Afforestation and plantation forestry

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Plantation forestry for the 21st century

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SUMMARY

Plantation forests now comprise around 135 million ha globally, with annual plantation afforestation and reforestation rates nearing 10% of total area. Some 90% of plantation forests have been established primarily to provide industrial wood, and their relative global importance in this role is increasing rapidly. Most of the remaining 10% of plantation forests were established primarily to supply fuel or wood for non-industrial use. About 75% of the existing plantation forest estate is established in temperate regions, but it is in the tropics that the rate of expansion is greatest. The expanding tropical plantation forest estate includes trees grown primarily as agricultural plantation crops and which now also supply wood to forest industries. Almost all existing plantation forests were established and are managed as even-aged monocultures; species and interspecific hybrids of a few genera dominate plantation forestry worldwide.

Effective research and development, based on appropriate genetic resources and good silviculture, are the foundations of successful plantation forestry production. Resolving relatively fundamental issues remain the priority in many young plantation programmes; in more advanced programmes, the application of more sophisticated technologies - particularly in biotechnology and processing - is necessary to maintain improvements in production. Many plantation forests, particularly in the tropics, are not yet achieving their productive potential.

The sustainability of plantation forestry is an issue of wide interest and concern. The evidence from industrial plantation forestry suggests that biological sustainability, in terms of wood yield, is likely to be sustainable provided good practice is maintained. The relative benefits and costs of plantation forestry in broader environmental terms, and in terms of its social impacts, are the subject of greater controversy, and pose the greatest challenge to plantation foresters as we approach the millennium. Our experience with plantation forestry as it has developed this century offers us an excellent platform for rising to these challenges.

PLANTATION FORESTS

It is difficult, as others (eg Evans 1992, Mather 1993) have commented, to define either "afforestation" or "plantation forests" precisely. In particular, it is often not easy to distinguish between afforestation and either rehabilitation of degraded forest ecosystems or enrichment planting, or between plantation forests and various forms of trees on farms. The definition proposed by FAO to the 1967 World Symposium on man-made forests and their industrial importance, which uses as its criterion land use changes associated with afforestation or reforestation, has been the basis of subsequent official estimates (eg Pandey 1995), and is adopted here for the sake of consistency. However, any consideration of plantation forests should acknowledge that the distinction between them and some other forms of forestry is not always clear; thus, definitions, discussion and estimates vary.

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The global extent of plantation forests in 1990 is estimated at around 135 million ha (FAO 1993, Gauthier 1991, Pandey 1995, Sharma 1992). About 75% of these plantation forests are in temperate regions and about 25% in the tropics and subtropics; some 5% of are found in Africa, a little more than 10% in each of the American continents, some 20% in the former USSR, and around 25% in each of Asia-Pacific and Europe (Gauthier 1991, Kanowski and Savill 1992). Species and interspecific hybrids of only a few genera - *Acacia*, *Eucalyptus*, *Picea* and *Pinus* - dominate plantation forests, with those of a few others - *eg Araucaria*, *Gmelina*, *Larix*, *Paraserianthes*, *Populus*, *Pseudotsuga* or *Tectona* - of regional importance (Evans 1992, Pandey 1995, Savill and Evans 1986). The ownership of plantation forests extends from governments and large industrial corporations to individual farmers, and their management varies considerably, from relatively simple and low-input to highly sophisticated and intensive.

Most plantation forests have been established as even-aged monoculture crops of trees with the primary purpose of wood production (Evans 1997). Around 90% of existing plantations have been established for the production of wood for industrial use, and most of the remainder to produce wood for use as fuel or roundwood. Some plantation forests are grown and managed, either primarily or jointly, for non-wood products such as essential oils, tannins, or fodder. The provision of a diverse range of other forest benefits and services, including environmental protection or rehabilitation, recreational opportunities, and CO_2 sequestration are also primary or secondary objectives for many plantation forests (Brown 1997, Evans 1992, Gauthier 1991, Kallio *et al* 1987, Lamb 1995, Myers 1989, Sedjo 1987, Sharma, 1992).

Trees grown as agricultural plantation crops - *eg* rubber or coconut - have not traditionally been considered as forest plantations. However, the distinction between the two forms of plantation culture is diminishing from two perspectives: from that of the forest manager, as rotation ages reduce and the intensity of forest plantation management increases; and from that of the agricultural tree estate manager, as these crops begin to be used for wood products. The recent example of forest industry development based on wood supply from Asian rubber plantations exemplifies the latter, and provides a striking example of how shifting supply factors and improved processing technologies can offer opportunities to non-traditional supply sources, and thus expand the plantation base. Rubberwood recovered from rubber estate re-establishment programmes now substitutes for many traditional industrial uses of natural forest woods from SE Asia, and provides the raw material for newer products such as medium-density fibreboard. Similar processing developments are in train, though as yet less advanced, for the other major tropical estate tree crops, oil palm and coconut. Given the substantial areas of these plantation crops worldwide - estimated at around 7 M ha of rubber estate, 4 M ha of coconut, and 3 M ha of oil palm - they have considerable potential to both supplement and compete with production from more conventional plantation forests.

The harvest rotations of forest plantations vary enormously, from annual or sub-annual for some non-wood products, to around 200 years for traditionally-managed high-value temperate hardwoods. With few exceptions so far, shorter rotation plantations - typically of 5 to 15 years - have been grown for fuel, fibre or roundwood, and longer rotation plantations - typically upwards of 25 years - principally for sawn or veneer wood products.

Notwithstanding successful antecedents in both temperate (*eg* oak in Europe) and tropical (*eg* teak in Asia and India; though see Keh 1997) environments, plantation forests on large scale are a twentieth-century phenomenon. The majority of the world's plantation forests have been established in the past half-century, and the rate of plantation afforestation has been increasing progressively during this period. Global rates of forest plantation establishment and re-establishment are poorly known, but are estimated at around 2.6 million ha annually in the tropics (FAO 1993, Pandey 1995), and perhaps 10 million ha in the temperate zones (Mather 1990, 1993). Recent plantation expansion has been greatest in the southern hemisphere: in South America (principally Argentina, Chile and Brazil), Asia (principally Indonesia) and New Zealand, where particular coincidences of public policies, opportunities and market forces have been most conducive to afforestation. In some countries, *eg* Indonesia or Chile, plantation establishment remains concentrated on sites converted directly from natural ecosystems; in others, *eg* New Zealand or Portugal, plantation establishment has shifted entirely to sites formerly used for agriculture. The quality of plantation afforestation varies widely, and has been especially problematic in some tropical environments (Pandey 1995, 1997).

Plantation forests currently provide around 10% of the world's wood harvest; this proportion is rising and will continue to rise rapidly, as the area of natural forest available for harvesting diminishes, as economic pressures and technological change favour plantation crops, and as the plantation forest estate matures and expands. The contribution of plantations to wood production within domestic economies varies enormously, reflecting different forest endowments and policies - from, for example, nearly 100% in New Zealand or South Africa, to around 50% in Argentina or Zimbabwe, to negligible levels in Canada or Papua New Guinea.

Given the wood production objectives of most plantation forests, and the commodity nature of most wood markets, plantation growth rates are of fundamental importance because of their implications for the cost of wood at harvest. Only around 10% of existing plantations can be classified as "fast-growing" (in SuttonÕs (1991a) terms, yielding more than 14 m^3/yr); most of these plantations are in the southern hemisphere, with around 40% in each of South America and Asia-Pacific. The majority of "fast-growing" plantations are of species such as *Acacia* or *Eucalyptus* grown on short rotations for the relatively low-value uses of fuel, fibre or roundwood; perhaps a third are longer-rotation crops, of either softwood or hardwood species, grown principally for sawn- or veneer-wood.

Global supply and trade forecasts, for both plantation production and its share of total wood harvest, are imprecise and complicated by the uncertainties of demand growth within developing economies - as Apsey and Reed (1996) comment, "the ... challenge is to sort out the hype from the reality with respect to fast growing plantations. Until this is done, a good share of strategic planning rests on a whirlpool of speculation". Imprecision notwithstanding, it is apparent that fast-growing plantation forests are already the most cost-competitive source of pulpwood globally, and that the expansion of the plantation resource is likely to constrain pulpwood price increases over the next decade. As the availability and relative importance in trade of higher-value wood products from plantation forests increase, so too will the influence of the plantation harvest on both supply and demand options for these products.

PLANTATION FORESTRY

Plantation forestry at a global or semi-global scale has been the subject of a number of recent reviews (eg Carrere and Lohmann 1996, Evans 1992, Kanowski et al 1992, Mather 1993, Pandey 1995, Sargent and Bass 1992, Savill and Evans 1986, Shell/WWF 1992). These reviews highlight some important common elements and trends:

- Use of well-adapted genetic resources, and good silviculture at all stages from nursery to harvest, are the two technical foundations of successful plantation forestry; each can make the difference between resounding success and abject failure. Many tropical plantations are not achieving their production potential because of inadequate attention to these fundamental elements (Pandey 1997). Successful plantation forestry is also based on sound and substantial research and development, its implementation in operational management, and the maintenance of close links between research and practice as each evolves. There is ample evidence of the adverse consequences of failing to link adequately research and practice (*eg* Evans 1992, Kanowski and Savill 1992, Napompeth and MacDicken 1990, Palmer 1988);

- Many plantation forestry programmes have been founded on and developed through international and regional cooperation; the century-long history of cooperative research under IUFRO auspices (Burley and Adlard 1992), and the more recent role of FAO, demonstrate the many benefits of collaboration to plantation researchers and managers. As Burdon (1992) and Williams (1996), amongst others, have observed, the increasingly proprietary nature of research challenges these cooperative foundations;
- The appropriate level of research varies with the stage of development of the plantation programme. For example, as many papers to this Congress (*eg* Aminah 1997, Biblis 1997, Genç and Bilir 1997, Kızmaz 1997, Lemcoff *et al* 1997, Salerno and Giménez 1997, Sharma *et al* 1997, Stanturf *et al* 1997, Tunçtaner 1997, Zoralıoğlu 1997) demonstrate, there remain many fundamental questions which must be resolved to support new plantation programmes. The continuing expansion of plantation forests onto sites for which there is as yet little plantation forestry experience will continue to demand such fundamental research. In contrast, as other papers to this Congress illustrate (eg Evans 1997, Popov *et al* 1997, Watt *et al* 1997), for programmes that are already well-established, increasingly sophisticated research and development will be necessary to deliver or maintain gains;
- As in other primary production enterprises, advanced technologies are playing an increasingly important role in plantation forestry:
    - Applications of biotechnology in forestry have recently been reviewed by Haines (1994); those currently of most relevance are genomic mapping, molecular markers, transformation and micropropagation. Their application in the production and propagation of interspecific hybrids is of particular interest to many plantation programmes. The implementation of many biotechnologies are interdependent, and most are dependent for delivery on successful clonal propagation techniques, which are now in operational use in many programmes. The optimal integration of biotechnologies with plantation forestry is programme-specific, as demonstrated by numerous examples (*eg* Griffin 1996, Watt *et al* 1997, Wilson *et al* 1995);
    - Advances in processing technologies are allowing the use of smaller and younger trees, and of species not previously considered suitable for value-added processing (*eg* papers to Topic 19, this Congress);
    - Adequate planning and decision support systems are central to successful plantation enterprises. Appropriate systems range from the relatively simple (*eg* AhlbŠck 1997) to the sophisticated (*eg* Pritchard 1989); the lack of effective systems has been a major constraint to, in particular, many tropical plantation enterprises (Pandey 1997);
- There is long history of concern for the biological sustainability of plantation forestry (Evans 1997). As plantation forests expand, so too have concerns for their sustainability in the broader sense (*eg* Hughes 1994, Carrere and Lohmann 1996). The sustainability of plantation forestry is now an issue in terms of each of its biological, economic and social dimensions, as well as in the more holistic sense of their conjunction (Barbier 1987); sustainability concerns in plantation forestry have a number of manifestations, as outlined below;
- Discussion of the biological or environmental sustainability of plantation forests has three principal strands:

- The first strand is the broad debate concerning the environmental costs and benefits associated with afforestation, particularly where it is preceded by conversion of natural ecosystems. Argument around this topic ranges across the spectrum of issues and views, from the imperative of meeting the wood products needs of growing populations in the face of declining natural forest resources (*eg* Pandey 1995, South 1997, Sutton 1991a), to the environmental impacts of forest conversion and plantation afforestation (*eg* Barnett 1992, Carrere and Lohmann 1996, Spellerberg 1996, WAHLI and YLBHI 1992);
- The second strand has a narrower focus, on concerns for the biological sustainability of plantation forests *per se*, particularly their composition as monocultures. This topic has been reviewed for this Congress by Evans (1997), and the evidence is encouraging; as Evans concludes, "plantation forestry is likely to be sustainable in terms of wood yield in most situations provided good practice is maintained".
- A third strand is manifested by increasing research into alternative plantation regimes, principally the feasibility, advantages and disadvantages of mixed-species plantations (*eg* Ball *et al* 1995, Keenan *et al* 1995, Montagnini *et al* 1995, Wormald 1992), as a means of enhancing sustainability. Although experience remains limited, there are clearly circumstances which favour mixed-species stands. Some of these are social and economic, as discussed below;

- The economic dimensions of plantation forestry have two principal current manifestations:
  - Firstly, the commodity nature of most forest plantation products - either fibre for pulp production, or utility grade timber - and the increasing globalisation of markets for these products maintains strong price pressure in favour of the lowest cost producers. Production costs are determined by the inescapable trio of land, labour and capital costs, and by forest productivity. The inevitable consequence of these pressures is the trend towards shorter crop rotations, which have been facilitated by advances in processing technologies, and the search for enhanced productivity. However, particularly for solid wood products, there remain trade-offs between harvest age, growth rates and product quality;
  - Secondly, as a consequence of imperatives which are at least as ideological as economic, the ownership of forest plantations is shifting from the public to the private sector as governments divest themselves, at least in part, of public assets. Issues associated with this transition in the ownership of plantation forests have been explored by, for example, Hurditch (1992), Kirkland (1989), Rickman (1991) and Roche (1992). The appropriate role of government in plantation forestry remains an issue of debate, regardless of the level of public ownership of plantation forests, reflecting the various responsibilities of government - for example, in fostering an environment conducive to investment in tree growing, in the regulation of industry and of land use, and as steward of the environment and other community values;
- The social dimensions of plantation forestry also have a number of manifestations:
  - The fuel and wood needs of the rural poor were the primary motivating force for the establishment of non-industrial plantations. Afforestation with this intent began on a large scale in the late 1970s (Pandey 1995), as the international forestry community began to focus on how trees could better meet the needs of the worldÕs poorest people. Non-industrial plantation establishment has been greatest in Africa and Asia (Pandey 1995); whilst the concern (*eg* as exemplified in the 1978 World Forestry

Congress, *Trees for people*) and intent were genuine, the social consequences of non-industrial forestry have been mixed (*eg* Andersen and Huber 1988, Chambers *et al* 1989, Evans 1992, Fortmann 1988, Morrison and Bass 1992, Shepherd 1992). However, the sometime bitter experiences gained in non-industrial plantation forestry have helped foresters develop the means to better assess and address the needs of the poor and of rural people (*eg* Bradley and McNamara 1993, FAO 1985, Cernea 1992, Gilmour and Fisher 1991);

- An emerging discussion of the social implications of industrial plantation forestry, which acknowledges that these are not necessarily positive, and may indeed be quite adverse. This discussion has occurred and continues at a range of scales - for example, focused on particular projects (*eg* Cavalcanti 1996, for the case of Aracruz, Brazil), in terms of national policy (*eg* WAHLI and YLBHI 1992, for the case of Indonesia; Roche 1992, for the case of New Zealand), or more global terms (*eg* Barnett 1992, Carrere and Lohmann 1996, Kanowski 1997, Shiva 1993). It is likely that the progress of this discussion will mirror , in many senses, that which has preceded it for non-industrial plantations.

THE FUTURE OF PLANTATION FORESTRY

I have suggested elsewhere (Kanowski 1995, 1997) that there is evidence of an emerging dichotomy in plantation forestry concept and practice, between what I have characterised as relatively simpler and relatively more complex production systems. Plantation forests as we know them are relatively simple production systems, typically even-aged monocultures, with the capacity to produce wood yields many times - often at least tenfold - greater than most natural forests. The importance of simple plantation forests in meeting the wood needs of societies will continue to increase; providing they are well-managed, these plantation forests should satisfy sustainability criteria (Sutton 1991b, Evans 1997).

This plantation forestry for commodity production benefits considerably from economies of scale and integration with industrial processing; it is also under strong cost and profit pressure, thus both demanding and permitting relatively high levels of resource inputs. Consequently, it will be increasingly concentrated on those sites which are inherently more productive than on those which are marginal, and from which the costs of transport to processors are least. The implication is of plantation programmes which are more intensive silviculturally and less extensive geographically, located where the forest land base is stable, secure and productive (Bingham 1985, Gauthier 1991), and where the economics of wood production - in terms both of cost structures within forestry and of relativities with other land uses - are most favourable. Prevailing political ideologies suggest these plantations will increasingly be under private, or quasi-private, ownership and management.

Whilst successful - sometimes outstandingly - in producing wood, simple plantation systems do not necessarily address well the other needs of societies in which they are embedded. Where - as in much of the less economically-developed world - land is scare, time horizons short, or demand strong for the non-industrial products and services of forests, the outputs of simple production systems are unlikely to meet the more complex needs of societies. In these circumstances, a broader conception of plantation forestry and range of plantation objectives, and a more intimate integration with other land uses, are essential if plantation forestry is to prosper and be sustained.

More complex plantation forestry explicitly recognises that wood is not the only product that people demand of forests, and seeks to maximise social benefits rather than just wood production. The particular expression of plantation forestry - where it lies along the continuum from simple to complex - will depend on the particular context; in developing a more complex plantation forestry, we have much to gain from our experiences of a wide spectrum of forestry activities, including agroforestry, community forestry, and simpler plantation forestry.

More complex plantation forestry will be characterised variously by:

- A more intimate association between forests and other land uses. Simple plantation forestry is typified by a sharp distinction between plantation forest and other land use. The boundary between plantation forest and non-forest use will become less distinct as plantation forestry becomes more complex. The various taungya systems, widely practised as means of afforestation in the tropics (Evans 1992), are an example of this complexity at the early stages of plantation forestry; much farm forestry (*eg* Grayson 1993, Lefroy and Scott 1994) demonstrates such integration at the level of the farm enterprise, irrespective of the particular configuration of tree growing;
- More direct involvement of local people in the conception and implementation of plantation forestry, and in the sharing of its benefits and products. The variety of joint venture or share farmer schemes, which recognise landownersÕ interests and priorities as well as those of the forest industryÕs, exemplify this for the case of farm forestry. There is increasing understanding of how participatory planning, management and use might be developed and practised in a forestry context (*eg* Arnold and Stewart 1991, FAO 1985, Griffin 1988, Gilmour and Fisher 1992), and this approach now characterises some programmes involving plantation forestry (*eg* Gilmour *et al* 1989, Arnold 1992). As the presence or absence of trees is important in determining land tenure in many societies (*eg* Arnold and Stewart 1991, Cornista and Escueta 1990, Fortmann and Bruce 1993), locally-appropriate tenure arrangements are essential to facilitate more complex plantation forestry (*eg* Sargent 1990);
- More diverse species composition and plantation structure, yielding an earlier and more continuing flow of a wider range of products and services than result from simple plantation forests. This does not necessarily imply that tree species will grown as polycultures, though this may offer advantages in particular circumstances (*eg* Ball *et al* 1995, Wormald 1992). In others, a mosaic of relatively small blocks of different tree species may be more easily managed, but still yield the desired range of outputs.

Although its rationale is broader, more complex plantation forestry may also represent an effective strategy for risk minimisation, as Sargent and her colleagues (1990) demonstrated for the case of proposed eucalypt plantations in Thailand. Their conclusions - that the cost of not implementing complex plantation systems will exceed the cost of doing so - are likely to apply increasingly elsewhere, and have instructive parallels in other land use contexts (eg Aumeeruddy and Sansonnens 1994). There are many examples of how foresters have responded to social and environmental imperatives by developing more complex plantation forestry systems which still meet wood production objectives. These include:

- The silvicultural manipulation of *Pinus* plantations in Nepal, principally to promote the development of native broadleaved species, to increase species diversity and the range of forest products of more direct benefit to local people (Gilmour *et al* 1990);
- Britain's National Forest and Community Forests (Countryside and Forestry Commissions 1991), in which plantation forests for wood production are designed and managed to emphasize amenity, conservation and landscape values. These new forests are paralleled by the "restructuring" of the British Forest Enterprise's simple plantation forests (*eg* McIntosh 1989), to enhance non-wood production functions, at an opportunity cost to simple wood production of around 10%;
- The integrated farm production systems, such as those associated with Spanish (Wilson *et al* 1995) or Australian (Inions 1995) forest industries, in which a variety of outgrower arrangements

are employed to generate an enhanced income stream for farmers and assured wood supply for industrial use;

- Recognition of the capacity of integrated tree-growing and farming systems to deliver substantial non-market benefits to the both the landowner and the wider community, in addition to the direct returns to the owner. For example, in AustraliaÕs lower rainfall zones, plantation forests integrated with the farm enterprise are playing the leading role in limiting the salinisation of agricultural land as well as helping to diversify farm incomes (Robins *et al* 1996); in many environments where catchment protection, stablisation or restoration are priorities, appropriate integration of tree growing and agricultural practices is an important element of watershed management and rehabilitation strategies (Brooks *et al* 1992).

The adoption of complex plantation practice does not preclude use of new technologies or innovative management regimes, as Wilson et al's (1995) description of integrated production systems based on genetically-engineered fibre demonstrates. On the contrary, as numerous examples demonstrate (eg Lefroy and Scott 1994, Mayers and Ashie Kotey 1996), innovation in forestry practice is more likely to follow from involving a greater number of growers and allowing a diversity of management regimes.

CONCLUSIONS

Successful plantation forestry will continue to depend on effective research, development and management, and on innovation and technological advances. It will also depend increasingly on recognition of and respect for the principle of sustainability, in its full sense. As Evans (1997) comments, plantation forestry is merely a technology for delivering the benefits of trees to society; the appropriate form of that technology will vary with social, environmental and economic circumstance. What is clear is that the sustainability of plantation forestry will be enhanced, and the benefits of investments most fully realised, where plantation purpose and practice are embedded within the broader social and economic contexts. Because these vary, so too will the appropriate form of plantation forestry.

In realising the considerable potential of plantation forestry to benefit society, one of the principal challenges to plantation forest owners, managers and scientists is to progress from a narrow focus, which Shiva (1993) has characterised as "monocultures of the mind", to a broader appreciation of plantation purpose and practice. We are well-placed to do so, by building on the considerable body of experience and information we have gained relevant to plantation and other forms of forestry in many environments. It is in doing so that we shall sustain plantation forestry in the next century, and maximise its benefits.

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The sustainability of wood production in plantation forestry

Julian Evans[1]

INTRODUCTION

Accurate data about the sustainability of plantation forestry are needed since future supplies of forest products will increasingly come from intensively managed forests and plantations. The concept of sustainability is central to sound forest management and the subject of much current debate. In the case of forest plantations established with the specific purpose of producing wood, whether for industrial purposes or domestic use, the question must be asked, can supplies be maintained in perpetuity? This biological or 'narrow sense' sustainability must first be satisfactorily addressed, then the technology of plantation silviculture can fulfil the potential worldwide expected of it with some assurance.

SUMMARY

Accurate evidence about the sustainability of plantation forestry is needed since future supplies of forest products will increasingly come from intensively managed forests and plantations. Sustainability is a central criterion for sound forest management. However, even in the 'narrow sense' of maintaining timber yields over successive rotations from the same site, few data exist owing to the difficulty of maintaining consistent records and research programmes over very long periods. This paper reviews available evidence and reports recent findings from comparing three rotations of pine in the Usutu forest, Swaziland.

In the last 40 years there have been only two significant examples of widespread productivity decline over successive rotations of trees: Pinus radiata in South Australia and Cunninghamia lanceolata in sub-tropical China. The situation in South Australia has been more than rectified by careful management of organic matter and tree nutrition, control of weed competition, and a genetic tree improvement programme. In China similar improvements in husbandry will probably overcome the decline problem, at least where Cunninghamia in not planted off-site.

In Swaziland the productivity of successive rotations of Pinus patula have been assessed in the plantations of the Usutu Pulp Company since 1968. After three complete rotations productivity levels have maintained or slightly risen over most of the forest without resort to use of fertilisers or genetic improvement. Over a small proportion of the forest (13%) productivity declined from first to second rotation, but not second to third. This localised problem is largely overcome by phosphate fertiliser application.

The Swaziland yield records are arguably the best dataset in the world for comparing three successive rotations of tree plantations on the same site. Evidence to date suggests that the intense plantation forestry practised is sustainable. Introduction of gentically improved material should increase yields of future rotations.

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Globally, evidence suggests that with sensible and sympathetic management plantation forestry is an entirely sustainable silviculture for the production of wood.

Keywords: Sustainability, plantations, long-term productivity, yield

IMPORTANCE OF PLANTATION FORESTRY AND SUSTAINABILITY

Although estimates vary, the total area of forest plantations in the world amount to between 120 and 140 million hectares. What is less uncertain is that the amount of new planting (afforestation) is increasing in both temperate and tropical countries. In the tropics especially the present rate of planting of 2-3 million hectares per year is double that recorded in the 1960s and 1970s (FAO 1992; Evans 1992). The purpose of such plantations is mostly either for industrial production or domestic use as building poles, fuelwood and fodder.

The great bulk of forest plantations are of uniform age and uniform composition (monoculture) and most are managed to optimise the yield of wood from the site. Also, clearfelling and replanting is the commonest silvicultural system, although, where appropriate, coppicing is used as a means of re-stocking. These features of plantation silviculture - uniformity of crop, intensity of production and concentration of working - have raised concerns that many of the sites on which trees are planted may be incapable of sustaining their productivity. Models of nutrient export, examination of physical damage of soil structure, and claims of greater risk from pests and diseases have all been advanced as reasons why intensive plantation forestry may be inherently unsustainable.

The question of sustainability, at least in the narrow biological sense, has long been a concern in agriculture particularly with arable cropping. Several long-term experiments exist in different countries of which the oldest and most famous is Broadbalk Field at Rothamsted Experimental Station, Harpenden, England. Since 1843 successive crops of wheat have continuously been grown and assessed. Over a long period yields from the control treatment, which received no fertiliser and only minimal cultural treatment to control weeds, has remained low but stable (Johnston 1994). This work has shown that even after 150 years the land itself has not become “wheat-sick” and that low yields arise from low external inputs (though these are rising, notably the anthropogenically derived nitrogen mainly in rainfall, currently up to c. 30 kg ha-1y-1).

Unfortunately, factual evidence concerning long-term productivity of forest plantations remains meagre. But without it foresters cannot properly demonstrate how robust their silviculture is and cannot refute claims that successive rotations of fast-growing trees inevitably leads to soil deterioration. This paper examines the evidence of yield decline and reports in detail on the best data sets in the world, which describe the performance of three successive rotations on the same site (Evans 1996). The subject was reviewed by the author in the 8th World Forestry Congress in Jakarta in 1978 (Evans 1978). Since then significant new information has arisen which is germane to the question of sustainability.

MENSURATIONAL EVIDENCE OF PRODUCTIVITY OF SUCCESSIVE TREE CROPS

A full review of this subject in Evans (1990) revealed how few examples exist of demonstrable and widespread yield declines, excluding those attributed to pollution and pathogen-related dieback - see Ciesla and Donaubauer (1994) and Freer-Smith (1997). Three main examples have been reported in the forestry literature.

Spruce in Saxony and Other European Evidence

Reports by Weidemann (1923) in the 1920s suggested that significant areas of second and third rotation spruce (Picea abies) in lower Saxony (Germany) were growing poorly and showed symptoms of ill-health. This became a much researched decline and was attributed to insect defoliation, air pollution, the effects of monoculture, and simply the intensive form of forestry practised. It is now clear that much of the problem arose from planting spruce on sites to which it was ill-suited as also happens with Silver fir (Abies alba).

Elsewhere in Europe reports of localised yield decline in Denmark, Holland and the Landes area of France have appeared but neither their extent nor magnitude of yield change were cause for alarm. In Britain most second rotation crops are equal to or better than the previous rotation and, in the case of restocking with Sitka spruce (Picea sitchensis), much the most important species in the uplands, there has been no requirement to reapply phosphate fertiliser even though it was essential for establishing the first rotation (Taylor 1990).

Pinus radiata in South Australia

First reports of significant productivity decline emerged in the early 1960s (Keeves 1966) and by the end of the decade it was clear that a fall-off in productivity in the second crop of about 30 per cent was occurring throughout the State. Not surprisingly, the problem generated a great deal of research and it gradually became clear that a combination of factors was causing the poorer growth of the replanted second rotation. Harvesting and site preparation practices, e.g windrowing, were causing great loss of organic matter from a site and high weed seed loads combined with inadequate weed control led to massive grass invasion. Experiments showed that conservation of organic matter and other more gentle handling of the site, along with adequate weed control greatly improved performance of the second rotation and largely overcame the decline problem. Today these and other changes in silviculture have eliminated it altogether (Woods 1990).

In restricted areas of New Zealand second rotation decline in Pinus radiata was also reported (Whyte 1973) but was confined to impoverished sites in the Nelson area of the South Island. Elsewhere, a carefully investigated study of second rotation Pinus elliottii in Queensland showed no evidence of yield decline. Nor has any such decline been reported among subtropical pines in southern Africa, apart from a highly localised and site related occurrence in Swaziland (Evans 1996).

Cunninghamia lanceolata in China

About 6 million hectares of plantations of Chinese fir (C. lanceolata) have been established in subtropical China. Indeed it is the most widely planted species. Most plantations are monoculture and worked on short rotations to produce small poles, though the tree itself, foliage, bark and even sometimes roots, are all utilised in some way. Reports of significant yield decline began to appear some years ago. Accounts by Li and Chen (1992) and Ding and Chen (1995) suggest a drop in productivity between first and second rotation of around 10 per cent and up to a further 40 per cent between second and third rotation. Data have been difficult to obtain to indicate how widespread this kind of decline is, but the importance attached to it by Chinese foresters is indicated by a large amount of research into questions of monoculture, allelopathy, soil changes, etc. It appears that the practices of whole tree harvesting, almost total removal of organic matter from a site after harvesting, and conditions which favour extensive grass and bamboo invasion all contribute substantially to the problem. The question of allelopathy and recruitment of coppice shoots for restocking on productivity remains unresolved. Yield decline in Chinese fir has been the subject of a cooperative research investigation by the British Overseas Development Administration and the Chinese Academy of Forestry.

Coppice

Plantations of some species, e.g. eucalypts, are often managed by coppicing for the second, third and sometimes fourth rotations. Much evidence indicates that typically the first coppice crop is the most productive followed by the poorer yields in each subsequent crop until replanted. Kaumi's (1983) report from Kenya and that from India reported by Jacobs (1981) are typical - see Evans (1992). This diminution in productivity mostly arises from stump death and poorer stocking per hectare and also the physiological feature that coppice shoots growing on an increasingly old root system exhibit "mature" characteristics at an earlier stage. There has been little evidence to suggest that the practice of coppicing itself depresses site productivity.

PRODUCTIVITY RESEARCH OVER THREE SUCCESSIVE ROTATIONS IN SWAZILAND

Research in the Usutu Forest, Swaziland, began in 1968 as a direct consequence of reports emanating from Australia about declining productivity of second rotation Pinus radiata. Since 1968 the productivity of each successive rotation of Pinus patula has been recorded using a network of sample plots throughout the forest. Data from three complete rotations now exist and were reported recently by Evans (1996).

The painstaking and carefully recorded measurements show that over the bulk of the forest where soils derive from granite and gneiss complex lithology there has been no decline in yield. Indeed, on these intermediate to slow weathering mineralogies (typically feldspars, biotite and muscovite), there is strong evidence that the third rotation is significantly superior to the second (Table 1). By contrast, on a small part of the forest (13% of area) dominated by gabbro derived soils of the Uusushwana complex of slow to very slow weathering mineralogy (plagioclase, quartz and horneblende), a significant yield decline occurred between the first and second rotations though not between second and third rotations (Table 2).

The importance of these data from Swaziland, apart from the long-term nature of the research which has itself been maintained, is that there has been no genetic improvement nor fertiliser addition from one rotation to the next. Moreover, the 1980s and especially the late 1980s and early 1990s, have been particularly dry, along with the rest of southern Africa (Hulme 1996), but this has not affected the yield as might have been expected. The data are also important because the plantation silviculture carried out in the Usutu Forest over some 62,000 hectares is intensive with Pinus patula grown in monoculture, with no thinning and on a rotation of 15-17 years which is close to the age of maximum mean annual increment. Large coupes are clearfelled and all timber suitable for pulpwood is extracted. These plantations are managed as intensive as any example that can be found and, so far, over three rotations there is no evidence that the practices themselves are leading to yield decline as measured by crop productivity. At least in the narrow sense the plantation silviculture carried out is demonstrably sustainable.

THE FUTURE

The Need for Research

Although the above short overview presents an encouraging picture, the serious lack of data recording yields in successive rotations is a major problem. It is not a new problem (Evans 1984), but at a time when all research budgets are being severely restricted maintenance of the essential long term records to answer the kinds of questions discussed in this paper will be increasingly difficult. This is none more so than in forestry research with rotations lasting from many years to many decades (Evans 1994). Managers responsible for permanent sample plots must ensure reestablishment in successive rotations and must ensure that data are recorded and maintained for posterity.

Understanding the processes which impinge on this site productivity question is generally more widely researched. For example, the US Forest Service (Powers 1991), the EU Level II Network under Europe's Air Pollution regulations and CIFOR (Centre for International Forestry Research) have established programmes which will lead to networks of sites to gather data recording the impacts (nutrient supply budgets, soil physical characteristics, etc.) of plantation forestry practices. These networks will be an essential resource for scientific investigation in the future.

Prognosis

Genetic improvement of tree plantations remains largely in its infancy with a few notable exceptions such as with eucalypts growing at Aracruz, work with poplars, and tropical and sub-tropical pines. It is clear that substantial yield improvement, as well as in other features such as disease resistance and better stem quality, flow from tree breeding programmes. With plantation forestry practice appearing essentially neutral as an impact on site productivity - trees as soil improvers being matched by intermittent nutrient export from a site - genetic improvement of the crop should lead to some increase in yields in the future.

A less strong case, but still one leading to growth enhancement, is judicious fertiliser application. Certainly in Swaziland the limited area of forest where yield decline did occur between first and second rotations is being corrected by application of phosphate on the essentially phosphate poor soils. Such targeting of inputs to site need will play a part in maintenance of productivity as with magnesium (dolomitic limestone) in Germany. Allied to this amelioration of soil nutrition is increasing recognition that harvesting practices should minimise physical damage to site and seek to conserve organic matter from one rotation to the next. Attention to weed control as part of good management must continue.

Overall, it is reasonable to conclude that the outlook is positive and that as a technology for producing timber efficiently, plantation forestry ought to be sustainable.

CONCLUSIONS

Evidence from across the world suggests that plantation forestry is likely to be sustainable in terms of wood yield in most situations provided good practice is maintained. Improvements in silviculture and tree genetics may enhance crop productivity. This suggests that in its simple form plantation forestry is a very useful technology, but this conclusion can be misleading since it is not always an appropriate technology where tree planting is needed. The concept of complex plantation forestry, able to deliver a variety of good services and values, will frequently be more appropriate (Kanowski 1995). By embedding plantation forestry within the broader social and economic context its 'broad sense' sustainability is enhanced. This paper shows that the 'narrow sense' sustainability should not be a threat to achieving these wider aims.

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Table 1: Yield of second and third rotation *Pinus patula* at age 14 years from 24 plots on Lochiel Hood granite or Ancient gneiss complex soils - 86 per cent of the forest.

Rotation	Stems per hectare	Mean height (m)	Basal area (m^2ha^{-1})	Volume ($m^3ha^{-1)}$	Mean annual increment ($m^3ha^{-1}y^{-}$)
First: 1R	[1266]*	17.52		[297.4]*	[21.2]*
Second: 2R	1298	17.28	42.63	284.16	20.30
Third: 3R	1273	18.01	43.58	302.36	21.60
3R:2R (%)	-1.9	+4.2	+2.2	+6.4	+6.4
't' statistic		2.94	1.28	1.89	
Significance		P<0.01	n.s.	P<0.1	

* Unreliable figures thought to be slight overestimates. ***From Evans (1996)***

Table 2: Yield of second and third rotation *Pinus patula* at age 14 years from 10 plots in Forest Block A on Usushwana complex soils - 13 per cent of the forest.

Rotation per	Stems height hectare	Mean area (m)	Basal (m^3ha^{-1}) (m^2ha^{-1})	Volume increment	Mean annual ($m^3ha^{-1}y^{-1}$)
First: 1R	[1239]*	18.18		[301.3]*	[215]*
Second: 2R	1170	17.03	37.57	248.22	17.73
Third: 3R	1025	16.87	38.93	255.12	18.22
3R:2R (%)	-8.8	-0.9	+3.6	+2.8	+2.8
't' statistic		-0.26	0.55	0.18	
Significance		n.s	n.s.	n.s.	

* Unreliable figures thought to be slight overestimates. ***From Evans (1996)***

"Whither goest Myanmar Teak Plantation Establishment?"

Saw Kelvin Keh[1*]

SUMMARY

A brief history of the past and present Myanmar teak plantation establishment is presented together with the guided advice of the "Old Masters" of Burmese forestry, such as Brandis, Baden-Powell, Troup, Blandford and Watson. Sustainable Myanmar Teak plantation establishment becomes questionable in the light of modern research findings and the warnings given by the "Old Masters". *Xylia dolabriformis* and *Pterocarpus macrocarpus* plantation establishment are advocated.

Keywords: Thinning in natural regeneration, improvement fellings, Burma Selection system, illicit felling, marketing.

INTRODUCTION

Since 1840, teak plantations have been established in India, Myanmar, Thailand and various other countries in south-east Asia, as well as in Central America, Africa, etc., and much earlier in Indonesia. The object of such establishment is for the utilization of such high-quality teak timber which is in constant demand for domestic use and also for export for trade and financial gains.

Due to the various problems that cropped up in the process of establishing teak plantations (White, K. J., 1991), some countries began to question the benefit of teak plantation establishment and some have discontinued teak as a promising species for plantation establishment (Keogh, R. M., 1979). Some have shortened the rotation of teak plantations down to 30, 25 or 15 years (Keh, K., 1995-96) so as to make their investments more remunerative and also to lessen the extent of soil erosion and site degradation due to teak plantation establishment (Dr Nair, 1995, KFRI; Keh, K., 1995/96; Chacko, K. C., 1995). Furthermore, the proportion of teak plantation to overall plantation establishment in the tropics had declined sharply from 11% in 1980 to 5% in 1990 (Kaosa-ard, A., 1995; Keogh, R. M., 1994). Even in Myanmar, the home of teak, there was a change in teak plantation policy in 1932, resulting from the discovery (Scott, C. W., 1932) that bee-hole borers attacked extensive areas of teak plantation with the result that the then British Government decided that teak plantations should now be established not for export but for the sole purpose of supplying the needs of the local population, which amounted to only 300 acres annually. H. R. Blandford (1921) warned that "teak should be planted with caution and he still believes that there may be great danger in creating large extents of practically pure teak". In Myanmar (at that time Burma), the colonial political pressures somehow prevailed over the guided advice of the British foresters and in later years teak plantation establishment again gained momentum and continues up to now. H. W. A. Watson (1923), an outspoken working Plan Circle Conservator, advocated the establishment of pyinkado (*Xylia dolabriformis*) plantation instead of teak. The wisdom of his advice had not been tested in full though pyinkado or pyinkado mixed with teak had been intermittently tried on an experimental basis.

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[*] The ideas presented in this paper are solely the opinion of the author and not of the Forest Department.

B. H. Baden Powell (1874), the then Inspector General of India, explicitly stated that "teak is a bad forester; it does not improve the soil and its leaves do not readily form humus". It should never be forced on unwilling localities "implying teak has a detrimental influence on the forest or soil and as such should never be cultivated except in suitable localities where its destructive effects can somehow be manipulated or controlled".

Dr D. Brandis (1881) did not encourage the Burma Forest Department to establish teak plantations in Burma. After more than 25 years' experience in tropical British Burma and India, he indicated that "the aim of the Forest Department (Burma) is not to grow pure teak forests as the tree thrives best if associated with bamboos and other trees and it will be well in this respect to follow the indications of nature". Pure or nearly pure natural teak forests are rare and, where they are found, their condition is not satisfactory. Troup, R. S. (1917) gave the same advice pertaining to tropical Burma. He said that ''Nature has to be studied closely, imitated and ever coerced to make fuller use of the productive capacity of the soil by increasing the proportion of the valuable species, improving the density of the crop and bringing the forest into the condition of producing the maximum amount of valuable timber or other produce year after year and century after century".

Nature itself shows that in the lower reaches of tropical Burma, where the rainfall is over 100 inches, teak is readily but surely weeded out due to invasive evergreen species and the scant natural regeneration of teak (Troup, R. S., 1921; Keh, K., 1993). Occasionally in localized areas where excessive natural regeneration of teak has taken place, cultural operation in the form of TNR (Thinning in Natural Regeneration) has to be introduced to curb the detrimental effect of teak in the form of excessive soil erosion even in the natural forest. Too much teak in any localized area is self destructive. In localities where the soil is friable, even a single teak tree, by itself, exerts the same destructive effect on the soil (Keh, K., 1995-96). Dr Brandis, therefore, evolved the Burma Selection system where great emphasis is placed on the improvement felling being carried out regularly with the object of inducing the natural regeneration of teak and, at the same time, improving the growth of the existing teak saplings and poles.

Past experience and the results of modern teak research findings on teak plantation establishment are fraught with problems and conflicts pertaining to soil, nutrient loss, site degradation, growth and yield decline, and insects and disease attack when it is established in unsuitable locality and an unfriendly environment (Chacko, K. C., 1995; Kaosa-ard, A., 1995). Thus it becomes questionable whether a teak plantation can be established sustainably without its accompanying detrimental effects on soil and the environment except in the most suitable side (Kaosa-ard, A., 1995) or by drastically shortening its rotation to make it more remunerative (Keh, K., 1995-96).

PAST AND PRESENT TEAK PLANTATION ESTABLISHMENT IN MYANMAR

In Myanmar, from 1856 to about 1896, experiments pertaining to teak and teak plantation establishments were tried out on a limited scale on a trial and error basis by Conservators and Divisional Forest Officers who took an interest in teak. Starting from 1896, plantation establishments were systematically organized by the Forest Department. For quite a long period, teak was the only species planted for plantation establishment, although in later years Pyinkado (*Xylia dolabriformis*) and catch (*Acacia catechu*) were also advocated for plantation establishment. At the close of 1896, regular plantations covered 55,371 acres, taungya plantations (chiefly teak) 16,119 acres and cultural operations of different kinds had been successfully practised over 237,664 acres (Stebbing, E. P. Vol. III, 1926).

By 1926, the total teak plantation area amounted to 100,000 acres. In 1942, it amounted to 113,000 acres (Champion, H., and Osmaston F. Vol. IV., 1962). The slow increase over a period of 16 years (1926-1942) from 100,000 acres to 113,000 acres was due to the depression and diversion of forest revenue and forest produce for the Second World War (ibid.). There seems to have been no plantation establishment during the Second World War and the years following it. From 1948 till 1994, a total of 452,200 acres (183,000 ha.) of teak plantations had been established. Since 1980, the average annual area of planting had been more than 11,000 ha. (Gyi, K. K., and Dr Tint, K., 1995).

The total teak plantation area up to 1994 amounted to 565,200 acres (113,000+452,200) although a substantial acreage was lost during the Japanese occupation in the Second World War, the insurrection, illicit logging and marketing, prolonged delayed thinning resulting in uprooted felled trees and irreparable soil loss, and the extensive bee-hole borer attack. The extent of the losses cannot be evaluated as most of the plantation registers and Working Plans were lost during the war years (1962, Champion, H. and Osmaston, F. C.; Stebbing, E. P. *The Forest of India*, Vol. IV). Some of the latter stage plantation establishments can now be evaluated but none has yet been done.

THE PRESENT MYANMAR TEAK PLANTATION SITUATION

In the early stages of Myanmar teak planting development, when teak plantation management was carried out on a manageable scale (Stebbings, E. P., 1926) and site very meticulously selected, with adequate staff to implement the plantation establishment, success was assumed in some way when timely implementation of tending operations was carried out in all its stages of development and the detrimental effects of teak somewhat curtailed. Partial failures may result when timely cultural operations cannot be implemented and disruptions due to shortage of funds and labour, inadequate and incompetent staff, war and insurrection occur (Chacko, K. C., 1995; Keh, K., 1995-96). In the latter stages of development, when large-scale teak plantations were established through projects aided by the Asian Development Bank and the World Bank, failures began to set in due to inadequate staff and labour shortage, selection of vast areas of unsuitable sites, resulting in untimely cultural operations, and accelerated erosion and site degradation thereby affecting the proper growth of the trees. Although a feasibility study had been carried out prior to the plantation establishment, the plantation areas were so vast that they could not be managed competently due to various constraints beyond the control of the Forest Department leading to unavoidable disastrous consequences such as irreparable soil and capital loss.

In the tropical conditions of Myanmar, especially in its lower reaches where rainfall is over 100 inches, even a single teak tree in the natural forest exerts a destructive effect on the soil and undergrowth under its canopy (Keh, K., 1995-96). So the cumulative destructive effects of hundreds of thousands of pure teak trees on the soil and vegetation can hardly be gauged - the destructive process going on year after year. The soil condition of such plantations, after a long rotation, will become very much degraded as the teak trees will have used up almost all the soil nutrients in their various stages of development (Jose, A. I. and Koshy, M. M., 1972. Jayaraman, K., 1995).

Thus the understorey, containing little or no teak, that grows up under the teak canopy is unhealthy and undersized and ultimately the teak plantations are left as they are to merge with the surrounding natural forest and be treated as natural forest after the last thinning had been carried out (Keh, K., 1995-96). Consequently, teak plantation establishment in Myanmar cannot be said to be satisfactory although partial success had been accomplished in certain suitable fertile localities where timely cultural operations had been implemented.

DISCUSSIONS AND CONCLUSIONS

The history of Myanmar forestry extends over centuries and at times has been tortuous. History has shown that civilizations had ceased or changed for the worse because of the misuse, mismanagement and destructive use of the soil and the natural resources abounding on it. Due to varying constraints which are beyond the control of the forestry organizations, the future yield of teak in Myanmar from natural forest will indeed decline, and their extent reduced through rampant cuttings and conversion to other land uses, illicit fellings and marketing, conversion of natural teak forests to extensive plantations of teak monoculture, adversely affecting the fauna and flora, bio-diversity, site quality and productivity of the forest (Gyi, K. K.; Tint, Dr K., 1955. Keh, K., and Kyaw, S., 1995), and establishing teak plantation in unsuitable sites (Keh, K., 1995/96 and Kaosa-ard, A., 1995). Certainly, from the purely economic view, the value of teak timber is so much greater than that of any other species that relatively poor teak is almost always a sounder financial proposition than any other possible alternative. Expenditure is therefore justifiable in order to overcome the silvicultural difficulties if such really exist.

"Old Masters" such as Brandis, Baden-Powell, Blandford, Troup and Watson had spent most of their productive and prime years in India and Burma and they had been very thorough in their investigations and deliberations. Modern research findings and past experience point to the truth of their statements.

In Myanmar, as in India and other countries, unsuitable sites, inadequate allotment of funds, failure of timely implementation of tending operations in all its stages of development, especially during the five or 10 years' very light and late thinning, most of which are beyond the control of the Forest Department, account for the failure of many teak plantations (Chacko, 1995). Research indicates that site quality declines with age (Jayaraman, 1995) and that site deterioration between and within rotation poses a threat to potential yield and sustainable management (Chacko, 1995)

Kaosa-ard (1995) referring to R. M. Keogh (1994) *Teak 2000* stated that the proportion of teak plantation to overall plantation in the tropics had declined sharply, from 11% in 1980 to 5% in 1990. Furthermore, India had reduced teak rotation to 30 years. (Nair, KFRI, 1995) while Thailand had reduced it to 16 years (* Kaosa-ard, 1995) and Malaysia is practising a 15-year rotation (Zakaria and Lokmal, 1995). These reductions in rotations are in line with modern research findings of site deterioration within and between rotations (Chacko, 1995) and the prevalence of insects and borers attack, yield obtained from plantations being far below expectation (KFRI, 1979).

As it now stands, Myanmar forestry may have to resort to the natural regeneration method of improvement fellings rather than teak plantation establishment, making use of the artificial-cum-natural regeneration procedure (Keh, K., 1993-94; Keh, K. and Aung, M., 1994/95). Teak plantations should be established only on very suitable sites on a limited scale with a very intensive system of management to the extent of creating a separate Plantation Division, and some of the budget or capital previously allotted for teak plantation establishment should be redirected or rechannelled towards natural forest improvement (Keh, K. and Kyaw, S., 1995). Instead of teak, *Xylia dolabriformis* and *Pterocarpus macrocarpus* plantations should be established. Watson (1923), as a Conservator of Working Plan Circle and having travelled widely all over Burma, advocated the planting of *Xylia* instead of teak. He made this statement against the policy of the British Government and I believe that his advice still holds good today as both *Xylia* and *Pterocarpus* are leguminous soil improving species and are of positive help in the productivity and sustainability of Myanmar's forest development.

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Man-made stands of quick-growing species and forest product quality in tropical countries

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INTRODUCTION

Plantations of rapid growing trees may offer a solution to the problem of relieving the pressure on natural forests yet meeting the wood needs of the population in tropical countries.

The criteria of product quality from man-made stands and regularity of the harvested product for the intended use - paper, constructional or other timber - are taking on an ever-increasing importance.

Developments in cultivation practices and genetic selection have now made possible considerable gains in productivity and homogeneity in harvested timber. Yet these gains would also seem to be accompanied by a falling-off in timber quality. Wood from man-made stands differs in anatomical, physical and mechanical properties as compared with wood from natural forests, with all the technical and commercial problems that this implies (JOFCA 1996). In practice, the gain in homogeneity is to some extent offset by a wider variability in the properties of the wood from one and the same tree, the differences showing in the sawn, veneer and pulp products.

Even so, resort to plantation wood is sometimes necessary in the interests of sustainable management of a country's forest assets, in such a way, also, as to satisfy the wood requirements of the population. Substitution is technically feasible, provided the properties of the "new" wood are understood, and provided suitable procedures for processing (felling, storage of logs and semi-finished products, sawing and peeling machinery) are also promoted. Further, the understanding acquired in these matters must also be a guide for forest practices (silviculture, genetic improvement) for both the present and the future.

The following pages illustrate the present state of the art at CIRAD Forêt in terms of understanding the technical properties of a range of plantation timbers in tropical countries. Background considerations on timber characterization are here followed by a closer look at certain general implications: (i) overall variations in properties observable within one and the same species as between the man-made stands and natural forests; (ii) variations in intra-tree properties; and (iii) forestry practices designed to improve these properties.

CHARACTERIZATION OF THE TECHNICAL PROPERTIES OF TIMBER

There are several official standards for characterizing the physical and mechanical properties of solid timbers whether defect-free or not (e.g. AFNOR 1988), and there are a certain number of tried and tested laboratory protocols for determining their natural durability or the anatomical characteristics (e.g fibre length). In any case CIRAD Forêt develops its own protocols, notably for tackling problems having to do with plantation timber, such as:

- Assessing constraints on growth. The purpose here is to evaluate prestressing effects on intra-tree timber and risks of heartwood splitting at the time of cutting, and sawing defects. The test

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consists in measuring the residual longitudinal deformation on drying (DRLM in the French acronym) at the outer surface of standing timber (Fournier et al, 1994, Gérard et al. 1995).

- Mechanical rupture testing. This is the most meaningful in determining resistance to splitting (measurement of energy required to produce a complete breakage in a pre-notched test piece) (Baillères 1994).
- Generally wood from man-made stands comes in small dimensions and, especially, is heterogeneous in character within one and the same tree. For this reason it often pays to use small-sized test pieces in order to have a characterization offering precision - but without resort to artefacts - of the properties of defect-free wood, together with that of any intra-tree variations in such properties.

At CIRAD Forêt most data obtained from the trials on the properties of logs, the physical and mechanical properties of timbers, their natural durability, their suitability for machining, their chemical composition and their thermo-chemical properties are computerized (Gérard & Narboni 1996).

THE SAME SPECIES IN MAN-MADE STANDS AND NATURAL FORESTS COMPARED

Marked differences frequently appear when the average properties of timber from the man-made stands and of timber from natural forest are compared. For example, mature plantation teak (Tectona grandis) has a more widely varying natural durability (fair to good) against fungus and insect attack, with the result that it is less reliable when used under severe conditions (CTFT, 1990). Another example concerns the physical and mechanical properties of limba (Terminalia superba) and shown in Table 1, where trees in the case of man-made stands have a somewhat lower density but most of all have a significantly lower mechanical resistance than timbers from natural forests.

INTRA-TREE VARIABILITY - JUVENILE WOOD AND REACTION WOOD

As one would expect, trees from plantations are more homogeneous than those from natural forests: man-made stands are usually even-aged or, at least, the age of the trees is known and determined at the time of felling; growing conditions are under close control through silvicultural practices (soil working, fertilizer applications, thinning, pruning, etc.); the genotype is kept homogenous through the use of select seed and even by a large-scale cloning, and so on. Yet, where wood quality is concerned, homogeneity is at a very low level in the products of primary processing, to be seen chiefly in the marked variations in properties of the wood from one part of the tree to the other.

A first source of intra-tree variability is the gradual passage over from juvenile wood to adult wood, varying from the heartwood to the bark and from the higher to the lower part, as a result of the ageing of the cambial meristem. Anatomic properties, which provide direct evidence of the functioning of the cambium, conform to fairly general and stable laws, at least where quality is concerned. Thus, fibre length and vessel diameter become greater as one goes from heartwood towards bark. In the case of fibre length, which is important for the paper industry, there is a wide range of variation, often as much as from one to two (Figure 1). For physical and mechanical properties the pattern is considerable looser. For example, wood density usually increases with conifers whereas with broadleaved species it may increase or decrease or, again, remain stable. Sometimes variations are impressive, from one to two in the case of density, and from one to three or more for the elastic modulus. Again, radial profiles vary to a greater or lesser degree with height (Gérard 1995, Gérard et al. 1996). Finally, despite the homogeneity to be expected, given the growing conditions and the condition of the seed, a considerable variability among individual trees ("tree effect") has at times been noted, though not for clone plantations of Congo eucalyptus.

In the case of wood with marked and heterogeneous rings, radial developments associated with juvenility are altered by the speed of growth, the latter significantly influencing ring structure and, thus, the average properties of the wood. In this way a resumption of growth following on stand thinning will result in heterogeneity in wood properties, e.g., lower (or higher) density in the case of conifers as compared with broadleaved trees with a porous initial zone. However, these timbers with marked rings and heterogeneous properties are seldom to be found in trees in the tropics (mention could be made of certain pines and teak) so that the effect of the speed at which the tree grows will be less marked than for temperate woods. For example, the teaks and gmelinas in figures 3 and 4 have very slow growth at the periphery but this does not translate into any observable variation in density.

A further source of variation is the formation of reaction wood in angular parts of the tree. Reaction wood here is evidence of tropism whereby the tree tends to turn in a given direction. This is because reaction wood has peculiar prestressing characteristics at the time it is being formed - it is under much greater tension than 'normal' wood in broadleaved trees (tension wood); and it is compressed in conifers (compression wood). The peculiar prestressing phenomena and the position of the wood bend, in contrast with "normal" wood (where the tension is "normal") bring about a curvature of the axis, which often allows wind-bent trunks to straighten up again (tension wood forming on the higher-facing side, and compression wood forming on the lower-facing side) but sometimes results in an active bending towards the light. Apparently, man-made stands, especially in the case of quick-growing species, tend to promote imbalances and, therefore, the formation of reaction wood. The peculiar prestressing of reaction wood derives from a different anatomical and chemical structure, making for different physical and mechanical properties where compression wood in conifers has shorter fibres, a somewhat higher density but poorer rigidity (elastic modulus), a less marked tangential shrinkage but a more pronounced axial shrinkage. Moreover, growth is faster in compression wood, with the result that the formation of such wood causes the heartwood to be out of centre. In broadleaved species these tendencies are less generalized, although tension wood often has a greater density and an axial shrinkage likewise more marked, while mechanical properties are not necessarily affected and the heartwood is rarely found out of centre. The main defects due to the presence of reaction wood are:

- In broadleaved species: heartwood shakes noted on felling and sawing, and even complete rupture, and deformations in the sawn product due to the high longitudinal stresses at the periphery; and
- In all types of tree: marked deformation in drying (buckling, warping) in the sawn product and veneers, due to widely varying rates of shrinkage - hence the description of such wood as "wiry".

Again, reaction wood sometimes gives rise to other defects - poor surface condition for planing and sanding (as with "woolly" wood in some species), off-colour (green grain associated with tension wood, red compression wood, etc.). Figures 6 and 7 show the evolution in certain properties as between normal wood and reaction wood.

In addition to these highly generalized phenomena (juvenile wood, reaction wood) in plantation timbers, certain tree populations have their own peculiar problems - abundant knots, ascribable to poorly done pruning, and a marked polycyclic tendency in certain tropical pines (e.g. Pinus kesiya), kino inclusions in eucalypts, abundant heartwood resin in pines (which explains the increased heartwood density to be noted in Figure 5). To these must further be added problems of natural durability; but only limited data are available here.

CONCLUSION: FORESTRY PRACTICES AND WOOD PROCESSING

Silvicultural practices and genetic selection are geared to increasing the speed of tree growth and shortening rotation periods with a view to meeting the needs of the population and of industry for fuel wood, pulp and construction timber. Even so, it is better that gains in productivity should not entail a marked fall-off in quality. For this reason it is important to understand the properties of the timber produced and the impact of forest practices on such properties if there is to be a comprehensive approach to rationalizing production and utilization and enhancing efficiency.

As the developments just described demonstrate, a major difficulty in studying the impact of these practices lies in the fact that the quality of plantation timbers is depressed by heterogeneity in the properties of the wood. The result is that studies are an inevitably onerous undertaking, since one has to observe the effect produced by silvicultural practices and by improvements in terms of any marked interaction with position effects (radial, longitudinal, circumferential) within the tree.

For a start, then, more and more observations are required. Figure 1, for example, shows that the radial evolution of fibre length varies from hybrid to hybrid and depending on the site. With the Madagascar Pinus kesiya, it seems that ‘efficient’ silviculture (two thinnings) limits compression wood formation, but that a single thinning to make good any delay does not yield positive results (Baillères 1996). Baillères has shown that, with some clones of Congo eucalypts, the formation of tension wood usually helps to explain the severity of heartwood shakes at the time of cutting into logs whereas, the wood from certain clones splits much more readily, the size of the shakes depending very much on the clone, where quantity and quality are otherwise similar. Further, it is important to develop several wide-ranging projects for the purpose of devising models for the distribution of the different intra-tree properties, making it possible to simulate, in stand terms, different silvicultural scenarios and, as appropriate, different strategies for genetic selection. Thought is currently being given to such models, for example by the IURFO Workshop on Biological improvement of wood properties (cf. Workshops on Connection between silviculture and wood quality through modelling approaches and simulation software). Two problems accordingly arise: (i) is it possible to extrapolate, from models established on data obtained in relation to young trees, the condition of trees at the time they will be processed?; and (ii) what are the indicators, that will be reliable, simple to acquire on a large scale (and, desirably, in a non-destructive manner), that can be used to provide convincing projections for the whole range of properties of timber and variations in these?

As a final consideration here, improving the quality of the timber product must go hand in hand with developing processing channels. This is because the time constraints inherent in forest production (except perhaps for rapid-growth plantations) are such that local and international timber markets are incessantly obliged to seek novel raw materials, when these will not necessarily be suitable for a given production tool. The models just referred to, or a simple, rapid, diagnosis of the properties of an exploitable resource, must be such that they can be used to enhance added value. For example, the “wiry” wood mentioned earlier has to be sawn early and seasoned in small sizes, and there are tools and sawing and seasoning procedures that are suitable in their case. Veneering may offer profitable returns for timber having a marked contrast between juvenile wood and adult wood, because it is possible to assemble batches of even-quality plywood and match them up when the plies are being put together (there are also tools adapted for peeling small diameter timbers). Obtaining greater value by conversion to panel boards offers good prospects, though this usually entails high installation costs. For the rest, in this field there are few generally applicable rules, and each procedure needs to be thought out within its technical context but especially within its own particular political, social, economic and - most of all - ecological context.

To conclude, it is clearly essential that research and development operations, which will be onerous in a greater of lesser degree but targeted and focusing on a given species and a given context, must be conducted jointly with a wider dissemination of knowledge acquired, so that those in the trade and the public at large shall be informed of the advantages and disadvantages of man-made stands. This could lead in some cases, for example, to deciding on a particular commercial description (attestation of origin?) for tropical plantation timbers as a means of recognizing their technical differences as against those from the natural forest, by emphasizing the advantages they offer, not least from the standpoint of safeguarding a country*s forest heritage, and from that of economic development.

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TABLES AND FIGURES

Table 1:

Average properties	Density	Resistance to axial compression (Mpa)	Resistance to static bending (MPa)
Forest and plantation trees	0.54	46.6	88.5
Plantation trees only	0.49	35.3	65.3

Density and mechanical resistance of Terminalia superba (limba) from plantations. The aggregate sample comprises 72 trees of various provenance in the limba area, most of them from the natural forest. In this sample it was possible to identify with certainty seven trees from plantations in Benin and Burundi.

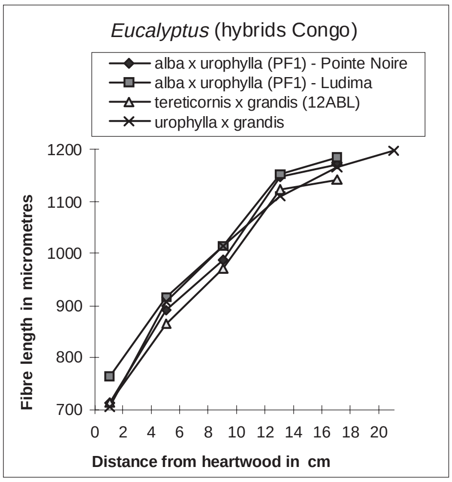


Figure 1. Radial evolution in fibre length in different eucalyptus hybrids (Congo) (average for ± 10 trees, 2 sites per hybrid PF1). After Détienne & Paquis 1989

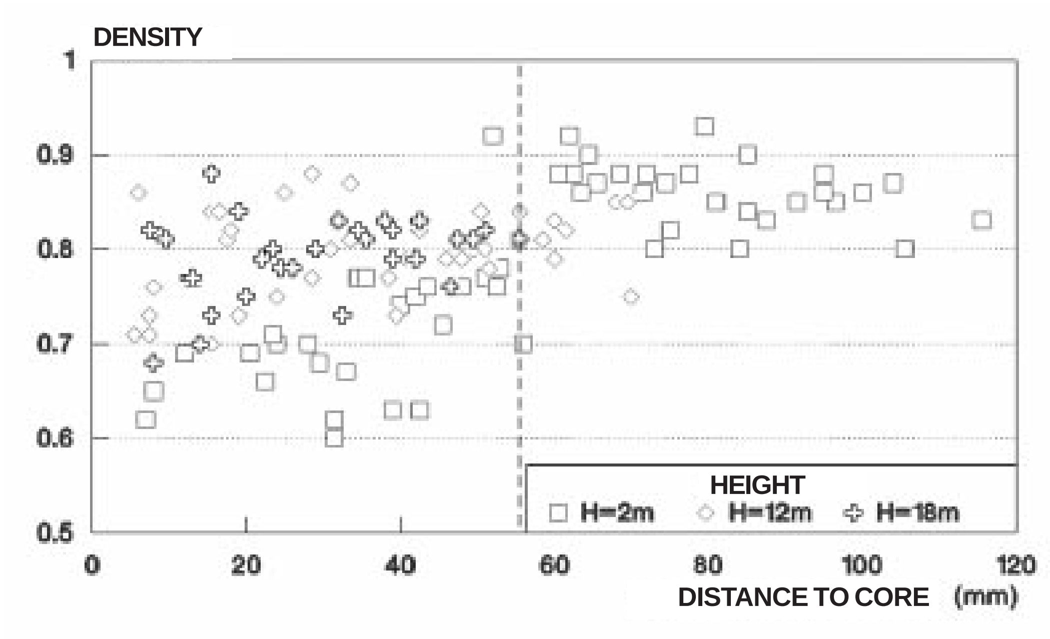
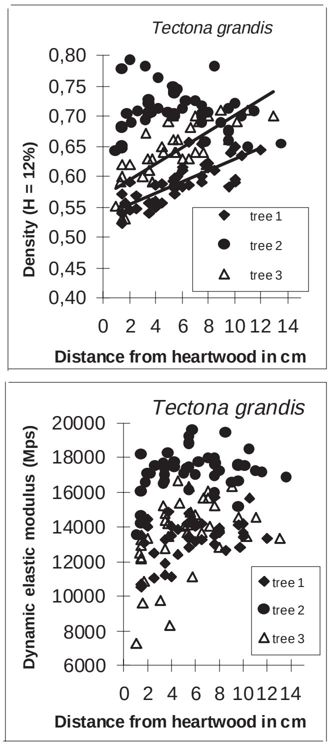
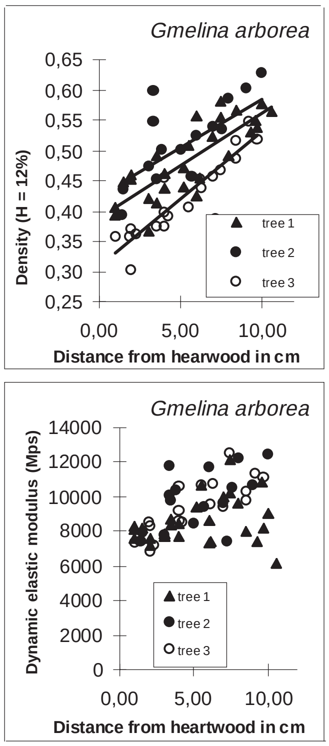


Figure 2. Radial variations of density and elasticity modulus in an eucalypt clone from Congo (1.45) From Gérard, 1994





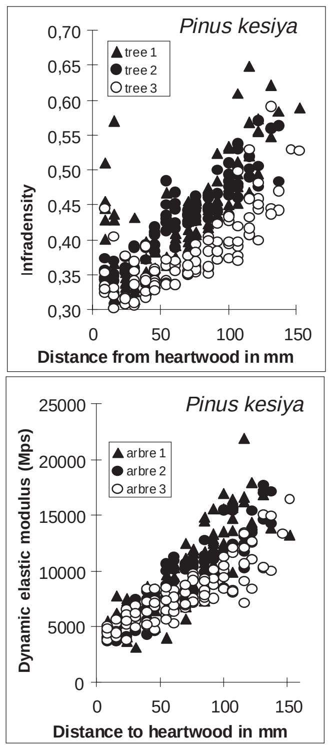


Figure 3. Radial evolution in density and elastic modulus in three teaks (Côte d'Ivoire)

Figure 4. Radial evolution in density and elastic modulus modulus in three gmelinas (Côte d'Ivoire)

Figure 5. Radial evolution in density and elastic modulus in three Pinus kesiya (Madagascar)

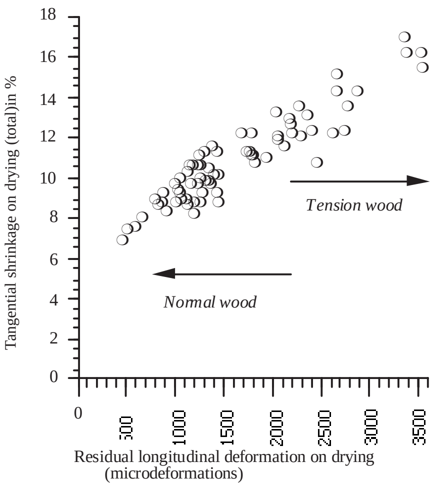


Figure 6. Evolution in tangential shrinkage in normal modulus in a normal tension wood in a clone of Congo eucalyptus

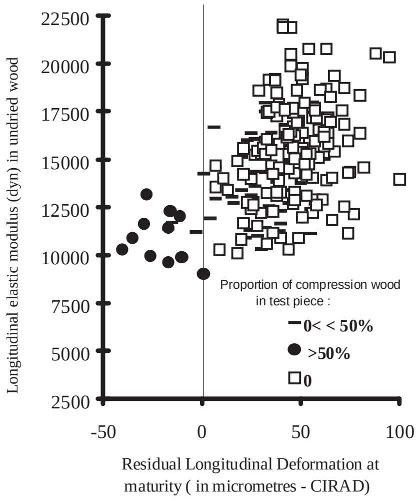


Figure 7. Evolution in elastic compression wood in Pinus kesiya (Madagascar), Baillères et al. 1996

Summaries of voluntary papers

(Also published in Spanish, French and Turkish)

PLANTATION GROWTH OF SOME WOOD SPECIES IN NORTHERN COTE D'IVOIRE

Dominique Louppe[1] and N'Klo Ouattara[2]

Despite their intrinsic value, several indigenous forest species in the Sudano-Sahelian area are scarcely known by local foresters. Since 1990, the Korhogo base (in northern Côte d'Ivoire) for forestry research of the Département Foresterie de l'Institut des Forêts (IDEFOR-DFO) has been setting up collections of more than 60 native species on large plots of land.

This paper presents the results five and a half years after the arboretum was planted in 1990. The authors also consider the type of silvicultural treatment that should be applied to some of the species planted.

Keywords: Côte D'Ivoire, Sudano-Sahelian climate, Acacia polyacantha, Acacia sieberana, Afzelia africana, Albizia zygia, Anogeissus leiocarpus, Blighia sapida, Ceiba pentandra, Cola cordifolia, Daniellia oliveri, Pterocarpus erinaceus, Tamarindus indica, Terminalia glaucens.

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FOREST PLANTATIONS AND SUSTAINABLE FOREST MANAGEMENT IN WEST AFRICA: THE GHANAIAN EXAMPLE

Emmanuel Ofoe Chachu[1]

It is recognized that Ghana's current total need for wood stands at 16 400 000 m^3/a. This volume is projected to reach 28 800 000m^3 by 2020 and 52 500 000 m^3 by 2050. The current generally accepted 17 million population of Ghana, as at 1996, is estimated to reach 30 million by 2020 and 60 million by 2050. Ghana's fuelwood consumption is expected to rise in response to increases in population but the wood requirement for the industry will be reduced, due to further processing trends. In the development of forest plantations in Ghana, and West Africa generally, clearing of natural forest ecosystems should be avoided and plantations concentrated in the savannah zone of the country. Adequate and sustainable funding support through plantation levies and endowment funds, grants and concessionary loans should be given and the envolvement of many stakeholders encouraged.

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RESTORATION OF FORESTED WETLANDS ON MARGINAL FARMLAND: GOALS, STRATEGIES, AND TECHNIQUES

John A. Stanturf[1], Callie Jo Schweitzer[2], Emile S. Gardiner[3] and James P. Shepard[4]

Restoration of bottomland hardwood forests on marginal farmland in the Lower Mississippi Alluvial Valley in the southern United States is being undertaken on a massive scale, supported by various public and private programs. Afforestation in the region relies on using native species, planted mostly in single-species plantations. Choice of species on a site is guided by landowner objectives, species tolerance to flooding, and soils. Current strategies adopted by public programs on both public and private land favor the planting of hardmast-producing species of *Quercus* and *Carya* because of their value to wildlife. Plantings are widely spaced to allow for natural invasion of other species. Wind and water dispersal are relied on to establish light seeded species of *Liquidambar, Fraxinus*, *Ulmus*, and *Platanus*. This strategy can be described best as extensive and low-cost. Increasingly, this extensive strategy is questioned on whether more intensive strategies might not yield greater landscape diversity quicker, and whether it is appropriate for a landowner whose objectives include timber production.

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IMPROVEMENT OF THE ROOTING OF CUTTINGS OF *POPULUS X DELTOIDES* CV. HARVARD

J. Bustamante[1] and R.I. Arreghini[1]

The aim of this study is to improve the rooting percentage of *Populus x deltoides* cv. Harvard.

The base hypothesis was that rooting defects were due to the dehydration of the cuttings or to them germinating without the appropriate root system having yet developed.

One-year old woody cuttings of this cultivar were divided into three groups: the first group did not undergo any treatment while in the second the apical extremity of the cutting was paraffined by immersion in liquid paraffin; in the third group both extremities were paraffined using the same method.

The cuttings were then placed in individual containers, half of which contained a substrate to which a hydrogel was added in order to improve their water retention capacity while the other half contained the same substrate without the incorporation of any hydrogel.

The results obtained after the data were analysed demonstrate that the application of gel to the substrate increases the number of rooted cuttings. The paraffining treatment, whether at one extremity or both, of the cuttings had no effect on rooting.

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DYNAMICS OF NATURALLY REGENERATED YOUNG POPULATIONS OF *PINUS ELLIOTTII* ENGELM. IN THE ARGENTINE HUMID TROPICS

Daniel A. Cabrelli[1], Silvia Rebottaro[2] and Claudio E. Winckler[3]

The dynamics of natural regeneration in the exotic *Pinus elliottii* Engelm. at the plantlet stage in northeastern Argentina are evaluated. The study concerns two distinct microenvironments: (a) natural regeneration subsequent to clear felling; and (b) natural regeneration after selective felling of the stands. A traditional-type plantation is also examined with a view to comparing performance here with the other regeneration process. Over a period of 18 months, diameter and height measurements were taken each successive quarter, mortality and recruitment also being recorded on each occasion.

The most important findings are that: (a) following clear felling there was a much greater density of young plants than after selective felling (162 800 and 91 000 per hectare, respectively). Annual mortality in the case of selective felling was 88%, while after clear felling density was retained; (b) in terms of structure, no post-clear felling situation revealed greater variability in plant size (9-55cm in height) as compared with that noted after selective felling (11-31cm) and in the traditional plantation (13-35 cm); (c) the traditional plantation was characterized by a greater annual average increment in individual plants in their diameter and height while there were no significant height differences as compared with the post-clear felling situation. Post-selective felling growth was extremely limited compared with that in the other stands; (d) after clear felling there was a strong correlation between initial plant size and subsequent growth (r = 0.87). With the traditional plantation the correlation was very weak (r = 0.26); and (e) in the sub-population of residual plants the greatest size after the clear felling growth was significantly more marked than in the traditional plantation.

Points (d) and (e) are likely to have silvicultural implications as regards thinning prior to the marketing stage for products from regenerated stands.

Keywords: *Pinus elliottii*; Argentine humid tropics; natural regeneration; young plants; population dynamics.

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SEEDFALL AND LITTERFALL UNDER A MATURE STAND OF *PSEUDOTSUGA MENZIESII* (DOUGLAS-FIR) IN SOUTH-WEST ARGENTINA

Fernando Caccia[1]

An adequate supply of viable seeds and environmental conditions conducive to seed germination and seedling establishment are critical requisites for regeneration of many forest stands. Litter can control seed germination and seedling establishment at microsite level. Seed and litterfall received at the forest floor were quantified for two levels of tree cover in an even-aged mature Douglas-fir stand to elucidate potential key factors and processes controlling Douglas-fir natural regeneration establishment in the understory.

Seed and litterfall were recorded during 10 days in autumm (first year) and 45 days (second year). Seedfall was higher in the lower tree cover sub-area for both years, but significant differences were found only for the second year. Litterfall was significantly higher in the lower tree cover sub-area for both years. Even with a higher seed supply, significantly less seedling density was recorded in the lower cover sub-area in a previous work. Additional records of litter depth and the seedbank during spring, jointly with the above results, strongly suggest that litter may inhibit germination and/or seedling establishment in the lower tree cover sub-area. Differences between seedfall (autumm) and seedbank (spring) densities indicate that seed predation may be an important process controlling seedling establishment.

Keywords: *Pseudotsuga menziesii* - natural regeneration - seedfall - litterfall

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SUBSTITUTION OF METHYL BROMIDE FOR DISEASE CONTROL IN FOREST NURSERIES*

María Isabel Salerno and Jorge Eloy Giménez[1]

Successful forest tree production in nurseries depends on many interacting factors. Seedling quality is reflected on subsequent tree growth and forest productivity. Consequently, the production system should be aimed at producing healthy and well-developed seedlings. Soil sterilization with methyl bromide is one of the traditional practices for controlling pathogenic microorganisms and weeds. This fumigant is effective but has a number of disadvantages: it affects the beneficial microflora (especially mycorrhizae), it is expensive and toxic to animals and people and may contribute to depletion of stratospheric ozone. An integrated disease control approach is proposed in order to protect the environment and human health through reduced use of methyl bromide.

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WATER STRESS TOLERANCE IN SEEDLINGS OF *EUCALYPTUS* CLONES

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Inter- and intra-provenance variation in relation to water stress was examined for five *E. camaldulensis* Dehn clones and one of *E. tereticornis Sm.* Behaviour after a drought cycle was examined, evaluating tissue water parameters and leaf area expansion, which is considered to be the plant feature most sensitive to stress. Leaf expansion was restricted in all the clones. Osmotic potential at full turgor decreased in a significant way in clones 106, 109 and 107. Water stress increased the cell wall elasticity modulus in all cases. The increase attenuated the effect of the osmotic adjustment and could explain the weak association between osmotic adjustment and leaf expansion.

Keywords: Eucalypts, interprovenance variation, water stress tolerance, osmotic adjustment, cell wall elasticity.

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A CASE FOR REFORESTATION WITH NATIVE SPECIES IN TRINIDAD, WEST INDIES.

Floyd M. Homer[1]

Reforestation efforts in Trinidad have generally been insufficient and focussed on non-native species, and particularly at the Melajo Forest Reserve, was continued partly due to the work of Bell in 1969. Some of these species however, for example, *Pinus caribaea*, appear ecologically inappropriate but have been used extensively on sandy soils after fires or harvesting have degraded the original vegetation. Little attention has been given to basic research on natural regeneration as a potential for future timber production. The objectives of this study were to identify and record the abundance of commercially important regenerating timber species and to provide suggestions for an appropriate management strategy. The field research was conducted over four consecutive years at the Melajo Forest Reserve in northeast Trinidad, where a fire in 1987 had devastated a mature mora (*Mora excelsa* Benth.) forest. Many commercially important species were regenerating in abundance especially *Byrsonima spicata*, *Mora excelsa*, *Sterculia caribaea* and *Terminalia amazonia*, which should be considered as natural alternatives for reforestation efforts at Melajo.

Keywords: Reforestation, Mora, Trinidad, Timber Species, Regeneration.

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STUDIES ON SOIL DEGRADATION OF POPLAR PLANTATIONS AND TECHNIQUES TO SUSTAIN AND INCREASE THEIR SOIL FERTILITY IN CHINA

Sun Cuiling[1], Zhu Zhanxue[2] and Guo Yuwen[3]

The effects of single species poplar plantations over one and two rotations and poplar grown in mixed plantations of Poplar with Black Locust (*Robinia psudoacacia* L.), Sea-buckthorn (*Hippophae rhamnoides* L.) and Indigobush amorpha (*Amorpha frutixosa* L.) on soil nutrients, soil microbes and the activities of soil enzymes were studied with data from 48 sample plots in Shandong, Liaoning, Henan and Hebei Provinces and Beijing. The results showed that (1) the soil nutrients of soils under single species plantations tended to be reduced. (2) the soil nutrients and the growth of the second crop forest were evidently reduced compared with those of the first crop forest. (3) the mixed Poplar forest could increase the soil fertility, and is an effective way to prevent soil degradation.

Keywords: Poplar, soil degradation, mixed forest.

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TEAK TIMBER PRODUCTION IN INTENSIVELY MANAGED PLANTATIONS OF THE TROPICS

K.M. Bhat[1] and E.P. Indira[1]

The scope for teak wood production in intensively managed plantations was examined with reference to timber quality. The data available currently on the effects of intensive practices are less than adequate for high input management. Nevertheless, they offer scope for intensive management in production of timber that is acceptable in the market. More research is warranted on the effects of wide spacing/thinning, fertilization, irrigation, shorter rotation, insect defoliation control and genetic manipulation. Attaining mechanical maturity of the timber at the age of 21 years shown in Indian plantations suggests that rotations can be reduced to this age if other harvesting requirements are not critical. The only anticipated problems in processing and utilisation of short rotation timber are reduced durability (due to lower proportion of heartwood/extractives) and lower grade/recovery of sawn wood and veneer (due to growth stresses in smaller diameter logs and higher proportion of knots). In fact, there exists opportunities for genetic improvement of basic properties such as specific gravity by exploiting tree-to-tree variation within the provenance rather than the variation between the local provenances of a region. However, it is cautioned that selection of specific gravity alone in genetic improvement of timber quality will be misleading due to its inconsistent relationships with mechanical properties. An international cooperative and integrated research programme is recommended among the teak producing countries for minimising taper, knot frequency and flutes and enhancing natural durability to meet the desired grade/log specifications for solid wood uses and veneer.

Keywords: *Tectona grandis* L.f; intensive silviculture, clonal/provenance selection, heritability, genetic gain, wood properties.

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MODERATING EFFECT OF TREE STANDS ON SOIL TEMPERATURE FLUCTUATION *VIS-A-VIS* LITTER ACCUMULATION IN STANDS OF *ACACIA AURICULIFORMIS* IN PONDICHERRY, INDIA

Buvaneswaran,C.[1], Jambulingam,R.[1] and Parthiban.K.T.[1]

Soil microclimate plays an important role in plant growth and development and thus in the nature and composition of vegetation. Change in the kind of vegetation in turn affects to a great extent, among other factors, the soil microclimate through the amount of litter produced and accumulated. But in studies on the ecological impact of afforestation on the soil microclimate these aspects are often overlooked. In the present investigation, the interacting effect of litter accumulation and soil temperature were studied in Auroville, Pondicherry both under mixed stands and under a pure stand of Acacia auriculiformis to achieve a better understanding of the effect of change in vegetation on microclimate under forest stands. Pure stands of ***Acacia auriculiformis***, by its higher litter production (14.0 t/ha/yr) and slower decomposition rate (K=1.62), recorded least daily soil temperature fluctuation both at 5cm (1.3^{o}) and 10cm (1.2^{o}c) soil depth when compared to mixtures of other species. Hence the role of such pioneer species as ***Acacia auriculiformis*** in high litter accumulation could be an important factor where the protective role of trees is the prime objective.

Keywords: Trees Stand - Soil Temperature - Litter Accumulation - *Acacia auriculiformis*.

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MAJOR ISSUES OF TROPICAL FOREST PLANTATIONS

Devendra Pandey[1]

Tropical forest plantations offer one of the major strategies to halt the process of tropical deforestation and to meet future demands of wood. Forest plantation development in the tropics speeded up in late 1970s when social benefits of forest plantations gained strong ground and community and social forestry projects were launched in a number of countries.

The area of plantations has increased many times since then. Doubt exists, however, about the actual area of plantations and volume produced at global, regional and at country levels. The reason is that most of countries do not monitor their plantations and maintain plantation records well. With a few exceptions, adequate attention has not been paid to the technical and planning aspect of plantations development and as a result most plantations yield low volumes compared to their productive capacity.

There is a lack of data on growth and yield of plantations. In order to achieve the full potential of tropical forest plantations and their sustainable development it is essential that the following major issues are given priority: land use and plantation policies, integrated planning, site species matching, quality control of planting material, growth and yield studies, tending and monitoring of plantations and maintenance of plantation data banks.

Keywords: major issues, uncertainty, tending, monitoring, policies, integrated planning, site species matching, productivity, planting material, data bank

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INFORMATION ON INDUSTRIAL FOREST PLANTATION POLICY AND PROGRESS IN INDONESIA

Herry Rousyikin[1]

The Indonesian forestry sector is very important in terms of foreign exchange earnings, the provision of job and business opportunities as well as contributing to the gross domestic product.The role of plantation forests in supplementing the output of the natural forest is very important for sustainable timber production and conservation purposes. In order to increase sustainable timber production to fulfil the demand for wood for raw material to industries, housing, fuel, etc., there is need for large scale forest plantation.

This paper provides information about forest plantation development in Indonesia. In general, the results are positive; forest plantation development has been quite successful in creating employment for rural people, decreasing the pressures on the natural forest, and providing jobs as well as business opportunities. Forest plantation development is one of the ways to sustain forest resources and to improve forest functions and benefits.

Keywords: Reforestation, regreening, timber estate, sustainable production.

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PLANTING STOCK PRODUCTION OF DIPTEROCARPS IN MALAYSIA*

H. Aminah[1]

Species-rich dipterocarp forest types comprise 88,9% of the Malaysian tropical rainforest. Dipterocarp species are among the most commercially important timber species in south-east Asia, but seed supply of dipterocarps is irregular and the viability is short. The seeds are incapable of withstanding desiccation, resulting in difficulty of prolonged storage by conventional methods. The nursery of the Forest Research Institute of Malaysia (FRIM) has successfully developed propagation techniques for production of planting stock of the species. The techniques developed include propagation by seeds, wildings and vegetative propagation by stem cuttings. The success in rooting stem cuttings from juvenile materials is a boon to the forestry of Malaysia. Methods of propagating and handling dipterocarps in the nursery until they reach plantable height are provided in this paper.

Keywords: Dipterocarps, seedlings, stem cuttings, nursery techniques

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CRITERIA FOR AN OPTIMUM STRUCTURE OF OAK STANDS WITH QUERCUS CONFERTA KIT IN BULGARIA

Grud Popov[1], Emilia Velizarova[2] and Dimitar Dikov[3]

The present work discusses the important issue of finding reliable criteria reflecting the optimum structure and dynamics in the development of oak stands. As a representative of the oak forests in Bulgaria Quercus conferta Kit was chosen.

Such a criterion was found to be the height of the trees in the stand. Strong correlational links were found between the height of the trees, on the one hand, and the following features of the stand, on the other: number of trees per ha, distance between the trees, diameter, height of the crown, and crown diameter.

Keywords: Forestry, oak stands, optimum structure and development

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THE REPRODUCTION OF MEDITERRANEAN FORESTRY PLANTS OUT OF THEIR HABITAT. EXAMPLE: THE ATLAS CEDAR

C. Argillier,[1] G. Falconnet,[2] D. Mousain,[3] and J.M. Guehl[4]

This paper presents the experimental results of assessments of choosing container, type, substrate, nutrition and controlled mycorrhization on plant growth. The results demonstrate the necessity of using anti-coiling containers with a 400 cm3 minimum volume.

Substrate plays an important part in root development and seedlings physiology. Height quality seedling are now being grown on a mixture of 50% long fibre peat and 50% composted pine bark. Supplying mineral elements to this substrate proved essential to allow seedling development. These supplies can consist in weekly waterings with a nutrient solution, complementing a fertilizer incorporated in the substrate during its preparation. As regards controlled mycorrhization, the first results show that inoculation success is tightly bound to type of inoculation: only sporal inoculation with *Tuber albidum* reached the mycorrhized seedlings.

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CRITERIA FOR HYDROLOGIC AND EDAPHIC CHARACTERIZATION OF SOIL PREPARATION SITES PRIOR TO REFORESTATION

J.A.Fernández[1], V.Gómez[2] and M.Roldán[1]

The recent introduction of machinery and implements specifically designed for soil preparation tasks prior to reforestation has brought in its train the need - from the technical standpoint - to establish a methodology for appraising the characteristics of the work done with the respective kind of instrument so that objective criteria can be used in selecting the most appropriate for the purpose. The actual device will be particularly important for reforestation in Mediterranean areas with their convergence of climatic, physiographic, edaphic and plant cover characteristics, making the reforestation of such plant cover especially difficult. Among the climatic factors two aspects are critical for the design, volume and execution of soil preparation with reforestation in view. One concerns the marked annual drought, which may compromise the success of the stand, particularly in the early years when the young plants are at their most vulnerable. The other concerns the frequent heavy rains, with the intense erosion to which they may give rise, breaking up and displacing more soil than normal rain will do in the course of several years. Parameters are defined, together with the relevant measurement techniques, for characterizing the hydrologic and edaphic effects of these operations. The following order is defined: 1. Define the hyrologic and edaphic effects of soil preparation operations for reforestation purposes; 2. Establish parameters for appraising these effects; 3. Establish methods for measuring the parameters.

Keywords: soil preparation for reforestation; runoff control; erosion control.

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MANAGEMENT PLANNING OF INDUSTRIAL PLANTATIONS IN TANZANIA - PRINCIPLES AND EFFORTS

Arnold J. Ahlbäck[1]

The Industrial plantations in Tanzania are mainly softwoods. They are divided into a number of forest projects spread over the country. As they were established during a much shorter time than the ideal rotation, and the yearly planted area varied in size, the yearly wood supply (potential or allowable cut) fluctuates. It needs to be levelled out. In addition the processing capacity for plantation wood is much lower than average wood supply and most existing softwood stands will be clearfelled much later than the ideal rotation.

Instead of harvesting planning based on a theoretical rotation only, the clearfelling age must be forecast for each stand. Thinning should make each stand fit to reach the forecast age; the first thinning especially must be carried out on schedule regardless of current processing capacity, market and road access. Silviculture planning should normally be based on needs, priorities, and resources available.

Management plans for the industrial plantation projects before 1981 included silviculture needs only; harvesting had hardly started. The management plans for 1981/82-1985/86 included silviculture and harvesting considerations but were characterized by recording rather than planning. The model introduced in 1985 (for 1986/87-1990/91 to begin with) is characterized by "rolling" planning (to be renewed every year) based on the above principles, and an aggressive marketing.

During the first years of the new planning approach, the project managers needed a lot of guidance which, however, was not provided sufficiently which reduced the success of the new approach.

Keywords: industrial plantations, wood supply, processing capacity, management planning

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THE OPPORTUNITIES AND THE NEED FOR FOREST PLANTATION INVESTMENTS IN THE WORLD AND IN TURKEY

Nibat GökyiXit,[1] Ali Sencer Birler[2]

Forest cover on the surface of the earth plays a critical role in maintaining the global climate balance. The explosive growth of the world's population, integrated with technological development, creates severe threats to forests. The global demand for wood will likely reach some 5 600 million m^3 by the year 2020, and this amount of wood cannot sustainably be met by removals from existing natural forests. Therefore, greater support must be given to industrial plantations with fast-growing tree species aimed at wood production to fill the deficit between demand and supply and to take pressure off natural forests in the interest of their conservation, biodiversity and environmental quality.

Keywords: Plantation, supply and demand, investment.

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INFLUENCE OF TRANSPLANTING ON SEEDLING GROWTH AND POST-PLANTING SUCCESS IN ORIENTAL SPRUCE

M. Genç[1] and N. Bilir[1]

The study was carried out in nursery stocks of *Picea orientalis* (l.) Link. Aged 5+0 (untransplanted control seedlings), 2+3A (transplanted in autumn), 2+2S (transplanted in spring), 2½+2½ and 1½+2½ (transplanted in mid-summer). The stocks were raised at "Of Forest Nursery", and plantation trials were set up at "Kapukőy-Maçka" in northern Turkey. According to the major morphological properties measured in the nursery, 2½+2½ transplants were the best quality saplings. However, differences between the other seedlings were not generally statistically significant. When the results of three years' survival and growth in the plantations were considered, the post-planting success of transplants was better than untransplanted stocks. Thus, the best height growth was obtained from 2½+2½ transplants, whereas differences between 5+0, 2+3A and 2+3S seedlings and between 2+3S and 1½+2½ transplants were insignificant. Besides, planting shock lasted for two years in all saplings, i.e. transplanting treatment and transplanting season did not affect the period of planting shock.

Keywords: Transplanting, transplanting season, morphological properties, planting success, planting shock

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STUDIES ON THE PROPAGATION BY CUTTINGS OF SOME BROADLEAVED TREE SPECIES IN TURKEY

Mustafa KÚzmaz[1]

An experiment was carried out on the propagation of six tree species (sessile oak, common oak, turkey oak, valona oak, Hungarian lime and Caucasian ash) using four IBA solution levels (0%, 0-5%, 1% and 2%) in sand plus perlite (1:1).

The experiment was designed to test the best solution level of indole butyric acid in the rooting of each species. Using the results of this experiment, a second experiment was carried out using eight tree species (black locust, common oak, oriental plane, Caucasian ash, Hungarian lime, oleaster, ashleaf maple and Turkish sweet gum), three rooting media and the most effective level of auxin (0-5% IBA). The results of the experiment are detailed in the paper.

Keywords: Cutting, vegetative propagation, softwood cutting, rooting percentage, root formation, root numbers, broadleaved tree species.

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THE EFFECTS OF DIFFERENT GROWING MEDIA FOR BLACK PINE AND RED PINE SEEDLINGS

Mehmet Sayman[1] and Halil Çolakoglu[2]

In Turkey, afforestation studies are increasing year by year. It is necessary to use high quality seedlings with a high growing performance and adaptation to afforestation sites which present problems relating to climate and medium in order to achieve a decrease in afforestation costs.

In these sites, the expected success is achieved with containerized seedlings raised with modern growing techniques.

In nurseries where such seedlings are propagated, the mixture of loam thatwas used consisted of soil, sand and organic material such as compost. However, these seedlings were not of an adequate standard because of some unfavourable features of the medium. This caused some failures in the afforestation areas.

In our study, we examined 21 media for black pine (*Pinus nigra* Arn.) and 64 media for red pine (*Pinus brutia* Ten.) that were prepared with different mixtures of materials to obtain a favourable medium. The physical and chemical features of the media were determined by analysis. The black pine seedlings were grown in media placed in three pot-trays, each pot having a volume of 200 cm^3
.

The seedlings were manured and irrigated according to a controlled standard. At the end of one growing season, the black pine and red pine seedlings which were produced in the media given below were found to be suitable for planting into afforestation sites in consideration of their morphological features such as height, diameter, stem and root weights.

The media which were used for growing black pine consisted of substrates 100% cameli peat, cameli peat-pine sawdust (5:5), cameli peat-thick reed (5:5), cameli peat-volcanic dust (7:3), mushroom compost-buldan reed (5:5), mushroom compost-thick reed (5:5), mushroom compost-sesame residual (7:3), mushroom compost-maize stalk (7:3), and mushroom compost-sawdust (7:3).

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CHOICE OF EXOTIC CONIFEROUS SPECIES FOR INDUSTRIAL PLANTATIONS IN TURKEY

Korhan Tunçtaner[1]

Considerable progress has been made on introduction of exotic species to Turkey in the last decade. Many species and provenances have been tested and industrial plantations have been established with promising species at the coastal sites of Turkey. The evaluations made in recent years on growth performances of promising species proved that *P. pinaster* and *P. radiata* were the most suitable exotic species in the Marmara and Black Sea regions for the establishment of industrial plantations. The indigenous species, *P. brutia*, should be considered as a fast-growing species for the plantations in the Aegean and Mediterranean regions.

Keywords: Exotic species, species introduction, trial site, provenance test, growth, performance

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MECHANIZATION TECHNIQUES IN INDUSTRIAL PLANTATIONS

Taneri ZoralÚoZlu[1]

Turkey's natural forests can be conserved and wood supplies supplemented by supplying the raw material to the industry from the private plantations. Such industrial plantations can be established by using intensive methods on medium to deep soils which have a slope of up to 20 %.

In this paper the best land clearing methods for soil preparation and weeding for different vegetative types are recommended together with estimates of man days required to complete operations. The most important point of the soil preparation techniques described is water conservation and the use of water economically in the rehabilitation of arid land and semi-arid areas.

Keywords: Mechanization, Plantation, site preparation, weeding, unit times.

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CONTRIBUTION OF THE SYSTEMS APPROACH TO THE MANAGEMENT OF THE SYSTEM OF NURSERY PRODUCTION

M. VukiDevic,[1] N. RankoviD,[1] A. VlainiD

The proposed modern concept of operations management in the systems of nursery production, which from the systems management aspect belongs to the category of open systems, is at the tactical level of dynamic systems management and consists of two stages. The essential elements, necessary for the understanding of the concept of operations management, are presented using an an example the first year of production of two-year old Austrian pine seedlings. Stage 1 involves the preparation of an annual plan for each species of seedling, and is presented by a network plan. This stage determines the required manpower and technical resources, the necessary quantities per type of material, finances, etc. Stage 2, based on the network plan, includes the preparation of quarterly plans according to term units (weeks) and is presented by a transplan. This stage enables the elimination of disturbances, e.g. parameter disturbances resulting from changeable microclimatic conditions, by open loop control, analysis of the limited resources in the time function, optimum strategy of managing material supplies, active analysis of changed direct costs resulting from the engaged resources or modified methods or work, etc. The presented concept of operations management in the systems of nursery production has been based on the principles of the theory of systems adapted to the specificities of plant production in nurseries, i.e. work with living material, in open and extensive areas, diversity of assortment and production of seedlings of various tree species, with different characteristics, age, purpose, etc.

Keywords: Nursery production, open system of management, open loop control, network plan, transplan, direct costs

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COMPARISON OF DIFFERENT METHODS OF SEED SOWING OF OAK SPECIES FOR REFORESTATION OF WESTERN OAK FORESTS IN IRAN

Mohammad Fattahi[1]

Western oak forests in Iran are situated in a semi-arid climatic region,where water deficit in the growing season is one of the important factors for reforestation of these forests.The object of this research project is the comparison of 4 methods of direct seeding(*usual pit, bowl pit, furrow, banquette*), with 3 oak Species(*Quercus libani,Q.persica,Q. infectoria*). The results show that:

1. There are significant difference between methods and species at 1% level and bowl pit and usual pit , and *Quercus libani and Q.persica* give the best result .
2. The average seedling survival was 47.7% at the end of the first growing season which after five years reduced to 22.4% .
3. Maximum average germination was 71.4% and germination period lasted one and half months after spring rainfall .
4. Stem/root ratio in the end of periods was from 1/5 to 1/12.
5. Banquette methods in addition to its high costs has low seedling survival and had most damage by fauna .

Keywords: direct seeding , oak (Quercus),seedling survival ,different methods ,human activity .

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CONTROL OF FOREST TREE SEEDLING DEVELOPMENT IN THE NURSERY BY GROWTH RETARDANTS

Nir Atzmon[1]**, Meir Ordan**[2]**, Joseph Riov**[2]

Uniconazole, a growth retardant, was applied as a foliar spray at different concentrations to seedlings of *Eucalyptus camaldulensis* and *Pinus pinea* in August (five months after sowing). The data show that uniconazole significantly decreased height growth of both species tested and increased root/shoot ratio at the end of the growing period in the nursery. Fourteen months after outplanting, treated seedlings of *E. Camaldulensis* recovered completely from the inhibitory effect of uniconazole, while treated *P. Pinea* seedlings were still shorter than control seedlings.

The results of the present study suggest that foliar spray with uniconazole might improve seedling quality of some species by inhibiting only shoot growth which results in an increased root/shoot ratio.

Keywords: Uniconizole, root/shoot ratio, field performance, *Eucalyptus camaldulensis*, *Pinus pinea.*

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Summaries of voluntary papers

(The following summaries are only published in original language)

ARACRUZ CELULOSE AND SUSTAINABLE EUCALYPTUS PULP PRODUCTION IN BRAZIL

Aracruz celulose s.a.

Aracruz Celulose is the world's leading supplier of bleached market eucalyptus pulp, used to produce tissue, printing, writing and specialty papers. More than 90% of our sales are exported, mainly to customers in Europe, North America, and Asia.

The Company's integrated operations include eucalyptus plantations — native wood is not used in the process nor for any other purposes —, a pulp mill and a private port facility. The pulp mill is located in the municipality of Aracruz, in southeastern Brazilian state of Espírito Santo, and the forests in northern Espírito Santo and southern Bahia State.

Out of the 203,000 hectares of Company-owned land, 132,000 hectares have been planted with eucalyptus and 57,000 hectares are kept as native reserves. The industrial complex consists of a pulp mill with a design capacity of 1,025,000 tonnes of pulp per year, facilities for chemicals recovery, water treatment and energy generation and an electrochemical unit to produce the chemicals used in the process. The port is located at 1.5 kilometers from the pulp mill, and is the only one in Brazil especially designed for shipping pulp.

Voting stock is controlled by the Lorentzen, Mondi Brazil, and Safra groups, each with a 28% stake, while the BNDES (Brazilian Social and Economic Development Bank) holds 12,5%. Aracruz stock is also listed on the Rio de Janeiro, São Paulo and New York stock exchanges. Investment to date in eucalyptus plantations, mill and social infrastructure exceeds US$3 billion, at replacement prices.

All of our activities are carried out under the principles of sustainable development, which involves promoting social and economic growth in harmony with nature. Aracruz is an active member of the World Business Council for Sustainable Development (WBCSD) and was among the first subscribers to the International Chamber of Commerce's (ICC) Business Charter for Sustainable Development.

REBUILDING DEGRADED ECOSYSTEMS: A SUSTAINABLE COMMUNITY FORESTRY APPROACH

Carlos Antonio Alvares Soares Ribeiro[1] and Laércio Couto[2]

In Brazil, over 20 million hectares of degraded land have currently been identified as being available and suitable for commercial reforestation projects (Ab'Saber, 1990). The common practice is to establish large areas of monocultures, mainly eucalypt or pine plantations. This alternative for land rehabilitation, however, does little to promote biodiversity. A key point for well-designed and successful reforestation projects is to take into consideration a broader range of both native and exotic species to re-occupy the land, as well as agricultural crops, if the approval and commitment of local communities is to be achieved. Ribeiro *et al.* (1996) proposed a new approach that generates a temporal and spatial mosaic of several species and promotes sustained yield by the end of the establishment of a reforestation project. This approach also ensures spatial rotation of species at the stand level, thus improving carrying capacity while reducing soil exploitation. The methodology is flexible enough to accommodate a large variety of designs, including those of agroforestry. The careful matching of species to sites plays a fundamental role in the improvement of biodiversity, not precluding antropic activities.

The objective of this paper is to address the problem of land rehabilitation through community forestry projects that promote a diverse, steady and solid agroforestry-based economy while being environmentally sound. Management guidelines are derived so as to achieve both forest regulation structure and different production goals for the different species that integrate the project. A hypothetical case study is thus presented.

Keywords: Reforestation, land rehabilitation, sustainable community forestry

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ECONOMIC EVALUATION ON COMPOSITE BREEDING SEEDLING ORCHARD OF CARIBBEAN PINE FOR SUSTAINABILITY

Su Xianfeng[1]

Establishing a Composite Breeding Seedling Orchard (CBSO) of *Pinus caribaea*, as one type of the Multiple Population Breeding System, has not only economic value, but environmental benefit as well. In this paper the economic evaluation of CBSO is conducted by using benefit cost analysis, profit and loss analysis, sensitive analysis.

The results indicate that establishing and managing the CBSO the benefit/cost rate from its seed and timber production is 4.4, the internal rate of return is 13.45%, the net profit is 11720 yuan (Chines RMB) per hectare per year, with an investment return period of 17 years. The social benefit, that is the benefit of planting with improved seed from the CBSO, namely the genetic gain benefit, will be 120 times as much as the direct profit of CBSO. Though the hereditary value and gene conservation value are not marketed, they are high and accrue to society. Since CBSO is a form of structured breeding populations, combining many functions together and with sustainability, some demand-side incentives should be given to develop the CBSO.

Keywords: Economic evaluation, *Pinus caribaea,* Composite Breeding Seedling Orchard, sustainability

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SHOOTS EMERGENCE, DEVELOPMENT CHARACTERISTICS AND PLANTATION MANAGEMENT OF *BAMBUSA BLUMEANA* IN THE PHILIPPINES

Yang Yuming[1] **and Armando M. Palijon**[2]

As a non-wood forest product, bamboo has supported both large and small-scale industries, creating employment for millions of people. As a result, the steady increasing demand for bamboo has contributed to the rapid and unregulated cutting of bamboo stands that are found in the country-side and are naturally distributed in the mountains. To ensure a stable supply of raw material for the bamboo-based industries, bamboo stands that have been cut down need to be replaced and developed.

This paper presents the results of a research on the biological characteristics and management technology for high-yield of economically important species in 1995, and can be considered as a good beginning to make continuous studies on the subject which is of interest to both the Philippines and China.

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NURSERY LEVEL EVALUATION OF SEEDLING QUALITY OF (*AZADIRACHTA INDICA* A. JUSS.) USING BIOMETRICAL TRAITS

K. Kumaran[1] and C. Surendran[1]

Seeds were collected from 28 one-parent families of Neem *(Azadirachta indica)* representing six agroclimatic zones of Tamil Nadu, India. Seedlings were raised from these seeds to evaluate the quality of the planting stock. Observations were recorded on six-month- old seedlings for biometrical traits, viz. height, root length, collar diameter, number of leaves, shoot, leaf and root dry weights. Three new secondary parameters, viz. sturdiness quotient (SQ), volume index (VI) and quality index (QI) were calculated, using the primary biometrical traits, to test the seedling quality. Lower sturdiness quotient, higher volume index and quality index reveal the best quality of the seedlings to be planted out. Hence these three parameters were used as selection indices in this experiment. Results revealed that there was a significant variation at one per cent level among 28 one-parent families for these indices. The one-parent family 7 (Vamban) showed the lowest SQ (2.10), family 27 (Thanjavur) recorded the highest VI (1929.25) and family 26 (Dharmapuri) exhibited the highest value (0.93) for QI. Thus it was concluded that these three one-parent families were the best planting stock among the 28 tested.

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IMPEDIMENTS TO SUSTAINABLE DEVELOPOMENT OF FORESTS FOR PULP AND PAPER INDUSTRY (PPI)

Manorama Savur[1] and Sunanda Karnand[2]

The history of the use of bamboo and eucalyptus species in Indian Forestry is critically reviewed and it is concluded that vested interests, rather than ecological understanding, have been the principal motivating forces in the use of the species.

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USE OF INTENSIVE SOIL WORKING TECHNIQUE IN AFFORESTATION OF WASTELANDS.

V. R. Singh[1]

The degraded forest wastelands are prone to heavy grazing and are consequently eroded and compacted. Therefore, 90% of rain water runs away leaving very little portion of it to percolate into the sub-soil. By traditional pit planting method only about 20.25 m^3 rain water can be harvested per ha at given time. This is highly inadequate. The paper deals with technique of water retention through ploughing and digging of 'V' shaped furrows intercepted by small bunds at 2m intervals. By this technique1500 mcube of rain water can be harversted per ha at a time. This technique is very relevant to plain areas of low rain fall and high temperature zones, particularly, the drought prone areas of Maharashtra state.

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IN MANAGING THE INDONESIAN PLANTATION FORESTS: IS EXPERT SYSTEM APPLICABLE?

Iman Santosa Tj.[1]

The Expert System (ES) is a computer system that uses expert knowledge to reach a level of performance akin to that achievable by a highly skilled expert. The system is an example in artificial intelligence application. This paper discusses some basic concepts of the Expert System in relation to Indonesian Plantation Forest development. Some aspects discussed among others are the benefits, limitations and application of the system.

Keywords: Indonesian Planatation Forest, Expert System, Inference Engine, Knowledge Base, User Interface, Artificial Intelligence.

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REFORESTATION OF CUT-DOWN FORESTS IN ARMENIA

Ruben Petrossian[1]

Armenia is a mountainous country with a limited forest cover of 334 100 ha. Due to the energy crisis, the forests of Armenia were considerably damaged. Illegal cutting and grazing brought to the partial or complete destruction of 27 000 ha (8.1% of the forested area) of forests and young plantations, of which 6 000 ha were clear-cut.

Soil erosion processes have already begun (on the clear-cut areas near the town of Vanadzor, more than 100 ditches of different depth appeared during the past 2-3 years). Landslides, salinization and other soil degradation factors have also been observed. The necessary arrangements for reforestation; description of work; management mechanisms; possible economic, ecological and social advantages and also obstacles are discussed.

Keywords: Illegal cutting, reforestation, soil degradation, ecological balance.

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SHORT ROTATION POPLAR COPPICE, A COMMON APPROACH TO PRODUCE PULPWOOD AND FUELWOOD

P. Bonduelle[1], A. Berthelot[1] and J. Sionneau[2]

Since 1983, the ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie) and European Union have been supporting AFOCEL R & D programs of ligno-cellulosic biomass, with Poplar Short Rotation Coppice (SRC), especially planted at 2,000 or 3,000 stems/ha. Cultivation and harvesting guidelines are aimed at pulpwood, with logs production. Cultivation and harvesting every two years in the case of very short rotation coppice (2 years and 10,000 stems/ha) create 3 problems:

- high cost of crop,
- low bearing capacity for chippers,
- very important exportation of nutrients: high ratio of bark.

Why not choose the same guidelines for pulpwood and fuelwood ?

These two utilisation possibilities provide a better guarantee to producers.

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EFFECT OF ABIOTIC ENVIRONMENT ON *PINUS SYLVESTRIS* HEIGHT GROWTH:A CASE STUDY AT THE NORTH-EASTERN BLACK SEA REGION

Zafer ÖLMEZ[1] and Zafer ASLAN[2]

The predicted rate of global warming and changes in precipitation patterns will strongly effect forest and ecosystems. Global climate modelling shows that with global warming on an annual average there will be a negative trend at middle latitudes. To define the abiotic environment effect, a set of average monthly temperature, precipitation and relative humidity observed at a nearby weather station was considered. In this paper some climatological parameters recorded in Artvin (41° 10' N, 41° 49' E) and Ardanuç (41° 10' N, 41° 03' E) between 1950 and 1996 have been statistically analysed. This study has been carried on a pilot area of 200 ha in Ardanuç (Artvin) covered with Pinus sylvestris. Height growth of trees has been measured for the sample area. Some results of single and multiple regression analysis amongst height growth and climatological parameters are presented. Air temperature variation plays an important role on the growing rate. It is inversely proportional to variations in relative humidity and precipitation.

Keywords: *Pinus sylvestris*, height growth and meteorological parameters

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WEEDS OF ORDU PROVINCE BEECH NURSERY AND THEIR CHEMICAL CONTROL

Rahim An• in[1] andœükran Gökdemir[2]

In this study, the most important weed species of Ordu Province Beech Nursery (Turkey) were determined and their chemical control with simazine and chlorthal dimethyl was investigated. The chemicals gave good control of weeds as pre-emergence (simazine: 3.0 kg/ha, chlorthal-dimethyl: 11 kg/ha) and post-emergence (simazine 1.0 kg/ha). The effects of the chemicals on seedling emergencies, seedling heights and seedling dry weights were also investigated and found to have no significant adverse effect on these parameters; the lower effective dosages were found to be recommendable.

Keywords: Chemical weed control, forest nursery herbicides, weeds, beech *(Fagus orientalis* Lipsky).

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A STUDY OF EXPANDING THE USE OF MEDITERRANEAN CUPRESSUS IN IRE LAND IN AEGEAN MEDITERRANEAN REGIONS

Selma Co• kun[1]

Two different experimental steps took place in this study and it was adapted to nursery conditions and similar experimental design of greenhouse. In the first step, the studies of uprooting of cuttings made real with optimum wet, heat and automatic spring watering systems under completely controlled conditions. In the second step, the studies were designed under nursery conditions without applying a special wet, heat and watering system.

The main reason of this study is to present an alternative production system for the problems caused by seed production in the production of Cupressus Sempervirens var. Pyramidals (Tar-et. Tozz). In addition to being a windbelt against wind which is an egologically limiting factor and having rapid-growth characteristics, cupressus can be used in the stabilisation of erosion land and the sides of fire security roads and plantation planning studies. It will also be possible to expand cupressus which can also be used as exploitable material by planting in ecologically suitable areas. For that reason, there was a 100% success in uprooting of cuttings taken from 2-year old seedlings after the implementation of IBA hormone with 0.3% concentration under greenhouse conditions, especially in the ponza environment.

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MULTICRITERIA DECISION-MAKING IN AFFORESTATION BY THE ELECTRE METHOD: AN EXAMPLE FROM TURKEY

Ahmet Türker[1]

It is estimated that about 8 million ha of degraded forest land in Turkey has to be restored by afforestation. It is necessary to determine an order of priorities, because it is impossible to carry out this task simultaneously, throughout the country. Since forests provide more than one benefit, it is necessary to take into account all of the benefits in each area when making decisions about the relation of afforestation locations, techniques and species. This paper describes a multicriteria decision-making process using the ELECTRE method that takes into account eight environmental, social and economic criteria without having to assign money values in choosing between 12 alternative plantation options.

Keywords: Afforestation, investments, decision-making, multiple criteria, alternative.

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FACTORS AFFECTING SURVIVAL AND EARLY GROWTH OF SEEDLINGS

Ulvi Tolay[1]

Between lifting and planting, seedling roots are exposed and vulnerable to environmental stress, particularly temperature and moisture extremes. Moisture and root growth potentials most often limit seedling establishment once the site is prepared to provide enough moisture for growth. Nursery practice such as irrigation, fertilizing and varying the bed density, transplanting, undercutting, wrenching and proper handling are all used to manage seedling survival and early growth in plantations.

Mortality or poor growth may be clearly due to a number of factors, in the nursery or as a result of handling practices, or site factors. The mechanical, meteorological, biological and other factors affecting the performance of the seedling certainly have physiological effects, no doubt often of a complex nature. While these may in time be elucidated by the use of controlled-climate laboratories, the final evaluation must always be the performance of the seedling in the forest.

Keywords: Nursery, plantation, seedling growth, survival.

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INVESTIGATION OF EFFECTS OF SEED MATURATION CHARACTERISTICS ON NATURAL AND ARTIFICIAL REGENERATION WORKS IN THE SCOTCH PINE (*PINUS SYLVESTRIS L.*) AND BLACK PINE (*PINUS NIGRA ARN. SSP. PALLASIANA LAMB. HOLMBOE)* STANDS OF THE WEST BLACKSEA REGION

Suat Tosun[1] and Metin KaradaZ[1]

Black pine (*Pinus nigra Arn. Ssp. Pallasiana Lamb. Holmboe)* and Scotch pine (*Pinus sylvestris L.)* are main tree species. Black pine forests cover 2 283 175 ha totally of which 1 474 098 haare of good quality, and 809 077 ha degraded high forest. Scotch pine forests cover 717 468 ha totally of which 454 612 ha are of good quality, and 262 856 hadegraded high forest (*O.A.E. 1980).*

When we looked at regeneration studies between the years 1964 and 1992 (age classes forest management was applied in these years), it seems that the natural regeneration success of species according to plans is only about 5-10%, excepting removals in natural storied Black pine stands.

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