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Afforestation and plantation forestry

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Abstract

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 realised 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.

Afforestation and plantation forestry

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* Pandy 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.

The global extent of plantation forests in 1990 is estimated at around 135 million ha (FAO 1993, Gauthier 1991, Pandy 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, Pandy 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, Pandy 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 (Pandy 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 Sutton's (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, Pandy 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 (Pandy 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, Kizmaz 1997, Lemcoff *et al* 1997, Salerno and Giménez 1997, Sharma *et al* 1997, Stanturf *et al* 1997, Tunçtaner 1997, Zoralioglu 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* Ahlbäck 1997) to the sophisticated (*eg* Pritchard 1989); the lack of effective systems has been a major constraint to, in particular, many tropical plantation enterprises (Pandy 1997);

- there is a 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* Pandy 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 (Pandy 1995), as the international forestry community began to focus on how trees could better meet the needs of the world's poorest people. Non-industrial plantation establishment has been greatest in Africa and Asia (Pandy 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 landowners' interests and priorities as well as those of the forest industry's, 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 Australia's 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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