Increasing pulp wood availability-some strategies

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Introduction :

Pulp and paper industry in India made its advent in 1832 with establishment of first paper mill at Serampore in West Bengal and thus is more mature than scientific forestry in the country. Its growth though initially slow but later picked up repidly after independence and since has undergone a sea change in technology and use of raw materials. Beginning with non-wood raw materials viz , sabal grass, rags, Jute cuttings, waste paper etc. for pulp production, a phase which lasted upto early twenties, bamboos replaced the bulk of raw materials used thereafter. Woods which were rarely used until 1960's have since registered a sharp increase in usage as the most favoured raw material. The growth of industry in the country could not keep pace with the demands as sustained availability of suitable raw materials, has, remained a major constraint.

Short supply of pulpwood-reasons

An all round spurt in demand of wood by wood based industries, for construction, domestic requirement and other sectors has led to shortages of pulpwood. Growing stock of temperate long fibre softwoods in the country is though estimated at about 4 70 million m^3 (Anon, 1981a), its availability to the pulp and paper industry is limited. The coniferous forests producing soft woods have been burdened beyond capacity with demands for packing cases for fruits and off season vegetables with their cultivation witnessing a boon in the hilly areas. Some states like Himachal Pradesh being obliged to meet packing case demands from hardwoods grown in adjoining states to enable save the Himalayan watersheds from denudation. Moratorium on green fellings to protect catchment areas in the mountains have also to an extent affected softwood availability.

The country has roughly 5 per cent of total land area under protection forest i e. national parks, sanctuaries, game reserves, catchment areas, biosphere reserves etc. International tropical timber organisation (ITTO) has recommended an increase in protected areas to 10 per cent (Anon. 1989). Implementation of these recommendations would further impinge on availability of wood, and increase pressures on remaining forests. Moreover, nearly half the natural forests have unsatisfactory regeneration due to multiplying biotic pressures and need urgent rehabilitation efforts.

Raw material required to cater to 300 odd paper mills in the country, by any means cannot be met exclusively from the existing forest resources. Man made forests of fast growing species are endowed with some advantages atleast in mitigating shortages of industrial raw material. Plantations for pulpwood production and improvement in their productivity is the immediate answer to ensuring sustained availability of pulpwood for the industries.

(i) High rate of productivity in plantations

Mean annual increment of natural forests in India is very low i.e. 0 5 to 0 7 m^3/ha (Anon 1974a). The potential productivity of these forests, however can go upto 13.33 m^3/ha (Champion and Seth 1968) or even more. This higher production can be achieved by converting poorly stocked natural forests into plantations of economic species. A comparison of the productivity of certain species raised in plantations vis-a-vis occuring in natural forests has been made (Anon 1974 b, 1982) and is given in Table I.

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Table I. MAI in m^3/ha from natural forests and plantations.

Locality	Species	Age of plantation (yr)	MAI (m^3 /ha) Plantation	Natural forests
West Bengal				
Rangiram	Acer campbelli Exbucklandia Populnea Quercus lamellosa Machillus odoratissima	55	4.82	1.26
Lopchu	Cryptomeria japonica	35	21 40	1.87
Apolchand	Shorea robusta	45	4 32	0.29
Maraghat	Shorea robusta	45	4.56	0.77
Bogdogri	Tectona grandis	30	3.00	0.68
Godambri	Gmelina arborea	26	5.77	1 02
Chunabhati (Kalimpong)	Terminalia myriocarpa	30	2.82	0.70
Uttar Pradesh				
Sawaldeh	Terminalia tomentosa	21	5.24	0.64
Lakhanamandi	T, grandis	21	12.05	0.63
Daulikhata	Toona ciliata	28	7.32	0.28
Haldwani	Dalbergia sissoo	25	3 24	0.26
Tanda	Eucalyptus hybrid	6.5	15.38	0.26

(Source : Anon 1974b. 1982)

Rough estimates of yields of some other potential hardwoods capable of producing high volumes have also been made (Anon. 1981b) and are tabulated below, (Table II).

Table II. Yields of some woods from plantations

Species	Age (yr)	MAI (m^3) ha/yr
Ailanthus grandis	60	10-22
Cryptomeria japonica	70	21-24
Gmelina arborea	60	8.6
Michelia champaca	60	8.5-10
Shorea robusta	90	4 1-11.3
Tectona grandis	75	3.3-12

(Source : Anon 1981 b)

Some eucalyptus at short rotation (five to seven years in most cases) have been reported to produce over 100 m^3/ha/year (Zobel 1988). High yields of Eucalyptus tereticornis were reported from various parts of the country viz., 15 m^3/ha/year from West Bengal (Thapliyal 1986). 13 m^3/ha/year from Punjab (Dogra and Sandhu 1986). Tiwari et. al. (1983) documented high yields of 80 t/ha eucalyptus wood from high density energy plantations at 3 years rotation. Singh et al. (1985) recorded as high as 92.7 t/ha yields of Eucalyptus hybrid at 1 m×1 m at 6 yrs (83.5% more than the mean yield obtained at wide spacing of 2 5 m ×2.5 m). Fotidar (1970) has reported high yields (upto 25 m^3 /ha/yr) of poplar stands from J & K, Populus deltoides raised in tarai region of Uttar Pradesh has yielded an MAI of 15 m^3 /ha at 10 years (Lohani 1979).

(ii) Wide gap between demand and supply

The present installed capacity of the Indian pulp and paper industry is about 5 million ADT pulp (Anon 1990). Utilisation of this installed capacity, would require over 10 million m^3 of wood and over 3 million ADT bamboos apart from non-wood raw materials. As against this demand, current pulp wood production from natural forests is about 0.81 million m^3 (Anon 1985) and constitutes about six percent of total industrial wood production from natural forests. Similarly, the producion of bamboos is estimated to about 0.92 million ADT (Anon 1981c). The exact production of pulpwood from plantations established in the past is not available, the estimates are that the average annual production from these plantations is about 5.46 million m^3 (Anon 1984a), the bulk of which is utilised by other industries. With the annual increase in industrial wood demand at the rate of 1 to 2 million m^3 ,its requirement by 2000 AD. will increase to about 64.5 million m^3 (Pant 1988). Further, a wide gap exists between demand (over 200 million m^3) and supply (18.5 million m^3) of fire wood from the natural forests (Anon 1981c). With an anticipated increase in population, pressures on existing natural forests for basic needs are likely to multiply. With the existing wide gap between demand and supply of raw material to the industries, the raising of plantations with high productivity is the only viable alternative to meet the growing demands.

(iii) Better quality pulp wood production

Wood from natural forests are so heterogenous in their character that the quality of end product is difficult to maintain. Plantation raised woods produce more uniform chips with minimum wastage. Chips obtained from short rotation plantation crops usually have lower proportion of extractives compared to slower grown trees from natural forests and, therefore, preferable over the latter as a pulp feed. Industry also favours use of green wood because of ease in processing i.e. debarking and cooking.

(iv) Ease in management

Plantations due to their higher productivity require considerably smaller areas in extent, than natural forests for the same production. Organising of pulp wood plantations in blocks with a series of age gradations equal to rotation would sustained availability of quality raw material. On the basis of productivity of plantations and ease of management, Singh and Singh (1977) estimated that on a 10 year rotation, a 200 t capacity mill would require a plantation area of roughly 275 km^2 for sustainable raw material supply compared to 7677.6 km^2 of natural hardwood forests.

The cost of pulpwood supply from natural forests may be lower than from plantations having higher establishment and maintenance costs, but the improved pulpwood yield, pulping properties and considerable saving in handling and transportation of raw materials of the latter could compensate for the initial high costs. Strategies to raise productivity of such plantations are discussed below :

Genetic improvement

Pulp and paper industry prefers supply of homogenous and uniform wood as raw material with special wood characteristics. Most tree species are, however, outbreeders. Their seed, therefore, produces heterozygous populations. Tree improvement work is related to screening and selection of desirable wood traits of trees and provenances, from naturally outbreeding populations. Intensive genetic selection from existing population of Eucalyptus grandis for desirable traits and large scale vegetative multiplication of the selected material in Aracruz. Brazil has produced far reaching results. Improvement in various pulpwood characters and productivity achieved with E. grandis selection in Aracruz are tabulated below. (Table III).

Table III. Results of intensive genetic improvement programme on productivity and pulpwood quality in *E. grandis*

(Rotation—7 years, Spacing 3.5m × 3.5m)

	Initial forest (7years old)	Today's forest (7years old)	Change by quty.	% Change
1. Yield (m^3/ha/yr)				
1.1 Minimum	26	54	+28	+108
1.2 Maximum	53	113	+60	+113
1.3 Average	33	70	+37	+112
2. Pulpwood characters				
2.1 Density range (kg/m^3)	300-900	500-600*		
2 2 Average density (kg./m^3)	460	575*	+115	+25
2.3 Pulp wood (%)	48	51	+3	—
3. Pulp content (kg cellulose/m^3 scc)	238	293*	+55	+23
4. Specific consumption m^3 scc/ton cellulose	4.20	3.41*	—0.79	—19
5. Forest productivity (cellulose/ha/yr)	7.85	18.45	+10.6	+135
6. Mill capacity (1000 t/yr.)	400	460	+60	+15

*Wood without bark

(Source ; Anon, 1984b)

In Australia, a volume increase to the extent of 45 per cent has been realised through phenotypic selection of fast growing trees of *E. grandis* (Ades and Burges 1982). Labosky et al. (1983) recorded differences in kraft pulp yields among three years old poplar clones, suggesting that there is an opportunity to improve wood and pulp quality through genetic selection at a very early age. Zobel (1988) reported a wide variation in specific gravity in *E grandis* i e. 0.35 to 0.65. Palmer and Tabb (1988) observed large differences in pulp strength and digestion capabilities of *Pinus caribaca* samples obtained from three countries i.e. Subah, British Hondurans and Trinidad. Similar differences were also reported by these authors in *Pinus khasya* grown in Zambia and Philippines.

Alike wood and pulpwood charateristics, response to nutrient applications are also influenced by geographic and varietal variations. In Aracruz, after achieving promising results in improving pulp yields and quality, future tree improvement works aim at exploring the possibility of selecting clones of *grandis* those are economical in nutrient uptake (Anon 1984b). Goddard (1969) in a phosphate fertilizer experiment with pines, observed that some clones grew well with no fertiliser while others grew well when phosphorus was added to soil. Fielding and Brown (1961) also recorded similar differences in phosphorus requirment with Pinus radiata. In Cupressus lusitanicar with fertiliser application growth on poor sites was recorded to increase from 4 to 12 m^3 /ha/yr. and on medium sites from 10 to 18 m^3/ha/yr. (Anon 1972.) Zobel and Roberds (1970) while studying genotype and fertiliser interaction observed that some individuals can effectively withstand severe nutrient shortages and continue to grow vis the others.

Most of wood and pulp characteristics of a species and its response to nutrients availability as mentioned, have a strong genetic control. Therefore, the improvement of stands for pulpwood quality and response of utilisation species to nutrient availability deserves attention of tree breeders. Screening and selection for suitable pulpwood traits and achieving their optima at harvesting stage through silvicultural parctices should form the basis of future improvement programme in quality pulpwood production.

Our country has a vast stretches of lands which are degraded, producing far below their potential, commonly termed as wastelands and nearly 175 m ha in extent. In the present scenerio where hunger for land is acute, the only land that could be available for pulpwood plantations could be such lands which are the least productive These lands are, however, characterised by skeletal soils and low moisture availability. Repeated failure of outplanted seedlings on these lands is generally encountered. Sometimes, varieties, provenances or individuals within a species exhibit potential to withstand extremes of site stresses. Venator (1976) reported very clear differnces in Pinus caribaea, var. caribaea being more drought hardy than var. hondurensis. Ferrel and Woodard (1966) also reported considerable differences in drought tolerence from different seed origins in Douglas-fir. Seeds or vegetative propagules from such trees growing on exacting sites have immense potential to provide site matching material. Selection for site specific seed and vegetative material for optimum growth coupled with desired pulp and pulpwood traits from within and between populations or provenances can provide site adaptable material to afforest wastelands.

Silvicultural aspects

As mentioned earlier, sites generally available for raising new plantations are degraded and the tree seedlings planted thereon are subjected to undergo different levels of stresses during establishment and growth. Current techniques for raising plantation of most species on such lands are limited to use of polybag seedlings for safety to minimise transplantation shock and dessication of roots. Such seedlings usually develop root coils due to limited growing space available in polypots and are more prone to wind-fall due to development of a shallow superficial root system on field planting. Fast growing species, in general, however, overcome this defect but invariably their growth is checked. Containerised seedlings also significantly add to plantation costs by added inputs of polybags and carriage charges for transportation from nurseries to planting site.

Hardened bare-root planting stock produced by conditioning procedures (root disturbance practices and witholding irrigation) have recently been recognized an economical alternative to polypot raised seedlings. Morphological manipulation of seedlings in nursery beds by under cutting, topping, root prunning and wrenching i.e. by physical removal of roots and sometimes shoots results inducing moisture stress and harmonal imbalances in seedling leading to their conditioning (Carlson and Larson 1977, Abod and Sandi 1983, Dhiman 1991). Such conditioning techniques also influence height growth of seedlings, reduce seedling mass but increase root-shoot ratio, produce abundant vigorous roots of small diameter instead of a large tap root, preventing root damage during lifting or deformation during planting (Van Dorsser 1972, Dhiman 1991). Such seedli-gs on outplanting in the field ensure increased survival rates, particularly on degraded sites (Menzies 1980).

Moisture conservation is yet another area which can be effective in the rapid establishment of seedlings on difficult sites. Failures of outplanting seedlings are encountered if they are unable to initiate new root growth after planting. Soil moisture is the limiting factor in the regrowth of roots. Increased earthwork coupled with appropriate moisture conservation methods to increase moisture availability and retention over extended periods can ensure successful seedling establishment and subsequent performance on outplanting.

Wood produced in plantations is strongly influenced by silvicultural treatments. The genetic potential of the species is not fully expressed until intensive silviculture is practised. Trees grown under intensive culture i.e. intensive soil working, cultural operations, irrigation, fertilization etc. results in faster growth. Slow grown trees as are found in natural forests being denser require stronger digestion and may give lower pulp yielde. Adoption of intensive silviculture practices for faster growth and uniform woods is, therefore, of primary importance to pulp wood production. Findings of Palmer and Tabb (1968) may be cited to support this argument. They reported that in Pinus patula from Malwa the slower grown young samples needed more severe digestion and gave lower pulp yields than faster grown older samples. Similar observations were reported by Palmer and Tabb for P. caribaea. A high yield of usable pulp was obtained in faster grown trees of this species in Trinidad compared to slow grown trees.

Productivity in short rotation intensive cultures (SRIC) though may be quite high for the first rotation, while for the subsequent rotations yields invariably drop considerably due to site deterioration. Rao(1967) observed gradual drop of yield in Casuarina equisetifolia on subsequents rotations after the first i.e. 185 t/ha in first rotation to 155 t/ha in second rotation and 140 t/ha in third rotation. Raising of high density plantation as advocated for pulpwood production (Tiwari et al. 1983), therefore, requires a second thought. The issue is also being discussed separately under management strategies.

Goerge (1986) while working with Eucalyptus plantations reported that 10 year old plantation (4.8m $\times$ 2.4 m) removed 30–50 percent of the total uptake of various nutrients. Some loss of nutrients have been reported to be compensated through litterfall, stemflow and inputs from geochemical cycles (George 1977), yet supplement fertilization is necessary to maintain site productivity.

Fertilization being a tool of silviculture, it would be justified to ensure that fertiliser use not only increases productivity of the existing crops but also sustains productivity over many rotations. Application of fertilisers particularly on marginal land as presently available for plantation endeavours thus becomes imperative.

Response to fertilizer application has often been spectacular. High yields in Eucalyptus spp. of about 80 t/ha with application of 50 g caster cake percent, 10 g N;P;K per plant, 20 irrigations in first year of planting and 6 to 6.5 t urea application per hectage in second/third year, were achieved (Tiwari et al , 1983). Average yield of 10 m^3/ha/yr has been reported in 3 m $\times$ 3 m spaced Eucalyptus hybrid and a possibility of raising it upto 40 m^3/ha/yr by irrigation and intensive cultivation (Uppin 1965). Investigations on Eucalyptus hybrid indicate that it can fair well in Ca and Mg deficient soils but it may not thrive in soils deficient in N and P. The study also indicated that N and P nutrients are of vital importance in the growth of the hybrid (Arunachalam 1972 .

In Australia, Waring (1980) reported that biomass of Pinus radiata increased from 20 9 to 79.5 t/ha with P and 175 t/ha with P and N (about 8 fold increase), seven years after applying fertilizers to transplanted seedlings. Similary, Cromer and William (1982) increased biomass production in E globulus from 21.4 to 61.6 t/ha as a result of N and P fertilization.

Reduction in pulp yield per unit of wood used and pulp quality in vigorously growing woods as a result of fertilization is still disputed, increased wood yields more than compensate for any change in wood properties which occur. Cultural operations in addition to fertilization can however over-ride the influence of growth rates. Choong et al. (1970) demonstrated significant increase in trachcied length of 7 year old Pinus taeda resulting from fertilization (2.49 mm),and fertilization and irrigation (2.78 mm) over controls (2.39 mm). Cown (1977) has pointed out that density of nutrient deficient trees can be abnormally high and the effect of fertilization is to reduce density to levels commensurate with those in trees growing under better conditions. Fertilization has the potential to improve not only biological yield and harvestable yield but it also influences recoverable yield through effects on stem straightness. Cromer et al (1977) provided one such example of the variation between harvestable yield and recoverable yield. In a study of pulp yields from 10 year old Pinus radiata, harvestable yield (merchantable vol. m^3 /ha of stem wood) following fertilization with NPK was 87 percent higher than with unfertilized controls. Reduction in wood density as a result of fertilization resulted in recoverable yield of Kraft pulp 79 per cent more than control. In a similar study on kraft pulping with N fertilized 5 year old Abies balsamea showed no change in density, Harvestable yield and recoverable yield both increased by 44 percent over unfertilized controls (Hunt et al. 1960).

Decline in yield in subsequent rotations has always been a cause of concern but researches have indicated possibilities of overcoming the situation. Many promising options being available as may allow industry to ensure sustained yields at increased levels. These options besides intensive silviculture practised in the early stage of stand development, include retention and management of harvesting slash to recycle nutrients and improve water retention Bark constitutes about 10-15 percent of total biomass in eucalyptus and contains 12-30 percent of total uptake of various nutrients with exceptionally high content of Ca. In-situ debarking of wood at harvest, retention of leaves and twigs (30-40 percent of harvestable yield) can contribute to recycling much of depleted nutrients to the soil.

Intercropping of legumes with the main crop and interrupting the monoculture cultivation with site enriching species like Sesbania in one of the subsequent rotation may prevent further deterioration of site and maintain high rate of productivity in addition to augumenting pulp wood production. Sesban in India have been reported to yield 32 to 43 t/ha yr dry matter that contains 3.8 percent N by dry weight (Macklin et. al. 1990). The intercropping of Sesbania for the first few years of a rotation cycle in pulpwood species can contribute to high economic returns. With assured irrigation and fertilizer treatment, West Coast Paper Mill produced annual increment in the range of 50 t/ha at a cycle ranging from one to three years (Seth and Kharbanda c.f. ledger files FRI, Dehradun). Kenaf could also be cultivated for pulpwood supply on same lines as Sesbania.

Management aspects

There is general recommendation to reduce rotation of fast growing species to meet increased demand of pulpwood. Reduction in harvestable age of Eucalyptus tereticornis to 5 or 3 years or even less has been advocated, based on certain minimum pulpwood quality requirements achieved at such early age (Guha et al. 1970, Unkalkar et al., 1977, Tiwari et al.,1983). One method recommended in the United Stated is to harvest trees at the age of 1, 2 or 3 years and then regenerate stands by sprouts over the next 4 or 5 rotations (Jett and Zobel, 1975). With poplars, some studies have demonstrated that satisfactory kraft pulping characteristics can be obtained from various poplar species grown on rotations as short as five years (Marton et al., 1968. Zarges et al., 1980).

Short rotation intensive cultures are thus harvested at a very young age before the current annual increment of crops culminates. In Haryana current annual increment of eucalypts has been reported to culminate at fifth year (Saxena, 1991). This practice of intensive culture may not be good from the point of view of soil fertility. Miller (1981) suggests that prior to canopy closure, tree growth is very much dependent on current uptake of soil resources. SRIC, like the once practised in our country concentrates on harvesting of crops as soon or before the canopy closes This practice results in higher removal of nutrient and water than recycled, and may lead to biological desertification. Our knowledge on nutritional requirement of tree crops is still very inadequate. Knowledge on fertilizer requirements of plantations are restricted to application of some major nutrients. Depletion of other minor and trace clements from soil may have far reaching consequences. It is this aspect of eucalyptus cultivation in the country that has invited wide spread criticism. Eucalypts have grown since ages in Australia but at sufficiently long rotations and thus did not attract much opposition. It is in this context that the rotation age for harvesting of pulpwood plantations have neither to be too short nor too long.

Adoption of short rotations may have other disadvantages as well. Closer spacings with shorter rotations produce more volume with trees of small diameter and consequently ratio of bark to utilizable wood is high. Chips with higher bark percent give lower pulp yields (Zarges et al., 1980) Low fibrous yields combined with high extractives contents in chips in trees of young ages having higher bark content result in reduced economic yields. In addition these pulps take longer to wash due to higher fatty acid content associated with bark extractives (Zarges et al.,1980).High bark in wood chips consumes alkali during wood digestion thus reducing the am ount of available chemicals to dissolve wood and bark lignin (Rydholm 1965).

Longer rotations on the other hand, results in older woods with more heartwood that contains higher phenolic extractives. This results in more alkali consumption in pulping, black liquor burning and evaporation problems (Hillis and Carle 1959, Baklian 1960), deposits on mill equipments and colour problems (Hillis 1969). Woods with high extractives may also create pitch problems during commercial kraft pulping or during the preparation process (Davis and Logan 1984).

Stocking at which plantations are maintained is another important silvicultural decision for realising optimum production. Higher crop densities no doubt increase volume production, the optimum stocking at a particular stage, however, is correlated to other factors viz. size of material required, wood quality, facility of working and economics of growing/processing

Pulpwood plantations at present are raised under varied growth conditions and cultural inputs i e. application of fertilizers, irrigation schedules and soil working Intensity. The concept of rotation based on MAI culmination is suited to natural forests where the levels of Productivity are maintained for all subsequent rotations, in perpetuity. Plantation inputs and site peculiarties in pulpwood plantations may be manifold and would accordingly require growth and yield tables for each site and cultural schedules. MAI culminates at an early age on more productive sites compared to the poor. Increased inputs i.e. irrigation and fertilizers increases the supply of inputs for growth and consequently alter the natural productive potential of the site Bevege and Simpson (c.f. Bevege 1984) reported that "in Pinus eliotii there is a difference of 15 years in MAI culmination between poor (site index 18) and better sites (site index 27) and this is reflected in the length of silvicultural rotation. The improved site potential is illustrated by the difference in MAI of 10 m^3/ha/vr. While these differences reflect combined soil profile characteristies in these stands, fertilization with 47 kg P per ha as superphosphate raised site index from 22.8 m to 27.6 m and merchantable MAI from 8 7 m^3/ha/yr to 17.8 m^3/ha/yr at age 17 yrs."

One alternative to managing rotations in sites with high differential in production potentials many be based on size-density relationships (Yoda et al. 1963). Practical application of this relationship in the analysis and management of stand density has been demonstrated for several species (Aiba 1975, Drew and Flewelling 1979). The relationship has been found to be independent of management strategies, growth conditions and crop age (Long and Smith 1983). This relationship requires estimation of maximum stand density index for a particular species and management alternative can accordingly be prescribed.

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