medicinal plants such as *Asparagus racemosus, Cassia senna, Decalepis hamiltonii, Gloriosa superba, Hemidesmus indicus, Plectranthus barbatus, Withania obtusifolia* and *W. somnifera* have been selected. Studies on cultivation of the medicinal plants with *Casuarina* and *Eucalyptus* and their compatibility in agroforestry system will open up a new vista and encourage the farmers to practice the system and get more remuneration than intercropping with any other agricultural crop.

Introduction and Evaluation of Fast Growing Tree Species under Agroforestry Systems in different Agro-climatic zones of Tamil Nadu

Identified the required land of 15 ha farm land in three zones (North-eastern, Cauvery delta and Southern zones of Tamil Nadu) and established agroforestry trials with fast growing tree species of *Melia dubia, Gmelina arborea, Neolamarkia cadamba* and *Sweitenia macrophylla* over 5 ha each in three zones. Intercropping activities were carried out and the biomass and yield of the intercrops have been assessed. From the intercropping activities carried out in the first year, *M. dubia* with Turmeric registered highest net annual returns of h 1, 25, 700/- followed by *G. arborea* with Banana (¡ 41, 550/-), *M. dubia* with Tapioca (¡ 32, 468) per ha basis. Allelopathy study was also conducted with the exudates prepared from the fast growing tree species leaf, stem and root and study completed in Maize, Sorghum and Black-gram. One training was conducted on "Capacity building on agroforestry plantation establishment and management" to farmers' of Pudukottai district.

Gmelina arborea and Sugarcane in Southern Zone of Tamil Nadu

Melia dubia with Turmeric Field in Cauvery Delta Zone of Tamil Nadu

Neolamarckia cadamba, Gmelina arborea and *Melia dubia* under Farmer's Field in North-eastern Zone of Tamil Nadu (Villupuram District)

Development of Agroforestry Models in *Wrightia tinctoria* R.Br and *Gmelina arborea* Roxb. as Tree Species in Semiarid Tropics of Andhra Pradesh

The experimental site was prepared for plantation at Chelmeda, Ramayampet Mandal, Medak District of Andhra Pradesh. Soil samples were collected from the study site and analyzed for physico-chemical properties. Seedlings of *Gmelina arborea* and *Wrightia tinctoria* was raised in FRC nursery and then planted out along with Red gram and Sorghum as inter crops. The inter crops were harvested upon maturation and yield data recorded. Growth data of *Wrightia tinctoria* and *Gmelina arborea* was recorded six months after plantation.

Ecological, Economic and Socio-cultural Evaluation of a Traditional Ficus Based Agroforestry System in Mandya District, Karnataka

Around 200 individual farmer surveys and 16 village level surveys have been completed covering 7 taluks in Mandya District. *Ficus benghalensis* is the most common species of ficus retained by farmers in cropping systems and mostly grown for fodder for livestock and for small timber. Ficus species are highly preferred by farmers in dry lands, but with irrigation, preference shifts to fast growing trees like eucalyptus and horticultural species like coconut which are financially more profitable. Logit analysis of factors influencing ficus adoption of ficus trees in farming systems revealed that adoption of ficus trees is positively related to livestock income and total land area and negatively related to percentage of irrigated area. Studies on litter fall pattern and nutrient input through litter reveled that total annual litter fall of *F. benghalensis* was around 2.5 ton/ha, out of which 60% was contributed by leaf litter alone. Peak litter fall months were found to be October–November. It was found that at an average density of 16 trees /ha, *Ficus* trees meet 77 % of N, 20 % of P and 68 % K requirement of dryland crops/ha/year. Litter decomposition studies showed that ficus leaf litter in subsurface treatment decomposed to half of its original mass in 169 days (half –life period) while when left at the soil surface took 200 days for decomposition of half of the mass.

Multilocational Introduction cum Demonstration trial and Field Evaluation of Six Important Bamboo species viz; *Bambusa balcooa. B. nutans, Dendrocalamus asper, D. hamiltonii, D. stocksii* and *Guadua angustifolia* in Andhra Pradesh, Karnataka and Goa

During May-June 2007 selection of sites in Andhra Pradesh and Goa were finalized in consultation of SFDs, whereas, the finalization of site for Karnataka was completed in June 2008. Production and establishment cultures of *Bambusa nutans, Dendrocalamus asper, D. stocksii* and *Guadua angustifolia* were carried out at IWST, Bangalore during 2006-2009. *Bambusa balcooa* and *Dendrocalamus hamiltonii* micro-propagated plants were procured from Grow More Biotech, Hosur, Tamil Nadu and IHBT, Palampur, Himachal Pradesh, respectively during 2007-2008. *Bambusa nutans* for Andhra Pradesh and Goa were also procured from TFRI, Jabalpur during June 2007. Field preparation and plantation was carried out during July- August 2007 in Andhra Pradesh (20ha at Chintalapudi, and Buggapadu) and Goa (5ha, Agalote). Field preparation and plantation was carried out during July-August, 2008 in Karnataka (20ha Navtoor, Shimoga). Achieved complete target of 45ha of demonstration trials (20ha in A.P., 20ha in Karnataka and 5ha in Goa) in 2008. Mortality replacement at all the three states was completed in September 2009. Regular data recording was carried out of the field trials to evaluate survival rate and growth performance in terms of number of tillers and average height. Training on bamboo macro-proliferation and vegetative propagation

was provided to the officials of Goa Forest Department (GFD), Andhra Pradesh Forest Development Corporation (APFDC) and Karnataka Forest Department (KFD) during February, September 2010 and January 2011 respectively as a part of objective i.e. validation of Packages of practices for high yield plantations for bamboo.

Sustainable Development of New Bamboo Agroforestry Techniques for Increased Income Generation in the Central Indian States

Two species of bamboos viz. *Bambusa nutans* and *Dendrocalamus strictus* were selected to establish the bamboo based agroforestry system at experimental area of TFRI and to create the awareness among the farmers of different villages of M.P. and Chhattisgarh state for the adoption of bamboo in their field. So far training through PRA technique was conducted for the farmers of Chhindwara and Gwalior district of Madhya Pradesh and Deopur and Raipur of Chhattisgarh during the 2008 and 2009 to train them about the benefits of bamboo based agroforestry system and its management. Distributed the seedlings of *B.nutans* as demanded by them. Standardized the Bamboo-Wheat and Bamboo-Urad silvi-agri system by repeating the system in two cropping season i.e. Kharif and Rabi.

Post Harvest view of Bamboo –Wheat silvi-agri System Established as an OSR at the Agroforestry Experimental plot, TFRI, Jabalpur

Demonstration and Training on the Benefits of Bamboo Based silvi-agri systems being Imparted to Progressive Farmers of Majhuali Block of Jabalpur District on 23rd December 2010 at OSR, TFRI, Jabalpur.

Director of TFRI Addressing to the Farmers About the Benefit of Agroforestry

PI of the Project is Giving Knowledge of the Sissoo-mays silvi-agri System During the Technical Session of Training

Prepared nutrient balance sheet through physico-chemical analysis of the soil samples collected before and after the each removal of the crop from the system. The data show the increasing status of nitrogen as compared to initial stage of land. Data of yield and growth parameters were recorded and statistically analysed to draw the effect of bamboo on grain yield under the intercropping. Data indicates the maximum grain yield of wheat under the *B.nutans* and minimum in *D.strictus.*

Evaluation of Productivity of Maize in *Dalbergia sissoo* (Shisham) and *Zea mays* (Maize) Agroforestry System

Dalbergia sissoo based agri-silviculture system was standardized by intercropping of Hybrid variety of *Zea mays* crops during kharif season under the age of 3 year old *Sissoo* plantation at the experimental area of TFRI. The data were collected on the various parameters (growth, yield, biomass and nutrient status) of tree crop under the system. Results, indicated that the maximum productivity of maize crop was in 5mx 5m spacing of sissoo, followed by 4m x 4m when intercropped with sissoo tree. Similarly the growth of *D.sissoo* plants showed gradual increase in height and girth, due to the fact that every cultural operation given to the associated crop provided benefit to the trees under the agroforestry system. Compilation, tabulation and analysis of data is under progress for the writing of report.

Organized one day training cum demonstration programme on *Dalbergia sissoo* and *zea mays* silvi-agri system for the farmers of four villages Padariya, Khamariya, Saliwada and Neemkheda of Jabalpur district.

Development of Multitier cropping (Silvi-Agri-Spice) System

Identified and selected two study sites as an OSR experimental area of TFRI and as an OFR in farmer's field, Neemkheda village, Jabalpur district to establish the multitier cropping system by raising Aonla intercropped with Arhar and Adrak. Preliminary cultural operations like clearing, weeding, ploughing, levelling of field, basal dressing with Farm Yard Manure were done. Procured and transplanted two varieties of *Phyllanthus emblica* (Aonla) viz. NA7 & NA 10 at the spacing of 10mx8m and 10mx6m intercropped with *Cajanus cajan* (Arhar) in Factorial RBD. Collected and analysed soil samples for the determination of soil properties (soil pH, EC and Organic matter content before the initiation of the system. Data on growth of aonla plants were recorded and tabulated.

Development of Lac based Silvi-Agri-Lac Systems

Surveyed the local area for the selection of farmer's field to establish the OFR under the project. Saplings of two species of Lac host viz. *Flemingia semialata* and *Flemingia macrophylla* were procured from the Natural Resin and Gum Research Institute (Jharkhand) Namkum, Ranchi and transplanted in the OSR and OFR selected as two study sites under the project. For the estimation of physical properties and nutrient status of land, soil samples were collected and analysed. Observation on growth and survival of both the species were recorded.

Standardization of Cultivation Protocol for *Asparagus racemosus* (Satawar)

Maximum germination was observed in the month of June (70%) and the depth 2.5-3.0 cm gave better results. The observation showed that T2- fortnightly irrigation is the best treatment in terms of fresh root weight, plant height, length, diameter and number of tubers as compared to other treatments. The doses of FYM, Vermi-compost @12.5t/ha (i.e. 250 gm/plant), and VAM @5t/ha (i.e.10 gms/plant) were proved as optimum dose in terms of highest number of roots and fresh root yield. Spacing of 60 x 60 cm resulted in minimum damage during harvest of tubers and also improved the growth of tubers.

The best harvesting age of satawar to get maximum yield was 18-24 months. Chemical analysis of tubers had been done for satavarin IV from MPMFP Processing & Research Centre, BHOPAL and for saponin content from Venkatesh Food Industries, NISO 9001 HACCP certified company, Chhindwara. Satavarin IV content 0.73% and Saponin content of 49.0% was found maximum in FYM treated plots.

Assessment of Land Use Practices in Jhum Areas and Investigation of Different Production Related Parameters

Three types of land uses systems were observed-settled, jhum and home gardens. In Jhum cultivation seasonal crop like tomato, cabbage, chilly etc. are in practices. In home garden the practice is pumpkin etc. Aquaculture is practiced traditionally. Activity calendar was prepared with the help of PRA tools and direct interaction with people etc. The activity performed in Singchung village, Tenga and Keopa village of Singchung block. Sakchi Kho watershed of West Kaming district was selected for second year. Collected all geographical details. Four type of land use system exist in Sacho-Kho watershed i.e: Jhum, settled, aquaculture and home gardens. With the help of PRA , RRA and questionnaire activity calendar was prepared. Soil analysis done using GPS point in Quantum GIS. Annual Report of Sakchi Koh is under progress, while data gathered from Tenga watershed are completed.

Productivity Enhancement in Abandoned Jhum Land Through Agroforestry Management and Value Addition

Study sites were selected for participating farmers in the on-farm research. The willing farmers were interacted for their problems and prospects. A questionnaire was also tested to record their socio-economic status based on seasonal market product. Participatory appraisal for their crop preferences and planning for field trials. The sites were prepared and lay out of the trials designed.

Quality and Yield Improvement in Agroforestry Based Food Product Under Integrated Nutrient Management

Soil samples and Plant samples (lady finger, bitter gourd , cucumber etc.) from Satra, Demo Village, Cachar, Sonitpur, Golaghat, Kokarajar, Nalbari Kamrup & Nagaon district were collected. Physical & chemical properties (pH, moisture content organic carbon, phosphorus etc) and iodine content of 37 soil samples have been analyzed. Field trial for iodine bio-fortification in bamboo based agroforestry crops (lady finger and cucumber) were established in Satra, Jorhat. Samples were collected and their iodine content under various treatments was analyzed. On the basis of preliminary data, it has been interpreted that correlation between iodine content and organic carbon is positive where as correlation between iodine content and pH is negative.

Development of Economically Viable and Integrated Agroforestry Models for Arid Region

An agroforestry model was established in August 2006 and maintained at farmer's field at village Harsh, Bilara and District - Jodhpur. *Sesbania aculeata* (Dhaincha) was grown in the field for green manuring. Survival, growth and crop production data were recorded, compiled and analyzed. Performance of *Cordia mixa* was found the best as horticultural species and *Prosopis cineraria* as silvicultural species. *Colophospermum mopane* plants attained maximum height (213 cm), followed by *P. cineraria* (203 cm), *A. excelsa (*200 cm) and *Cordia mixa* (183 cm) whereas *Z. mauritiana* attained minimum height (117 cm).

Collar diameter was maximum in *A. excelsa* (8.13 cm), followed by *Cordia myxa* (7.00 cm), *Colophospermum mopane* (5.60 cm) and *P. cineraria* (5.32 cm). The plant growth and survival was higher in agroforestry plots as compared to the control (without crop). Wheat crop production was recorded 14.03 quintal /ha during the year. Wheat crop production was found

reduced significantly in *C. mopane* and *Cordia myxa* tree combination plots in fifth year.

Introduction and Performance Trials of *Gmelina arborea* for Agroforestry in Lower Hills of Himachal Pradesh and Jammu & Kashmir

Procurement/collection of seeds of *Gmelina arborea* from five locations was accomplished through Institute of Forest Productivity, Ranchi and was later sown in the Field Research Stations of the institute locted at Johron (Paonta Sahib) and Bir Palasi (Nalagarh), falling in the District. Sirmour and Solan respectively. These two stations are located in low hill zone of the state and accordingly, have been used for the production of planting stock of the species. After field survey, four sites in lower hill zone at Puruwala and Kot in Himachal Pradesh (HP) and Nudh and Basanterbella in Jammu and Kashmir (J&K) measuring 5.0 ha have been identified and experimental trials with three replications and following Randomized Block Designs (RBD) were established. Preliminary growth data indicate that the *G. arborea* is performing well on all the study sites and have attained an average height of about 250 cms within three years of its establishment. Though very early to predict, yet, keeping in view the permormance of the species with special reference to the growth data and its short rotation period as well, it can be a potential species for carrying out future plantations in the lower hills of both these mandated states.

Evaluation of Soil Fertility Status and Nutrient Return from the Important Indigenous Agroforestry Tree Species in Himachal Pradesh with Special Reference to Hamirpur District

Quantitative parameters of agri-silvicultural system have been recorded for developing correlations and recommendations. The results indicate that the six important agroforestry species (frequency > 56%) selected for taking up the present study were also integral part of the naturally occurring agri-silvicultural agroforestry systems in the region. Collected soil samples have been analyzed. Nitrogen has been observed higher in the upper soil horizons which tend to decrease towards lower horizons of soil in most of the agroforestry species under the study. The preliminary results of soil analysis indicate a positive role of agroforestry species in maintaining the fertility status of the soil.

Nutrient contents in the litter of six important agroforestry species i.e., *Grewia optiva, Mours alba, Celtis australis, Bauhinia variegata, Toona ciliata* and *Albizia chinensis* had been undertaken. Litter samples collected from the experimental area were further segregated into various litter parts. These are oven dried in hot air oven at 80±2°C till the constant weight reached and are then ground in Wiley Mill for further chemical analysis. Results of litter production by important agroforestry species indicate that *Grewia optiva, Mours alba, Celtis australis, Bauhinia variegata, Toona ciliata* and *Albizia chinensis* all together contributes significant amount of litter-fall annually through various litter fractions. Results on nutrients contents in litter of agroforestry species indicated that leaves of these six important species have higher concentrations of either of the five nutrients (Nitrogen, Phosphorous, Potassium, Calcium and Magnesium) studied. Study showed that significant amount of nutrients had been returned to the ground/ soil by these agroforestry species.

Enhancement of Soil Carbon and Nitrogen Sequestration Potential of Mined/Overburden Soils in Jharkhand through Management Practices

Two coal mine over burden sites, viz., Khilaris Coal Mines (CCL,Ranchi) and Sikini Coal Mines (owned by private licensee) were selected for the study. Nursery was established for seedlings production for planting at overburdens. Soil samples were collected from the overburden

soils and physico-chemical properties were analysed. Pot trial experiment is in progress with four tree species in the Khilari overburden soil, which is reclaimed by vermicompost and green manuring. As bulk density of the overburden soil is high, 50% of sand was added to the overburden soils. Performance of species with respect to germination and growth are being recorded.

2.2.4 Forest Soils & Land Reclamation

Bioremediation of Bauxite Residue Through Bio-inoculants

A team of scientists visited HINDALCo for surveying the Red Mud Production. Red Mud is produced during the Bayer Process. HINDALCo dumps Red Mud, after drying process called dry stacking of Red Mud in nearby area closed to the forest. Red Mud Samples were collected and analyzed. Effect of bioinoculant in the bioremediation of Red Mud is being studied.

Phyto-remediation of Water Logged Waste Land Through Biodrainage and Soil Amendments

Irrigation potential has been increased in recent years for the increased and sustained yield of agricultural products. The introduction of canal irrigation has caused a rise in ground water table leading to water logging and secondary salinisation. Presently, about one-third of the world's irrigated area facing the threat of waterlogging. About 4981.43 sq km area in Uttar Pradesh is suffering from water logging resulting in reduced productivity. The present study is aimed to phyto-remediate the waterlogged area through plantation of biodrainage species. Water logged site of eastern U.P. has been surveyed and nursery of selected species has been established.

Soil Organic Carbon Inventory of Uttarakhand

Total SOC pool in the soils in Uttarakhand under Quercus forests was 36.95 million ton, Miscellaneous forests 36.22 million ton, Chir forests 24.10 million ton, Sal forests 18.30 million ton, unproductive barren lands 15.01 million ton, silver fir & spruce forests 13.03 million ton, deodar forests 2.22 million tons, kail forests 1.26 million tons, *Eucalyptus* forests 0.91 million ton, teak forests 0.82 million tone, shisham forests 0.50 million ton, khair forests 0.24 million ton and the least was cypress forests 0.20 million ton. Total SOC pool under forests owned by forest department (24,41,480.41 ha area) was 149.73 million ton in Uttarakhand. 65.43 million ton SOC pool was under the forests of Garhwal zone (which is 43.69 % of total SOC pool in UK forests), 47.13 million ton was in the soils under Park and Sanctuaries (which is 31.48% of total SOC pool in UK forests) and the least was in Kumaun zone i.e. 37.17 m t (which is 24.83% of total SOC pool in UK forests). Maximum SOC pool was in the soils under forests in Bhagirthi circle (26.36 m t and 17.60 % of total SOC pool of UK forests) followed by North Kumaun circle (17.17 m t and 11.47 % of total SOC pool of UK forests), Western Circle (16.32 mt and 10.90 % of total SOC pool of UK forests) and the least was in South Kumaun circle (3.69 m t and 2.46 % of total SOC pool of UK forests). SOC pool in the soils under Apple orchards was 80.80 t ha^{-1}, Mango 50.69 t ha^{-1}, Citrus 47.55 t ha^{-1}, Litchi 44.92 t ha^{-1} and Guava 40.21 t ha^{-1}. Total SOC pool in the soils under Horticulture (1,93,787 ha area) was 10.75 million tons in Uttarakhand. SOC pool in the soils of grass land below 2750 m altitude was 86.57 t ha^{-1} while in the soils above 2750 m altitude, it was 143.76 t ha^{-1}.

Total SOC pool in the soils under grassland in Uttarakhand was 26.77 million ton. SOC pool in the soils under block plantation was maximum in cypress 66.32 t ha^{-1}, followed by *Eucalyptus* 46.39 t ha^{-1}, Chir 43.30 t ha^{-1}, teak 42.93 t ha^{-1}, shisham 37.67 t ha^{-1} and the least was under poplar 31.41 t ha^{-1}. SOC pool in the soils supporting sugarcane–poplar model was maximum 33.48 t ha^{-1} while under wheat – poplar model it was 24.81 t ha^{-1}.

Relative Effect of Geology, Vegetation & Climate on Soil Formation of Uttarakhand

Uttarakhand forests of North-Western Himalaya are a confluence of all the rock formations resulting in different soil and vegetation types on different climatic zones. Mineralogical studies have special importance in forestry where tree growth lasts over a long period and depends to a large extent on the minerals as a source of nutrients in the soil. The underlying parent material plays a vital role in determining the success or otherwise of the plantations especially over a number of rotations in a given year on different climatic conditions The plant nutrients are chiefly derived from the weathering of minerals. The reserve and availability of nutrients depends largely on the mineralogical composition of soils and their parent material. The importance of geology in forest is of great significance in evaluating the soil fertility status and in managing the soils for greater production. Keeping in view the importance of soil mineralogy its study was carried out in Uttarakhand.

Extensive survey of natural forests in Uttarakhand was carried out. Suitable sites were selected on the basis of different forest vegetation, geology, altitude and climate in Dehradun, Tehri Garhwal, Pauri Garhwal, Uttarkashi, Chamoli, Rudraprayag and Nainital districts of Uttarakhand. In each site three subsites were selected and soil samples collected from different genetic horizons viz. 0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm and 90-120cm with the help of soil auger. Further one soil profile at each site was excavated to study morphological features of soil. These samples are being analyzed for different physical and chemical attributes. The rock samples were collected from different sampling points having similar or different vegetation and geological formations. Suitable numbers of 10 x 10 m. quadrates were laid down in each sampling points and the trees within the quadrates enumerated for dbh, height and crown area. Different physico–chemical attributes of soil and rock samples collected so far are being analysed.

Soil Organic Carbon Store Under Different Land Uses in Haryana

Soil organic carbon is very important component of global carbon cycle. It is very sensitive to anthropogenic activities so it may readily depleted by anthropogenic disturbances such as land use changes and cultivation. Land is being used for different purposes viz. for forestry, agriculture, agroforestry, pastures, horticulture, plantations, habitat etc. Land use and soil management practices can significantly influence soil organic carbon dynamics. Accurate quantification of soil carbon is necessary for detection and prediction of changes over a period of time. Most of the data in literature is in the form of per cent soil organic carbon. Whenever it is converted in soil organic carbon pool / store, some assumptions have to be used especially for calculation of weight of the soil. No systematic study had been conducted in Haryana to estimate SOC pool neither in forests nor in any other land uses. Therefore, this project was undertaken to estimate SOC pool in different land uses in Haryana. Information generated from this project on SOC store in different land uses will serve as benchmark information for the future investigations and provide authentic information on this very important aspect of climate change.

Soil organic carbon is being estimating under four land uses viz. forests, block plantations, agroforestry and horticulture land uses in this project. Surveyed the different districts viz. Bhiwani, Mahendragarh, Rohtak, Jhajjar and Yamunanagar in this year in Haryana. Selected the sites at different locations and collected the soil samples under forests; plantations; agroforestry

and horticulture land use. Little over 1000 soil samples were collected from different land uses for soil organic carbon estimation and bulk density and coarse fragment estimation from more than 150 locations.

Identification of Suitable Tree Species and other Vegetation for Bio-drainage in Bargi Command Area (Jabalpur, M.P.)

The study was conducted with the objective to drain out excess water of the soil in water logged/canal seepage areas through vegetative means and to enhance the site productivity along left bank canal of Bargi command area, Jabalpur. Out of seven tree species planted along canal, *Eucalyptus* hybrid (FRI-4 and FRI-5 clones), followed by *Terminalia arjuna* and *Pongamia pinnata* showed a better performance of growth and biomass and lowered down the water table, regularly measured by observation wells. Lysimetric experiments conducted to simulate the field experiments also showed the similar trend.

Integrated Nutrient Management for Improved Growth of Trees on Overburden Dumps

Survey was conducted in Kanhan region of Western Coal Fields Limited, Junnardeo and Pench area of Western Coal Fields Limited, Shivpuri area for selection of coal mine overburden site for laying out experiment. Shivpuri open cast mine-1 has been selected for taking up the experiment. Overburden samples were collected from the selected site and the samples were analyzed for its physico-chemical properties viz, texture, bulk density, pH, EC, organic carbon, Available N,P, K, Cation exchange capacity, Exchangeable Ca, Mg, available micronutrients viz. Fe, Mn, Zn and Cu. Seeds of the selected species viz, *Albizzia lebbeck, Acacia auriculiformis, Cassia siamea, Delonix regia, Emblica officinalis, Mangifera indica Moringa oleifera, Dendrocalamus strictus, Terminalia bellerica* and *Gmelina arborea,* were sown in polybags for raising seedlings. Seedlings are being maintained in the nursery. Further work is under progress.

Rehabilitation of Jhum Land Through Potential Bamboo Species with Reference to Carbon Sequestration and Livelihood Development

Plantations were carried out in three different bamboo species (*Bambusa balcooa, B. nutans* and *Oxytenanthera parvifolia*) in selected sites of Karbi Anglong District, Assam. Sites were selected based on the criteria like willingness of farmers, status of degraded jhum land, easily approachable for monitoring etc. Geo-coordinates of the project site has been recorded and mapping done on image obtained through Google earth. Documentation of bamboo resources were carried out through extensive survey. Progressive growth data, plant and soil carbon, bulk density, biomass estimation of different species of bamboo in different spacing were carried out at regular intervals. Results showed highest value of plant carbon in *B. balcooa* followed by *O.parvifolia* and *B. nutans*, respectively. Growth and biomass estimation also follows the same trend. No significant difference was noticed in terms of soil carbon and bulk density up to second year of study.

Enhancing Productivity of Saline Wastelands in Kachchh-Through Improved Tree Planting Techniques and Silvipasture

Research trials were laid with *Acacia ampliceps, A. bivenosa* (exotic) and *Salvadora persica* (indigenous) on black silty clay (medium), soil depth: 40-75 cm at Kordha, Sami Range in Patan, Gujarat at the fringe of Wild Ass Sanctuary (WAS) in July 2007 to find out suitable exotic and indigenous fodder plant species with appropriate planting practice. *S. persica* proved to be the best species surviving in the extemely harsh conditions of high salinity, heat stress after two consecutive summers (2009 & 2010) and one drought year (2009) suffering almost no casualities and maintaining nearly the same mean survival (91.5%) after 45 months of planting . Fifty per cent

prunning was done in winter 2009 to over come water stress. *A. bivenosa* was at second place surviving one summer and one drought year with 77.3% at 30 months . However, survival was significantly reduced in summer 2010 and recorded as 46.3 % at 45 months. Survival of *A. ampliceps* was drastically reduced to only 12.7% ranging from 06.0 % in control to 18.7% in T_3 (Wheat husk) treatments. In general, causalities were high in shallow soil depth for both the *Acacia* spp.

S. persica attained height after pruning with a mean increment was 12.1%. Despite suffering with high casualities, *A. bivenosa* attained height (mean 126.7cm) in all the treatments. However, there was no growth in crown diameter. Treatments influenced the biomass yield and all the treatments recorded higher biomass as compared to control (3.43 kg).

Aacacia bivenosa (up) and *Salvadora persica* (down) in Salt Affected Site after 38 and 46 Months, Respectively

Zygophyllum simplex (Pat Lani)

Taverniera cuneifolia (Jathi moth)

Maximum 12.68 kg biomass yield was obtained for T_3 (Wheat straw) treatment, followed by 10.22 kg for T_2 (FYM) treatment.

Green weed-mass was studied by laying random quadrats (1m x 1m) size in the entire experimental area. Among the plant species, halophytes were not dominated during 2010-11 due to very good rain creating water logging and salt leaching and favoured species appearance. Grasses dominated and *Chloris virgata* was the most dominant species, followed by *Dactyloctenium aegypticum, Cynodon dactylon, Aristida* spp, *Cyperus* spp. and *Echinochloa colonum. Sporobolus* spp. also appeared for the first time. Among herbs, *Zygophyllum simplex* was the most dominant, followed by *Taverniera cuneifolia*

A
Z mauritiana,

B
C. ciliaris and *Cordia gharaf*

C
Field Visit of VVK Trainees at Mochirai, Bhuj

(Jathi moth), *Sueada fruticosa*, *Vernonia cinerea* and *Polygala erioptera* .

Overall 406 gm^2 yield was recorded however, tree species-wise, variation was observed and it was 419.0 gm^2 (*A. bivenosa*) 391.2 gm^2 (*S. persica*) and 357.9 g in the shallow water logged area.

Silvipastoral Study: Trials with four tree species, viz; *Cordia gharaf, Prosopis cineraria, Zizyphus. mauritiana* and *Colophospermum mopane* and two grass species, namely, *Cenchus ciliari* and *C. cetigerus* were laid in RBD in three replication at Mochirai, Bhuj in July 2006.

Survival: In both the experiments, survival at 52 months was 93.8 % in *C. setigerus* and 92.6% for *C. ciliaris*. There was no significant difference between with grass and control treatments. Species-wise, *Cordia gharaf* recorded overall highest 98.6% survival, followed by *Z. mauritiana* (92.1%) and *P. cineraria* (88.8%).

Height: Plant species attained height between 38-52 months growth period. The mean incremental height was more of *C. setigerus*, 13.7 & 23.5% as compared with *C. ciliaris* 7.1 & 9.3% for control and with grass treatments, respectively. In *C. setigerus* experiment, the mean height was more for control plants (188.2 cm) as compared with grass treatment (148.3 cm), while reverse was true with *C. ciliaris* (Control-(184.9cm) and with grass treatment-166.5cm). During this period, species wise *Z. mauritiana* and *C. gharaf* recorded same mean height (221.0 cm), followed by *P. cineraria* (74.5 cm), although incremental height was maximum in *P. cineraria*.

Crown Diameter: After good rains in the year 2010, crown diameter at 52 months, the incremental crown growth was 20.0 & 32.7 % and 6.7 and 9.9 % for control and with grass treatments respectively, in *C. setigerus* and *C. ciliaris* experiments. *Z. mauritiana* continued to attain significant crown growth (211.3 cm) as compared to *C. gharaf* (190.0 cm) and *P. cineraria* (63.2 cm). It recorded 81% & 22.3% incremental crown growth with grass treatment and 41.5% & 10.3% in control with *C. setigerus* and *C. ciliaris*, respectively as compared to growth at 38 months, while it was 6.0 & 0 and 4.6 & 4.3 % only for *C. gharaf* at the same time.

Green Grass Yield: A long heat spell delayed monsoon, followed by downpour resulted in water stagnation, which adversely affected the green grass yield in both the experiments in the year 2010 and it was 0.67 and 0.45 kg/m2 for *C. ciliaris* and *C. setigerus* , respectively.

Physico-chemical Properties: Soil samples were collected in March 2010. In case of *C. ciliaris*, soil pH values were in normal range (>8.2) for both the soil layers (0-25 & 25-50 cm) inside plant pit and at a distance of 2 m from plant pit. However, with *C. setigerus* values were slightly higher both for pH and EC inside plant pit. Due to depression in field water collection resulting in hydrolysis of salts from soil.

In the summer months, percent (SOC) inside plant pit was higher in case of *C. setigerus* for both the soil depths. In both the experiments, control recorded lower SOC values as compared to with-grass-treatment. Percent SOC values at 2 m distance were higher for both the soil depths as compared to plant pit for control and with grass treatments.

A field visit of participants officials to Silvi-pastoral trial at Mochiri, Bhuj was also organized during three days of the farmers and forest officers (Guards, Foresters, RFOs and ACF) training, organized by VVK, Rajkot, AFRI, Jodhpur at Van Chetna Kendra, Bhuj from 14th to 16th December 2010.

Characterization and Classification of Forest Soils of Rajasthan

The project was initiated in September 2007 with the objective to characterize and classify the forest soils of Rajasthan following the USDA classification system. During the reporting period, soil profiles were studied at 215 places in Chittorgarh, Bhilwara, Jaisalmer, Baran, Tonk, Alwar, Bharatpur, Dungarpur, Jaipur, Pratapgarh, Jodhpur and Rajsamand districts covering 207 forest blocks. Soil texture, structure, consistency, colour, pH, electrical conductivity, organic carbon, NO_3 and NH_4–nitrogen and phosphorus were estimated for 780 samples covering 12 districts. In the vast sandy northwestern region, soils were predominantly saline or alkaline and sandy in nature. Sand content varied from 66% to 93%. In the eastern and southern districts, soils are neutral to alkaline in nature and soil texture varied between loamy sand to sandy loam with few soils in the category of sandy clay loam (22% clay content). Highest clay content of 32% was found in Bandikui, Dausa and Guapada, Banswara.Overall 46% soils were found to be sandy loam, 29% - loamy sand, 20% - sandy, 3% - sandy clay loam, 1.5% - loam and 0.5% - clay loam. In general, soils of western

Clay Loam Soil (up) and Landscape (down) at Guapada Forest Block, Banswara

districts are poor in nitrogen and phosphorous. Available nitrogen and phosphorus varied between 7- 42 kg ha^{-1} and 8-56 kg ha^{-1} respectively. Soils of Chitrimata block (Fig 6), Pratapgarh has higher nitrogen (86 kg ha^{-1}) and phosphorus (78 kg ha^{-1}) content.

Identification of Soil-Vegetation Relations and Indicator Species for Assessment and Rehabilitation in Lower Aravalli of Rajasthan

This project was started with the objectives (i) to study on physical properties and nutrient status of soil derived from different parent material and (ii) to study on vegetation structure and indicator species on dominant soil types, for its utilization in assessing land degradation and rehabilitation programme. The study areas are Aravalli/upper Malwa plateau covering five different locations with varying rainfall i.e., Banswara (Bara Nandra kho forest block), Rajasmand (Sabalia forest block) and Pali (Borvad forest block) in Rajasthan and Sabarkantha (Motimori forest block) and Palanpur (Trisulia forest block) in Gujarat.

Twenty five plots of 0.1 ha were laid out in 1 km^2 area following systematic sampling. Number of trees and shrubs were counted and measured for diameter at breast height, crown spread and height. Bara nandra kho site showed highest number of tree species, species richness and species evenness. The highest tree population (32.48 tree 0.1 ha^{-1}) and species diversity (1.08) were in Trisulia, whereas, highest tree dominance (0.54) was at Motimori forest block. *Tectona grandis*, *Lanea coromandelica*, *Anogeissus pendula*, *Wrightia tinctoria* and *Tectona grandis* were the dominant tree species in Banswara, Rajasmand, Pali, Palanpur and Sabarknatha sites, respectively. Total number of species was highest (12 ha^{-1}) at Banswara site, but species population was highest (95.56 trees 0.1 ha^{-1}) in Motimori forest block. Species richness (0.57) and diversity (1.18) were highest in Borvad forest block, whereas dominance (0.84) was at Trisulia forest block for shrubs. *Nyctanthes arbor-tristis* as shrub dominated both sites in Gujarat, whereas, *Euphorbia caudicifloia*, *Lantana camara* and *Rhus mysorensis* dominated at Borwad, Banswara and Rajsmand sites, respectively in Rajasthan.

Trisulia Forest Block Dominated by *Wrightia tinctoria* Trees (up) and Pit Opening and Growth and Diversity Study (down) near Ambaji in Palanpur division in Gujarat

Species Suitability and Reclamation Strategy for Degraded Forest Soils of Chhotanagpur Plateau, Jharkhand

Developed 0.10 ha nursery and prepared 2.41 ha land for field trials and raised 100-150 seedlings of 60 species for species suitability studies and 2000 seedlings of *G. arborea*, 1000 of *Madhuca indica*,1000 seedlings of *Pongamia pinnata* for reclamation of degraded soils. Rehabilitation and restoration of degraded sites through tree plantation with suitable species hold promise because of soil improvement, economic gain, ecological stability and landscape beauty and, thus, the objectives of the present project are relevant considering the constraints associated with the degraded soils of Chhotanagpur plateau. Over more than four years' of observations with 60 species, we have shortlisted 21 species, performing better in degraded soil of the region. Higher doses of NPK (50:30:30 g for 1-2 yrs & 100:50:50 g for 3 yrs old *G. arborea*, *M. indica* & *P. pinnata*) in addition to 1.5 kg Organic Manure for 1-2 yrs & 3.0 kg for 3yrs supplemented with 100 mg each of B, Fe, Mn, Zn , 25 mg Cu & 2.5 mg Mo per plant for 1-3 yr are essential for normal growth. Liming with either Lime or dolomite enhanced nutrient (N,P,K, Ca & Mg) uptake by *P. pinnata* than *M. indica* and improveed their growth. OM addition improved soil moisture status under *G. arborea*, more with rice husk and saw dust but for limited period (25-35 days). Liming reduces soil moisture more under *P. pinnata* than *M. indica*.

Development of Low Cost of Enriched Vermicompost for Commercial Production

A permanent low cost vermicomposting unit has been established at FRC, Mandar. The nutrient content of vermicompost has enhanced

significantly through application amendments (oil cakes, poultry feed, poultry manure and phosphobateria). Enriched vermicompost applied in different doses along compost and fertilizers on food crops viz., potato, tomato, radish and beans and their effects were documented. Enriched vermicompost @ 5 ton/ha and 10 ton/ha were showed highly significant results on growth and yield food crops. Vermicompost was also used as component of potting media. The enriched vermicompost production technology was imparted to 200 local farmers through 11 one day trainings. The results of field trials too were demonstrated to the famers.

2.2.5 Watershed Management

Efficacy and Economics of Water Harvesting Devices in Controlling Run-off Losses and Enhancing Biomass Productivity in Aravalli Ranges

Experiment was started in July 2005 with financial assistance from Rajasthan Forest department upto three years, later on by ICFRE with the objectives (i) to study the potential of different rainwater harvesting (RWH) devices in controlling run-off losses in different topographical conditions; (ii) to study the effect of different rainwater harvesting devices on biomass productivity and (iii) to study the economic viability of RWH devices for their adoption in large scale. For this, a total 75 plots of about 700 m^2 area were laid in 0-10, 10-20% and >20% with control, contour trench, gradonie, Box trench and V-ditch rainwater harvesting treatments. Seedlings of different species were planted and run-off measuring device installed. Plant growth, soil nutrients, run-off water and nutrient losses, soil water content and vegetation diversity and productivity were recorded throughout the study period.

Pooled data of four years indicated an average run-off of 12.58% of the total rainfall. Most effective rainwater harvesting treatments for controlling run-off losses are V-ditch in <10% slope and Contour trench in 10-20 and >20% slope area. The run-off was 14.63% from 10-20% slope area as compared to 10.22% from <10% slope and 12.90% of the total rainfall from >20% slope area. Among the treatments, highest run-off (13.55%) was from the control plots, whereas the lowest water loss was from V-ditch plots (11.05%). Overall soil loss of 3.43, 2.40, 1.21, 0.90, 0.24 and 0.19 g soil l^{-1} water was observed from the area in September 2005, July 2006, October 2006, July 2007, August, 2007 and July, 2009, respectively. This indicated a decreasing trend in soil loss per litre of water loss under increased vegetation cover in the area.

Growing vegetation influenced PAR reaching to the ground surface and maximum reduction in PAR was in 2010 by both tree and herbaceous vegetation. Soil water, which was retained under the influence of diverse vegetation during monsoon period, was utilized efficiently in rainfed period. There was a decrease in soil pH, EC and nitrogen and increase in PO_4-P (by 2.04-fold) in June 2010 than in June, 2005. The decrease in nitrogen concentration was lesser (by 9.7%) whereas the increase in PO_4-P was greater in >20% slope (greater than in <10% slope). The decrease in soil pH, EC and available nitrogen was greatest in gradonie, contour trench and control plots, respectively but the increase in the concentrations of PO_4-P was highest in the control plots.

Application of rainwater harvesting, improved plant growth. Soil characteristics was the most dominant factors influencing survival and growth, indicating greater height and collar growth of *Acacia catechu* and height of *A. indica*, *E. officinalis* and *Z. mauritiana* in >20% slope (relatively heavy and well drain soil) than in 10-20% slope (shallow loamy sand soil). Plant growth and MAI was lowest in the control plots, but gradonie structure was poor for plant growth. Plants were taller with highest MAI for height in CT plots, but thickness was relatively greater in

BT plots. *Dendrocalamus strictus*, *Emblica officinalis*, *Zizyphus mauritiana*, *Holoptelia integrifolia* and *Syzygium cumini* were the best suited to contour trench, *Acacia catechu* and *Azadirachta indica* were best suited to VD structure and *Gmelina arborea* was the best suited to BT rainwater harvesting structures. Interestingly, all the species of *Acacia* either planted or regenerated performed the best with V-ditch RWH treatment.

Number of herbs and grass species increased from 39 in 2005 to 92 at the end of the experiment. The number of species, population and species dominance increased with time. Species diversity and richness decreased to the lowest value in 2010. Pooled data for the dry biomass of six years ranged from 275.39 to 535.22 gm^{-2}. The lowest biomass was in <10% slope and the highest ($P<0.05$) was in >20% slope area (26.7% increase over <10% slope). It was lowest in the control plots. The increase in herbage biomass over the control plots were 28.22% in CT, 34.92% in Gradonie, 23.95% in BT and 18.84% in VD plots. But most interesting is the positive relation of species dominance (which increased with time with negative relation with species evenness) with herbage biomass and vegetation height. In general, grass production increased from 15 ton in 2005 to 36 ton in 2010 in about 17 ha area.

Treating the area with different rainwater harvesting structures/ plugging of the drainage lines in 2006 enhanced the water availability, which was utilised by ladies for bathing purpose and by livestock for drinking. Soil fraction, Soil Organic Carbon (SOC) and soil carbon stock increased significantly in June, 2010 and average increases in soil fraction were 3.7-fold in <10% slope, 3.2-fold in 10-20% slope and 4.1-fold in >20% slope. The increase in SOC and soil carbon stock were 0.98-fold and 3.6-fold in <10% slope, 1.3-fold and 4.36-fold in 10-20% slope, and 1.4-fold and 5.9-fold in >20% slope, respectively. Among RWH treatments, the increase in soil fraction was from 3.4-fold in control to 4.2-fold in VD plots, but SOC increased by 12.20% in BT to 28.16% in CT plots. The increase in soil carbon stock was by 4.1-fold in BT plots to 4.9-fold in VD plots.

A General View of Plants and Growing Vegetation (top left) and Growing Plants (top right). Collection of Fuelwood and Fodder from the Experimental Area, Gauapada, Banswara (bottom Left & Right)