Pulp and Paper Industry Raw Material Scenario - ITC Plantation A Case Study

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ABSTRACT

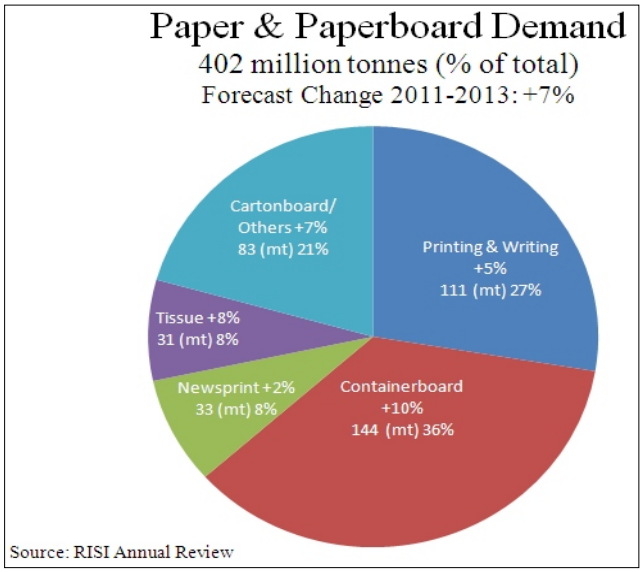
The pulp and paper industry is one of the key industrial sectors contributing to the Indian economy. There are 759 paper mills in India with an operating capacity of 12.7 million tonnes and consumption at 11 million tonnes with 9.3 kg per capita consumption of paper. The annual pulp production is 2.71 3.3 million tonnes using 9.83 million tonnes of wood. Under Private-Private partnership, ITC promoted 140,989 ha plantation using R&D to increase productivity to 20-58 t/ha/yr compared to 4-6 t/ha/yr from seedling plantations favouring fast wood forestry.
Paper mills in India continue to face challenges with forest-based raw material. Out of the annual paper production capacity of nearly 10.11 million tonnes, around 31% (3.19 million tonnes) is produced by 26 major wood-based mills and the rest 69% by waste paper and agro-based mills. The present annual requirement of wood is 9.83 million tonnes. The projected demand for Paper by 2025 is 24 million tonnes with indigenous production of 22 million tonnes leading to a shortfall of 12 million tonnes of wood. The strategy to be adopted by the paper industry, to meet its ever-growing demand of wood on continuous and sustainable basis is to enlarge social and farm forestry plantation apart from raising plantations by forest development corporations.

Keywords: *pulp and paper, farm forestry, clonal technology, Eucalyptus, Casuarina, Leucaena*

Introduction

Global Scenario

Paper and paperboard has become an essential requirement of our life. The current global paper and paperboard demand is 402 million tonnes per annum and there are more than 7745 mills producing 192 million tonnes of pulp. The paper demand has doubled in 20 years from 242.79 million tonnes in 1990 to 402 million tonnes in 2011 (Fig. 1).



The forecast for paper production by 2021 is projected at 521 million tonnes per annum (1). Asia produces nearly 177 million tonnes (44%) while; rest of the world produces 225 million tonnes (56%). The demand of paper is strongly linked to GDP growth. The 6.84 billion people of our planet consume 56.7 kg paper. Forest products sector is estimated to contribute about 1.2% of world GDP and 3% of international merchandise trade. Industry annual turnover exceeds US$ 200 billion for round wood and sawn wood, panels, pulp and paper (2).

Indian Scenario

The papermaking in India is almost two centuries old with first unit commissioned in 1832 in Serampur, West Bengal (3,4). Rags and waste paper were the raw material used for producing paper in 1867. Commercial production started in 1882 with non wood fibers. Bamboo pulping process was developed in Forest Research Institute, Dehra Dun during 1922-24 which provided impetus to pulp and paper industry in India. The growth of paper mills (Table 1) is quite rapid during the last two decades (5).

Today, there are 759 pulp and paper mills with an installed capacity of 12.7 million tonnes producing 10.11 million tonnes of paper and paperboards which is 2.52% of the total world production of 402 million tonnes per annum. Apart from 10.11 million tonnes production, 1.04 million tonne is imported annually. Therefore, the present consumption of paper and paperboard including news print is at 11.15 million tonnes.

The per capita consumption in India is 9.3 kg as against 42 kg in China, 22 kg in Indonesia, 25 kg in Malaysia, 250 kg in Japan,

Table 1. Growth of paper mills in India

Year	No of units	Installed capacity (million tonnes)	Production (million tonnes)	Capacity utilization (%)	Per capita consumption (kgs)
1950	17	0.13	0.11	85	0.9
1970	57	0.77	0.75	99	1.9
1990	325	3.3	2.43	62	3.6
2000	380	3.94	4.87	99	5.5
2006	660	8.5	6.8	80	6.7
2007	667	8.5	8.3	100	8.3
2010	759	12.7	10.11	80	9.3

325 kg in USA and the world average of 56.7 kg. In India the paper consumption is predominantly domestic and t**he demand is driven by GDP growth.** The main growth drivers for paper demand includes enhancement in government spending on education (6% of GDP), increase in literacy rate, improvement in standard of living, booming retail sector, construction boom, unprecedented growth in industries like food, pharmaceuticals and apparels, increase in packaging and advertising expenditure etc. The printing and packaging industry is growing at 14% CAGR. The population of 1.2 billion and the changing demographic profile, which will put over 65% of the population in the working class and half of that is less than 30 years old, following western consumerism, will further fuel the demand for paper and paperboards.

With the GDP expected to average around 9%*, growth in consumption of paper and paperboard is expected to be about 7.8%. The Indian pulp and paper industry mirrors its impressive growth rates in the GDP at 8% CAGR (6). This translates in to consumption of about 24 million tonnes and production of 22 million tonnes by 2025 resulting in per capita consumption of 17 kg. All this means rapid growth of pulp and paper industry in India that ultimately requires wood as raw material. Indian pulp and paper industry being the 15th largest industry in the world is an important industrial sector having a bearing on the socio economic development of the country as it provides employment to nearly 1.5 million people (7). The paper industries market size in 2009-10 was Rs.317 billion (US $ 6.34 billion)** and is expected to touch Rs.526 billion (US $ 10.52 billion) by 2014-15. Annually, India exports 0.527 million tonnes and imports 1.582 million tonnes of paper products (5).

Indian paper industry is highly fragmented. In terms of product wise segmentation, the printing and writing is 38.58% while, packaging is 53.61% and newsprint is 7.81%. Depending upon the production capacity paper mills are classified as large (33000 tpa), small (7500 tpa) and medium (between 7500 to 33000 tpa). The paper production from small and medium mills accounts for 60% while 40% comes from large mills. Out of 759 mills, 114 (15%) are large, 342 (45%) small and 303 (40%) medium. Further, the industry is divided in to 3 sectors (Table 2 and 3) based on raw material (8,9) usage.

Wood and Bamboo: Mills using wood and bamboo contribute 31% production which is 3.19 million tonnes and there are 26 large integrated paper mills.

Agro-based: There are 150 mills using agro residues like bagasse, wheat and rice straw etc., produce 2.2 million tonnes which is 22% of the total production. The agro based fiber usage has decreased considerably.

Recycled fiber: Mills using waste paper contribute almost 47% of the country's current production which is 4.72 million tonnes and there are 538 mills in operation. Over the years recycled fiber usage has considerably increased.

The agri waste is finding its way for power generation and availability is becoming tight and expensive. Moreover, the agro based mills are shutting down on account of pollution related problems and non availability of agri waste on sustainable basis as seen in the Table 2. Waste paper quality and price has also put paper industry under pressure. Wood based mills have done some work on raising plantations but still the availability of wood is a major concern to the mills. Wood being a renewable resource to produce paper, it becomes necessary to look in to the trends of its demand and ways and means to meet the raw material requirement to produce it.

Wood Requirement and Generation

India has a total forest area of about 75 million ha which forms only 22.8% of the total geographical area (328 million ha) of the country. Forests in India are fast disappearing. At the time of independence more than 22% of India's geographical area was covered by dense forests. Recent satellite surveys show that hardly 11% of the area now supports closed forests, *i.e.* forest with 40% crown cover even though the National Forest Policy enunciated soon after independence in 1952 that at least 33% of geographical area of the country should be under forest cover. Further, the per capita forest area in India is only 0.064 ha against the world average of 0.64 ha (10). Out of 69.09 million ha of the recorded forest cover, nearly 28.84 million ha are degraded forest lands. The productivity of Indian forest is only 1.34 m^3/ha/yr against the world average of 2.1 m^3/ha/yr. Earlier forests were the main source for wood and bamboo based raw material for the paper industry. Depletion of forest areas and reduction in volume of extraction of wood and bamboo has hit badly the supply of raw material to the industry.

In recent times, the demand for the fire

Table 2. Segment-wise composition trend in usage of raw material

Segment	Unit	1970	1995	2000	2002	2005	2009	2011
Wood based	%	84	39.18	29	36.8	35	39	31
Agro based	%	099	32.36	36	32.4	30	31	22
Recycled fiber based	%	07	28.44	35	30.8	35	30	47

Table 3. Total number of pulp and paper mills in India -2010 year

	Unit	Wood based	Agro based	Recycled fiber based	Total
Mills	No.	26	150	583	759
Production	Million tonnes	3.19	2.2	4.72	10.11
Share	%	31	22	47	100
Installed capacity	%	4.00	3.00	5.7	12.70
Capacity utilization	%	80	73	83	79

wood, timber and industrial wood in the country continuous to grow because of increasing population and the growth of economy. The Indian forest Act-1927, The Forest Conservation Act-1980, The National Forest Policy-1988 and The National Forest Commission 2003 are the umbrella legislation and frame works for forest protection and conservation. Under these Acts and Rules and Policy, the supply of raw material to wood based industries is phased out from forests. Participation of the private sector, even in reforestation of 28.84 million ha degraded forest lands and Joint Forest Management is not allowed as per the policy guidelines. In the National Forest Policy 1988, the wood based industries have been advised to encourage agro forestry for raising plantation to meet the raw material demand. Agriculture sector in the country covers about 143 million ha out of which 40 million ha is classified as degraded (11). Hence, non forest lands such as private lands are explored for raising tree crops to augment the available wood resources. In course of time, social and farm forestry plantations emerged on large scale for meeting the wood demand of the paper industry.

The wood based paper mills in India continue to face challenges with forest-based raw material. Pulp and paper industry consumes 3% of total national requirement of wood while, the major consumption being fuel wood (89.5%) and timber (7.5%). The annual pulp production is 3.03 million tonnes from 10 million tonnes of wood, agro-residue and waste paper. Nearly 20% of wood is procured from government sources while, 80% is from agro farm forestry sources. The bamboo and wood requirement is 0.82 and 9.27 million tonnes per annum respectively (Table 4). The strategy adopted by the industry to meet the ever growing demand of wood on a sustainable basis is to obtain wood from social and farm forestry plantations. Over a period of 23 years the paper industry has promoted nearly 657,093 ha plantations which is estimated to produce 39.42 million tonnes of wood at 60 tonnes per ha yield. However, if we consider last 5 years plantations of Eucalyptus, Casuarina, Leucaena and Acacia, it is 300,000 ha which can produce 18 million tonnes of wood. At the felling cycle of 4 years, the wood production annually is 4.5 million tonnes. The current level of planting by the paper mills is around 50,000 ha per annum. Apart from the industrial efforts, farmers on their own are raising plantations. In the recent years several private Eucalyptus clonal nurseries have sprang up and an additional 20,000 ha area every year is planted. This is adding to the general availability of wood to the industry. Hence, the industries wood demand of 10 million tonnes annually is somehow met through farm forestry plantations.

In addition to pulpwood, the farm grown wood is required for mine props, scaffolding, plywood, particle board and biomass based energy industries, which is creating stiff competition to paper industry. There is drastic increase in pulpwood prices alone from 25 to 45 US $ tonne (Rs.1250 to Rs. 2250) in a span

Table 4. Wood requirement and generation by paper mills through farm forestry

SL. No.	Company	Wood Pulp (t)	Wood Requirement (t)			Area Planted (ha)	Estimated Wood Generation (t) @ 60 t/ha
			Bamboo	Wood	Total		
1	ITC Ltd.	300000	0	1125000	1125000	140989	8459340
2	Tamil Nadu News Print Ltd. *	280000	0	400000	400000	34542	2072520
3	Century P & P Ltd. *	280000	168750	958125	1126875	2340	140400
4	JK Corp (Orissa)	220000	50000	850000	900000	59974	3598440
5	JK Corp (Gujarat)	55000	80000	126250	206250		
6	Orient Paper Mill Ltd.	80000	167000	173000	340000	33043	1982580
7	Star Paper Mill Ltd.	70000	100000	180000	280000	72740	4364400
8	Mysore Paper Mill *	60000	0	225000	225000	27500	1650000
9	Sirpur Paper Mill Ltd.	120000	0	375000	375000	30921	1855260
10	BILT Ballarpur/Asthi	220000	200000	175000	375000	36055	2163300
11	BILT Sewa	100000	40000	335000	375000		
12	BILT Yamunanagar	100000	0	375000	375000		
13	BILT Kamalapur	100000	0	375000	375000		
14	BILT Chowdwar (Not Operational)	0	0	0	0		
15	Seshasai P & B Ltd.*	160000	0	400000	400000	18534	1112040
16	Andhra Pradesh Paper Mill Ltd.	220000	18000	800000	818000	124040	7442400
17	Circar Paper Mill *	0	0	5000	5000	0	0
18	West Coast Paper Mill Ltd.	280000	0	900000	900000	44260	2655600
19	Rama News Prints *	0	0	0	0	0	0
20	HNL Kottayam	80000	0	300000	300000	32000	1920000
21	HNL Naogaon	100000	0	375000	375000		
22	HNL Kachar	100000	0	375000	375000		
23	HNL Nagaland	20000	0	75000	75000		
24	Nepa Paper Mill *	0	0	50000	50000	0	0
25	Yash Paper Mill	5000	0	16500	16500	150	9000
26	Delta Paper Mill *	80000	0	300000	300000	0	0
27	Emami Paper Mill *	0	0	0	0	5	300
Total		3030000	823750	9268875	10092625	657093	39425580

* Mills using Agro residues and waste paper for Pulp Production apart from Wood and Bamboo

of 6 years. Prices of hardwood increased at a CAGR of 8% to around Rs. 3,525 per tonne (US $ 70.5) in 2009-10 from about Rs. 2,450 per tonne (US $ 49) in 2004-05 (Fig. 2 & 3). Due to competition and high demand, the wood is transported from faraway places. Presently, the cost of wood-based raw material to Indian mills is US $ 70/t compared to US$17/t in Indonesia and US$25/t in Brazil. As one tonne of paper requires 4 tonnes of wood, there is a straight disadvantage of about US$ 180 to 212 /t of paper produced. If this trend continues, India will have to import pulp and paper instead of making it domestically. Paper companies are aggressively looking at farm forestry to cut down on the landed cost of wood. With transportation cost accounting for nearly 30 to 50% of the wood cost, developing farm forestry plantations near the manufacturing units are being pursued vigorously by the mills.

Andhra Pradesh State has four mega pulp and paper unit and has become a wood surplus state in India. Andhra Pradesh has brought in legislation wherein Eucalyptus, Casuarina and Leucaena wood is declared as agricultural produce and marketed through agricultural market committee (12). Pulpwood from social forestry district *viz.,* Prakasham and Krishna in Andhra Pradesh meet the wood demand of mills not only of Andhra Pradesh but also of mills located in Karnataka, Maharashtra, Gujarat, Orissa, Uttar Pradesh, Uttaranchal and Madhya Pradesh (13). The plantation efforts lead to net increase of 939 km^2 in forest cover in 5 years time including 3000 km^2 in non forest areas and nearly 400,000 ha is with trees outside forests (14,15,16). The present consumption of wood is at 9.83 million tonnes. Considering the future demand of paper by 2025, an additional 12 million tonnes of wood is required from 1.2 million ha of pulpwood plantations and 0.36 million ha (30% extra) for fuel, fodder and local usage. The total land mass therefore required to raise pulpwood plantation will be around 1.56 (say 2) million ha with an assumption of 50 tonnes per ha productivity for a felling cycle of 5 years.

completely shifted to hardwood. Presently, 8 paper mills use 0.82 million tonnes of bamboo per annum. Few mills have given up bamboo and replaced it with hardwood and promoting more pulpwood plantations.

Recent Wood Availability Crisis

Though there appear to be excellent efforts of raising plantations by the paper industry, the availability of wood has dwindled in the recent past on account of up-rooting of plantations by the farmers due to Eucalyptus Gall disease and fall in wood prices during 2009-2011. Cultivation expenses of pulp wood plantations have gone up considerably and farmers shifted to agricultural crops. This situation could have been averted provided certain mills have raised plantations commensurate with their consumption. Now mills are procuring wood spending huge amount on transport from far away distance. The wood prices increase from May 2012 is more than 46% (Rs.1400 on Rs.3000 mill delivered). Mills are exploring import of wood chips or logs to overcome the present shortage.

ITC R&D and Farm Forestry

ITC Paperboards & Specialty Papers Division, Unit: Bhadrachalam, which is one of the leading pulp and paper manufacturing companies in India - took major initiatives to launch a Tree Improvement Research (18,19). The division produces 300,000 tonnes of pulp with 1125,000 tonnes of wood. To meet the wood requirement, the company embarked on an ambitious farm forestry project with dual objective of achieving self-sufficiency and improving productivity while, giving agri farmers an alternative land use option. ITC devised the *strategy to raise pulpwood plantations commensurate with wood consumption* and also to fulfill its social responsibility towards the rural population.

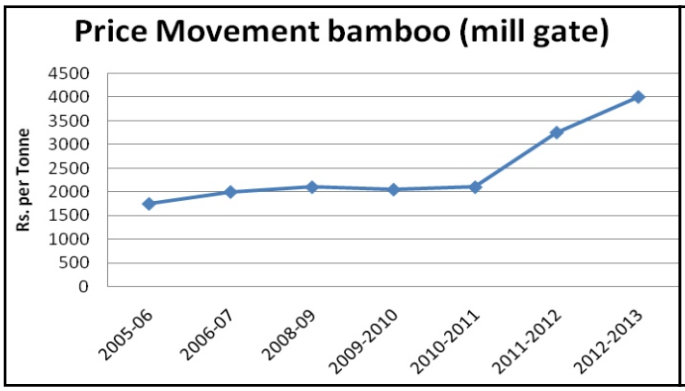


Fig. 2. Bamboo Prices

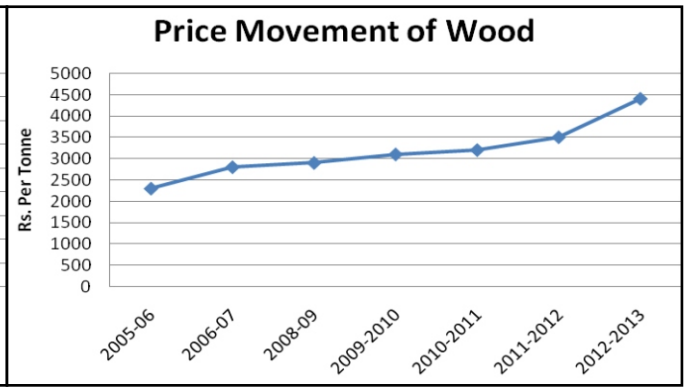


Fig. 3. Hardwood Prices

Bamboo in Paper Industry

In Asia, India leads in the utilization of bamboo for paper manufacture. The estimated forest area covered by bamboo in India is nearly 8.96 million ha. The general consumption pattern of bamboo in India indicates that 8.4% of bamboo is being consumed by pulp and paper industries while, cottage, furniture and implements industries consume 65% bamboo (17). In earlier days, more than 70% bamboo was used for paper and paperboard production. Now there is a drastic shift in usage of bamboo as it reduced to less than 10% and even some mills have

Plantation Programme: A Learning Experience

In the start of the programme, the company distributed 4.67 million seedlings to cover 2000 ha from 1982 to 1986. Later, from 1986 to 1995, it distributed 17.4 million seedlings covering 7441 ha of land under ITC-NABARD (National Bank for Agriculture and Rural Development) scheme. The resultant plantations showed poor survival (30 to 50%) and low productivity (6 to 10 t/ha/yr) due to high genetic variation, leaf blight disease, termite damage, hybrid breaking, primitive nursery practices, mismatch of species and provenances to site,

close spacing, lack of follow up of correct package of practices etc., Further, because of Eucalyptus Controversy (20) farmers were also scared to take up Eucalyptus plantations and realized that tree-farming option is uneconomical. In case of Casuarina, its cultivation was largely limited to coastal belts in Andhra Pradesh. Narrow genetic base, site specificity, mycorrhizal association, frequent droughts and disease pest problems hindered extensive cultivation of Casuarina. For Leucaena also, the genetic base was narrow and psyllids and other diseases with primitive cultural practices reduced the productivity and cultivation. Hence, a decade ago, Farm Forestry plantations of Eucalyptus, Casuarina and Leucaena were becoming unpopular in spite of the incentives, subsidies and loans to the farmers. This adverse scenario changed after 1989 when the Clonal Technology based plantations started appearing on the horizon (21).

The experimental site and Clonal Research Station is located at 17° 40' N latitude and 81° E longitude. The altitude of the place is 100 m above mean sea level. The climate is sub tropical with annual rainfall of 1033 mm, mostly from southwest monsoon. The maximum temperature recorded is 49 °C and minimum 10 °C. The predominant soils are red sandy and black cotton. Soils are either normal or alkaline. Saline soils are also found.

For Eucalyptus, Casuarina and Leucaena, the seeds were imported from CSIRO, Australia and Hawaii, USA to raise provenance trials. Candidate Plus Trees were selected from provenance trials, Government and Farm Forestry plantations. Selected plus trees were propagated vegetatively from coppice cuttings and cladodes under mist propagation. Root Trainer Technology was adopted for the production of plants. Successful ramets were planted in Gene Banks. The clones were tested under multi locational field trials and promising clones were short-listed. Clonal Seed Orchards were established. Clonal Demonstration Plots were raised under the extension scheme. Inter and Intra-specific hybridization was carried out between selected best clones and other species. Social forestry scheme (Mission Sunehra Kal) was undertaken with the help of Non-governmental organizations under poverty alleviation programme while, farm forestry was practiced in marginal agricultural lands under rain fed conditions.

The Tree Improvement Research (TIR) on Eucalyptus, Casuarina and Leucaena actually begun in 1989 to improve the productivity and profitability of plantations for making Farm Forestry an attractive land use option. The major emphasis was on genetic improvement of planting stock and improvement of package of practices. Significant gains in productivity of Eucalyptus, Casuarina and Leucaena have been achieved through Clonal selection, Vegetative propagation combined with Root Trainer Technology and Clonal testing. These clones, developed in India, for the first time, are known as `ITC-Bhadrachalam' clones. Development and deployment of hybrids, locality-specific, high yielding, fast-growing, disease-resistant clones of Eucalyptus, Casuarina and Leucaena have been followed by rapid adoption and raising of large-scale clonal plantations under Social and Farm Forestry. At the beginning of the programme, the main handicap faced was the non-availability of a wide genetic base for the improvement of Eucalyptus, Casuarina and Leucaena. Therefore, "***breed the best with the available best***" strategy was followed.

Eucalyptus

Eucalyptus tereticornis was the main species for improvement as it was most suited to the mill catchment area. More than 1000 trees were selected having characteristics such as straightness of stem, annual growth rate, disease resistance, crown structure, wood density, fiber morphology, cellulose / lignin balance, bark to solid wood, under bark relationships etc. Clones were evaluated in 159 trial plots of various soil types spread over 36 ha area, based on comparative genetic superiority and 107 promising clones were short-listed.

The most important commercial clones are - 3, 6, 7, 10, 27, 71, 72, 99, 105, 115, 122, 128, 130, 223, 265, 266, 271, 272, 273, 274, 175, 277, 284, 285, 286, 288, 290, 292, 316, 319, 405, 411, 412, 413, 417, 439 and 470.

The most adaptable clones for alkaline soils are - 1, 10, 27, 71, 99, 105, 115, 116, 122, 128, 130, 158, 223, 266, 271, 272, 273, 274, 277, 290, 316, 318, 328, 410, 411, 412, 413 and 417.

The plastic clones are - 27, 71, 83, 99, 105, 116, 128, 130, 147, 271 and 285.

The outbreak of diseases caused by various fungi on Eucalyptus in nursery and field revealed main pathogens as *Cylindrocladium* spp. and *Alternaria* spp. The fungal disease resistant clones short-listed are 1, 3, 6, 7, 288 and 316.

Eucalyptus has a very satisfactory health record in India concerning insect pests. However, *Leptocybe invasa* Fisher and La Salle, a gall inducing insect (22) attack on Eucalyptus was reported in 2002 is posing a great threat to Eucalyptus clonal forestry. Clone 10 and 27 are recorded as highly susceptible while, clones 1, 6, 7, 320, 411, 413, 513, 612, 2008, 2145, 2253, 2254, 2306 and 2313 are found free of gall attack amongst 107 Bhadrachalam clones of Eucalyptus (23,24). Parasitoides *Quadrastichus mendeli* and *Megastigmus* spp. as biological control agents were introduced in 2010 and the gall insect attack is under control.

The survival percentage for majority of clonal plantations is more than 95 (19,21). The productivity of "ITC-Bhadrachalam" clone's range from 20 to 58 t/ha/yr compared to 6 to 10 t/ha/yr from seedling origin plantations. Apart from increase in productivity by 4 to 6 times the rotation period is reduced by half. Therefore, farmers are now harvesting plantations at 4 years instead of 7 years. To quote a few cases:- Mr. D Satyanarayana a farmer of Prakasam district in Andhra Pradesh obtained a yield of 190 t/ha in 5 years under rain-fed condition, while Mr. Venku Reddy of Nellore District obtained 250 t/ha in 5 years under partially irrigated conditions.

One hundred plantations were felled in different districts to assess productivity for authenticating the clonal trial results. The Mean Annual Increment (MAI t/ha) figures are - 23 in Khammam, 28 in Prakasam, 21 in Guntur, 24 in Krishna and 39 in West Godavari districts of Andhra Pradesh. The average MAI (t/ha) works out to 27. The farm forestry plantations average IRR per hectare in different districts worked out to 40 in West Godavari, 48 in Khammam, 32 in Prakasam, 26 in Guntur and 30 in Krishna (25). Further, equally higher yields and returns from second and subsequent coppice rotations of "ITC-Bhadrachalam" clones resulted in economic prosperity of farmers.

Clonal demonstration plantations (CDP) were raised by the Company resulted in large-scale adoption of genetically superior clones by the farmers and State Forest Departments / Forest Development Corporations. As "*seeing is believing*", farmers meetings were regularly held in these plots which enabled them to pick and choose the clones most suited to their land.

The Hybridization programme was initiated in 1994. A breeding orchard was set-up with *E.tereticornis, E.camaldulensis, E.alba, E.urophylla* and *E.grandis*. Inter-specific hybridization was attempted to combine desirable complementary attributes of promising clones and eliminate defects keeping in view the customers (growers / mill) view point *viz*., high yields (volumetric productivity), felling cycle of 3 to 5 years (economic rotation), adaptability to sites, superior wood quality and uniformity of raw material.

Development of inter-specific hybrids such as *E.tereticornis* Smith x *E.urophylla* Blake.; *E.tereticornis* Smith. x *E.grandis* Muell.; *E.tereticornis* Smith. x *E.camaldulensis* Dehnh.; *E.tereticornis* Smith. x *E.alba* Reinw. and *E.tereticornis* Smith. x *E.torelliana* Muelli; *E.urophylla* Blake x *E.grandis* Muell was attempted. Teretigrandis and Urograndis hybrids have adapted well to drought conditions and are producing maximum volume of wood. These hybrids are now planted on large scale. By controlled pollination between the best 32 clones of *E.tereticornis,* the derived full-sib hybrids have shown good heterosis at 2 years age. The full-sib progeny trial showed a maximum of 33% improvement over the parents for production of wood volume. Nearly 358 full-sib hybrid trees have been cloned. Heterobeltioisis studies on 18 hybrid clones showed 82% improvement in wood volume production over the best parent. A few hybrid clones from the crossing of clone 6, 10 & 27 gave hybrid clones 2011, 2014, 2045, 2050, 2052, 2053, 2120, 2121, 2149, 2155, 2156 & 2313 which are totally devoid of the defects and surpassed in growth. In addition, some of the clones showed a narrow crown which is required for closer planting at a spacing 3x1.5 m enabling harvesting of trees at 4 years age.

Wood, Pulp and Paper Properties

Significant variation in wood basic density was recorded in Bhadrachalam clones of Eucalyptus (Table 5). By and large wood density increased with age up to 9 years in all the clones studied. Clone 4 displayed densest wood (710 kg/m³) which was significantly different from clone 6 with lightest wood. As the basic density value higher than 600 kg/m³ is not desired in Eucalyptus. For better pulp yield trees, clones such as 3, 6 and 7 are better compared to clone 4. Among 98 clones studied, clones 10 (699 kg/m³) and 433 (676 kg/m³) also have high density. The fiber length varied from 0.7 to 1 µm and with age (for clone 3 - at 3 yrs 0.82 and 9 yrs 1µm). Clones gained considerable superiority over seedling crop with optimal basic density and longer fibers. Wood quality is significantly influenced by various factors such as clone, age, site/soil type, spacing, irrigation etc. Age seems to be the most crucial factor that determines the pulp wood quality up to the age of 9 years (24).

More than 225 clones are evaluated for pulp and paper properties. The high pulp yield of 50 to 53% is recorded for *E. tereticornis* clones 3, 6, 7, 10, 27, 158, 273, 274, 279, 286, 288, 411, 412, 2014, and its hybrids 2050, 2121, 2129, 2135, 2140, 2143, 2156, 2294, 2306, 2315 and 2401 as against 44% from the wood derived from unimproved seed source plantation (Fig. 4). Yield increase from 48.4 to 51% for clone 3 and 47.4 to 49.8% for clone 7 from year one to year four indicated influence of age on pulp yield. The holo-cellulose content varied from 54.3 to 70% with a mean value of 63.5%. Lignin (range 24.7 to 35.7%) and pentosans (9 to 17.2%) content showed high variation with mean values of 29.4 and 13.9% respectively. The strength properties indicated by strength index value varied considerably from 20 to 85 with a mean value of 41 (Table 6).

Table 6. Variation in pulp & paper properties for *E. tereticornis* clones

Parameter	Unit	Min	Max	Mean
Ash	%	0.37	4.20	1.3
A-B extractives	%	1.24	8.40	3.3
Lignin	%	24.7	35.7	29.4
Holo-cellulose	%	54.30	70.00	63.7
Pentosans	%	9.00	17.20	13.9
Screen pulp yield	%	44.00	53.00	47.9
Rejects	%	0.23	4.10	1.2
Kappa	No.	19.00	29.70	22.0
UBV	Cps	11.90	22.80	14.8
Brightness	%	24.40	39.00	32.8
R.A.A.	Gpl	3.10	13.30	6.9
Solids	%	11.00	19.20	14.4
Organics	%	51.50	62.00	56.8
In-organics	%	38.00	48.50	43.0
Bulk	cc/gm	1.34	1.97	1.7
Strength index		20.00	85.00	41.0

Significant increase in pulp yield from 46 to 50.8% and strength index from 33 to 87.8 is shown by the hybrid progeny clones 2120, 2121 and 2156 over their parent clone 6, 10 and 27 (Table 7). Pulp yield and strength properties are the important characteristics which are financially rewarding and advantageous to the paper mills. Bhadrachalam clones of Eucalyptus are ranked according to the pulp yield and strength properties and top 25 clones are recommended for large scale multiplication and

Table 5. Estimated adjusted means of clones with regard to selected wood properties

Clone No.	Tree Vol. m³/tree	Basic Density kg/m³	Moisture content %	Heart wood %	Fiber length µm	Fiber dia. µm	Lumen width, µm	2 x fiber wall thickness µm	Vessels per mm²	Vessel dia. µm
3	0.238	575.8	31.8	20.3	0.88**	19**	8**	10**	2.2*	131
4	0.169	613.9**	18.8	34.8	0.81*	16*	7	9*	2.6	136
6	0.138*	573.1*	21.4	32.2	0.86	16*	7*	9	2.5	144
7	0.346**	580.7	30.4	17.8	0.84	18	8	10	2.7**	141

* Significantly lower value, ** significantly higher value

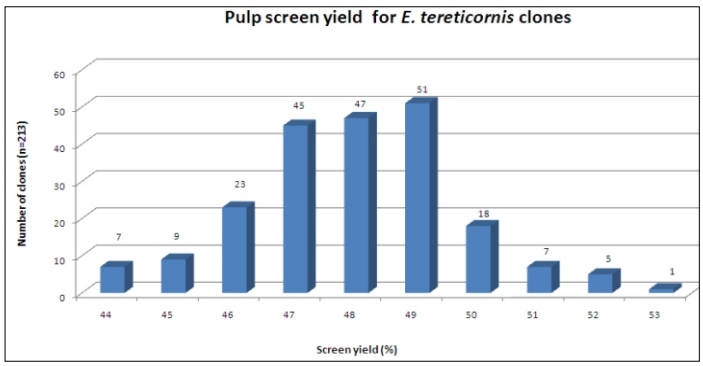


Fig. 4. Pulp screen yield for *E. tereticornis* clones

Table 7. Comparison between parent and hybrid progeny for improvement of pulp & paper traits in ITC Bhadrachalam clones of Eucalyptus.

Properties		Unit	Parent (at 6 yrs age)			Hybrid clone (at 3 yrs age)		
			6	10	27	2120	2121	2156
						10x6	10x27	10x27
Proximate Chemical properties	Lignin	%	30.4	31.1	28.2	32.8	29.6	26.7
	Holo-cellulose	%	64.2	63	68.5	66.7	67.1	70.1
	Pentosans	%	11.4	9.5	16.1	11.8	13.9	14.1
	Screened pulp yield	%	48.9	49.5	46	50.2	50.8	50.6
Strength properties	Bulk	cc/gr	1.5	1.5	1.9	1.7	1.5	1.6
	Strength index	-	60.4	57.3	33	81	87.8	56

planting under farm forestry programme of the company (26).

Clonal nursery

For a successful clonal forestry programme, a good nursery is a pre-requisite. A world class, state of the art, modern clonal nursery with an annual production capacity of 2.5 million ramets was established on 12 ha area in 2012. The old infrastructure for clonal propagation with a capacity of 1.5 million plants, started in 1989 is on 10 ha land consisting of 120 mist chambers covering an area of 12000 m^2, hardening area of 5000 m^2 and 100,000 m^2 for open nursery. The Clonal Technology with Root Trainers has given considerable improvement in the production of quality planting stock. The root development is better than seedlings raised in polypots as multiple roots form in the Root Trainers and root coiling is totally avoided. The out planting results were quite high thereby increasing survival and productivity.

Package of Practices

Innovative package of practices for raising and maintenance of clonal Eucalyptus plantations were developed and demonstrated the benefits of the same to the farmers. Study of soil profiles and analysis of soil samples was carried out to match adaptable clones to the planting sites. Deep ploughing of the soil with disk ploughs or mould-board ploughs in both directions is recommended for preparing the fields for transplanting of clonal saplings. Spacing of 3 x 2 or 3 x 1.5 m (with 1666 or 2222 trees peer ha) is preferred for the production of poles and pulpwood, and larger spacing is desirable for production of timber. Transplanting in 30 cm^3 pits is carried out during the early parts of the monsoon rains so that plants establish and grow well benefiting from the good moisture availability throughout the monsoon rains. Soil in and around the planting pit is treated with 2 ml of Chloropyriphos in 1 litre of water to prevent damage to the young clonal saplings by termites during the critical establishment stage. Application of extract of botanical pesticides like kodesa (*Clistanthus collinus*) for controlling termites was introduced as an eco-friendly replacement to chemical pesticides. Cultural practices recommended include timely weeding and soil working, protection against damage by insect pests and cattle and raising of leguminous crops in between the 3 m wide planting rows for green manuring.

In addition, inter-cultivation with cotton, chili, tobacco, pulses, vegetables and even dry land paddy was encouraged during the first year of planting which gives additional earnings to the farmers. A new concept was evolved after a series of experimental trials with different planting geometry is "Agro-forestry" model (27,28). Under this model, pulpwood trees are planted apart either in a single or double row leaving a wide gap of 8 m to allow maximum sunlight for growing food crops in-between the lines. Every year, the farmer can cultivate food crops and harvest the trees after 4 years interval. The income from crops ensure an annual income and trees are felled after 4 years. In case of crop losses due to draught, flood, pest and diseases, the income from tree harvest hedge the risk. The model accommodate 2000 trees per ha without impacting wood productivity. Land allocation to forestry is only 25% and remaining 75% land is available for agriculture crop (poly culture). The novelty of the agro-forestry is to improve the farm productivity and profitability while conserving the environment and bringing diversification on farm lands. ITC therefore, is popularizing this agro-forestry model for *wood and food security* so that more trees are planted in the farm land without sacrificing the crop production. This programme commenced in the year 2009 and by 2012 nearly 2427 ha of agro forestry plantations have come up (Fig.5 a,b).

As most of the soils in India are deficient in nitrogen and phosphorous, application of fertilizers to supplement availability of these deficient plant nutrients was provided. Soil

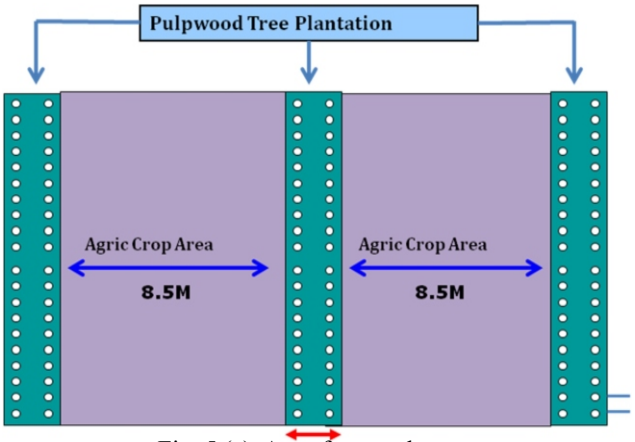


Fig. 5 (a). Agro forestry lay out

Fig. 5 (b). Agro forestry plantation

and water conservation measures like raised field boundaries and staggered trenches were taken up in well-drained planting sites for holding the rainwater. However, in low-lying areas or poorly drained heavy black cotton soils, drainage was improved to drain excess water in rainy season.

Casuarina

The company started TIR on Casuarina in the year 1993. So far, 240 CPTs from *Casuarina equisitifolia* and *C. junghuhniana* have been selected and cloned. The plus tree ramets produced through cladodes from mature trees were planted in a hedge orchard. (29,30) and were maintained at 1 to 2 m height as hedge. Juvenile cuttings were obtained for clonal propagation. Six to seven year old clonal trials revealed that the MAI of 27 t/ha/yr was put up by the best performing Casuarina clones in comparison to 6 t/ha/yr by the seedling plantations. Casuarina clone 50 put up 162 t/ha compared to the plot mean of 77 t/ha. Promising clones CHCE 893004, CPCE 890108, ITC-Bhadrachalam 28, 32, 49, 50 were short-listed with respect to growth and apparent disease resistance for mass multiplication for raising farm forestry plantations. Blister bark wilt disease caused by *Trichosporium vesiculosum* was recorded on Casuarina trees and it was also reported on Casuarina hybrids in Tamil Nadu (31). Casuarina trees were also affected by Loranthus epiphytic parasite.

Leucaena

In recent years Leucaena is becoming an increasingly popular species for production of pulp and paper, especially in Southern India. The Leucaena TIR was started in the year 2001. ITC is promoting plantation of 5,000 ha annually under Farm Forestry in Andhra Pradesh. Several Leucaena varieties were planted in India. Pure seeds of K-8 and K-28, which were planted on large scale, are not available because of seed mixture. The species (32) introduced are *L.leucocephala*, cultivars, K-8, K-28, K-636; *L.diversifolia* cultivars, K-156, K-784; Leucaena hybrid cultivars, KX2 (*L.leucocephala x L.pallida*) and Leucaena hybrid cultivar, LxL (inter specific hybrid of five sub species of *L.leucocephala*) are reintroduced in to Leucaena TIR programme from Hawaii.

The selection of CPTs was made in existing plantations of K-8, K-28 and K-636. Nearly 141 CPTs are selected and domesticated. The coppice cuttings were rooted under mist conditions. Nearly, 76% rooting is achieved. Age of coppice cuttings is very much crucial as three month old coppice cuttings showed less (20%) rooting while, one month old juvenile cuttings rooted (76%) well. The ramets belonging to 141 CPTs were planted in one hectare gene bank in mill premises. The assessment of clonal trials revealed that clone 16 attained 33 t/ha/yr and the average productivity was 27 t/ha/yr. Whereas, the productivity of seed route plantations was 8 t/ha/yr. So far, 12 promising clones were short-listed. The best spacing found to be 2.5 x 1.5 m.

ITC Form Forestry Plantations

The Company has promoted farm forestry plantations over 140,989 ha with 607 million saplings from 1992 to 2012 (Fig. 6 and 7). The species wise plantations promoted are - Eucalyptus 60,352 ha, Leucaena 67,007 ha and Casuarina 13,630 ha. The core area planting (200 km radius of the mill) is 69,283 ha and in non-core area 71,706 ha involving nearly 75,000 farmers. ITC provides R&D support, genetically superior high yielding disease resistant clonal planting stock, marketing & extension services to growers from selection of sites, planting and maintenance till harvest of produce along with buy back arrangement (33). By 2020, ITC plans to cover additional 160,000 ha and with 140,989 ha, the total plantation area will be 300,000 ha.

Societal Gains

Asset Creation and Employment Generation

The Plantation programme has introduced an alternative means of livelihood for the rural community. It is estimated that, the plantation of 140,989 ha over a period of 33 years (1992 to 2025) gives an estimated wood asset value of US $ 2727 million (Rs. 13637 Crores) at an average farm gate price of Rs. 2500 per tonne (Price range from Rs. 700 in 1992 to Rs. 3000 in 2012 and likely to be Rs. 4500 by 2025). The average net income to farmer from clonal plantation is about US $ 500 /ha/yr under rain-fed condition and US $ 800/ha/yr with irrigation on a four-year rotation cycle. This is significantly higher compared to traditional crops grown in the operational area and at much lower risks. The impact of clonal technology can be measured from the fact that since 1992 when meager 17 ha was under cultivation, the situation has drastically changed in 2012 as 140,989 ha area is planted. Thus, plantations are playing an increasingly important role in rural economic development and poverty alleviation in company's catchment area. Since employment generation for farm labours is important for reducing poverty, the 140,989 ha of plantations provide an estimated 63 million person days of employment from tasks such as nursery, planting, logging and maintenance operations. Social and farm forestry have already contributed greatly to rural livelihood and created more jobs for local people.

Environmental Gains

Clonal plantations have additionally been able to mitigate environmental degradation on a large scale greening efforts. It is estimated that, 140,989 ha of plantations have an estimated potential to sequester 93.28 million tonnes of carbon by reducing 171 million tonnes of CO_2 over a period of 33 years (1992 to 2025). On an average the annual CO_2 reduction works

out to 5.18 million tonnes. ITC therefore is a carbon positive company as it sequesters more carbon through plantations than it emits from all of its operations. By promoting plantations on such a large scale, the project has increased the green cover in the country. Apart from the innumerable benefits of such large-scale afforestation, clonal plantation directly contributes to *in-situ* moisture conservation, groundwater recharge and significant reduction in topsoil losses due to wind and water erosion and help in conservation of natural forest resources. Equally, as a result of the leaf-litter from multi-species plantations and the promotion of leguminous inter-crops between rows, depleted soils are getting constantly enriched, making these farmlands more productive. In the near future, the increase in soil fertility will lead to a decline in fertilizer and pesticide consumption, thus reducing the pollution of groundwater sources through leaching of such chemicals.

Reforestation CDM Project

The Clean Development Mechanism (CDM) reforestation project (UNFCCC Reg. No. 2241) covering 3070.19 ha in Khammam district of Andhra Pradesh is registered on 5-6-2009. This project generates 57791 Certified Emission Reduction (CERs) annually and for a period of 30 years 1.87 million CERs are estimated. The estimated value for these 57791 annual CERs at US $ 4 per CER, works out to US $ 231,164 (Rs. 1.15 Crore). There are 3398 tribal beneficiaries in the project (34,35,36). The project has been verified recently for a period of 9 years (2001 to 2009) and on 14-12-2012, UNFCCC has issued 403,610 CERs. Such CDM forestry projects will help paper mills in generating more wood through plantations.

Forest Stewardship Council Certification

Forest Stewardship Council (FSC) certification is becoming a non-trade barrier for the Indian paper industry and the farmers. ITC took proactive initiatives in obtaining Chain-of-Custody (C-o-C) and Forest Management (FM) certification. The FSC FM Certificate for 8028 ha is the first of its kind for the paper industry in India. Farmers are paid premium price for the FSC FM wood.

Hence, the efforts of ITCs Social Farm Forestry lead to greening the bottom line such as,

- for the farmer it is commercially attractive land use option in taking care of climatic uncertainties
- for the agricultural labourers there is additional on farm employment every year
- for ITC it is cost effective procurement of pulp wood at its door step
- for the nation it is converting waste lands into productive assets adding to the green cover and
- saving public forests and foreign exchange

Research Needs

As degraded and exhausted sites are to be afforestated, agronomic research becomes a necessity to grow variety of tree corps for obtaining sustained productivity. Presently, block planting method is adopted on large scale in farm forestry plantations; research on various agro forestry models is essential for maximizing productivity and returns per unit area. Industry should intensify (Sustainable Forest Management (SFM) based

4 year old Clonal Eucalyptus Plantation

3 year old Clonal Casuarina Plantation

3 year old Clonal Leucaena Plantation

Fig. 6. Clonal Pulpwood Plantations

plantation research to ensure that the trend in plantation productivity is non-declining and increase over successive years. The insect born diseases on Eucalyptus such as the little leaf disease (caused by Thrips) and gall disease (caused by Leptocybe invasa gen. & sp.n.) (22,23) reported in the recent times in India are creating havoc in nurseries and plantations and Eucalyptus clonal forestry is under threat. Research on evolving control measures and long term breeding programme to breed resistant varieties is therefore essential.

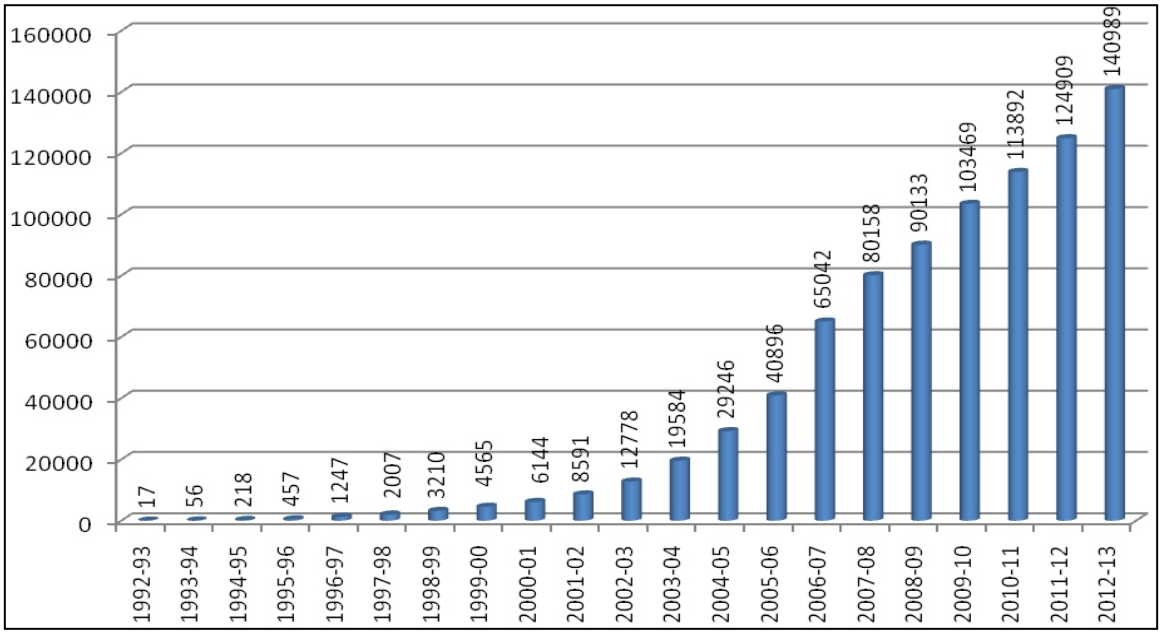


Fig. 7. ITC Agro Farm forestry Plantations (1992 to 2012)

Plantation Strategy For Future

As the paper consumption is going to increase to 24 million tonnes by 2025 which requires planting of 1.2 million hectares to obtain 12 million tonnes of wood. A strategy to enlarge farm forestry and raise plantations with the help of Forest development corporations appears to be the solution for meeting the demand. Clonal plantations covering 1.2 million ha of the degraded forest areas if taken up can yield 25 million tonnes of pulpwood annually. That would be sufficient for meeting India's entire pulp and paper requirements. Likewise, high yielding short rotation clonal plantations on 20 million ha of wastelands / degraded forestlands could meet country's current firewood requirements on a sustainable basis. That would minimize biotic pressures on remaining natural forests and conserve their rich bio-diversity. In addition to restoring marginal lands to high sustainable productivity, clonal plantations will generate vast employment opportunities for the rural poor, contribute to environmental amelioration and help conservation of precious soil and water resources. Such plantations will also create opportunities for significant value addition through local processing of plantation wood and save large amounts of scarce foreign exchange used to import of wood based products. Therefore, clonal forestry can bring "***Brown revolution***" in India.

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