

2.2 Forest Productivity

Overview

The productivity of Indian forest is quite low while compared to the world's average. Key factor for this and the related issues impinge directly upon the quality of the planting stock selected during establishment of plantations which 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 planting, yet, these are not adhered to for want of the number of seedlings 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. Seeds 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. The research on collection, processing and storage of the forestry seeds, standardization of nursery techniques of important commercial forestry species including Lesser Known Tree, threatened species and bio-fuel species and plantations of superior exotic and indigenous species of commercial importance and their management can enhance productivity.

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. Government of India has declared a moratorium on the green felling and this issue of ban is always taking the back seat while the question of scientific management of the forest resources is discussed across, mainly because of the lack of scientific data behind. In

addition to the number of parameters multiplying the problem, lack of data on the assessment of floral components always remains the concern. On the top of it, all these factors have got some bearing on the productivity of forest.

Increase in the population and over-exploitation of the forest resources for meeting the requirements of the growing populace is the major factor responsible for degradation of forest and its productivity. 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. The development of medicinal plant based agroforestry system and sustainable development of bamboo based agroforestry systems for increased income generation are being undertaken. No doubt, some of 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 it needs to be documented and understood with reference to its ecological, bio-physical and socio-economic aspects.

Development of low cost vermicompost for commercial production, selection and evaluation of potential seed sources and/ clones, integrated strategy for evaluation of indigenous fast-growing multipurpose trees and species and reclamation of degraded forest soils also need urgent attention for increasing the productivity.

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

The population of *Diploknema butyracea* (cheura) is almost localized in Pithoragarh district (Uttarakhand) particularly in the areas bordering Nepal. The principal objective of seed storage of *D. butyracea* was to assess the longevity, viability & vigour of seed and to enhance the seed longevity through conventional



storage method. Observations on morphological traits i.e. length, width, thickness, colour, etc of seed were recorded. For storage studies, the seeds were desiccated to three moisture levels i.e. 20 %, 15 % and 10 % and desiccated seeds were stored at four temperature viz., ambient room temperature, 15°C, 10°C and 5°C. Stored seeds were subjected to germination test every week and observations recorded on germination %, viability and vigour. Observations on growth parameters (height & collar diameter) of seedlings raised from stored seeds were recorded monthly. Seedling Vigour Index (SVI), Seedling Quality Index (SQI) and leaf area were measured for seedlings raised in different containers i.e. root trainers, polybags and in nursery beds. Least Safe Moisture Content (LSMC) for seeds of *Diploknema butyracea* was 20% and they are tropical recalcitrant in nature.

The three species of *Bauhinia* viz. *Bauhinia variegata*, *Bauhinia purpurea* and *Bauhinia retusa* have good fodder value. A survey was conducted in Doon valley, Tons valley, Uttarkashi District and Nainital and Pithoragarh Forest divisions to locate the populations of these three species of *Bauhinia*. Pods were collected at maturity from Manduwalla, Vikasnagar, Katapathur, Kainchidham, Bhatwari, Srinagar, FRI, Dehradun, Mussoorie and Tehri. Variations 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. Fresh seeds from all the sources had 85-95% germinability. Seeds of all the three species from two sources each were stored at 15°C and subjected to germination and moisture content determination every three months to observe the deterioration in seed viability. *B. variegata* seeds retained 92%, *B. purpurea* 78% and *B. retusa* 68% germinability after eight months in storage.

Buxus wallichiana is very important species for wood carving. Population surveys were conducted for *Buxus wallichiana* in Chakrata Forest Division and Mandal Forest (Uttarakhand). Fruits were collected at



Population of *Buxus wallichiana* at Jadi Village, Chakrata Forest

different stages of development/maturity and morphological parameters of fruits and seeds were observed. Stages of development and maturation of fruits were studied. The fruits were collected from Chakrata Forest Division in September and from Mandal Forest in November.



Cuttings of *Buxus wallichiana* in Mist Chamber

Seeds were extracted and almost 55-60% of the seeds were found empty. Fresh seeds yielded 15-20% germination and that too was very slow. Since the seeds were dormant, they were given various pretreatments like soaking the seeds in 0.05% and 1% GA₃ solution for 24 and 48 hours, in 0.02% KNO₃ for 24 and 48 hours and moist stratification. 0.05 % GA₃ treatment for 48 hours resulted in higher (40%) and early germination/growth of radical in seeds. For vegetative



propagation of *B. wallichiana*, its hard wood and leafy cuttings were collected from Chakrata and treated with 2000 and 6000 ppm of IBA and with combination of 1000 ppm each of NAA+IBA.

The nursery of important forestry species, prioritized by State Forest Department viz. *Terminalia arjuna*, *Bombax ceiba*, *Pongamia pinnata*, *Tamarindus indica*, *Azadirachta indica*, *Artocarpus heterophyllus*, *Syzygium cumini*, *Pithecellobium dulce*, *Heterophragma adenophyllum*, *Dalbergia sissoo*, *Tectona grandis*, *Albizia procera*, *Ficus glomerata* and *Acacia auriculiformis* were raised. The suitable age of the seedlings of fast growing and slow growing species was assessed for transplanting in the field. Species like Semel, Shisham, Imli, Kathal and Siris performed well for 1 yr old seedlings in plantations. Other species like Eucalyptus, Jungle Jalebi, Katsagaun, Karanj and Australian Babool performed well for one as well as two year old seedlings in the trials. Thus, it can be concluded that later five mentioned species can be planted even if two years old but former five species should be planted with one year old seedlings for better growth performance and survival.

Seeds of *Hippophae salicifolia* were collected from Uttarakhand seed sources and their germination study was carried out in field and laboratory under different lights and temperatures conditions. Plants were raised in the high altitude nursery at Chakrata and vegetative propagation study was carried out by using growth regulators.



Fruiting in *Hippophae salicifolia*

Mature and immature fruits of four *Ficus* spp. viz. *Ficus religiosa* (Peepal), *Ficus lacora* (Pakad), *Ficus bengalensis* (Baragad) and *Ficus glomureta* (Gular) were studied for their germination trial after different pre-sowing treatments viz. Biotreatments and chemical treatments. The effect of different chemical and bio-treatments on the seed germination of selected *Ficus* spp. was compared. In case of Baragad, germination of partly matured seeds was better than that of fully matured seeds. In case of *Ficus religiosa* (Pipal), matured seeds germinated well and biofertilizer treatments performed better in comparison to other treatments. In *Ficus glomureta* (Gular), matured seeds germinated well and treatments with hot water performed best.

Soaking of seeds of *Strychnos nux-vomica* and *S. potatorum* in cow dung slurry proved best to give 88% and 54% germination respectively. Nitrogen and phosphorus separately or in combination significantly boosted the growth of seedlings. Soaking of seeds of *Terminalia chebula* in water for 7 days and then drying for 2 days proved best to give 82% germination.

The seeds collected from the plus trees of *Pterocarpus marsupium* treated with cold water for 24 hrs before sowing in July gave higher germination. Potting mixture consisting of 80% organic compost, 20% soil and 250cc size root trainer found to produce healthy seedling. Branch cutting from mature tree collected in February-March and treated with 500, 1000, 1500 and 200 ppm for 24 hours resulted only shoot formation after 14 days in mist chamber. Root-shoot cuttings treated with 400 ppm IBA for 24 hours produced 96% healthy plants.



Germination of rattan seeds was found greater by pricking method instead of sowing normal seeds in nursery beds. Seed germination studies were also conducted on seeds of *Acacia nilotica* and *A. catechu* collected from various seed sources of Gujarat (AFRI). The second fortnight of March was found to be optimum time for collection of seeds of *Anogeissus latifolia*. The seeds of *Juniperus polycarpos* treated with different pre-sowing treatments, recorded an excellent germination under nursery conditions.

With the objective to collect information pertaining to raising of the nurseries of the mandated species, the deodar and ban oak nurseries, as maintained by the State Forest Department, Himachal Pradesh, were surveyed. Considering the various morphological parameters of the nursery stock of deodar and ban oak, the experiments to assess their field performance were established. The nursery and field trials were laid and maintained for standardization of tall-planting techniques in deodar.

The potential seed sources and/ clones of selected species of Jharkhand and adjoining states were evaluated in nursery. Precision silviculture practices for *Casuarina junghuniana* have been developed for both nursery management and plantation management.

Natural regeneration failure is one of the characteristics of high level conifer forests (*Abies pindrow* and *Picea smithiana*) in western Himalayas. Since 19th century, the problem is supposed to be associated with the presence of excessive litter in the forests. As allelopathy played a major role in regeneration failure in many cases, research was undertaken on allelopathic influences of litter, humus and foliage of trees & under-storey plants on seed germination of the species in laboratory. It was found that leachates of humus reduced and deteriorated radicle growth completely but enhanced germination at higher concentrations;

however, litter leachates had no pronounced effect. Foliage leachates of *Sarcocoocca saligna*, *Viburnum nervosum* and ferns (under-storey plants) also had inhibitory effects on germination and radicle growth but stimulation in germination by one species at higher concentrations. This research concludes that humus and foliage of specific plants are responsible for regeneration failure in these conifers and not litter as supposed till date.

Multi location Bamboo trials on micro and macropropagated plants, nutrient management, organic and inorganic farming methods and water management were carried out to develop a species specific packages of practices for larger adoption of the species under farm land cultivation.

Training was organised for 145 Officers of State Horticulture Department on bamboo diversity, nursery techniques, plantation techniques, management of pest and disease problems, bamboo based industries and bamboo value added products.

Bamboo model plantations were established in different locations covering six agroclimatic zones of Tamil Nadu namely North-Western Zone, North-Eastern Zone, Cauvery Delta Zone, Western Zone, Southern Zone and High altitude and hilly area Zone using seven species. The seedling, macropropagation and tissue culture of *Bambusa bambos*, *Bambusa nutans*, *Bambusa tulda*, *Bambusa vulgaris*, *Bambusa balcooa*, *Dendrocalamus strictus* and *Dendrocalamus stocksii* were used in the plantations and the performance of species within a location and across locations were studied. Package of practices for bamboo cultivation and management was developed.

Ninty accessions of 31 bamboo species were assembled from Forest Department, Assam and State Forest Research Institute (SFRI), Itanagar, Arunachal Pradesh, Kerala Forest Research Institute (KFRI), Peechi and Ladpur Nursery of Uttarakhand Bamboo and Fibre



Development Board (UBFDB), Dehradun for establishment of bamboo Germ plasm. 65 Accessions of Candidate Plus Clumps (CPCs) of 4 species of bamboos have been obtained from Rain Forest Research Institute (RFRI), Jorhat for establishing bamboo multiplication garden.

Suitability of different bamboo species in non-forest areas was also studied. It was observed that *Bambusa vulgaris* had maximum height in yellow soil (Granite), whereas, *B. bambos*, *B. longispathus*, *B. tulda*, *B. nutans* and *Dendrocalamus strictus* showed maximum growth increment in black (basaltic) soil.

On farm innovation in macroproliferation technique for edible bamboo species and promotion of their commercial plantation through capacity building of the Self Help Group members was conducted by imparting training and demonstration on nursery practices. Sustainable development of quality bamboo resources for employment generation and socio-economic development in North-Eastern India was achieved through development of suitable agroforestry models for promoting bamboo cultivation outside forests in NE region.

Clonal material comprising 1,08,000 cuttings and 48.5 kg seeds of *Jatropha curcas* accessions having more than 30% oil content were supplied to Department of Biotechnology, Govt. of India for nation-wide trials. Clonal trial, progeny trial, clonal seed orchard and seed seedling orchard were established during the year. Seed oil content was not found to have any significant correlation with seed germination. Variation in seed oil content was caused by variation in germination percentage of the accessions rather than to variation in intrinsic adaptability of germinated seedlings of different accessions to the nursery environment.

Performance of *Jatropha curcas* in un-reclaimed sodic soils was found to be unsatisfactory. At 3½ years of age, the plants exhibited poor survival and growth. None of the accessions could record growth rate comparable to plantation of this species on a good site. Less

than 10 per cent plants produced flowers; the seed yield was negligible. Accessions viz. FRI-WB-Banku-0306-C-31, FRI-WB-Banku-0306-C-32 and FRI-WB-Midna-0306-C-33 of *Jatropha* were found to possess the following unique features: presence of hermaphrodite flowers, rough bark, resistance to frost damage and resistance to viral attack. This indicates that clonal plantations of *Jatropha curcas* are not suitable for un-reclaimed sodic land.

In Dehradun valley, at two years of plantation age, 2m x 2m spacing gave greater seed yield per hectare. However, long term monitoring of the trial is required to optimize the spacing.

Fifteen thousand numbers of Neem and Pungum quality planting stock were raised for taking up 50 ha of model plantations in different agroclimatic zones of Tamil Nadu.

Physiological and nutritional parameters studies have been undertaken in 30 *Eucalyptus* clones developed by the institute by establishing field trials in four locations viz., Pudukkottai, Tirunelveli, Sivaganga and Coimbatore. Wood samples have been collected from the 30 clones for carbon isotope analysis to determine the water use efficiency of the selected clones.

For evaluation of indigenous fast-growing multipurpose trees of eastern India for plantation forestry, information was collected on natural populations and plantations of kadamb and semul in Jharkhand and West Bengal. 30 candidate plus trees have been identified.

Agroforestry demonstration plots were established in five agro-climatic zones (3ha per zone) with tree components viz., *Casuarina equisetifolia*, *Casuarina junghuhniana*, *Melia dubia*, *Tectona grandis*, *Eucalyptus* spp. and *Ailanthus excelsa* and horticultural components viz., Mango, Guava, Sapota and Lemon along with the annual crops to enhance the livelihood opportunities for farmers.

The agroforestry systems with *Casuarina equisetifolia*, *Casuarina junghuhniana* and



Eucalyptus camandulensis and medicinal plants viz. *Decalepis hamiltonii* and *Asparagus racemosus* as intercrop were also established at four locations namely Karaikudi, Sendurai, Jeyamkondam and Karaikal in Tamil Nadu.

Agroforestry model being maintained at farmer's field at village Harsh, Bilara, District - Jodhpur revealed that performance of *Ziziphus mauritiana* was the best as horticultural species and *Colophospermum mopane* was the best as silvicultural species. The plant growth was higher in agroforestry plots as compared to the control (without crop). Wheat crop production was recorded 13.67 quintal/ha during the year.

An agroforestry model by growing tomato and potato in between *Emblica officinalis* and *Moringa oleifera*; medicinal plants *Andrographis paniculata*, *Asparagus racemosus*, *Rauvolfia serpentina*, *R. tetraphylla* and *Withania somnifera* under *Aegle marmelos* and *Moringa oleifera* was developed.

On the basis of experiments conducted to develop medicinal plant based agroforestry system, teak-turmeric system proved significantly best.

Productivity of maize in *Dalbergia sissoo*- *Zea mays* agroforestry system was studied to conclude that the tree distance of 5x5m with 60cm tree to crop line spacing proved best for maximum yield of maize crop.

After field survey four sites in lower hill zone at Puruwala & Kot in Himachal Pradesh and Nudh & Basanterbella in Jammu & Kashmir measuring 5.0 ha have been identified and experimental trials of *Gmelina arborea* established.

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

A library of soil samples of NE is being set up at Rain Forest Research Institute, Jorhat. Soil samples from 29 forest sub-group types have been collected and analyzed from 7 North-East states.

Restoration of jhum land was carried out through intercropping Rhizobium inoculated legume trees with agricultural crops in Assam.

In order to characterize forest soils of Rajasthan, the soil profiles were examined and sampled at 210 places covering Sri ganganagar, Hanumangarh, Jhunjhunu, Sikar, Bikaner, Nagaur, Barmer, Sirohi, Jalore and Jaisalmer districts in 170 forest blocks of 89 forest ranges.

In a lysimetric study, *A. nilotica* and *Tamarix aphylla* showed higher tolerance towards salinity as compared to *E. camaldulensis*. However, under water logging condition at shallow depth *E. camaldulensis* outperformed *A. nilotica* and *T. aphylla*.

Acacia bivenosa proved to be the most hardy plant surviving the extremely harsh conditions of high salinity, heat stress and drought conditions and achieving adequate growth on highly saline black soil after 30 months of growth.

Effect of different rainwater harvesting techniques (contour trench, gradonie, box trench and V-ditch) and hill slopes on plant growth, runoff loss and soil moisture status were studied on a degraded hill in Banswara district. Performance of *E. officinalis*, *S. cumini*, *A. catechu* and *H. integrifolia* were better in contour trench plots, *G. arborea* and *Z. mauritiana* in box trench plots. *A. indica* and bamboo performed better in V-ditch plots. Contour trench reduced run-off losses to a greater extent.

Cordia ghara and *Cenchrus ciliaris* combination was the best silvipastoral on arid sandy degraded forest soil at Bhuj after 38 months of establishment.



The assessment of bio-drainage potential of tree species indicated that *Eucalyptus rufa* performed the best with respect to growth, biomass, transpiration rate and overall bio-drainage potential where ground water level receded by 145 cm within a period of 54 months.

Species suitability and reclamation strategy for degraded forest soils of Chhotanagpur Plateau, Jharkhand were developed. Works relating to nature and degree of degradation and other limiting factors of the soils have been covered before taking up the reclamation measures.

While studying the impact of invasion Forest Invasive Plants on the biodiversity, the following plants were found to invade in different forest covers:

- Deodar (*Cedrus deodara*) Zone (Temperate): *Sarcococca saligna* : killing deodar seedlings due to roots competition.
- Banj (*Quercus leucotrichophora*) Zone (Sub-tropical): *Eupatorium odoratum* and *Artemisia vulgaris*.
- Sal (*Shorea robusta*) Zone (Tropical): *Lantana camara* and *Ageratum conyzoides*.
- Burnt Plots of sal: *Eupatorium adenophorum*, *Viburnum erubescens*, *Adathoda vasica* and *Lantana camara*.
- Burnt plot of banj: *Prinsepia utilis*, *Berberis lycium*, *Viburnum stellatum*, *Rubus ellipticus*, *Cotoneaster tetraptera*, *Mahonia nepaulensis* and *Rosa moschata*.

The Govt. of India banned green felling above 1000 m elevation in early eighties in the Himalayas. To observe the impact of ban on green felling in coniferous forests, twenty four sites were selected in the coupes which were prescribed for felling but felling was not carried out and



Unfelled Coupes of Deodar & Kail
Uttarkashi Forest Division



Felled Coupes of Spruce & Fir Forests-
Chopal, Shimla

where felling was actually done in deodar, kail, fir and spruce forests. The coupes were selected in Badrinath, Uttarkashi and Chakrata forest divisions of Uttarakhand, and Kullu, Shimla and Chamba forest divisions of Himachal Pradesh. Data were collected on phyto-diversity, growth of trees, regeneration status, socio-economic condition of the people and humus and soils from felled and unfelled coupes. Data is being analyzed.

Projects under the theme

Project	Projects Completed During the Year	Ongoing Projects	New Projects Initiated During the Year
Plan	13	25	03
Externally Aided	13	15	04
Total	26	40	07



2.2.2 Silviculture

Evolving Silvicultural Practices for *Casuarina junghuhniana* ssp. *Timorensis*

The project envisaged developing silvicultural techniques for establishing *C. junghuhniana* plantations under different agro-ecological conditions. Trials under nursery and field conditions had been carried out under these project. Nursery trials were carried out to study the effect of different potting media formulations (30 nos) and container types and sizes (10 nos) on quality seedling production of *C. junghuhniana*. Also trials to study the effect of cutting height on rooting success as well as effect of biofertilizers on seedlings were carried out. Field trials were laid out in 8 locations spread over different agro climatic zones of Tamil Nadu— both in inland and coastal conditions— to study the survival and growth performance of *C. junghuhniana* in comparison with *C. equisetifolia*. The results are under analysis.

Bamboo Location Trial (N MBA)

The project funded by National Mission on Bamboo Applications (NMBAs), Technology, Information, Forecasting and Assessment Council, Department of Science and Technology, Government of India was part of a network project being coordinated by G.B. Pant University of Agriculture and Technology (GBPUAT), Pantnagar, Uttarakhand. Five field trials involving multilocation species trial, trials on micro and macropropagated plants, trials on nutrient management, trials on organic and inorganic farming methods and trials on water management were laid out in the IFGTB Field Station, Bharathiar University Campus, Coimbatore as per the approved technical programme. Periodical data at three month interval were collected on survival and growth of bamboo clumps established under the trials. The data are being analysed.

Field Functionaries Training on Bamboo under National Bamboo Mission (TANHODA-I)

The Tamil Nadu Horticulture Development Agency (TANHODA), Chennai - nodal agency to carry out various activities envisaged under the National Bamboo Mission in Tamil Nadu identified the Institute of Forest Genetics and Tree Breeding, Coimbatore as training Institute to impart training to 150 Officers of Horticulture and Agriculture Departments of Government of Tamil Nadu. Accordingly, Institute imparted training to 145 Officers - at the level of Deputy Directors of Horticulture to Horticulture Officers - on various aspects of bamboo. The issues covered under the training ranged from bamboo diversity to nursery techniques to plantation techniques to pest and disease problems to bamboo based industries to value added products. Demonstrations on nursery techniques and field visits to bamboo field trials, bambusetum, bamboo industries etc formed part of the training schedule.

Establishment of Bamboo Model Plantations in Different Agro-climatic Zones of Tamil Nadu using Quality Planting Stock (DBT)

Bamboo model plantations were created in 20 ha area during 2006-07, 40 ha in 2007-08 and 30 ha in 2008-09 and 10 ha in 2009-10 using quality planting stock raised through seedling, macropropagation and tissue culture of *Bambusa bambos*, *Bambusa nutans*, *Bambusa tulda*, *Bambusa vulgaris*, *Bambusa balcooa*, *Dendrocalamus strictus* and *Dendrocalamus stocksii*. The plantations were raised in different locations covering six agro-climatic zones of Tamil Nadu namely North-Western Zone, North-Eastern Zone, Cauvery Delta Zone, Western Zone, Southern Zone and High altitude and Hilly area Zone. A total of 100 ha plantations have been raised. The growth performance of bamboo species within a location and across locations have been assessed periodically. Data on rainfall,



temperature, humidity have been collected and soil analysis both for macro and selected micro nutrients were completed for all locations. *B. vulgaris*, *B. tulda*, *B. nutans*. and *B. balcooa* grow well in all the zones except in clay soil, soil



Bamboo in North-Western Zone



Bamboo in Western Zone

Bamboo in North-Eastern Zone

with low water holding capacity and waterlogged areas. *Bambusa vulgaris* produces more culms when compared to *B. tulda*, *B. balcooa* and *B. nutans*. *B. bambos* and *Dendrocalamus strictus* grow moderately well in all locations with moderate culm production. The performance of *Dendrocalamus stocksii* is poor in all the locations.



Bamboo in Cauvery Delta Zone

Bamboo in Southern Zone



Banana and Bamboo

Improving Productivity of Bamboo Cultivation in Farmlands of Tamil Nadu (NBM-1)

The project funded by National Bamboo Mission envisages establishing silviculture trials in 3 locations each in three agro-climatic zones of Tamil Nadu apart from establishing a Bamboo germplasm bank and Bamboo multiplication garden. Around 11,500 bamboo plants belonging to five species were procured from North- East India - apart from raising seedlings locally - for meeting planting stock requirement of field trials. Silvicultural trials at seven locations were laid out spread over 3 agro-climatic zones. For establishing bamboo germplasm bank, 90 accessions of 31 bamboo species were assembled from Forest Department, Assam and State Forest Research Institute (SFRI), Itanagar, Arunachal Pradesh, Kerala Forest Research Institute (KFRI), Peechi and from Ladpur Nursery of Uttarakhand Bamboo and Fibre Development Board (UBFDB), Dehradun. Sixty five Accessions of Candidate Plus Clumps (CPCs) of 4 species of bamboos have been obtained from Rain Forest Research Institute (RFRI), Jorhat for establishing bamboo multiplication garden.

Development of Elite Planting Material and Model Plantation (NOVOD)

The project envisages raising of model plantations of Neem and Pungam - 25 ha each- totaling 50 ha, spread over the 5 agro-climatic zones of Tamil Nadu suitable for raising them.



Around 15,000 numbers of Neem and Pungum quality planting stock have been raised and are being maintained for raising model plantations during the 2010 monsoon season.

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, Sivaganga and Coimbatore. For the short-listed 30 *Eucalyptus* clones, parameters like chlorophyll A, B and total chlorophyll, total leaf area were worked out. For assessing the water use efficiency of 30 clones, wood samples were collected and powdered and sent for carbon isotope analysis at University of Agriculture and Sciences, Bangalore. Nursery studies have been completed for the above selected clones for root characterization and biomass. Observations on physiological parameters have been completed under the four locations. The study is continuing.

Standardization of Nursery Technique of *Strychnos nux-vomica* and *Strychnos potatorum*

Seed germination studies of *Strychnos nux-vomica* and *Strychnos potatorum* under different physical and hormonal treatment were conducted. Seeds of *S. nux-vomica* and *S. potatorum* were sown in polythene bags to conduct fertilizer trial in order to accelerate the growth of seedlings. Data on germination, survival and growth of both the species under different experiments were recorded. On the basis of three year's observation, it may be inferred that 72 hrs soaking of seeds of *S. nux-vomica* and *S. potatorum* in cow dung slurry gave maximum 88% and 54% germination respectively. Nitrogen and phosphorus separately or in combinations significantly boosted the growth of seedlings height, root length and collar diameter. The highest value for the different

components of the seedlings was observed to be under the treatment receiving 100 ppm nitrogen with 100 ppm phosphorus.

Development of Nursery Techniques for *Terminalia chebula* Retz. (Harad)

Studies on seed germination of *Terminalia chebula* under different physical and hormonal treatment were conducted from the seeds collected from Chandrapur (Maharashtra), Bhilaigarh (Chhattisgarh), Tamia (Madhya Pradesh) and Sambalpur (Orissa). The maximum 82% germination was noted under 7 days soaking and 2 days drying of seeds collected from Sambalpur (Orissa). The maximum 86% germination was observed under IBM 500 ppm + 7 days soaking and 2 days drying of seeds collected from Sambalpur (Orissa).

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

Seed storage trials were continued this year on *Schleichera trijuga*, *Hardwickia binata*, *Sapindus laurifolia*, *Rauvolfia serpentina*, *Moringa oleifera*, *Mimusops elengi*, *Holoptelea integrifolia* and *Emblica officinalis* and *Terminalia chebula*, for assessment of viability and moisture contents. The results from the effect of temperature and moisture content on viability of seeds indicated that the seeds of *Schleichera trijuga*, *Hardwickia binata*, *Sapindus laurifolia*, *Rauvolfia serpentina*, *Moringa oleifera*, *Emblica officinalis*, *Holoptelea integrifolia* and *Terminalia chebula* are of orthodox type as there was negative relation between them. Storage experiments on *Mimusops elengi* seeds supported its intermediate nature. The viability constants for the orthodox seeds were estimated for prediction of storability of seeds at a particular storage condition. Protein and carbohydrate contents of different stages of three types of seeds were estimated and data were analyzed.



Standardization of Nursery Technology of *Pterocarpus marsupium*

Seeds of *Pterocarpus marsupium* (bijasal) were collected from healthy trees from Gondia (Maharashtra) region and experiments were carried out in the nursery to study the effect of different seed treatments on the germination and growth of seedlings in the nursery. The seeds treated with cold water for 24 hours showed better germination as compared to hot water treatment. The bigger sized seeds gave higher germination percentage and germination value as compared to the small size seeds. Higher germination percentage observed in July and minimum percentage of germination was recorded in January. Potting mixture in the ratio of 80% organic compost + 20% soil was found to be best combination where as 250cc size of root trainer gave better results with respect to root and shoot biomass production. Urea, di- ammonium phosphate and murate of potash @ 2, 4 and 6 gm respectively per plant was applied, but initially no effect of inorganic fertilizers on growth and development of seedlings was observed. Collected branch cutting from matured tree of *P. marsupium* (Bijasal) in the month of February and March and experiment was laid out in mist chamber by treating the cuttings with different concentration of IBA 500,1000,1500 and 2000 ppm for 24 hours. Shoot formation was recorded after 14 days but no root formation was observed. Root shoot cuttings of *P. marsupium* treated with different concentration of IBA 100, 200, 300 and 400 ppm for 24 hours produced 62%,76%,84% & 96% healthy plants. A field trial of different types of seedlings (seedlings raised in polybags, root-trainers and root-shoot cuttings) has been established at Centre for Forestry Research and Human Resource Development, (CFRHRD) campus with three replications at spacing of 5x5 metre in randomized block design for evaluating the planting stocks of *P. marsupium*.

Ninty eight percent success was achieved in nursery trials carried out by pricking method- sowing pre-germinated seeds of rattan in poly bags, instead of normal seeds of nursery beds at Rain Forest Research Institute, Jorhat.

Enhancing Productivity of Saline Wastelands in Kachchh- through Improved Tree Planting Techniques and Silvipastoral Study (Gujarat SFD sponsored project)

Silvipastoral Study:

Silvipastoral trial was laid in 2007 in Bhuj. Survival rate of plant species was more than 90% in both the experiments at 38 months of age. Species wise maximum survival was *Cordia gharaf* (99.5%), followed by *Zizyphus mauritiana*, (92.5%) and *P. cineraria* (91.2%). Overall periodic percent survival recorded was 95.64 in *Cenchrus setigerus*, and 93.8% in *C. ciliaris*, there was slight decrease, 1.9% with *C. setigerus* and 2.3% with *C. ciliaris* as compared to survival at 24 months. However, survival with grass was higher in case of *C. ciliaris* (97.5% to 90.1 % in control) as compared to *C. setigerus* (92.0% to 98.1% in control). At 38 months, maximum mean tree height was recorded with *C. ciliaris* (162.4 cm), followed by *C. setigerus* (142.8 cm). Mean tree height was significantly higher for control trees as compared to with grass in case of *C. setigerus*. However, trees with *C. ciliaris* grew 3-5% taller. Species wise, maximum mean height was recorded in *Z. mauritiana* (203.5 cm), followed by *C. gharaf* (192.3 cm) and *P. cineraria* (62.1 cm). Except for *Z. mauritiana*, other species did not record crown growth. *Z. mauritiana* recorded 31.3% and 14.2% incremental growth for control and with grass treatment at 38 months of age.

Based on mean height and crown diameter component wise, aboveground biomass estimation was carried out for *Z. mauritiana* and *C. gharaf* in control and with grass treatments.



With *C. setigerus* sowing was done at high seed rate biomass yield for control trees was 2-3 fold more with *C. gharaf* (7.5 kg/tree) and *Z. mauritiana* (4.0 kg/tree) as compared to trees grown with grass *C. gharaf* (4.8 kg) and *Z. mauritiana* (1.6 kg tree). While, in case of *C. ciliaris* (sown in scattered manner at low seed rate) biomass yield was 4.5 to 5.3 kg/tree for *Z. mauritiana* and 8.0 to 8.6 kg/tree for *C. gharaf* with grass and control treatments, respectively. Result suggests that at low seed rate grass sowing promote tree growth.

During the year 2009, total rainfall was 419 mm and most of which (202 mm) was received late in August in three days (29-31, 2009) after a long day spell of nearly 30 days. The mean yield was 1.01 kg/m² for *C. ciliaris* and 0.76 kg/m² *C. setigerus*. It was 57.5% and 61.7% more as compared to that of last year. Tree growth did not influence the grass yield and green grass yield was maximum with *C. gharaf* (1.11 kg/m²) for *C. ciliaris* and *Z. mauritiana* (0.83 kg/m²) for *C. setigerus*, respectively, which was comparable to control. A green weedmass of 0.35 kg/m² mainly unpalatable grasses was obtained from the experimental area.

Improved Tree Planting Techniques

Research trials were laid with *A. ampliceps*, *A. bivenosa* (exotic) and *S. persica* (indigenous) on black silty clay (medium), soil depth: 40-75 cm at Kordha, Sami Range in Patan, Gujarat at the fringe of WAS in July 2007 to find out suitable exotic and indigenous fodder plant species with appropriate planting practice. *S. persica* proved to be most hardy plant surviving the extremely harsh conditions of high salinity, heat stress and drought conditions and suffered minimum casualties and maintained high rate of survival (92.8%) at 30 months of planting, followed by *A. bivenosa* with 77.3% survival at 30 months.

Among the selected species *A. ampliceps* suffered the maximum damage due to salt laden hot winds from rann side in May 2009, probably due to its being on the border area and also with maximum height. Initial sprouting was observed in most plants. However, there was 41% decrease in mean survival (which was 44.1% at 30 months and 74.6% at 12 months).

All the three plant species displayed shrubby nature favoured more crown diameter than height after two years of growth. In *S. persica* mean height was 120.8 cm as compared to mean crown diameter 154.2 cm at 24 months. Comparatively, *A. bivenosa* attained maximum crown growth among all the plant species at 24 months. The mean height, 112.6 cm, was significantly less than the mean crown diameter (208.5 cm). Two factor ANOVA analysis showed that treatments influenced the growth and both FYM and Wheat husk treatments favoured significant higher growth (height and crown diameter) as compared to other treatments. The individual plant had 4-19 branches in different treatments. Initially, up to 18 months, *A. ampliceps* attained very high growth and flowered and produced viable seed within a year, but after heat shock, growth in term of height showed declined trend. Nearly 90 % plants of *S. persica* flowered in January 2010, however, fruit setting was in 6 % plants in March 2010. No flowering was observed in *A. ampliceps* and *A. bivenosa* in a deficient monsoon year.

Per cent soil moisture was ranging from 8.1 to 12.6 % in 0-25 and 25-50 % soil layer inside plant pit for *A. bivenosa* in January 2010 (there was 8 mm rain on 14th December 2009), which was reduced to 2.4 to 4.73 % in the upper soil layer inside plant pit. Soil working may have resulted in moisture loss as moisture content in inter row space was more (3.02 to 5.01%) in upper soil layer. Soil pH and EC were analysed from



A. ampliceps in summer 2009. The soil pH values were in normal range. However, EC values were higher ranging from 1.7 to 4.06 dSm⁻¹ and 2.30 to 4.01 dSm⁻¹ in 0-25 and 25-50 cm soil layer. EC values after the heat shock were ranging from 1.2 to 3.9 dSm⁻¹ and 1.4 to 5.5 dsm⁻¹ indicating that salinity levels were high during heat shock.

Plantation activities promoted weed growth, *Chloris virgata* was the most dominant species, followed by *Sueada fruticosa*, *Aristida* spp. and *Zygophyllum simplex*. Overall, 517.3 gm² yield was recorded. However, tree species wise, variation was observed and it was 503.8 gm² (*A. bivenosa*) and 530.8 gm² (*A. ampliceps*).

Studies on Seed Traits of Seeds Collected from Seed Stands

Due to poor seeding in the Gujarat state, SFD was unable to supply quality seeds of desired species. Instruction manual for establishing seed certification system has been prepared and submitted to CCF/DCF, Gandhinagar and Rajpipla for implementation.

Seed samples of 12 seed sources (2 seed stands and 10 CPTs) of *Acacia catechu*, 14 Jatropha CPTs were collected and tested for seed parameters. Seeds were examined physically and none was defective and all seeds were healthy. Seeds of *A. catechu* were golden-brown in colour. *Acacia catechu* seed lot no. 2557 showed 77.5% germination and 143.38 vigour Index, while seeds collected from outside area (accession no. 2558) showed 77.5% germination and 145.7 of vigour Index. Seeds of 10 CPTs of *A. catechu* showed variation in 100 seed weight from 3.79-5.48g, seed germination from 69 to 91.5% and vigour index from 88.14 to 152.73. Removal of seed coat from seeds of *Terminalia chebula* enhanced percent germination from 10% control to 72% after kernel removal. Number of seeds in 10g of seed weight in 14 CPTs of jatropha varied from 17-23 and oil from 27.6 to 41.1% on seed basis.

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

The nursery stock of deodar (6,000) and of ban oak were raised and maintained (24,000) at Model Nursery, Shimla and Shilly Nursery, Solan respectively. Sites were selected for carrying out experimental plantations in Shimla and in Solan Forest Divisions. To achieve the objective pertaining to the development of interim minimum standards of quality of the planting stock of deodar and ban oak through interviews of regular producers and users of nursery stock of these species, visited nurseries (35 no.) of the forest department of Himachal Pradesh and collected information regarding nursery raising and quality parameters from the field functionaries being adopted for deodar and ban oak. The survey has been done through structured questionnaire developed for that purpose. It has been found that only one physical parameter i.e. height (shoot length: 9" or more) of the nursery stock is adopted in the SFD's nurseries for measuring the quality of these species. As far as another objective of the project is concerned, experimental plantations after inclusion of the other parameters like morphological parameters, root collar diameter, type of production system (polybag or bare root), age, site conditions of plantation area etc. of these species were established during August 2008 & August 2009 on six sites three for each of the species. 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. However, the experimental sites received very less snow fall/rains during 2008 and 2009 followed by continuous drought like conditions during summer resulted in heavy mortality in experimental plantations. Growth and survival



data pertaining to experimental plantations are being recorded regularly. The project activities were also evaluated by the external expert during 2009.



Inspection of the Deodar Stock and Ban Oak Plantation

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

Field survey was conducted and experimental area was selected near Shillaru in Shimla district for establishment of trial by using deodar wildlings/tall plants. Established experimental plantations of deodar wildlings during August 2008, February 2009 and August 2009 in the identified sites at Shillaru and

Kandiali. Wildlings were planted on the basis of height and root collar diameter classes. Experiments were also carried out on the basis of time of root exposure, root desiccation, protecting substances and planting wildlings directly in the field as well as in the nursery in Gunny bags. Nursery studies initiated during March 2009 as



Experimental Plantation of Deodar Wildlings



Raising of Deodar Tall Plants in Nursery

per the availability of tall plants in nursery beds. 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. Experimental plantations are being maintained in the field intensively. The data pertaining to field survival recorded regularly. The plantation success through wildling is still a critical issue and is being investigated under this project. However, field survival results of Deodar wildlings are not encouraging till date.

Standardization of Methodology for Seed Collection, Seed Handling, Storage and Breaking Seed Dormancy in *Juniperus polycarpos* C. Koch and *Fraxinus xanthoxyloides*

The germination studies to overcome seed dormancy in *Juniperus polycarpos* seeds treated with different pre-sowing treatments recorded excellent (70%) germination under nursery conditions. The seedlings raised through seeds are being continuously monitored in the nursery. The repeat trials laid out to find the optimum time of seed collection in both the species are being maintained.



The seed storage trial in *Fraxinus xanthoxyloides* and *Juniperus polycarpos* by using different type of storage containers/storage environment was maintained and viability test of the seeds carried out periodically. The *Fraxinus xanthoxyloides* seeds stored in different type of storage containers/environment showed decreasing trend in seed viability and seeds stored in airtight polysac container placed in refrigerator ($<5.0^{\circ}\text{C}$) retained $>70\%$ viability after 24 months of storage whereas other storage containers/storage environment showed decreasing trend in seed viability. Similarly, *Juniperus polycarpos* seeds also showed decreasing trend in seed viability and seeds stored in airtight polysac container placed in refrigerator ($<5^{\circ}\text{C}$) retained $>50\%$ viability after 24 months of storage, whereas, other storage containers/storage environment showed decreasing trend in seed viability. Fresh seeds were collected and repeat trials laid out.



Seedlings of *Juniperus polycarpos* in the Nursery Conditions

Study on Impact of Ban on Green Felling in Deodar, Kail, Fir and Spruce Forests of Uttarakhand and Himachal Pradesh.

Basic information pertaining to study sites from the offices of respective divisional officers collected and forests in Chamba, Shimla and Kullu districts identified for the detailed investigations. Survey undertaken in Chamba, Chopal and Kullu Forest Divisions of the

identified districts. Basic information/ details of the forests collected from Compartment History Files from the respective ranges. After having the basic details, preliminary discussions were held with the concerned Divisional Forest Officers in their respective divisions and the matter was also deliberated upon at the institute as well. It was finalized internally that the institute will propose the sites falling in three districts viz., Chamba, Kullu and Shimla in the state of Himachal Pradesh. 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. Meeting with the PI and the Head of Silviculture Division were also held for more clarifications and discussions on the issue. Sites in the various ranges/ blocks of the above Forest Division of the identified districts as referred to above were visited with the PI and accordingly, identified for finalization by the team from FRI, Dehradun. Thereafter, basic details of the areas were recorded and literature consulted. Floristic survey in fir and spruce forests conducted in Riuni & Riyana sites falling in Chopal Forest Division. HFRI now will undertake field activities at its own because of separate allocation of budget but will discuss the detailed from time to time with the PI at Dehradun.

Production of enriched vermicompost & analysis of vermicompost samples and training & demonstration have been carried out under the project, "Development of low cost of enriched vermicompost for commercial production"

Collection of seeds/clones and establishment of nursery have been done under the project "Selection and evaluation of potential seed sources and/ clones of selected species from Jharkhand and adjoining states".



2.2.3 Social Forestry, Agroforestry/ Farm Forestry

Development of Agroforestry Models for Eastern Uttar Pradesh

Farmers practicing agroforestry in their fields were identified. Agroforestry plots of Aonla, Eucalyptus, Teak and Poplar were studied, soil samples analyzed for their physico-chemical characteristics. Aonla based agroforestry system was identified as the most suitable and profitable option of agroforestry in Allahabad District. Whereas, for Jaunpur region, Teak based agroforestry system, for Gorakhpur region, teak and poplar and for Barabanki Eucalyptus and Teak based agroforestry were found suitable. The major constraints in adoption of agroforestry was also identified and it revealed that market linkages of forestry produce is very poor other constraints are lack of agroforestry wood based industries viz Pulp & Paper, Plywood and furniture etc, poor accessibility of state run marketing agency e.g. Forest corporation for agroforestry products, Non Lucrative Minimum Support Prices for Agroforestry products, Timber and Forest products transit rules and regulations and lack of agroforestry products' based Marketing Information System etc. in marketing. Further, less availability of agricultural land, long span of period required for getting benefits, legal problems in harvesting, unavailability of market, lack of awareness, unavailability of planting material, personal disputes, are other major factors identified as constraints in adoption of agroforestry by the farmers.

Demonstration of Agroforestry Technologies for Enhancement of Livelihood Opportunities in Different Agro-climatic Zones of Tamil Nadu

The project is being implemented in collaboration with the National Research Centre for Agroforestry, Jhansi and Forest College and

Research Institute, Mettupalayam. The existing agroforestry systems being practiced by the farming communities in five agro-climatic zones were documented along with major tree species and annual crops. Agroforestry demonstration plots were established under 15 ha in five agro-climatic zones (3 ha per zone) with tree components like *Casuarina equisetifolia*, *Casuarina junghuhniana*, *Melia dubia*, *Tectona grandis*, *Eucalyptus* spp. and *Ailanthus excelsa* and horticultural components like Mango, Guava, Sapota and lemon along with the annual crops. Under the established agroforestry demonstration plots, intercropping activities have been carried out under above mentioned agroforestry systems and the yield was assessed. Also biomass samplings have been carried out under the established agroforestry systems with annual crops and the same have been compared with sole



Mango with Groundnut based Agri-horticulture System in Villupuram of Tamil Nadu



Teak with Sugarcane based Agri-silviculture System in Cuddalore District of Tamil Nadu



crops. *Casuarina* with cotton registered higher net income of R` 31,250/ha in Cauvery delta zone followed by Lemon with sunflower (~ 18,750/ha) in Southern zone, Teak with black gram and cowpea (~ 14,650/ha and ~ 12,500/ha respectively) in western zone and Ailanthus with black gram and cowpea (~ 12,840/ha and ~ 10,230/ha respectively) in North-Eastern zone.



Lemon with lab-lab based Agri-horticulture System in Tirunelveli District of Tamil Nadu

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

The planting of tree species like *Casuarina equisetifolia*, *Casuarina junghuhniana* and *Eucalyptus camandulensis* has been completed at four locations namely Karaikudi, Sendurai, Jeyamkondam and Karaikal in Tamil Nadu. Planting of medicinal plants viz. *Decalepis hamiltonii* and *Asparagus racemosus* as intercrop along with the tree species has been completed. Soil samples from all the planting locations were collected before undertaking the planting, for understanding the nutrient status.

Studies on Assessing Growth Performance of *Guadua angustifolia* Kunth under Different Management Schedules (NMBA)

Field trials were established viz; spacing (5mx5m and 5mx9m) and fertilizer trials consisting seven treatments at two sites viz; Yelwala near Mysore and Gottipura (Hoskote) near Bangalore in 2005. Survival rate < 50% in

Hoskote and < 10% in Mysore by the end of third year indicating the unsuitability of *Guadua angustifolia* under semi-arid conditions.

Cultivation of *Guadua angustifolia* Kunth and *Dendrocalamus asper* Backer in Kerala and Karnataka (NMBA)

Farm demonstration trials were established in tropical humid conditions in 2 sites (Aluva and Palakkad) in Kerala and in Thithimathi, Coorg, Karnataka at two spacings to study growth performance. Intercropping was carried out with nutmeg, sandal and *C. sappan* in these 3 sites. Growth performance data collected for the 3 sites in 2008 indicate best performance in Coorg, followed by Aluva and then, by Palakkad.

Bamboo Locational Trials – BLT (NMBA)

Eight bamboo species viz; *Bambusa bambos*, *B. balcooa*, *B. nutans*, *B. tulda*, *Dendrocalamus asper*, *D. hamiltonii*, *D. giganteus* and *D. stocksii* (in Bangalore) and *Guadua angustifolia* in place of *D. stocksii* (in FRC, Hyderabad) trials were established during July-September 2005 and maintained at Nallal, Bangalore and Dulapally, Hyderabad using 5m x 5m spacing. Maximum (100%) survival rate was in *B. balcooa* and minimum (50%) in *D. asper*. Among the eight species, *D. hamiltonii* proved the best in terms of height of culm (5.89m) and diameter (31.8 mm) in Bangalore as well as at Hyderabad, followed by the *D. stocksii*, *B. balcooa* and *B. nutans*. Minimum height (1.6 m) exhibited in *D. asper*.

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

Around 140 individual farmer surveys and 11 village level surveys have been completed



covering 6 taluks in Mandya District. Litter traps were setup in farmers field, litter is being collected monthly and analysed for various nutrients. For litter decomposition studies litter bags are retrieved monthly, processed and analysed for assessing the decomposition pattern. Micro climatic parameters are being recorded monthly in the field.

Development of Multitier Cropping Models for Medicinal Plants in Andhra Pradesh (Funding Agency: (NMPB)

Three crops of medicinal plants namely, *Andrographis paniculata*, *Ocimum sanctum* and *Withania somnifera* were raised in six hectare area in combination with Teak+Sandal, Rosewood+Sandal, Eucalyptus+Sandal trees and in combination with Teak and their respective sole crops. Rosewood+Sandal combination was found to be very suitable for the growth of all the three medicinal plants. *A. paniculata* followed by *O. sanctum* and *W. somnifera* are found to be better suited in that order. The growth data of Teak trees reveal better growths in inter crop as compared to control. Two training-cum-workshops were organized for extension of the research findings. Further, two on-farm trials were laid out in Munnanoor and Thiruppalapuram villages of Gopalget mandal with Sandalwood, Rosewood and all the three medicinal plants.

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 (DBT)

Periodically, data collection at all the four sites [Buggapadu (10ha) & Chintalapudi (10ha) in Andhra Pradesh, Navtoor (20ha) Karnataka and Agloe (5ha) Goa] carried out during 2009-2010.

Mortality replacement at Navtoor site, KFD carried out during July-August 2009. Officials of Goa Forest Department were trained on bamboo macroproliferation and construction of low cost polytunnel for macropropagation of bamboo species. Vegetative propagation techniques like; culm cuttings, branch cuttings and rhizomatous cuttings were demonstrated to the officials of Goa Forest Department.

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

A farmer's field has been selected and prepared for laying out trials. Seedlings of *Gmelina arborea* have been raised and seeds for *Wrightia tinctoria* have been collected for planting as tree component of the various treatments.

Evaluation of Medicinal Plant based Agroforestry System (Silvi-medicinal) under Existing Teak Plantations

Medicinal plant based agroforestry (Silvi-medicinal) system viz. teak-turmeric, teak-keokand and teak-kalihari were developed. The developed models were transferred to the user groups through demonstration of field trial and training. Among these three silvi-medicinal systems, teak-turmeric system was widely appreciated by the user groups.



Field Demonstration to the Farmers of Jabalpur District



Evaluation of Productivity of Maize in *Dalbergia sissoo* - *Zea mays* Agroforestry System

Laid out an OSR trial with hybrid maize at TFRI campus in two year old *Dalbergia sissoo* plantation with 21 plots of size 10m x 10m at 3 different spacings of 4m x 4m, 5m x 5m and 6m x 6m and 3 plots were kept as blank outside the plantation area. Hybrid maize seeds were sown at same spacing of 60cm x 20cm with tree to crop



D.sissoo - *Z.mays* Agroforestry System

line spacing of 60cm and 120cm following Randomized Block Design. The maize crop was harvested and yield data recorded, tabulated and analyzed statistically. The tree distance of 5m x 5m with 60cm tree to crop line spacing proved best for maximum yield of maize crop. Growth parameter i.e. collar diameter and height of *Dalbergia sissoo* plant was recorded at the time of planting and harvesting of maize crop. Maximum increase in height and collar diameter were observed in block with the tree spacing of 5m x 5m. Soil samples collected at the time of planting and harvesting of maize crop were analyzed for pH, EC, organic carbon, available N,P,K and Ca++, Mg++.



Samples of Harvested Maize Intercropped under Sissoo-Maize System

Sustainable Development of New Bamboo Agroforestry Techniques for Increased Income Generation in Central India

Harvesting of wheat from the Bamboo-Wheat agroforestry system established as an On Station Research (OSR) trial in the agroforestry experimental plot at TFRI, Jabalpur was done in the month of April 2009 and wheat yield was estimated following threshing and cleaning.

The casualty replacement was done in the two bamboo species, i.e., *Dendrocalamus strictus* and *Bambusa nutans*. Soil samples were collected from the Bamboo-Wheat agroforestry system after the harvesting of wheat and analysed for various physico-chemical properties and constituents.

A Participatory Rural Appraisal (PRA) exercise was conducted to identify progressive farmers at the Rawan Range, Barnawapara Project Division, Chhattisgarh. Training on the benefits of adopting bamboo based agroforestry system was imparted to the farmers on the 14th and 15th May 2009. Thereafter, polypot seedlings, as per needs expressed by the farmers, were provided for planting on their agricultural field boundaries. Similar exercise was conducted to identify progressive farmers at the Bamboo Centre, Gwalior, Madhya Pradesh. Training on the benefits of adopting Bamboo based agroforestry systems was imparted to these farmers on 25th-26th May 2009. Thereafter, polypot seedlings, as per needs of the farmers, were provided for planting on their agricultural field boundaries.



Training on the Benefits of Adopting Bamboo based Agroforestry Systems



A Bamboo-Urad (Black gram) agroforestry system was established as an OSR by sowing Urad seeds in the Bamboo plantation created while establishing bamboo-wheat agroforestry system. The growth data, viz, collar diameter and height of every bamboo plant of *D. strictus* and *B. nutans* present in the OSR were recorded before the sowing of Urad seeds. Soil samples were collected from the experimental plot before the sowing of Urad seeds and are being analysed for various physico-chemical properties and constituents in the laboratory.

The growth parameters i.e. collar diameter and the height of the leading culm of *D. strictus* and *B. nutans* were recorded and tabulated. Soil samples were collected after the harvesting of Urad and are being analysed for their chemical constituents and physical properties.

The experimental plot was prepared for sowing of wheat to establish a Bamboo-Wheat agroforestry system as an OSR trial in the second cycle. Soil samples were collected before the sowing of wheat were analysed for various physico-chemical and physical properties and constituents. The growth parameters i.e. collar diameter and the height of the leading culm of the two bamboo species viz, *D. strictus* and *B. nutans* were recorded before the sowing of wheat.

Wheat was sown using a seed driller among the two planted bamboo species i.e. *D. strictus* and *B. nutans* for establishing a Bamboo-Wheat agroforestry system in the several cycle as an OSR trial. Germination of wheat was observed and the said agroforestry system so established is being maintained till date.

Agroforestry Model with Medicinal Trees and Herbs

Quality seeds of important medicinal plants and trees were collected from identified sources. About 30,000 seedlings of *Aegle marmelos*, *Andrographis paniculata*, *Asparagus racemosus*, *Moringa oleifera*, *Rauvolfia serpentina*, *R. tetraphylla* and *Withania somnifera* etc. were raised in the nursery for distribution to farmers. *Emblica officinalis* and *Moringa oleifera* based agroforestry plantations were established with the existing annual crop like tomato and potato. Established medicinal plants plot of *Andrographis paniculata*, *Asparagus racemosus*, *Rauvolfia serpentina*, *R. tetraphylla*, *Withania somnifera* under the shade of *Aegle marmelos* and *Moringa oleifera* as well as in the open to study the effect of shade on growth of medicinal plants. FYM and biofertilizer, soil and sand have been purchased and distributed to the 12 farmers under the project. To make awareness among the people about the importance and cultivation of medicinal plants to get additional benefit both from top storey of medicinal plants and other agricultural crops, 100 people have been given training under the project.

At Rain Forest Research Institute, Jorhat, a total of 77 villagers from 65 families have been trained in different aspects like macro proliferation techniques, bamboo agroforestry management, fishery, bee keeping, nursery technique of bamboo and rattans, low cost and short duration nursery technique of Gamar. Five nos. of villagers were trained on artisanship/craftsmanship at CBTC, Guwahati. The agroforestry model developed by RFRI has been adopted by the villagers for optimised and sustained productivity. Two bio-gas plants were also installed in the village and the benefit goes to maximum no of families. The study reveals that



there has been improvement in availability of energy for household purposes besides saving their time to engage themselves in other productive works and also minimize the extraction of fire wood and thus reduced environmental pollution. The villagers were trained on various aspects of fish farming viz. soil testing, size and shape of a pond, proportion of slope; maintain pH level, selection of different fish species and feeding pattern etc. Fingerlings of different species like Rohu, Catla, Grass Carp, Mirika, Silver Carp and Common Carp, were prescribed suitable to the local condition for rearing. One thousand two hundred fingerlings of assorted species was introduced and made a net profit of ` 10,500.00 in the first year. In the subsequent year, the income will enhance marginally and the villagers will get more profit on a sustainable basis. Fifty villagers were trained on bee keeping. During the training, various aspects of beekeeping like selection of bee, colony cleaning, placement of extraction chamber, requirement of food materials in absence of flowers, catching of swarm bee, method of extraction of honey, fixing and fitting of honeycomb, time of displacement and other management aspects were covered. Each beneficiary extracted honey in one bee box and obtained 6 to 7 kgs of honey earning ` 1,200/- to ` 1,400/- in a year. The crop harvested from the inter cropping with bamboo and Gamar and introduction of horticultural and seasonal vegetable more particularly the Bhot jolokia (HOT CHILLI) also provided additional income to the farmers in phase manner.

Under the project on farm, innovation in macroproliferation technique and promotion for commercial plantation of edible bamboo, capacity building of the Self Help Group members was done through training and demonstration on nursery practices using macropoliferation technique and bamboo plantation management for

edible shoot production. Villagers have also been motivated to utilize the interspaces by intercropping locally preferred crops for an additional income. Liaison meeting with the local entrepreneurs has also helped them in marketing of edible shoots by developing linkages to shoot processing industries located in Jorhat (60km from the site). The results were found to be very much encouraging and the model was replicated in nearby villages.

Under the project documentation of baseline information on shifting cultivation in NE India, eleven representative sites were selected throughout NE states. Field survey was done for collection of information/data on shifting cultivation practices. Time series data showed a declining trend in area under shifting cultivation in NE states. Four typologies of shifting cultivation were observed in NE states. Among the transformations recorded in shifting cultivation areas, major ones are conversion of fallow jhum lands into horticulture and forestry plantations. The methodologies adopted in this study for isolation of Rhizobium, inoculation technique, Physico chemical analysis of soil, yield analysis of crops are appropriate and effective to meet the set objectives of the project.

Development of Suitable Agroforestry Models for Promoting Bamboo Cultivation outside Forests in NE Region

Under the project, agroforestry plantations have been established. Inter cropping trials on horticulture and agricultural trials; experiments on the effect of biological root barriers and canopy manipulation are undergoing. The technical programme and methodologies proposed under the project as mentioned above have been found suitable to achieve the objectives.



Development of Economically Viable and Integrated Agroforestry Models for Arid Region

Agroforestry model was established and maintained at farmer's field at village Harsh, Bilara, District - Jodhpur. *Sesbania aculeata* (Dhaincha) was grown during the year in the field for green manuring. Performance of *Ziziphus mauritiana* (grafted ber) species was found the best as horticultural species, while *Colophospermum mopane* was the best as silvicultural species.

Colophospermum mopane plants attained (average) maximum height of 181 cm, followed by *Prosopis cineraria* (173 cm), *Cordia mixa* (169 cm), *Ailanthus excelsa* (165 cm) and *Ziziphus mauritiana* (136 cm). Collar diameter was maximum in *A. excelsa* (5.96 cm), followed by *Cordia mixa* (5.83 cm), *C. mopane* (4.52 cm) and *P. cineraria* (4.19 cm). The plant growth was higher in agroforestry plots as compared to the control (without crop). Wheat crop production was recorded 13.67 quintal/ha during the year.

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

Procurement/collection of seeds was done through the Institute of Forest Productivity, Ranchi, from five locations. Nurseries of the institute located at Johron (Paonta Sahib) and Bir Palasi (Nalagarh) representing the low hill zone were used for the production of planting stock. After field survey, four sites in lower hill zone at Puruwala & Kot in Himachal Pradesh and Nudh & Basanterbella in Jammu & Kashmir, measuring 5.0 ha have been identified and experimental trials following RBD design with three replications established. Though very early to predict, yet preliminary growth data indicated that the *G. arborea* is performing well on the study sites and have attained an average range height of about

two metres within two years of establishment. However, growth data of preliminary results shows that *G. arborea* may be a future planting species for the lower hills keeping in view its short rotation period.

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 indicated that the six important agroforestry species (frequency > 56%) selected for taking up the present study are also integral part of the naturally occurring agri-silvicultural agroforestry systems in the region. Collected soil samples were analyzed and Nitrogen was 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 major (five) agroforestry species were to be assessed, whereas, experimentation on six important agroforestry species i.e., *Grewia optiva*, *Mours alba*, *Celtis australis*, *Bauhinia variegata*, *Toona ciliata* and *Albizia chinensis* was undertaken. Litter samples collected from the experimental area were further segregated for grinding and further chemical analysis. Preliminary results of litter production by important agroforestry species mentioned above indicated that these species all together contributes significant amount of litter-fall annually through various litter fractions. Results on nutrients contents in litter of agroforestry species preliminarily indicated that leaves of these six important species have higher concentrations of either of the



five nutrients (Nitrogen, Phosphorous, Potassium, Calcium and Magnesium) studied, which may be helpful in drawing various correlations/conclusions at the end of the study.

Information on natural populations and plantations of kadamb and semul have been collected and 30 candidate plus trees have been identified in Jharkhand and West Bengal. Relative analysis of CPTs on physiological parameters and experiments designed for evolving clonal propagation procedures have been completed under the project viz.: "Integrated strategy for evaluation of indigenous fast-growing multipurpose trees of eastern India for plantation forestry".

2.2.4 Forest Soils & Land Reclamation

Status of Soils and Organic-C Store in Giri Catchments, H.P.

The study was carried out in Giri catchments of Himachal Pradesh. Geologically, the study area comprises of the Pre-Tertiary rocks. Lithologically, the rock formations consists of Limestone, Dolomite, Slates, Shales, quartzites, Sandstones, Schist, Phyllites, Conglomerates, Boulders etc. Giri catchment has 8,165,593.15 (8.16 million) tons of soil organic carbon store in the forest area. Under agriculture land use, soil organic carbon store is 3,167,521.58 tones (3.16 million tons). Alkaline soil reaction are found on Mandhali formation, neutral on Infra Krol formation whereas acidic soil reaction are observed on Krol formation. Soil pH in dense forests was observed in decreasing order of pine (6.42), deodar (5.91) and spruce (5.00). Available phosphorus was found poor on Blaini and Krol formations, medium on Mandhali and Krol formations and high on thrust and faults locations. Available potash was high on thrusts and Krol formation and medium on Mandhali and Blaini formations.

Recommendation of Landuse Model for Degraded Forests of Nainital

The study was carried out in Nainital and adjoining areas, Nainital forest division. Different landuses were identified and studied in the area:

Pine Forests:

Dense: The soils are acidic in reaction, low in conductivity and have sandy loam texture. Organic matter in these soils varies from 1.63 to 3.85 %.

Open: The soils are acidic to alkaline in reaction, low in conductivity and have sandy loam texture. Organic matter varies from 3.35 to 3.70 %.

Sal Forests:

Dense: Soils are generally loam to silty loam. It has low to medium electrical conductivity, low to medium in organic matter (1.66-3.79 %).

Open: The soils are acidic in reaction (5.15 - 5.68), low in conductivity and have sandy loam texture. Organic matter in these soils varies from 1.66 to 3.10 %.

Miscellaneous Forest:

Dense: The soils are acidic in reaction (5.31-5.95 pH), low to medium in conductivity and have sandy loam texture. Organic matter in these soils varies from 1.62 to 5.41 %.

Open: The soils are acidic to alkaline in reaction (5.40- 7.85 pH), low to medium in conductivity and have sandy loam texture. Organic matter in these soils varies from 1.66 to 4.38 %.

Oak Forests:

Dense: The soils are acidic in reaction, low to medium in conductivity and have sandy loam texture. Organic matter in these soils vary from 3.7 to 6.1 %.

Open: The soils are acidic in reaction, low to medium in conductivity and have loam to sandy loam texture. Organic matter in these soils vary from 3.7 to 5.40 %.



Plantation techniques for degraded sites have been given and suitable species for afforestation on different degraded lands were suggested.

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

Uttarakhand forests of North-Western Himalaya is a confluence of all the rock formations resulting in different soil and vegetation types on different climatic zones. The importance of geology in forestry research is of great significance in evaluating the soil fertility status and in managing the soil for greater production. The area was surveyed and collected the soil samples from Dehradun, Chamoli, Pithoragarh, Almora and Bageshwar districts of Uttarakhand under different natural forests from predetermined depths. Representative sites were selected in each location depending upon the variation in geology, vegetation and climate. Three soil profiles were also excavated at each sampling points and samples have been collected from different genetic horizons. Soil samples collected so far are being analysed for their physico-chemical attributes. The fresh rock samples have been collected from different sampling sites having similar or different vegetation and geological formations. Suitable number of 10x10 metre quadrates for tree species were laid down in each sampling site and the trees within the quadrates will be enumerated for dbh, height and crown area. Sand and clay fractions separated from soil are being prepared for mineralogical investigations.

Soil Organic Carbon Inventory of Uttarakhand

Concentration of atmospheric CO₂ can be lowered either by reducing emissions or by taking CO₂ out from the atmosphere and stored in the terrestrial, oceanic or aquatic ecosystems. Soil especially, the forest soil, is one of the main sinks

of carbon on earth because these soils normally contain higher carbon as compared to vegetation. No systematic project/ study has been undertaken to estimate the soil organic carbon in forests, as well as in other land uses in Uttarakhand, by following uniform methodology for field and laboratory work. This project would generate comprehensive and authentic information using standard IPCC methodology, about the soil organic carbon by ground truthing in the different land uses in all the districts of Uttarakhand. During 2009–10, total 1108 soil samples were collected from different land uses for soil organic carbon estimation from 202 different locations spreaded over in all the districts of Uttarakhand. 846 samples from different forests covers, 135 samples from different plantations, 94 from different horticulture land use and 34 samples from agroforestry models in different districts of Uttarakhand have been collected during this year. In addition to the above samples, 404 soil samples have also been collected for bulk density and coarse fragment estimation from the above 202 locations. All the samples were analysed for Soil Organic Carbon, Bulk Density and Coarse fragments.

Litter Decomposition in Sal Forests of Central India and its Impact on Nutrient Status of Soil

Study sites were selected from sal forest of Madhya Pradesh, Chhattisgarh and Orissa. Litter samples from different layers were collected for study of microflora and fauna involved in decomposition of litter. Forty five isolates of fungi are maintained in the laboratory. Carbon flux in 3 different sites was recorded. Identification and documentation of selective decomposing fungi is under progress. The present study will highlight litter decomposition and its conversion into nutrients which will be recycled and used by sal for their growth and biomass production.



Bamboo Species Suitability for Different Non-Forest Areas of M.P.

Nine different bamboo plantation sites were selected in non forest areas of M.P. namely Sinduri bharri (Shahdol), Majgaon (Katni), Ghugri (Jabalpur), Sanaidongri (Lakhnadon), Rajgarh (Rewa), Barelipar & Dhokli (Sarni/Betul),



Bamboo Plantation in Non-Forest Degraded Area at Ghugri, Jabalpur

Delakhadi & Sonapipri (Chhindwara) for undertaking observations on growth performance (average height & collar diameter) of bamboo culms. Two pot culture experiments were laid out at TFRI nursery to study a) Suitability of different bamboo species in two different parent material of soil, and b) Performance of *D. strictus* in three different parent material of soil. Growth data of



Library for Soil Samples of North-East

bamboo seedlings raised in two different pot culture experiment are being recorded quarterly. Growth increment of three months old bamboo seedling indicate that *B.vulgaris* had maximum

height in yellow soil (Granite), whereas rest of other bamboo species viz. *Bambusa bambos*, *B.longispathus*, *D.strictus*, *B.tulda*, *B.nutans* had maximum growth increment in black (basaltic) soil. Ninty soil samples from 29 forest sub-group types collected from North-East states have been analyzed. A library for soil Samples of North East is being set up in Rain Forest Research Institute, Jorhat.

Characterization and Classification of Forest Soils of Rajasthan

With the objective to characterize and classify the forest soils of Rajasthan, following the USDA classification system, soil profiles have been studied at 210 places covering Sri Ganganagar, Hanumangarh, Jhunjhunu, Sikar, Bikaner, Nagaur, Barmer, Sirohi, Jalore and Jaisalmer districts in 170 forest blocks in 89 ranges. Physico-chemical characterization of the soils has been done in the field as well as in laboratory. Soil structure, consistency, colour,



Northern Dry Mixed Deciduous Forest (5B/C2) on Very Shallow Soil, Ratapani, Dungarpur; pH: 6.32-6.45; Ec: 0.06-0.09 dSm⁻¹; SOC: 0.27-1.26; Carbon stock: 22.1 Mg ha⁻¹



Desert Dune Scrub (61S1) on Deep Aeolian Deposit in Ganganagar; pH: 8.67; Ec: 0.16 dSm⁻¹; SOC: 0.11-0.13; Carbon stock: 31.9 Mg ha⁻¹



pH, electrical conductivity, organic carbon, NO₃ and NH₄ – nitrogen and phosphorus have been estimated for 751 samples. Ecological study in an area of 0.1 ha near each of the soil profile pit has been completed. Soils in Shri Ganganagar district are mainly aeolian deposits in the form of desert dunes, inter-dunal plane and old alluvial plains, where no vertical development of horizon has taken place, indicating nature of Entisol. Soil carbon stock varied greatly among different sites, depending on % organic carbon and depth of soil, being high in Gander, Pratapgarh (341 Mg per ha). Very low stock of carbon was estimated for Panch kunda (12.6 Mg ha⁻¹) and Kala Bhakar (13.5 Mg ha⁻¹) blocks in *Euphorbia* scrub and *Anogeissus pendula* scrub, respectively having very shallow soil depth and low soil organic carbon.

Studies on Characteristic Features Pertaining to Biodrainage Potential of Some Selected Tree Species

Performance of *Corymbia tessellaris*, *Eucalyptus camaldulensis*, *Eucalyptus fastigata* and *Eucalyptus rufa* in a canal side (Indira Gandhi Nahar Pariyojana) waterlogged area and their impact on ground water depletion and soil nutrients was studied. *E. rufa* performed the best among the tree species with respect to growth, biomass, transpiration rate and overall bio-drainage potential. Ground water level receded by

145 cm (from stagnant water of 20 cm to a depth of 125 cm) in *E. rufa* plot. In *C. tessellaris*, *E. camaldulensis* and *E. fastigata* water level receded by 90 cm, 70 cm and 60 cm, respectively. Soil electrical conductivity, SOM, NH₄ and NO₃ – N and PO₄ – P varied significantly among different species. All these parameters, except PO₄ – P were high in *E. rufa* and low in *E. fastigata*. No significant variation was observed in the soil pH in these species.

Interesting observation was also on heavy natural regeneration of *Eucalyptus camaldulensis* in a water logged area in Indira Gandhi Nahar Pariyojana (IGNP) as a result of soil working (tractor ploughing) that was done before raising an experimental plantation. The regenerated plants were mostly concentrated between 6 and 10 m from the tree trunk of the mother trees situated at the edge of the experimental site. Number of seedlings varied between 13 and 36 per m² area. Ground water table has receded from 25 cm to 201 cm depth within a period of five and half year. Apart from the planted species, *Prosopis juliflora*, *Tamarix dioca* and *Saccharum munja* also have come up in the area with recession of ground water table as natural succession and contributed significantly for further lowering of ground water table and increasing productivity.

Transpirational response of *A. nilotica*, *E. camaldulensis* and *T. aphylla* to different water regimes and salinity were studied under controlled condition [water logging at 50 cm (W₃) and 100 cm (W₂) soil depth along with a control treatment (W₁) in in-filled non-weighing type of lysimeters and S₁: No salinity; S₂: 7/12 dSm⁻¹ and S₃: 12/24 dSm⁻¹]. High transpiration rate was recorded in *A. nilotica* plants, followed by *E. camaldulensis* and *T. aphylla*. Species wise height, and collar girth was significantly high in



Growth of Different Tree Species under Waterlogged Condition in Indira Gandhi Nahar Pariyojana (IGNP)



E. camaldulensis whereas, crown growth was high in *A. nilotica*. With increase in salinity, *E. camaldulensis*, *T. aphylla* and *A. nilotica* registered 33%, 20% and 20% reduction in growth respectively as compared to the control. With increase in water logging, higher growth was recorded in *E. camaldulensis*, however, a decrease in growth parameters recorded in *A. nilotica* and *T. aphylla*.

Water use per day per tree was significantly affected by salinity level and depth of water logging. Under water logging at 50 cm soil depth with normal water, *E. camaldulensis*, *T. aphylla* and *A. nilotica* used 64, 55.6 and 30.3 litre water per day, respectively. In *E. camaldulensis* and *T. aphylla*, increase in water use has been observed with increase in water logging at non-saline condition. However, in *A. nilotica* water use increased up to W_2 and reduced drastically in W_3 treatment. Under non-saline condition, highest water use of 73.6 litre per day was recorded in *A. nilotica* in W_2 treatment. With increase in salinity level, a decrease in daily water use was observed, which was greatest in *E. camaldulensis* (66%). Whereas, *T. Aphylla* and *A. nilotica* recorded 57% and 51% decrease in water use, respectively. *Eucalyptus camaldulensis* plants in W_3S_3 treatment started wilting permanently at the age of two years (22 months after the water logging and salinity treatments initiated). The native species showed higher tolerance towards salinity as compared to *E. camaldulensis*. However, under water logging condition at shallow depth, *E. camaldulensis* outperformed *A. nilotica* and *T. aphylla*.

Studies on Species Suitability & Reclamation Strategy for Degraded Forest Soils of Chhotanagpur Plateau, Jharkhand were conducted with a view to assess the species suitability under degraded soil condition of Chhotanagpur plateau areas of Jharkhand and

strategizing the mode of reclamation of these soils optimally. Works relating to nature and degree of degradation and other limiting factors of the soils have been covered before taking up the reclamation measures. The limiting factors for tree growth of the sites have been assessed. Nursery and field trial plots have been developed on stress and barren sites at Lalgutwa. Seedlings of 60 tree species have been raised and utilized for pot and field trial on species suitability and reclamation strategy of degraded soils. Species suitability under degraded soils of Chhotanagpur plateau area have been assessed from growth and biomass data. Impact of amendments as indicators of moisture conservation and growth performance of the planted species will be assessed after final data collection and analysis of samples. All the achievable data would facilitate to develop packages for practice for these type of degraded soils.

2.2.5 Watershed Management

Efficacy and Economics of Rain Water Harvesting Devices in Controlling Runoff Losses and Enhancing Biomass Productivity in Aravali Ranges

Effect of different rainwater harvesting techniques (contour trench, gradonie, box trench and V-ditch) and hill slope on plant growth, runoff loss and soil moisture status were studied on a degraded hill in Banswara district. Plants were taller and thicker in <10% slope area and decreased with increase in slope gradient. *Embilica officinalis*, *Azadirachta indica* and *Zizyphus mauritiana* performed better in <10% slope, Bamboo and *Acacia catechu* in > 20% slope and *H. integrifolia* in 10-20% slope. Among the treatments, *E. officinalis*, *S. cumini*, *A. catechu* and *H.integrifolia* performed better in contour trench plots, *G. arborea* and *Z. mauritiana* perfrmed better in box trench plots



and *A. indica* and bamboo performed better in V-ditch plots. In 2009, runoff loss was 12.71% in <10% slope and 17.61% in 10-20% slope, it was highest in control (17.59%) and lowest in the Contour trench plots (12.99%). Losses of $\text{PO}_4\text{-P}$ was highest from >20% slope, but the losses of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ were highest in 10 - 20%.

Soil Water Content (SWC) of June 2009 did not differ ($P>0.05$) due to both slope and rainwater harvesting treatments. However, SWC was highest in <10% slope and lowest in >20% slope. Among the treatments, it was highest in

Box trench area and lowest in Gradonie plot in upper 0-40 cm soil layer. In <40 cm soil layer, SWC was highest ($P<0.05$) in <10% slope and lowest in 10-20% slope, whereas, it was highest in Gradonie and lowest in V-ditch plots. Soil carbon stock in 0-40 cm soil layer increased significantly from 2005 to 2009 as a result of soil and water conservation. Highest increase in carbon stock was in >20% slope. Though not differed significantly, the highest increase in carbon stock was in V-ditch plots, than in the other rainwater harvesting structures.