Ecological and Socio-Economic Impacts of Close-to-Nature Forestry and Plantation Forestry: A Comparative Analysis

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Preface

Close-to-Nature Forestry or *Plantation Forestry?* Which concept should be applied in forest management? This question is discussed controversially and often emotionally. The impacts of the two contrasting management concepts were discussed at the EFI Scientific Seminar in conjunction with the annual EFI conference in Lisbon in September 2000. The papers were presented in four sessions:

1. Ecological impacts: biodiversity and genetic diversity;
2. Ecological impacts: water and nutrient cycles and ecosystem stability;
3. Wood production and resources in terms of quantity and quality; and
4. Political and socio-economic aspects.

The wide range of the impacts is discussed in a comparative analysis. The results of the scientific discussion show that there is not one single answer to this question. The growing human population is placing ever-increasing demands on the world's forest resources. The increase in the population, expected to be 10 billion by the middle of the twenty-first century, will require at least 2.5 billion m^3 more wood each year, than can be supplied from the forests existing at the end of the twentieth century (Tomé, this proceedings). As well as requiring increased timber supply, society also places demands on forests for other goods and services: provision of non-timber forest products, protection of water and soil resources, habitat for wildlife, maintenance of biodiversity, forests for recreation, forests as a unit of socio-cultural identity. Although one function might be emphasized over others in a particular case, all types of forests may serve a number of these functions to some extent. Plantation Forests and Close-to-Nature Forests and the complete range of forests between these extremes may provide various goods and services that society demands. We hope that the selection of papers presented in this volume will contribute to the important debate on how the world's forest resources should be managed.

The Seminar was organised by the Instituto Superior de Agronomia, the National Forest Research Station (Portugal) and EFI. I would like to express my deepest thanks to the organisers of this seminar, the authors and Tim Green for his assistance in editing the proceedings.

Heinrich Spiecker
Chairman of the Scientific Advisory Board of EFI

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Ecological Impacts of Plantation Forests on Biodiversity and Genetic Diversity

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Abstract

The rapid demographic evolution of the human population has increased pressure on forest areas and the demand for forest products: deforestation in natural forests (mainly tropical) as well as creation of new plantations are the direct consequences. Genetic diversity and biodiversity (and their assessments) are briefly reviewed within the context of plantation forests. Ecological impacts of plantations (essentially monospecific and even-aged) are analysed and discussed, covering the effects on:

- number of plant and animal forest species, as well as genetic diversity within forest tree species. Forest gene transfers and exchanges between wild and genetically improved populations;
- spatial and temporal forest structures:
  - size and shape of forest stands, between stands and agriculture-forest interactions;
  - rotation time;
  - impact on genetic variability, percentages of old and dead trees;
- regeneration processes:
  impacts of clear cuts on biodiversity, soil erosion and landscapes, adaptation of the forest gene pools to rapid climatic changes and demand for new forest products.

Ecological impact of plantation forests on biodiversity can be improved through traditional methods (habitat and genetic resource conservation areas) and innovative techniques (e.g. biodiversity ‘islands’ included within new monospecific plantations). With some limitations and recommended improvements, the planted forest option remains acceptable, even when taking into account its consequences for biodiversity. New research and monitoring areas, where the impact of plantations on biodiversity can be measured, are always necessary. A co-ordinated European research programme involving private and public foresters will develop

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sustainable plantation forest management practices that minimise adverse impacts on biodiversity.

Keywords: forest plantations, biodiversity, genetic diversity, indicators, sustainable forest management

1. Introduction

The rapid demographic evolution of the human population has increased pressure on forest areas and the demand for forest products. This pressure on natural forests is partly alleviated by the 120 million ha of plantation forests in the world. These plantations are potentially able to produce 370 million m^3 of roundwood per year, and represent about 25% of the global roundwood production (1995 FAO statistics, cited in Whitman and Brown 1999). From the same source, it has been estimated that the world demand for wood and wood products could increase by 25% over the period 1996–2010, requiring another 120 million ha of forests to be planted during the same period. The expected tendencies would, therefore, be to move more away from natural forest towards forest plantation and non-forest supply sources. The whole context is also characterised by an increasing consumption of energy in the industrialised nations, the dramatic rise of $C0_2$ concentration, and global warming of the atmosphere. The increasing anthropic pressures and the rapid changes in physical environment justify more plantation forests using fast growing species, to improve wood production and carbon fixation, but at the same time requiring a high level of biodiversity and forest tree genetic variability to maintain the adaptive potential of the forest ecosystems. Are these contradictory trends compatible, and how can we sustainably meet such a technical and social challenge?

2. Genetic Diversity, Biodiversity and their Assessment

2.1 Biodiversity

Biodiversity is a recent and general concept integrating all levels and forms of the diversity of living organisms: from genes to ecosystems and communities, including between and within species genetic diversity itself. The term ‘biodiversity’ appears for the first time in 1986 in a National Research Council report dedicated to “The crisis of biological diversity” (NRC 1986, reported by Wilson 2000).

In our case, this concerns the survival over time of all different forest life forms: trees, other plants, birds, mammals, insects and micro-organisms. There are three complementary approaches to studying biodiversity. The first attempts to provide as complete a description as possible of the different species belonging to a given ecosystem (involving species inventories and mapping of localisation), for example Bordères et al. (1997). The second tries to assess biodiversity, classically through the number of species existing within the ecosystem. The third approach aims to explain the functional role of biodiversity: sharing the species between different functional groups, searching to identify redundant or key species, and establishing relationships between species and their role in controlling ecosystem stability.

The ultimate aim is to identify the main mechanisms and the key species, able to explain or to predict the evolutionary trends and the means of survival of the ecosystems (Di Castri and

Younes 1990; Naeem 2000). It is commonly accepted that complex ecosystems (with numerous inter-related species involved) are more stable than simple ones (Elton 1958; MacArthur 1955), but observations and experiments are still scarce (Yachi and Loreau 1999; Loreau 2000) and they do not systematically confirm this principle (Goodman 1975; Grime 1997). The functional characteristics of the species belonging to one plant community could be more important than their number, in explaining the stability or instability of a community. In such an approach, the functional mechanisms (able to control genetic diversity and demography, themselves linked with competition phenomena and adaptation to environmental conditions), become the major focus, and they could justify research and characterisation of a limited number of species sufficient to explain the evolution of the ecosystem. According to information coming from the few experiments to date, or from systematic observations, it would appear that the fewer the number of species in any one functional group, the greater the control that may be exerted by any dominant species over ecosystem processes (e.g. the observed degradation of the Pacific Northwest kelp ecosystem, caused by the rapid extension of sea urchin, which in turn was caused by a dramatic decrease in sea otter numbers).

Before confirming the importance of number of species with respect to ecosystem stability, we need more experimental designs focusing on the functional role of biodiversity (Loreau 2000). This would address the question of identifying criteria or indicators relevant to the estimation of forest biodiversity (in particular for the assessment of forest ecosystem stability). In spite of the fact that biodiversity continues to be frequently expressed in terms of inter-specific variability and number of species within a given ecosystem, it would be more useful to characterise the variations between ecosystems and communities by fuller description of forest biodiversity, in order to identify a representative sample of forest ecosystem to study and to preserve. Even if we can be doubtful about the interest of an indicator of biodiversity only based on the number of species, a more systematic description and mapping of the species composition of the forest habitats, can serve the conservation of a representative sample of forest habitats, and therefore, the conservation of genetic diversity of more numerous forest tree species, including those of minor or no economic importance to date.

More sophisticated approaches of biodiversity indicators for a sustainable management of European forests were recently reviewed (Ferris and Humphrey 1999) or initiated (e.g. through the BEAR project, a new European project aiming at developing a system of indicators of forest biodiversity; BEAR 2000).

2.2 Forest tree genetic resources

Within biodiversity, the concept of forest tree genetic resources addresses only the genetic part of the differences between forest tree populations (races, ecotypes and provenances) and between individuals within these populations.

2.2.1 Assessment of the genetic variability

For a limited number of forest tree species (those economically important and used for wood production, often planted and genetically known through selection programmes) we can make two complementary assessments of the genetic variability (Petit et al. 1997):

- using molecular markers (supposed to be neutral regarding the effects of the natural selection); and
- using adaptive traits (growth, phenology, stem and branch form, insect and disease resistances, etc.).

The significance and value of these two kinds of assessment are different (Godelle et al. 1994; Petit 1999; Kremer 1994):

- molecular diversity is more a result of the past genetic history (variations over time in population size, migrations and geneflows – as illustrated by Kremer et al. 1998; Petit et al. 1997); and
- adaptive variability is supposedly influenced mainly by natural selection and adaptation to environmental and anthropic pressures (clear-cuts, silvicultural practices, air pollution, global warming, etc.). It is assessed by lengthy and costly provenance and progeny tests.

The fast development of tools for genetic studies and plant genetic resources conservation (Karp et al. 1997) enables the precise location of the ice age refugiums, the corresponding expansion routes of forest tree populations, and the characterisation of genetic differences between populations, if any, as well as the genetic diversity within each population (rare alleles, allele numbers and frequencies). All these parameters result in a typology of the forest genetic resources, useful for identifying a representative sample of individuals and populations to conserve *in situ* or *ex situ*. These molecular tools also allow us to assess the pollen flux between individuals and populations, the spatial distribution of genetic diversity within a stand, and subsequently, to better understand the effects of the silvicultural practices on the long-term evolution of the genetic diversity of forest trees (Streiff et al. 1998). The molecular characterisation of the forest tree populations and improved varieties will also enable us to control the movement of the forest reproductive materials (seeds and cuttings: Ditlevsen 1993) or to set up a tracking of timber origins useful for an efficient forest certification system (Petit 1999).

The results concerning the genetic variability of adaptive traits, assessed in old provenance and progeny field trials are to be combined with those obtained more recently from molecular markers, in order to better sample the forest genetic resources to conserve in each European country (Turok 1998; Turok et al. 1999).

We still lack experimental data to confirm a general relationship between the number of plant species and the resilience of a forest ecosystem, but on the other hand it is generally accepted that the adaptive potential of a forest tree species (or population) is directly dependant on its genetic variability. Consequently, we must set up a forest gene conservation network in every country, integrate scientifically-based recommendations for conservation into daily forest management practices, and use relevant breeding strategies that are able to maintain a sufficient level of genetic variability over several generations for planted species (Namkoong 1988; Eriksson et al. 1993; Eriksson 1996).

2.2.2 Setting up a national forest gene monitoring and conservation system

It is a well-recognised duty for each nation to conserve and to manage biodiversity and forest genetic resources present on its own territory (Conférence Ministérielle pour la Protection des Forêts d'Europe 1998). To succeed in such duties, several conditions must ideally be satisfied:

a) There should be a genetic inventory and monitoring system. Such a system must be able to: pinpoint those major genetic resources and threatened habitats needing priority protection; identify the nature, the level and the expected evolution of the present threats; and precisely map the distribution of genetic resources. Existing public forest services, associated with national forest inventories, relevant university laboratories, private forest owner organisations and associations of nature protection, could be co-ordinated to achieve this efficiently.
b) There should be a genetic conservation initiative. *In situ* and *ex situ* gene conservation reserves and projects (structured species by species) for major forest tree species, completed

by habitat conservation projects for forest tree species with currently low economic value and associated biodiversity. Application of such principles are co-ordinated in Europe through the programme EUFORGEN (Arbez 1994; Turok et al. 1998; Lefevre 2000).

c) There should be a long-term breeding strategy.

The strategy must aim to sustainably maintain the genetic variability of the major forest tree species over several generations (Namkoong 1988; Eriksson 1996). It would ideally include:

- recurrent selection scheme;
- clear separation between breeding population and seed production population (seed orchards);
- continuous control of inbreeding (important number of non-related initial parent trees, subdivided breeding populations, as recommended by White et al. 1993); and
- several non genetically related varieties, available at the same time for a given planted species.

3. Impacts on Biodiversity and Genetic Diversity

Before discussing the ecological impacts of plantation forests on biodiversity and genetic diversity, we need first to define what we mean by ‘plantation forests’. As pointed out by Kavanagh in 1999, “planted forests occur on every continent in all forest types and with many different objectives”. Plantation forests are diverse and have:

- multiple objectives: intensively managed wood production forests, multiple-use forests, agroforestry, ornamental urban and peri-urban forests, protection forests (sand dunes and mountainous soils fixation, watershed protection), restoration forests or conservation forests (Harrington 1999);
- various genetic material: native or exotic species, wild provenances, highly improved varieties (including clonal varieties today and GMOs tomorrow); and
- different management regimes (various structures and rotation ages).

There are probably some other forms not mentioned above. However, “the usual tendency is to limit the scope of examination to the most simplified forest monoculture that contrasts sharply when compared to natural forests” (Kavanagh et al. 1999). In spite of this, for the sake of simplicity and because most of the criticisms levelled at plantation forests essentially concern monospecific even-aged forests, we deliberately choose to focus first on the genetic impact of this special type of planted forest.

3.1 Impacts on inter-specific forest tree diversity and biodiversity

To maximise profit, the foresters often plant exotic, fast-growing species in monospecific stands. At the stand level, however, this reduction of inter-specific diversity can be logically interpreted as a potential decrease in adaptability (increased vulnerability to insects and diseases). At the regional or even at the landscape level, the use of a variety of exotic species can also increase the inter-specific genetic diversity.

Provided these introduced plantation species were previously tested during a significant part of their normal rotation time in the new environment, they can offer new adaptive possibilities for the local forest. For example, Greek fir and Mediterranean cedars offer these possibilities in the medium-elevation mountains on the northern side of the Mediterranean

Sea. The well-known summer drought resistance of these species seems advantageous in the perspective of global warming.

As in agriculture previously, introduction of exotic species in forestry has increased productivity and carbon-fixation efficiency, but also inter-specific diversity in a given region. For example, in France there are about 70 native forest tree species, and about 30 introduced species are commonly used in plantation forestry. These introduced species increase the inter-specific genetic diversity of the forest at landscape and regional levels (Le Tacon et al. 1999). To date, the fast-growing exotic species are especially recommended in Europe for plantation on abandoned farmlands.

Long-term confirmation of adaptation to local soil and climate conditions is necessary for the use of exotic species in extensive plantation programmes; particular attention should be paid to summer drought and winter frost resistance, and tolerance to hydromorphic soil conditions. However, either for economic reasons, or because of its invasive potential, an exotic fast-growing species can also supplant native forest tree species, as frequently observed with eucalypts in north-western Spain.

Impacts of plantations on associated plant and animal biodiversity, have been rarely assessed, in comparison with natural forests growing in similar conditions. Nevertheless, it is commonly accepted that plantation forests (often monospecific and even-aged) have a lower biodiversity (in terms of associated plants, mammals and birds) than natural forests. Several authors report on the unfavourable impacts of exotic species plantation on animal biodiversity (Southwood and Kennedy 1983; Kennedy and Southwood 1984; Hunter 1990; Helle and Mönkkönen 1990; Baguette et al. 1994; Gjerrde and Saetersdal 1997). Cannell, in his review of environmental impacts of forest monocultures (Cannell 1999) thinks that it is the degree of shade combined with the species *per se*, which is of overriding importance in determining the type and diversity of plant species that can exist in the understorey. In the United Kingdom, many of the same plant species occur in the ground vegetation of broadleaved plantations as do in that of native broadleaved woodlands (given similar soil and climate), and surprisingly, conifer plantations can have ground flora similar to those of broadleaved plantations, provided the conifers are thinned or consist of species that cast light shade (Hill 1987; Hill and Wallace 1989).

These observations suggest that managing the plantation densities and creating irregularities within the spatial structures – favouring the proportion of borders and clearings, preserving natural plant communities along rivers and in swampy areas – would logically increase the level of associated plant and animal biodiversity. The plantation option frequently includes soil preparation, fertilisation or amendment and these silvicultural practices are able to induce an increased microbiological biodiversity through an accelerated turn-over of organic matter (Toutain et al. 1987; Nys 1999; Le Tacon et al. 1999). On the other hand, soil fertilisation can result in homogenisation of pre-existing differences in soil fertility, and subsequent reduction in plant biodiversity. Other silvicultural practices, often associated with intensive management of plantation forests, like herbicide or insecticide application, result in decreases in plant and insect biodiversity (Dreyfus 1984).

3.2 Impacts on intra-specific genetic diversity of forest trees

Progressively, more information is being obtained on the possible impact of plantations on intra-specific genetic diversity of forest trees, but there is no one satisfactory answer to the question. This impact is clearly influenced by the type of Forest Reproductive Material (FRM) used in plantations, the quality of the FRM genetic information available and registered, and the feasibility of the control applied to it (Ditlevsen 1993). In the first European Community Seed Certification System (European Directive 66/404, now to be replaced), only two categories of

FRM were allowed to be used in plantation: selected material collected on registered seed stands; and tested material coming from tested seed orchards, elite seed stands or tested clonal varieties. Many advantages derive from the precise knowledge of the origin and the genetic characterisation of the FRM, optimising the matching of genetic planted material, ecological conditions (soil, climate, and phytosanitary context), pre-existing genetic environment of the planted site, and economic objectives of the plantation. The impact of the plantation on genetic diversity depends on the level of genetic variability of the FRM itself, as well as on the possible gene exchanges between the planted FRM and surrounding forest tree gene pools. The final impact of plantations set up with a controlled FRM, at the regional forest tree diversity level, depends also on the total area afforested with this FRM and duration of its use.

3.2.1 Use of FRM collected on registered seed stands

In most cases, it means, wild, genetically diversified, but rather imprecisely known forest reproductive material (effective parent population size, inbreeding level?). The level of genetic diversity of the forest plantation is most often similar to the wild population from which it comes. The main genetic impacts depend on the level of adaptation of the introduced population to its new environment (winter frost, summer drought, soil, phytosanitary factors) and the possible gene transfers from it to the surrounding native populations (especially when the local gene pools are original and under threat). In this respect, the possible non-desirable impacts of long-distance seed transfers must receive special consideration.

3.2.2 Use of genetically improved forest reproductive materials

This brings new facets to the problem. The level of genetic diversity of the planted material can be much more restricted than that from wild forest tree populations (for examples, clonal varieties, single or controlled mixtures of full sib families), with a consequently lower adaptability and an increased ecological risk with the same rotation time (Gadgil et al. 1999; Evans 1999; Wingfield 1999). On the other hand, the genetic information must be much greater, allowing the forest-owner to better manage the expected economic gain and the ecological risk. Genetically improved varieties exclude use of natural regeneration and imply a high level of intensification in silvicultural practices, in some respects implying a long-term option (returning to a ‘close-to-nature’ forestry seems difficult). Compared with a ‘close-to-nature’ scenario, the level of genetic diversity of the future plantation forest, its performance, as well as its expected ecological adaptation, are totally pre-determined by the tree breeder. The results are theoretically predictable but to be effectively realised, they imply a strict respect of the recommended silvicultural regime (soil preparation with optional drainage and fertilisation, well planned thinning, control of weed competition, insect and disease control, usually short rotation time). In such a situation, as with agriculture, the expected revenues are high, but the flexibility is low. There are some relevant and known breeding strategies (already mentioned in section 2.2.2, *point c*), able to maintain the genetic variability of the plantation species over several generations (Namkoong 1988; Eriksson 1996; White et al. 1993).

3.2.3 Extreme genetic scenarios (clones and GMOs)

The most profitable regimes for plantation forests are technically sophisticated and investment-demanding. They are also risky. Of those intensively managed plantations, clonal and GMOs plantations have to be especially analysed for their ecological impact. Clearly, monoclonal or oligo-clonal varieties result in a spectacular decrease in genetic diversity, with an increased risk of damage caused by climate or pests and diseases. This risk can be moderated by:

- decreasing the rotation time (but with unfavourable effects on biogeochemical cycles; Trichet et al. 1997);
- limiting the plantation area and the time during which a given clonal variety is permitted to be used; and
- increasing the number of commercially available tested clonal varieties.

Combined with the legal constraints in European regulation allowing only tested clones in a commercially approved clonal variety, the recommendations listed above can limit the risks. They would finally result in a multi-clonal mosaic forest, when genetic diversity within a stand in a given time is replaced by genetic diversity between stands. Such intensive plantation forestry appears highly profitable, but demands a high level of technical competence from nursery to clear-felling, effective land use policy and regulations, and the possibility to control of the whole forestry scenario. Acceptable use of GMOs in forestry needs to step back more than we can do today. Economic and biological constraints limit the number of GMOs created, and therefore, a very limited number are practically available for use in plantations. In addition to the restrictions recommended above for clonal varieties, attention needs to be paid to the following aspects of GMOs use:

- male sterility, preventing pollen contamination of the surrounding forest related tree species;
- conditions of testing, in space and time, for GMO behaviour, not only in clonal tests (comparing one clone with a limited number of standard other clones, in well controlled conditions of experimental plantation) but within the real forest ecosystem conditions (weed competition and disease). In such an extreme genetic scenario we must be especially cautious:
  - verifying the real and acceptable expression of the genome after the gene transfer process (concerning the transfered genes, but also possible interactions with the remaining genome);
  - suggesting or imposing a maximum area for GMO plantation in a given region, with a limited time approval for use, and a periodic re-examination according to monitored performances of the GMOs in plantation (climatic and phytosanitary susceptibilities).

4. Impact on Spatial and Temporal Forest Structures

Impact of plantation forests on biodiversity and genetic diversity depends not only on the level of genetic diversity of the planted material itself, but also on the associated spatial and temporal structures.

4.1 Effect on spatial structures

Except for the case of planted protection forests (not to be forgotten), plantations have generally been favoured for national or regional economic reasons, as well as for better profitability of the forest owner’s investments. This profitability aspect, and associated reasons concerning facility of management (possible mechanisation, cost of establishment: drainage and soil preparation, silvicultural management: weed control and thinnings, etc.) and clear cuttings, clearly favour monospecific, even-aged, and rather large planted stands (often more than 10 ha, when the property size and topography allow it). From a landscape aspect and functioning, smaller stands would probably be preferable (Bell 1999). The variety perceived from intermingling of small plots of different tree species, of different ages and heights, is usually considered aesthetically pleasing.

For ecological reasons (mainly phytosanitary), mosaics of diversified small stands and the intermingling of forest and farm plots of limited areas would be recommended (food reserves for numerous species of parasites of forest-damaging insects, exchanges of forest and farmland fauna). Plantations result in clear cuts and clearly distinct lines of forest trees that are clearly visible in hilly regions. These are not desirable from a landscape point of view. Here also, the small size of the plots can temper this negative aspect.

4.2 Effect on rotation time and associated consequences

For species of Northern European or American origin (Norway spruce, Scots pine, Douglas fir, etc.), the rotation times used in plantation for timber production allow several selective thinnings and progressive elimination of ecologically unfavoured or genetically unadapted planted trees. This possibility disappears when systematic thinnings are used. For fast-growing species (such as poplars, pines and eucalypts), the economic strategy implies a short rotation time and, often, a lack of thinning. In this case, the genetic composition of the tree population does not change from plantation establishment to clear-cut (no possibility for adaptive fitting remains during the rotation time). Conversely, it is clear that a short rotation time decreases the probability of damage from forest fires, extreme climatic phenomena, or unexpected phytosanitary problems.

Plantation strategy and short rotation times do not favour the maintenance of old or dead trees, which otherwise would tend to stimulate and favour biodiversity (through their associated insect and bird species). Intensive weed control, short rotation times and repeated clear-cuts also impede complete development and sexual reproduction of certain plant species, and directly decrease the plant biodiversity associated with a given plantation forest.

4.3 Regeneration processes

In most cases, plantation strategy implies a clear-cut, whose negative impacts depend largely on local ecological conditions (topography, soil, climate), but also on the rotation time and the size of the stands. However, plantation methods allow the forester a total mastery of the regeneration process, including rotation time and a total genetic independence between two successive generations of trees on the same site (species and variety). This could bring relevant solutions for rapid and discontinuous adaptation to climatic change. In spite of the large genetic diversity of forest trees (Hamrick and Godt 1990) and their adaptation to some spectacular climate changes in the past, nobody can confirm that this genetic diversity is sufficient to successfully ride this new, but accelerated, climatic change.

5. How to Improve the Ecological Balance of the Plantation Forests?

On a global scale, the demand for wood will continue to increase (Whitman and Brown 1999) and the plantation option can efficiently contribute to the solution of increased wood supply without contributing to the continuous decrease in natural forest area (except the case where natural forest is being cleared in order to establish more economically viable plantation forests). Nevertheless, some corrective or compensatory measures could be recommended to make the plantation option more acceptable from the ecological point of view:

1. First of all, new research is needed in order to better manage biodiversity and forest genetic variability:
   - what genetic variability should be assessed and preserved?
   - what are the precise effects of plantations and silvicultural practices on the long-term evolution of biodiversity and forest tree genetic variability?

   Without waiting for all the scientific answers to the questions asked above, traditional measures to better preserve and manage biodiversity can be recommended, and innovative new techniques could also be suggested and tested (Kerr 1999).
2. Negative impacts on biodiversity or unacceptable risks of damage have been identified, mainly with respect to:
   - very restricted genetic basis of improved varieties (clonal and GMO options)
   - large areas planted with the same improved variety of restricted genetic basis, during several decades;
   - succession of monospecific plantations of very short rotation time on the same site; and
   - large and repeated clear-cuts (more than 10 ha).

   Concerning these points, common sense recommends a relevant compromise between ecological and socio-economic factors, taking into account regional characteristics (species, soils, climate).
3. Besides innovative improvements coming from this research, traditional solutions exist to preserve or to better manage forest genetic diversity and biodiversity. They can be recommended and implemented to reduce some of the adverse effects of plantations on biodiversity:
   - long-term breeding strategies already mentioned;
   - inventory and monitoring at regional and national levels, to pinpoint original genetic resources and threatened habitats needing top priority conservation; identification and grading of present threats to these resources and habitats, and estimation of their evolution; and
   - a genetic reserve network, including *in situ* and *ex situ* gene conservation reserves and projects, (structured species by species), covering the major domesticated forestry species, completed and co-ordinated with an habitat conservation network for the preservation of biodiversity and genetic resources of forestry species of currently low economic value.

Prospects for a more complex model of plantation appear desirable (Kanowski 1995). If we consider that irregularities and perturbations in space and time, very often generate and maintain biodiversity and genetic diversity in nature, then we can imagine and experiment new plantation strategies 'better mimicking nature'. "However, obstacles to these changes exist and it is concluded that unless benefits to biodiversity can be clearly demonstrated, which outweight increased costs, any large scale modifications to existing silvicultural systems will be limited" (cited from Kerr 1999).

We shall mention only some new paths to explore. In south-western France, Jactel et al. (1998) suggested maintaining, or creating 'biodiversity islands' within the monospecific forest of maritime pine (*Pinus pinaster*). The corresponding experimental design, finalised in 1995, deals with a network of 1 and 4 ha plots of broadleaved forest tree species at around 2 km intervals, included within the pure maritime pine plantation forest. The preliminary results show that the effect of an 'oak spot' on the level of damage caused by four different species of insects on maritime pine, is significantly beneficial and effective up to 1 km from this ‘oak spot’. Together with pre-existing broadleaved trees (along rivers, roads, and fire-breaks), such a planted broadleaved network will improve the biodiversity level and the natural protection of the pine forest, decrease the insect damage and reduce the need for insecticide spraying.

In environmental situations where full-size plots would be unsuitable or too costly, ‘planted island forests’ for further extension by natural regeneration, should be considered. They could be appropriate in several situations. For instance:

- afforestation using Greek Fir or Mediterranean Cedars in the Mediterranean hills;
- ‘island plantations’ of usually scattered noble hardwoods (*Prunus avium* for example) for an expected further natural extension; and
- extensive afforestation from ‘planted islands’ in mountainous harsh conditions.

6. Conclusion

To satisfy the increasing global demand for wood, and to limit the corresponding pressure on natural forests, the plantation option seems difficult to avoid. Despite the diversity of plantation forests overall, essentially monospecific even-aged plantations over large areas raise ecological criticisms and we must honestly seek scientifically-based improvements to plantation forestry for better forest biodiversity and genetic diversity. New theoretical research is necessary including:

- assessment procedures addressing and combining neutral and adaptive genetic diversity;
- population genetics, demographic models and geographic mapping approaches able to elucidate the natural mechanisms creating and maintaining genetic diversity in the forest ecosystem (what we could call ‘landscape genetics’);
- risk analysis allowing better prediction of the average-term risks of climatic and phytosanitary damage associated with a given genetic basis for a planted forest tree population.

Such approaches would generate advanced plantation strategies, integrating a controlled proportion of irregularities and disturbances able to mimic natural processes of maintaining biodiversity (species mixtures, clearings and borders, small ponds, old and dead trees, etc.). In addition, these approaches could achieve better organisation of forest stand and agricultural field mosaics at the landscape scale (limitation of size of clear cuts, optimisation of the stand ages distribution, preservation of natural ponds and wet-lands), and they would develop use of ‘biodiversity islands’ in the monospecific forests or ‘planted islands’ in empty or sparsely forested sites.

However, research also needs to address sustainable forest management practices, through ‘model forests’ able to test the feasibility of operational indicators of biodiversity (Ferris and Humphrey 1999), and to associate all the actors of the regional forest wood sectors. Immediate application of traditional corrective procedures already known would limit the negative impact of monospecific even-aged plantation forests, while results of more recent research and experiments are being gathered.

Plantations and natural forests do not have to be mutually exclusive; they are in fact complementary. We must conserve and manage our surviving natural and sub-natural forests as irreplaceable sources of biodiversity. At the same time we must continue to develop and improve plantation forests, which are absolutely necessary to supply the increased quantity of wood and the diversified forest services requested by society, at an acceptable ecological price.

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Ecological Impacts of Close-to-Nature Forestry on Biodiversity and Genetic Diversity

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Abstract

The developments in forestry, with respect to the impacts of close-to-nature forestry on biodiversity, are analysed. Forestry began in Central Europe as a result of the lack in wood that was experienced at the end of the 18th century as a result of the rapid industrial development. The state of the forests of that era in combination with the prevailing views of rationalism invoked the application of agricultural practices in forestry (e.g. clear-cuttings, soil cultivation, change of the species, and artificial reestablishment of the forest through mainly planting or seeding). The above practices have turned mixed uneven-aged forests to even-aged ones, thus causing a decrease in biodiversity and stability in these forests. By the end of 19th century, the disadvantages of this type of forestry had already been recognized after some mass destruction events caused by climatic or biotic factors (e.g. insect and disease epidemics). At this time there was a move towards close-to-nature forests natural regeneration, and cultivation of forests not only of timber yield, but also of stands as a whole. The application of close-to-nature forestry through natural regeneration, cultivation of the ecosystem and positive selection secures genetic biodiversity as well as species biodiversity. Genetic biodiversity is expressed as a variety of forms among the individuals of a species.

Keywords: close-to-nature forestry, biodiversity, clear-cutting, positive selection, natural regeneration

Introduction

The need for systematic and sustainable forest management was identified in Central Europe around the middle of the 18th century. The reason was the shortage of wood supply that was

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experienced following the industrial revolution and the lack of capacity of forests to satisfy the increasing energy demands for fuelwood, and wood for shipping and construction.

The science of forestry appeared during that time and the first forestry schools were established. Forestry is a relatively new science that was born as ‘a child of need’ even if some of its branches, such as timber harvesting and forest protection, have their roots in much earlier times. The main aim of forestry was the rehabilitation, the restoration and the creation of new forests and also their management in a way that through the growth in quantity and improvement in quality of the wood production the increasing demand in forest products would be satisfied. The main concern at that time was the quantity increase and quality improvement of growing stock.

The main principle that forestry was based upon, was the principle of ‘crops-continuity’, better known as the principle of sustainability. According to this principle, forests should be managed to produce, over time, the same annual quantity and quality of wood. It was shown that in order to apply the principle of sustainability, two other principles were appropriate: the principle of conserving the forest as forest; and the principle of conserving and improving soil productivity.

In the beginning, the entire construction of forest management was based in pure agricultural methods and knowledge. The prevailing idea was that as farmers sow or plant and harvest, forest owners could also sow or plant and harvest at the appropriate time.

The application of sustainable-scientific management coincided with the peak of the industrial revolution and the predominance of rationalism, (i.e. the effort to maximize production and minimize cost without considering any ecological impact). Ecology was still unknown. This approach led to the practice of clear-cutting, of changing the species composition and the formation of a ‘normal forest’ with definite order in space and time. The whole effort to develop forestry was based on the Cartesian philosophy and rational that man is the master of material nature.

The results of practicing these rational methods were impressive. The yield of the new artificial single-species forests raised sharply and so did the income of forest owners. As a result the method was generally accepted in Central and Northern Europe.

The impacts became apparent at the end of 19th century and were even more intense at the beginning of the 20th century, when severe damage to plantations caused by insect and disease epidemics, and natural catastrophes caused by strong winds and snow occurred. These were mainly due to the inferior endurance of even-aged monocultures. As well as this destruction, there was a sharp decrease in the productivity of the artificial forests was observed, wit yields falling from 20 m^3/ha/year to 10-13 m^3/ha/year during the second rotation, and to 3-5 m^3/ha/year at the end of the third rotation. Rotation is defined as the time needed for a tree to reach at a mature age for cutting. This phenomenon was attributed to overexploitation of soil productivity, and consequent soil fatigue and finally soil degradation, which is not directly recoverable.

At the same time, various physical and biological scientific branches of forestry were developed, such as plant sociology, ecology, ecophysiology, site quality science, syndynamics, synecology, soil science. This demonstrated that the forest is a complex ecosystem that functions under its own rules and cannot be compared with a potato field or a maize field.

The Move Towards Close-to-Nature Forestry

Famous foresters like Gayer declared in anxiousness the slogan “back to nature”, while Bop and Parade quoted “imitate nature, speed up its performance, this is the fundamental axiom of forestry”. Thus started a move towards natural forestry, which is based on natural regeneration and continuous cultivation of forests and the preservation of the forest natural structures (i.e. a forest with uneven-aged individuals and a variety of species). However, in parallel the traditional practices, such as clear-cuttings and artificial reestablishment of the forests, continued in these countries.

Since the beginning of the 20th century there were two trends in forestry due to the two different schools of thinking (i.e. natural and artificial forestry). The basic concept of artificial forestry is that the forest is the result of human intervention and that its formation and management is dictated by the principle of avoiding the dominance of nature. This requires the designed input of additional energy to the system. The basic concept of natural forestry is that the forest is a product of natural processes, and its management is dictated by the principle of conscious exploitation of the natural processes and the minimization of input of additional energy. In the first system clear-cuttings and uniform, even-aged stands of monocultures prevail, while in the second system natural regeneration of the forest and uneven-aged diverse forms of mixed natural forest prevail.

Cultivation of growing stock, during which the main concern was the increase and improvement of its composition, developed to become forest cultivation that takes into consideration the conservation and amelioration of forest climate and also soil productivity. The latter dictated the conservation and cultivation of the secondary stand (of middle- and sub-floor).

The Current Situation

Today, following the acknowledgement of the major importance of conservation of biodiversity, and its relation to the ecological balance and ecosystem stability, forest cultivation has developed to become ecosystem cultivation. Great efforts are made to conserve biodiversity through improvement of the forest habitats and their different plant and animal species. To succeed, a high level of scientific knowledge is required along with collaboration among experts in the development of management and silvicultural plans.

The strategy of forest management, according to which the forest is regarded as an ecosystem and the principle of best potential exploitation of the natural resources is applied, should be developed in such a way that the social benefits from the forest (wood production, protective, water regulative, recreational and hygienic impacts) are met in a sustainable way.

Sustainability does not only concern cropping (cultivation of forest products), but also impacts on public benefit. In particular, while the importance of wood production is continuously decreasing without losing its value, the importance of social benefit is continuously increasing on a global level.

Today, along with the increasing knowledge of the role of biodiversity, the practice of natural or close-to-nature forestry is of special interest and importance for the conservation of genetic and species biodiversity. Natural or close-to-nature forests use species that belong to natural plant communities of the region. The species have been tested in, and are adapted to the climatic, soil and biotic conditions of the region, and there is a large range of genetic inheritance (desirable or not). This property is depicted in the great polymorphism of the species, which enables cultivating interventions, but also favours tolerance of adverse conditions (e.g. droughts, and insect and disease epidemics).

The natural forest is, in this respect, an invaluable gene bank. Every individual of a natural population of a species can have properties (features) that are attributed to particular genetic inheritance, and although not directly identifiable (tolerance to stress, insects and fungi) would be very useful to geneticists for species improvement.

For the above mentioned reason contemporary cultivating interventions are not confined to the ‘witch hunting’ of undesirable characteristics. That is, we do not remove those individuals that are apparently not desirable in relation to growing stock (removal of those trees with distorted or forked stems, etc.). By applying a strict positive selection in the form of high thinnings, we conserve all the badly formed individuals that do not prevent the development of the selected ‘exquisite individuals’. Negative selection confines the polymorphism of species, while in parallel, indirectly, the range of genetic inheritance contributes only a small amount and by chance to growing stock cultivation. The conservation of gene-banks should comprise the main concern of cultivating interventions.

Of equal importance is the impact of natural or close-to-nature forest on plant and animal diversity. The main characteristics of natural or close-to-nature forest is that it retains its natural composition or a composition very similar to that of the natural plant communities or ecosystems of the region. All the species of a natural forest, in all its storeys and trophic layers (producers, consumers, and decomposers) are tested in the abiotic and biotic environment of the region. This fact in combination with the greater species diversity of a natural forest meet the requirements for the creation of more food chains, denser food webs, more ecological nests and biosystems. Thus, sustained ecosystem functioning, best feedback functions, increased self-regulation capacity, and therefore, increased elasticity and stability of the system are secured.

Apart from the fact that natural forests are normally mixed, the increased biodiversity of the natural forest is attributed to the fact that they are also normally uneven-aged, and therefore, present a multi-storey structure and gradual canopy, offering living conditions to a variety of animals (insects, birds, arboreal mammals) according to the tree age.

Apart from contributing to the conservation of genetic and species biodiversity, to the stability and unimpeded functioning of the ecosystem (biomass and energy flow and nutrient recycling), close-to-nature forests contribute also to the conservation of the physiognomy and ecological stability of the landscape. The characteristics of close-to-nature forestry is compared with afforestation and fast-growing plantations in Table 1.

Table 1. Comparison of three types of forestry.

Attributes	Type of Forestry		
	Close-to-nature	Artificial (afforestation)	Accelerated Fast-growing plantations
Energy input	Low	Moderate	High
Stability	High	Moderate	Low
Species biodiversity	High	Moderate	Low
Genetic biodiversity	High	Moderate	Low
Economic risk	Low	Moderate	High
Productivity	Moderate	Moderate	High
Conditions	Existance of close-to-nature forests	Need for forest expansion	Availability of productive agricultural land

Concluding Remarks

In order to practice close-to-nature forestry, there should be natural or close-to-nature forests (i.e. forests that keep, at least qualitatively, the natural composition of natural or semi-natural plant communities, and therefore, of ecosystems). Wherever these forests are present, even if their production ability is restricted, it would be an ecological crime to transform them in an artificial forest by changing the existing species and by introducing fast growing species in order to increase production.

The introduction of new species, unrelated to the natural plant community, does not only change the ecosystem's composition and structure, but also creates new ecological nests and a new basis for the development of food chains with consequences that cannot be predicted, and that in several cases have proved to be catastrophic. In the past, when this practice was common, there was a lack of knowledge relating to these processes. Today all this knowledge exists, and therefore, the main aim of silvicultural treatment should be the conservation of a high degree of the ecosystem's ecological balance. This is not only relevant to natural or close-to-nature forests, but also to the created artificial forests, where the material for establishing the forests (seeds or seedlings) should be derived from neighbouring areas and from species of pre-existing plant communities.

The question to be addressed is not the practice of natural, artificial or accelerated forestry, because all three are practiced at present, and they will continue to be practiced in the future. However, close-to-nature forestry should be practiced wherever there are natural forests or forests that have retained their natural composition. In the case of productive, agricultural soils that are susceptible to agricultural methods, accelerated forestry should be practiced, using genetically improved material of fast growing species or clones. Natural forests should never be transformed into plantations.

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Ecological Impacts of Plantation Forests on Water and Nutrient Cycles and Ecosystem Stability

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Abstract

How do we assess the impact of plantation forests on cycles of water and chemical elements in ecosystems? Should the changes that occur as a result of the establishment of the plantation be viewed as good, or bad, or do they have any significant influence at all? The impact of the plantation forest should be viewed in the context of the broad demands being made on the forest by society today. To cope with these demands, the forest manager must assume the role of ecosystem manager. Our increasing knowledge of ecosystem processes can provide the manger with the tools for this task. It can also be used to assess the ecological stability of plantation forest ecosystems. However, the dynamic nature of the plantation forest environment may impair our understanding of these ecosystems. An approach to the quantification of the sustainability of the plantation forest is suggested and the limitations of its application considered. The development of tests for the assessment of sustainability is an important step towards grappling with this nebulous concept in the context of these forests.

Keywords: plantation forests, nutrient cycles, hydrological cycle, sustainable forest management, ecosystem management

Introduction

In this paper, I focus on the last word of the title, ‘stability’, which I take to mean something very similar to ‘sustainability’. ‘Sustainability’ is the ultimate buzzword of the times we live in, a word so full of significance, so fundamental to our survival on this planet, and yet, so imprecise, so difficult to define. Bell and Morse (1999), in their book, “Sustainability Indicators”, describe the quest for sustainability as “chasing a moving shadow”. The situation appears to be, they write:

> *that, at the end of the 20th century, a word has been decided upon to conjure up the desirable outcome of social and political endeavours. Scientists and professionals have taken (or been given) the impossible task of achieving definitive measurement of this word. The impossible task was to measure what was never potentially measurable: the immeasurable 'sustainability'.*

The various definitions of sustainability or sustainable development will not be discussed here, nor will I offer my own definition, but a view of sustainability is presented, a view which is, I believe, legitimate and which is pertinent to the subject of this paper. Life on earth depends upon the maintenance of the major life-support systems of the planet. If life is to be sustained, these life-support systems – air, water and soil – must be at least maintained, if not improved. We have a responsibility to ensure that our actions must, at least, cause minimum damage to the air, the soil and the water on which they impinge. To repeat, this is not a definition of sustainability, but rather a view of it; a view, which provides us with a template against which we can compare an ecosystem. In the case of a plantation forest, it helps us to assess whether it is 'good' or 'bad' or effectively neutral in its impact on these life-support systems.

The establishment of a plantation forest results in severe disturbance of the ecosystem it replaces. I deliberately avoid saying the 'natural ecosystem' it replaces, because of course, this ecosystem is very often itself the result of a previous period of human disturbance involving, perhaps, degradation and neglect. The sustainability of this ecosystem is often itself an issue, but not one for this paper. It is relevant, however, to important questions which should be considered in the establishment and management of plantation forests. How do we assess the impact of the plantation? How do we know if this ecosystem that we have created is sustainable or not, and whether it is 'good' or 'bad'? In this paper, some of the processes, which are influenced by plantation forests, will be described and their impact considered in the context of sustainability, sustainability not only of the forest, but also of other ecosystems. I will then suggest empirical tests that could be used for the objective assessment of these impacts.

Impacts

Of the three life-support systems (air, water and soil) the soil exhibits the greatest degree of resistance to change, but perhaps, the least resilience. In other words, the soil is robust, it is not easily disturbed or modified, but if it is degraded, then its ability to recover is low. Forest managers must ensure then that disruptions of ecological processes that occur are managed within the boundary of resilience and amelioration of the ecosystem (Nambiar 1996). The most obvious form of damage to the soil is erosion. Erosion is one of a number of processes of degradation that reduces the capacity of soils to support plant life and may lead ultimately to desertification. Erosion is brought about by wind and by water, water erosion being generally the most serious. Although it is a natural process, the rate of erosion is dramatically accelerated by exposure of the soil surface through overgrazing, fire, soil tillage and cropping practices, and by deforestation. The impact of deforestation on erosion has been known at least since the time of Ancient Greece (Hamilton and Cairns 1961). Today, in many countries in the developing world, deforestation continues because it is necessary to compensate for the reduction in productivity brought about by soil degradation, chiefly erosion. Ironically and tragically, the clearance of the forest itself accelerates erosion contributing to further degradation.

Following the establishment of a plantation, a gradual modification of water and nutrient cycles occurs. As the stand develops, it intercepts incoming precipitation. As a result, the soil beneath the canopy becomes drier. Typically, interception accounts for 20–85% of total precipitation in conifers, and considerably less in broadleaved stands (Cannell 1999).

Evaporation of interception is one component of water use by forests. Total water use is the sum of interception and transpiration. If we assume that the plantation forest is markedly different in structure and species to the vegetation it replaces, the transpiration loss may also differ significantly. Transpiration loss is influenced by many factors, but species differences are important. Broadleaved species typically have higher transpiration rates than conifers per unit leaf area, but because this applies only when the trees are in leaf, and also because the total leaf area is less than in conifers, total transpiration on a land area basis may not be very different. Coniferous plantations replacing short vegetation will result in increased water use.

In the UK, it is reported that upland coniferous forests result in a decrease in water yields of 1.5–2.0% for every 10% of the catchment afforested (Cannell 1999). This is in accord with the general finding that the presence of forests leads to a reduction in both peak flows and total streamflow. However, a long-term study at Coalburn, in northwest England, suggests that the hydrological impact of plantation forests established on wet sites, with high precipitation and soils of low permeability may be more complex (Robinson 1998). A significant proportion of the plantation forests in both Britain and Ireland have been established on such sites. These forests require intensive artificial drainage and in many cases the separate influences of the forest and of the drainage are confounded. The study at Coalburn has shown that rather than reducing total streamflow, the immediate effect of afforestation was to increase water yield. This was due to the influence of the drainage network reducing evaporation losses and suppressing transpiration from newly exposed bare soil. It was several decades before water yields fell below pre-forestry levels. The influence on peak flows also ran contrary to general experience. Rather than reducing peak flows, they increased for several years following afforestation.

It is impossible to separate the hydrological impact of plantations from their influence on nutrient cycles. Canopy interception results in a reduction in the amount of water reaching the soil. In the absence of significant interaction with the canopy, throughfall (the water reaching the soil under the canopy), will have higher ionic concentrations than precipitation. This is the case for ions such as sodium. This effect is further enhanced by the interception of ions which

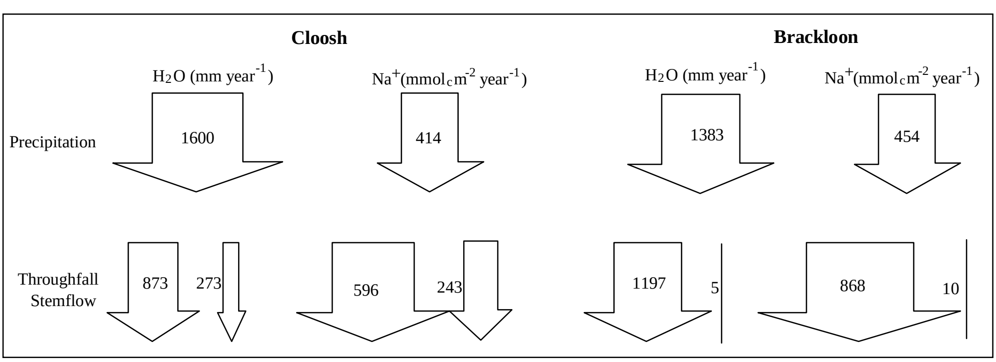

Figure 1. Average annual deposition loads (1991–1994) of sodium in precipitation, throughfall and stemflow in: a *Picea sitchensis* stand at Cloosh, Co. Galway; and a *Quercus petraea* stand at Brackloon, Co. Mayo (Farrell et al. 1996).

are deposited on plant surfaces. Such interception by the canopy results in higher fluxes, in addition to higher concentrations, in the throughfall (Figure 1); deposition to the forest floor is increased. Throughfall composition is significantly influenced by interaction with the canopy. Some ions such as ammonium are intercepted and absorbed by the canopy, others such as potassium are leached in large quantities from living leaf or needle tissue.

Coniferous forests are generally considered to be more efficient scavengers of ions from the atmosphere than broadleaf species. The results of a study at Gisburn, northwest England follow this well-established pattern (Brown and Iles 1991). However, a comparison of throughfall in a Sitka spruce (*Picea sitchensis*) plantation with a semi-natural oak (*Quercus petraea*) woodland in western Ireland gave very different results (Figure 1). Despite the fact that interception of precipitation by the forest canopy was much higher in the coniferous plantation, the throughfall flux of sodium was very similar in both stands (Farrell et al. 1998). This is thought to be an effect of the luxuriant development of lichens and mosses on oak in the humid, low-nitrogen environment of western Ireland.

In polluted regions, acid deposition can deplete base cations in sensitive soils and increase surface water acidity. Replacing short vegetation with coniferous plantations, will exacerbate this effect, increasing acid deposition to the soil through the interception of acidic ionic species such as nitric acid vapour and ammonia. The impact varies depending on the level of pollution, the interceptive efficiency of the forest canopy and crucially, the sensitivity of soil parent materials. Plantation establishment can result in streamwater acidification, particularly in regions where the soils have low critical loads and hence are highly susceptible to acid stress. These are the same regions that are favoured by anglers, as the oligotrophic waters, which occur there, encourage migration of salmonids.

Plantation forests are, almost by definition, managed forests and their impacts cannot be considered in isolation from management practices. I have already referred to drainage, but other forest operations are also significant. Road building, especially in mountain regions, can have an enormous environmental impact, accelerating erosion and disturbing hydrological processes. Clearfelling also brings sudden and drastic changes to a forest ecosystem. The site microclimate is altered as is the hydrology of the ecosystem, atmospheric deposition, litter turnover and biogeochemical cycling. Harvesting raises the possibility of nutrient depletion, particularly of calcium on acid sensitive soils (Reynolds and Stevens 1998). In certain circumstances, nitrate pulses may be observed following clearfelling (Neal et al. 1998) leading to potentially high nitrate concentrations in drinking water or to surface water acidification.

Assessment of impacts

It is quite clear that the ecological impact of plantation forests can be significant. It is also clear that no general description of this impact is possible because the outcome represents the interaction of a series of hydrological and biogeochemical processes involving all of the life support systems, the air, water and soil and influenced by their specific properties and by the ecosystem itself.

Nambiar (1996) has highlighted the problems associated with the development of indicators of sustainability for soils, the task becoming more difficult as the range of functions for which the forest is valued increases. He has suggested that the dynamics of soil organic matter could serve as a suitable indicator, although to be useful, any indicator should respond quantitatively to the impacts of management practices. Ranger et al. (1999) proposed input-output budgets as a diagnostic tool for sustainable forest management. In a recently completed exercise (Farrell et al. in press), the long-term viability of forests in a region of eastern Ireland was assessed by testing the results of computations based on data from long-term monitoring of a coniferous plantation (pure Sitka spruce, planted 1955) against a number of chemical criteria. Continuous monitoring of open-land bulk precipitation, forest bulk throughfall and stemflow have been carried out at the study site since 1991 (Table 1). The soil is a peaty podzol derived directly from weathered bedrock (schist and quartzite) or thin drift. Soil pH values, in H_2O, vary between 3.5 (O horizon) and 4.6 (C horizon), which is in the range of strongly acid soils characterised by aluminium buffering. Cation exchange capacity and per cent base saturation are very low. The region is subject to a moderately high level of atmospheric pollution. Monitoring data was used to calculate input-output balances, proton budgets and critical load of acidity for the stand. The results showed that: anthropogenic sources are making a major contribution to soil acidification; critical load was exceeded; soil solution pH was below a suggested critical value of pH 4.4; and the stand was nitrogen saturated (Farrell et al. in press).

While the results of this study strongly suggest that this plantation forest ecosystem is unsustainable, one must be cautious about reaching this conclusion. Forest condition is good, the stand is very productive and shows no visible signs of stress. When the plantation was established, in the mid-1950s, it replaced low-intensity agriculture. The site had probably not been under forest for some hundreds of years. Nevertheless, the legacy of previous land-use may be significant for a very long period of time. A study of the influence of deforestation of an oak wood in southwest Ireland (Farrell et al. 1996) gives some insight into the long-term influence of land-use change on pedogenic processes and soil morphology. At this site, deforestation, estimated by radiocarbon dating to have been carried out in about the year 1600, resulted in the replacement of deep-rooted oak (*Quercus petraea*) trees with shallow-rooted heathland vegetation. This change in vegetation has impaired the nutrient cycling in the ecosystem; the heathland species are unable to bring to the surface basic cations released by weathering deep in the soil. As a result, the rate of soil acidification has increased, increasing the intensity of the podsolization process. The removal of the tree canopy also reduced interception of both rainfall and nutrients. Under the wetter conditions, soil structure deteriorated and the thickness of the organic surface horizon increased which, in a region of large water surpluses such as the west of Ireland, will lead ultimately to the development of blanket peat. In many instances, such as the plantation forest site in eastern Ireland, previous land-use change can only be guessed at, but its impact may still be influencing soil processes today. Current evidence of instability may be the consequence not of plantation establishment, but of previous land-use change. The time required to establish a new equilibrium is, as yet, unknown. Further work is required, both to refine the criteria of sustainability, and to monitor change through the clearfell and beyond into the next rotation.

Conclusions

The traditional forestry concept of sustained yield management is a perfectly valid view of sustainable forest management. It was developed in the German, Austrian and French forestry schools in the late eighteenth and early nineteenth centuries and reflected the changing attitude towards the manipulation of ‘nature’ (Farrell et al. 2000). The forest was seen as a resource to be utilised, but very importantly, to be utilised in a controlled, sustainable manner. In the implementation of the principle of sustained yield management, the manager balances output with growth, ensuring that, over time, an even supply of material to the market. Underlying the concept is the idea that the productive capacity of the site must be protected and maintained.

Table 1. Eight-year mean water fluxes (mm yr^{-1}) and ionic fluxes ($mmol_c$ m^{-2} yr^{-1}) in all water sources sampled at Roundwood, 1991–1998; and estimated eight-year mean total deposition (input) and deep soil water fluxes (output) at Roundwood, 1991–1998.

Parameter	pH	H^+	NH_4^+	NO_3^-	Ca^{2+}	Mg^{2+}	K^+	Na^+	Cl^-	SO_4^{2-}	Mn^{2+}	Al^{3+}
Precipitation	4.6	38	40	29	16	28	5	141	179	58	0.3	2.5
Throughfall	4.2	54	63	65	47	76	51	308	372	139	13.0	3.9
Stemflow	3.8	8	7	9	10	15	12	44	54	27	3.2	0.7
Total depositition (input)	3.9	123	82	74	40	70	13	352	426	166	0.7	4.6
Deep soil water (output)	4.2	56	2	170	27	82	6	358	397	165	49.0	179.0

Al^{3+} = Total monomeric aluminium quoted as if all was present as the tripositive aluminium ion.

Despite its inherent validity, the concept of sustained yield management is too limited in scope to accommodate the demands that society now places on the forest. Modern ideas of sustainable forest management embrace all the goods and services of the forest and suggest that 'sustained yield' should be replaced by the broader concept of 'sustainable forest management' (Wiersum 1995).

This broader definition of sustainable development puts new demands on the forest manager, expanding the scope of management to embrace a wider range of goods and services. The challenge facing forest ecosystem scientists is to provide the manager with the tools to perform this new job of ecosystem manager. An added difficulty facing the plantation forest manager is the reality that many of the plantation forests, established for one purpose only, timber production, are now expected to fulfil this wider range of objectives for which they were never designed.

Our growing understanding of ecosystem function has increased our ability to equip the manger with the knowledge required to manage the whole ecosystem. But this increased understanding has also made us more aware of our own inadequacies. We have come to understand more clearly the dynamic nature of the forest ecosystem, particularly the plantation forest ecosystem and through that understanding we see the gaps in our knowledge. The environment of the plantation forest is dynamic, influenced by changes in the atmosphere ranging from increasing concentrations of carbon dioxide to rapidly varying fluxes of nutrients and acidifying substances in precipitation and throughfall. Less obvious, but perhaps equally important, are the impacts of previous land-use. These effects of land-uses, long forgotten or often unknown may still be influencing ecosystem processes today, restricting our ability to interpret research and detracting from its utility. The approach discussed in this paper for the quantitative assessment of sustainable forest management merely allow us to take the first faltering steps towards measuring the immeasurable, the elusive 'sustainability'.

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Ecological Impacts of Close-to-Nature Forestry on Water and Nutrient Cycles and Ecosystem Stability

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Abstact

An operational definition of close-to-nature forestry is given that is extracted from a number of criteria for forestry certification. The problems in defining the concept close-to-nature forestry are discussed. So far, few experimental studies have been done that explicitly compares close-to-nature forestry and more intensive conventional silvicultural methods. However, information on these close-to-nature practices may be extrapolated from studies on other issues that are partly relevant also for analyses of likely consequences of close-to nature forestry (e.g. harvesting experiments, fertilization experiments, mixed species experiments, etc.). Different aspects of close-to-nature forestry may affect soil processes in quite different ways. Thus, close-to-nature forestry may lead to stronger retention of nutrients within the ecosystem (e.g. when gap and shelter wood regeneration systems are used instead of clear-fellings and plantations). But it could also lead to increased nutrient leaching as is the case when forest or slash burning is practised.

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Wood and Non-Wood Production from Plantation Forests

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Abstract

The boundary between planted and natural forests is often indistinct. The roles fulfilled by planted forests are diverse and a continuum of forest types exists from highly protected conservation forests to productive, short-rotation planted forests. As for any other forest, plantations may have multiple functions: preservation, protection, production, socio-economic functions. However, they are usually managed towards a specific objective, giving priority to one of these forest uses. Of course this does not mean that other complementary uses are not possible, as can be illustrated in the Portuguese experience with plantations. In this paper, special attention is given to the productive functions of plantations, with special emphasis on wood production. Wood is one of the most important raw materials used by man. Over millennia, most of the wood needs came from the harvesting of natural forests, but the current and future wood demand of a growing human population cannot be covered by the natural forests of the world. The increase in the global population, expected to be 10 billion by the middle of the twenty-first century, will require at least 2.5 billion m^3 more wood each year than can be supplied from the forests existing at the end of the twentieth century. The dilemma for the world is how to satisfy this increased wood demand without significantly increasing the wood harvest from natural forests. Plantation forests play an important role in the solution to this problem. Assuming planted forests with an average annual yield of 20 m^3ha^{-1} (a very high standard in fact), an extra 100 million ha of additional planted forests will be needed to satisfy the potential future demand for wood, maintaining the same level of harvest in natural forests. The productivity of planted forests around the world is reviewed with the objective of analysing whether the target of an annual yield of 20 m^3ha^{-1} is a reasonable one. The importance of selecting the right genetic material for tree planting (including tree species) as well as the use of optimised management practices, both in relation to the available sites, are discussed. The problem of wood quality is also addressed, mainly in relation to genetic improvement. Eucalypt plantations in Portugal are used as an example to

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show the variability that can be induced in wood yield and quality by plant material and silviculture.

Keywords: plantation forests, forest resources, timber production, non-wood forest products, sustainable forest management

Introduction

The processes and conditions leading to the establishment of large-scale planting in different parts of the world have been analysed by several authors (*e.g.* Dyck 1999; Emborg and Larsen 1999; Kock and Skovsgaard 1999; Powers 1999; Sanhueza and Weber 1999; Sutton 1999a, 1999b). Over millennia, most of the wood needs have come from the harvesting of natural forests. The general attitude of ancient human societies towards forests was to destroy them in order to increase the area devoted to agriculture and grazing. At that time, man perceived the forests as if they were inexhaustible and their products were not perceived as critically scarce. Another important cause of forest clearing, occurring some centuries ago, was the demand of wood as fuel for industrial uses, mainly in the iron industry. This attitude led to a generalised deforestation originating in large areas of marginal lands, no longer appropriate for agriculture, occurring together with a generalised lack of wood. The shortage of wood and the availability of land gave impetus to the development of planted stands and, at the same time, to the genesis of planned and well-regulated forests managed towards an optimised and sustained wood production. The industrial revolution of the nineteenth century stressed the focus of silvicultural practices on wood production on a sustained-yield basis. The principal focus of traditional forestry on wood production led to some intensively managed forests made up of monospecific and even-aged stands, sometimes with the loss of biodiversity and of multiple-use forest values. Today, the products and demands on forests are much more diverse. Wood is certainly still one of the main products that is expected from the forest, but the importance of other values such as shelter, recreation, nature and habitats protection, gene conservation, etc., have an increasing value for society. The urbanisation of the present society, with a great majority of the population living in cities without a real dependence on nature for living, led to a romantic, idealistic attitude towards forests (Koch and Skovsgaard 1999) also had important consequences for forest management. Present forest management is concerned not only with maintaining wood production on a sustained basis, but also guaranteeing ecosystem stability and satisfying the changing social values of forests.

In this paper, special attention is given to the productive functions of plantations, with special emphasis on wood production. Management of planted forests whose main objective is the production of wood or non-wood products is discussed, as well as how it may (or may not) be compatible with the maintenance of the sustainability of the system.

Plantation Forestry

According to UN-ECE/FAO (1997):

> *Plantations are forest stands established by planting and/or seeding in the process of afforestation or reforestation that are either (1) of introduced species (all planted stands), or (2) intensively managed stands of indigenous species which meet all the following criteria: one or two species at plantation, even age class, regular spacing.*

Stands that were established as plantations, but have been without intensive management for a significant period of time are considered as semi-natural according to this definition.

As mentioned by Canaveira et al. (1999), this definition is not straightforward because the concept of intensive management is somewhat ambiguous. Where is the border between intensive and non-intensive management? In this paper a simplified – but more objective – definition will be used:

Plantations are forest stands established through man's initiative *in the process of* afforestation *or* reforestation, *usually by planting and/or seeding, but sometimes through natural regeneration. Stands whose main species is* exotic *are considered as plantations as, at least in some point in time, the species was introduced by man's initiative.*

The boundary between planted and natural forests is often indistinct. The roles fulfilled by planted forests are diverse and a continuum of forest types exists from highly protected conservation forests to productive, short-rotation planted forests (Figure 1). As with any other forest, plantations may have multiple functions (preservation, protection, production, socio-economic functions). However, they are usually managed towards a specific objective, giving priority to one of these forest uses. Of course this does not mean that other complementary uses are not possible. The usual tendency, when discussing the problem of planted forests, is to limit the scope of examination to the most simplified forest even-aged monoculture that contrast sharply when compared to natural forests. Another tendency is to consider each plantation on its own, as if it had to be self-sufficient in providing all the multiple uses of natural forest, instead of considering it as a piece of a large universe where forests can complement each other in order to satisfy society demands.

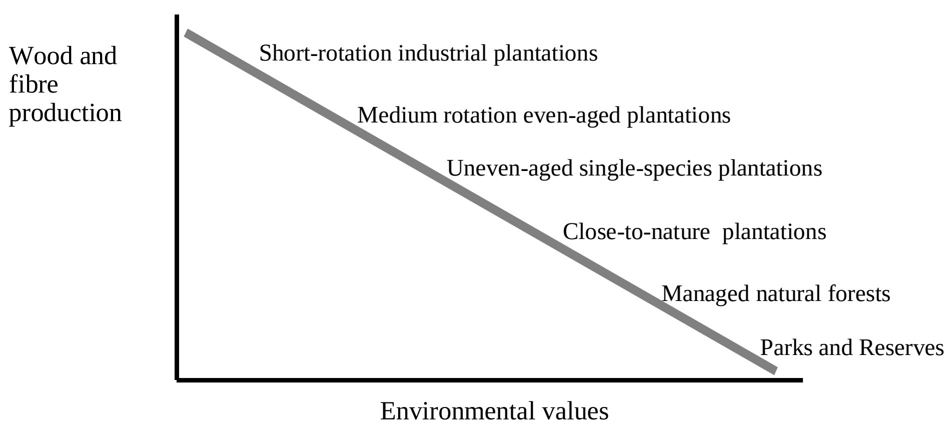

Figure 1. Relative importance of wood and fibre production and environmental values in different types of plantations (adapted from Dyck, 1999).

There is evidence of the tendency of some to consider a dichotomy in plantation forestry: (1) on one hand, close-to-nature forestry described, for instance by Koch and Skovsgaard (1999) or Kanowsky (1997), as an integrated, sustainable, multiple-use forest management concept achieved with complex production systems; and (2) on the other hand, plantation forestry, associated with simpler systems that imply the use of a certain level of segregation of forest uses. These two concepts should not be seen as alternative, but rather as complementary. Between the two extremes – total integration and total segregation – there is a range of forest conditions leading to a more or less rich mix of products. The maximum value to society, at a global scale, may be achieved by an optimal combination of both concepts.

The Portuguese Experience with Plantations

The Portuguese experience can be used to show the diversity that can be found among plantations. The country has a long tradition in the use of plantations that is expressed by the large increase of forest area, from 600 000 ha in 1874 to more than 3 million ha in 1995 (Figure 2). The increase in forest area resulted from policy options adopted over times. These are described in Canaveira et al. (1999). As in many other European countries, natural forests were cleared as agriculture developed and the remaining forests were over-utilised in order to cover the wood demands of an increasing population. Therefore, the first important afforestation efforts have occurred since the second half of the nineteenth century, and were aimed at the rehabilitation of forest cover. The main concern was the protection of agricultural land on coastal areas, and attempts were made to stabilise sand dunes in the most critical areas. Maritime pine (*Pinus pinaster*) was the main species used. Almost in parallel, the culture of cork oak (*Quercus suber*) began in the south of the country (Sousa Pimentel 1888; Natividade 1950). These species were responsible for the first large increment of forest area in the country.

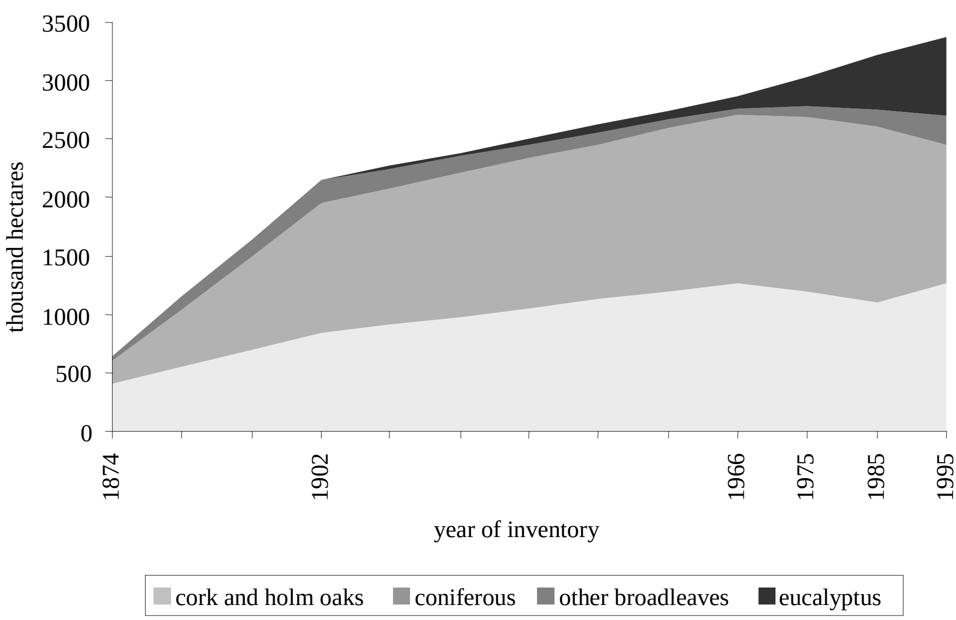

Figure 2. Evolution of Portuguese forest area (1874–1995) (source: General Direction of Forests, Ministry of Agriculture, Rural Development and Fisheries).

The next effort of afforestation was focused on mountainous areas: These areas, owned mainly by local communities, were extremely degraded as a consequence of centuries of deforestation, over-grazing and fire. Two main reasons were anticipated from this program, implemented between 1939–1968: (1) to increase the economic profit of the local populations and; and (2) soil protection and rehabilitation using pioneer species. Maritime pine was again the most used species. When soil conditions were more favourable, other species were utilised, like oaks, chestnuts and various coniferous species. Cork oak increment continued in the south of the country, jointly with holm oak (*Quercus ilex rotundifolia*).

The next priority of the national forest policy was to support afforestation on private areas, which account for the majority of the land in Portugal, by establishing a Fund for Private Forest Promotion in 1945 that was in place until 1986. A large area was planted during this period, with a large variety of species and objectives. The Portuguese Forest Project, financed by the World Bank in the 1980s, provided a considerable amount of funding for such plantations. The major expansion of *Eucalyptus globulus* plantations occurred in the last third of the twentiety century, in parallel with the expansion of the pulp industry's capacity. Although *E. globulus* was introduced into Portugal in 1830, mainly for ornamental purposes, and the first large plantations date from 1880, it was only in the last 20-30 years that the major expansion occurred. From 1986, new financing systems in support of afforestation measures were established with the support of the European Community. These programs gave special emphasis to the multiple functions of the new plantations.

The most recent trends, reflecting new policy objectives and international commitments, and also market opportunities, show that traditional oaks, and specifically cork oak, are the main species chosen for afforestation of former agricultural lands. Diversification of species and of landscape is being promoted, in many cases to counteract the problem of forest fires by using broadleaf species as fire breaks. Slow growing and indigenous species are being given higher rates of subsidies and afforestation in protected areas has special legislation.

Planted forests in Portugal have therefore performed many functions and provided multiple goods and services. Tables 1 to 3 (based on Canaveira et al., 1999) exemplify the diversity of present silvicultural systems, species, productivity and products that can be found. Table 1 also shows the importance, both in area and wood production, of each one of the different types of plantations that were identified. These examples clearly show that wood and non-wood products obtained from a plantation are largely dependent on the objectives for which the plantation was established. The amount of wood and non-wood products that can be obtained from several plantations established with the same objective depends, in its turn, on site productivity, which (as will be shown), can be manipulated, to a certain extent, through appropriate management practices.

The Need for High-Yield Wood-Oriented Forests

Wood is of course one of the most important raw materials used by man and the fast demographic growth of human population induces an increasing pressure on forest areas and demand for forest products. The natural forests of the world cannot cover the current and future wood demand of a growing human population, as has been stressed by several authors (*e.g.* Sutton, 1999a, 1999b; South, 1999). Sutton (1999a, 1999b) states that the additional wood demand has to be provided by newly established plantations and estimates the additional area of plantation that is needed to cover this increasing wood demand. Annual wood consumption was maintained from 1960 to 1996 in the range of 0.58–0.65 m^3 per person. Even if we assume that there will be no future increase, and fix annual wood

Table 1. Wood and non-wood production from plantations in Portugal.

Plantation objective	Main product	Other products	Area* (10^3 ha)	Wood Production** ($m^3 ha^{-1} yr^{-1}$)
Wood production long rotation, softwoods	Wood for sawmills and carpentry, poles, piles and posts, wood panel industries and pulp industries	Resin, bark	897 (872 of *Pinus pinaster*)	4–12
Wood production long rotation, hardwoods	Wood for sawmills and carpentry, poles, piles and posts	Handcrafts (baskets), fruits	90	2–4
Wood production short rotation	Wood for pulp industries and a small share for construction	Leaves, honey	677 (mostly *Eucalyptus globulus*)	6–40
Bark (cork) production	Cork	Firewood, coal, game and hunting, grazing, agriculture and fruit	649	not significant cork 100–500 kg $ha^{-1} yr^{-1}$
Fruit production	Fruits for humans and animal consumption	Wood for sawmills and carpentry, firewood, game and hunting and agroforestry	101 (86 of *Pinus pinea)*	not significant
Agroforestry	Understorey grazing and agriculture, game and hunting	Firewood, coal	552 (mostly *Quercus ilex rotundifolia*)	not significant
Soil conservation	Soil fixation, soil conservation, erosion control, combat to desertification	Firewood	109	not significant
Water conservation	Water course protection	Wood for sawmills and carpentry, firewood	58	not significant

* Estimation based on the National Forest Inventory (1999) and on a tentative re-distribution of areas among objectives by the author.
** Estimation by the author based on the National Forest Inventory (1999), on several yield tables and on its own growth and yield database.

Table 2. Wood and non-wood production from plantations in Portugal. Species with a share in total forest area bigger than 20% are underlined.

Plantation objective	Native	Exotic
Wood production long rotation, softwoods	Maritime pine (*Pinus pinaster*), Scots pine (*Pinus sylvestris*)	Austrian pine (*Pinus nigra*), Douglas fir (*Pseudotsuga menziesii*), Cypresses (*Cupressus* spp.), Japanese red cedar (*Cryptomeria japonica*), Lawson cypress (*Chamaecyparis lawsoniana*)
Wood production long rotation, hardwoods	Common oak (*Quercus robur*), Pyrenean oak (*Quercus pyrenaica*), Sweet chestnut (*Castanea sativa*), Narrow-lwafed ash (*Fraxinus angustifolia*), Wild cherry (*Prunus avium*), Willows (*Salix* spp.)	American red oak (*Quercus rubra*), Black walnut (*Juglans nigra*)
Wood production short rotation		Blue gum (*Eucalyptus globulus*), Red gum (*Eucalyptus camaldulensis*), Poplars (*Populus* spp.)*
Bark (cork) production	Cork oak (*Quercus suber*)	
Fruit production	Stone pine (*Pinus pinea*), Sweet chestnut (*Castanea sativa*), Carob (*Ceratonia siliqua*), Strawberry tree (*Arbutus unedo*)	Common walnut (*Juglans regia*)
Agro-forestry	Holm oak (*Quercus ilex rotundifolia*), Cork oak (*Quercus suber*)	
Soil conservation	Maritime pine (*Pinus pinaster*), Stone pine (*Pinus pinea*)	Acacia (*Acacia* spp.)
Water Conservation	Narrow-leafed ash (*Fraxinus angustifolia*), Common alder (*Alnus glutinosa*), Willows (*Salix* spp.), White poplar (*Populus alba*)	Italian alder (*Alnus cordata*)

* *Populus alba* and *Populus nigra* are indigenous species, but hybrids are more important for wood production.

Table 3. Characterisation of silviculture in the different types of plantations in Portugal.

Plantation objective	Silviculture system*	Age structure	Rotation age (years)	Stand density*** (trees ha^{-1}) planting	Stand density*** (trees ha^{-1}) mature
Wood production long rotation, softwoods	clear cutting system or uniform system	even or uneven-aged	30–80	1100–2500	300–600
Wood production long rotation, hardwoods	coppice and clear cutting systems	even-aged	50–70	1100–2500	200–300
Wood production short rotation	clear cutting system, followed by coppice in eucalyptus	even-aged	10–15	1100–2000	
Bark (cork) production	uniform system	uneven-aged stands, new plantations even-aged	120–150** bark extraction every 9–10 years	500–1000	50–100
Fruit production	uniform or coppice systems	even or uneven-aged	very variable**	variable, according to species may vary between 100–800	
Agroforestry	uniform system	uneven-aged stands, new plantations even-aged	120–150**	500–1000	20–70
Soil Conservation	no management or uniform system	uneven-aged	generally, no extensive cutting occurs	1400–1700	
Water conservation	no management or coppice selection system	uneven-aged stands	20–40	800–1000	

* Based on Matthews (1996); just the most common silviculture systems are indicated.
** Tree rotation age in uneven-aged stands, cutting occurring mainly when trees reach decrepitude or by sanitary purposes.
*** Subjective estimation by the author based in Canaveira et al. (1999) and supported by the mean stand densities of new plantations given in Fontes (1997).

Table 4. Worldwide timber yield (Sedjo 1999).

Site	Mean annual increment ($m^3ha^{-1}yr^{-1}$)	Rotation (years)
Temperate and boreal softwood forests		
Canada, average	–	–
British Columbia	1.5–5.3	–
Sweden, average	3.3	–
Finland	2.5	60–100
Russia	1–2.9	–
Siberia	1–1.4	70–200
Softwood plantations		
Britain (*Picea sitchensis*)	14	40
South Africa (*Pinus* spp.)	10–25	20–35
New Zealand (*Pinus radiata*)	18–30	20–40
East Africa (*Pinus* spp.)	25–45	20–30
Brazil (*Pinus* spp.)	15–35	15–35
Chile (*Pinus radiata*)	20–30	15–35
Eucalyptus plantations		
Portugal and Spain	10–15*	8–12
South Africa	15–20	10
Congo	30–40	7–20
Brazil	30–70	5–20
Chile	20–30	8–20

*As can be seen from the paper presented here, the value for Portugal is underestimated.

consumption at 0.6 m^3 per person, the increase in the global population, expected to be 10 billion by the middle of the twenty-first century, will require an annual global wood harvest of 6 billion m^3, at least 2.5 billion m^3 more wood each year than that which can be supplied from the forests existing at the end of the twentieth century.

The dilemma for the world is how to satisfy this increased wood demand without significantly increasing the wood harvest from natural forests. Plantation forests play an important role in the solution to this problem. Assuming planted forests with an average annual yield of 20 m^3ha^{-1} (a very high standard in fact), an extra 100 million ha of additional planted forests will be needed to satisfy the potential future demand for wood, without significantly increasing the wood harvest from natural forests. Even if some may think that this estimation is exaggerated, there is no doubt that part of the future wood demand has to come from new wood-oriented high yield plantations.

Table 4 (from Sedjo 1999) reviews the productivity (mean annual increment at harvest, in m^3ha^{-1}) of planted forests around the world. It also shows, for comparison, the productivity of boreal softwood forests. It is evident that annual productivity of boreal softwood forests

(1–5 m^3ha^{-1}) is much less than the annual productivity that is easily achieved with softwoods or *Eucalyptus* plantations (10–70 m^3ha^{-1}). On the contrary, rotation length is shorter for *Eucalyptus* plantations (5–20 years) and higher for boreal softwood forests (60–200 years). Generally, it can be said that plantation forests produce more than boreal forests and that this production is achieved in a shorter period. From the analysis of these tables we may conclude that, as a mean, an average annula yield of 20 m^3ha^{-1} is not unreasonable. However, in order to guarantee the achievement of such high standard, it is essential that the right genetic material is used in the right site and that the correct management practices are adopted. The following sections will therefore focus on site productivity management.

The Concept of Site Productivity

The concept of site productivity, as well as the factors that determine it, have been widely discussed in the literature (e.g. Assmann 1961; Barnes et al. 1980; Begon et al. 1996; Cannell 1989; Ek et al, 1998; Nambiar and Sands 1993; Powers 1999; Waring and Running 1998). Gross primary productivity (GPP) is the primary synthesis of organic matter from carbon dioxide, water and nutrients through photosynthetic activity of plants, generally expressed as units of carbon fixed per unit area per unit time. A portion of the total carbon fixed by the plants is lost through respiration. Net primary production (NPP) represents the difference between GPP and plant respiration. Net secondary production (NSP) is the increase in biomass of all organisms obtaining their energy from NPP, including decomposers and heterotrophic organisms. Finally, the rate of biomass accumulation in live plants, live animals, and soil organic matter is called net ecosystem production (NEP).

Powers (1999) suggests the use of NPP as a working definition of site productivity and makes the distinction between actual and potential site productivity. To better understand the difference between these two concepts, it is important to analyse the factors limiting terrestrial productivity. The ultimate limit on the productivity of a community is determined by the amount of radiation that it receives; however, the radiation is used inefficiently by all communities (Begon et al. 1996). Climate, soil water and nutrients availability all play an important role in the expression of a site's potential productivity, which is determined by the inefficiency in light use due to: (1) shortage of water restricting the rate of photosynthesis; (2) shortage of essential mineral nutrients which slows down the rate of production of photosynthetic tissue and its effectiveness in photosynthesis; (3) temperatures that are lethal or too low for growth; and (4) an insufficient depth of soil. However, the actual biomass produced by a forest in a certain period, being limited by its potential, largely depends on the degree of stocking which, in turn, determines the leaf area present in that particular period. The efficiency with which leaves photosynthesise, may also play a role in the determination of actual productivity, although relatively little is accounted for by the intrinsic differences between the photosynthetic efficiencies of the leaves of the different species and genotypes (Begon et al. 1996). A site's potential productivity may be defined by its carrying capacity for leaf area, or the maximum amount of leaf that the site can support. This carrying capacity is a fundamental property distinguishing one site from another and can be used as a precise measure of site quality (Powers 1999).

Current or actual site productivity, in turn, is the actual biomass produced by a forest in a certain period. It depends on the degree of stocking (if a forest is understocked, the leaf area will be lower than the site's carrying capacity, and therefore, productivity will be less than the potential). In plantations or even-aged stands it also depends on the stage of stand development.

The trend for biomass production (NPP) in a plantation or even-aged stand follows a well-known pattern from stand establishment to maturity (*e.g.* Assmann 1961; Waring and Schlesinger 1985; Powers 1999). Production rates are low when trees are young and leaf area is low. Much of the carbon assimilation is directed to production of leaves and of its supporting structures. As leaf area increases, there is a rapid increase in productivity and nutrient demand as trees use site resources, followed by a peak productivity and nutrient uptake at crown closure. After crown closure, leaf area stabilises at the site's leaf area carrying capacity and there is a relatively stable productivity to maturity with increasing maintenance respiration. Crown mass is fixed and much of the stand's nutrient demand is met through internal recycling. Finally, there is a rapid decline as the stand senesces from natural causes.

Although this general pattern can be found irrespective of initial stocking, the age at which crown closure is attained as well as peak NPP are greatly affected by stocking. Some variation may also occur due to annual weather variation or to damages caused by natural disasters (wind, fire) or by insects or disease. The 'law of constant final yield', first recognised by Kira et al. (1953) and Kira and Shinozaki (1956) for agricultural crops, expresses the fact that there is a maximum amount of biomass that a site can support, the constant final yield, over a considerable range of initial stocking. Potential site productivity may also be expressed as a function of this maximum amount of biomass, which is, of course, related to the site's carrying capacity for leaf area. Pienaar and Turnbull (1973) tested the hypothesis of constant final yield (expressed by stand basal area) for *Pinus elliottii* in South Africa, using growth data from spacing and thinning experiments, and concluded that the hypothesis is not unreasonable. They also concluded that: (1) basal area growth rate at culmination decreases progressively with decrease in initial density; (2) the age at which the growth rate culminates increases as initial stocking density decreases; (3) after culmination, the growth rate declines much faster for higher stocking densities; (4) for any given basal area, the growth rate increases with increasing initial stocking; and (5) at younger ages, the greater the total basal area then the greater the growth rate, while at more advanced ages, the greater the total basal area then the smaller the growth rate. These findings are of particular importance for the management of plantations, as it implies that the forest manager may manipulate stocking in order to control the pattern of plantation production, anticipating and maximising the production of the desired product.

Another important aspect of site productivity is that it refers to the accumulation of biomass in all the vegetation present in the site. The way it is distributed among trees and other plants (herbaceous and shrubs) and, within the tree-component, the way it is distributed among the different biomass components is of high importance when thinking about wood production.

Wood and Non-Wood Production Improvement Through Management

As mentioned by Ek et al. (1998) and Powers (1999), by understanding the processes controlling forest productivity, forest managers can manipulate conditions in the environment and in the trees themselves in order to achieve increased productivity of the forest components of economic interest. Both actual and potential productivity can be modified. As previously mentioned, climate and soil determine the natural limits of site productivity (potential site productivity). Each species has genetically determined physiological potential, presenting, however, a large genetic variability. It may be said that the genetic potential (species, provenance, family or clone) sets a biological limit to the expression of site potential productivity. Finally, stocking determines how quick (if ever) the potential limit fixed by site and/or genetic is achieved.

The objective of forest management is to find the combination of site condition, genetic potential and stocking that allows for sustained maximum production of the desired product (wood, cork, fruits, etc.).

Most species achieve their best growth under a fairly narrow range of climate and soil conditions. The first step to the success of a plantation is therefore the matching of species to site. Many of the problems of plantation health, low productivity, bad tree quality or lack of economic viability verified in some plantation programs were the result of using a promising species in an inappropriate site. This problem is clearly illustrated by the expansion of eucalypt plantations in Portugal. Figure 3 shows a summary characterisation of eight climatic regions that were defined in Portugal (Ribeiro and Tomé, in publication). As can be seen there is a large variation in rainfall and temperature, which combined with the occurrence of frost, determines the appropriateness of each region for eucalypts. During the expansion of the species, plantations were established in all these regions, although plantations are more highly represented in the best sites. The consequences of this uncontrolled expansion can be seen in Figure 4, which shows the range of site indices for each regions, based on data from permanent plots and forest inventories of pulp companies. Site indices in some of the inland and drier regions are mostly below 14 m at 10 years which, for the stockings commonly used by industry, corresponds to a mean annual increment at 12 years close to 4 m^3ha^{-1}, indicating that the *E. globulus* was not the best choice for these regions. In the more favourable sites, along the coast, where precipitation is higher and frost is not important, most of the plantations have site indices above 20 m at 10 years, corresponding to a mean annual increment in volume of industrial stands above 14 m^3ha^{-1}. On the best sites, site index and the corresponding mean annual increment in industrial stands can be close to 28 m and above 30 m^3ha^{-1}, respectively.

Once the site and the species are chosen, the next stage is the selection of tree varieties or clones that are well adapted and grow fast on that site, optimising yield and quality of the desired product. As an example, tree breeding programs for *E. globulus* in Portugal have been described as attaining genetic gains in yield of 20–40%, both due to increases in volume and wood density (Borralho 1999).

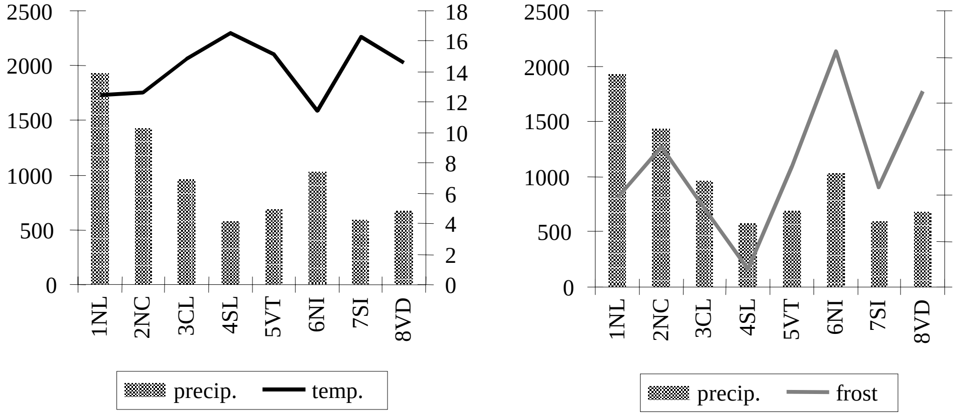

Figure 3. Summary characterisation of the eight climatic regions in which Portugal has been classified.

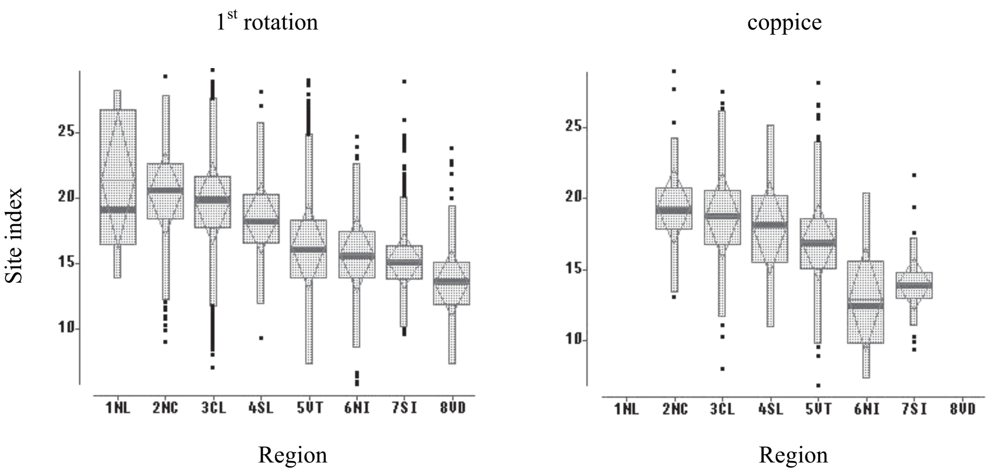

Figure 4. Range of productivity of eucalypt plantations, expressed by site index (dominant height at 10 years), in each one of the 8 climatic regions of Portugal.

During plantation establishment, a critical phase for the future success of the plantation, there is the opportunity to increase potential site productivity through soil mobilisation, application of fertilisers or even irrigation. These treatments may (or may not) be applied throughout the rotation. In Portugal, site preparation has changed significantly since the early large-scale plantations in the 1950s and 1960s and consists now of some type of mechanical site preparation, fertilisation at planting and weed control. Tomé (1994) used permanent plots of *E. globulus* to analyse the effect of the more recent practices of site management at planting and found that it affects both the productivity and the shape of the volume growth curves, anticipating the culmination of wood production. The high intensity of response to improved environmental conditions, particularly availability of water and nutrients, is illustrated by the results of a field experiment established in March 1986, in central-coastal Portugal, to study biomass production of *E. globulus* under different irrigation and fertilisation regimes (Pereira et al., 1989, 1994). The experiment was laid out as a randomised complete block design, with two blocks and four treatments. The plots were either given a near optimal supply of water and mineral nutrients programmed to meet the needs of potential transpiration and nutrient demand to sustain maximum growth (*Optim*), left unfertilised (except for starter fertiliser) but irrigated as in the *Optim* treatment (*Irrig*), fertilised with pelleted fertiliser twice a year (*Fert*) or left unfertilised and rainfed (*Cont*). Figure 5 illustrates the increase in volume production that was induced by these treatments in comparison to measurements obtained in permanent plots established in industrial stands of the same climatic region. The plots that received the *Optim* treatment produced practically the double of the control plots, presenting volumes at 6 years that could only be expected close to 10 years without the treatment application.

The effect of stocking manipulation in total volume production is shown in Figure 6, in which data are presented from one of the blocks of an *E. globulus* spacing trial (initial stocking between 500 and 1667 trees ha^{-1}; details can be found in Ribeiro et al., 1997) established in a site of medium-high productivity (site index between 21–22 m at 10 years) in comparison with measurements obtained in permanent plots established in industrial stands (initial stocking of 1000–1300 trees ha^{-1}) of the same climatic region. Manipulation of stocking induces almost as much variation as the one that can be observed in different sites with similar stocking. The results from this and other spacing trials (described in Soares, 2000) suggest that Portuguese industrial stands may be understocked. The possibility to

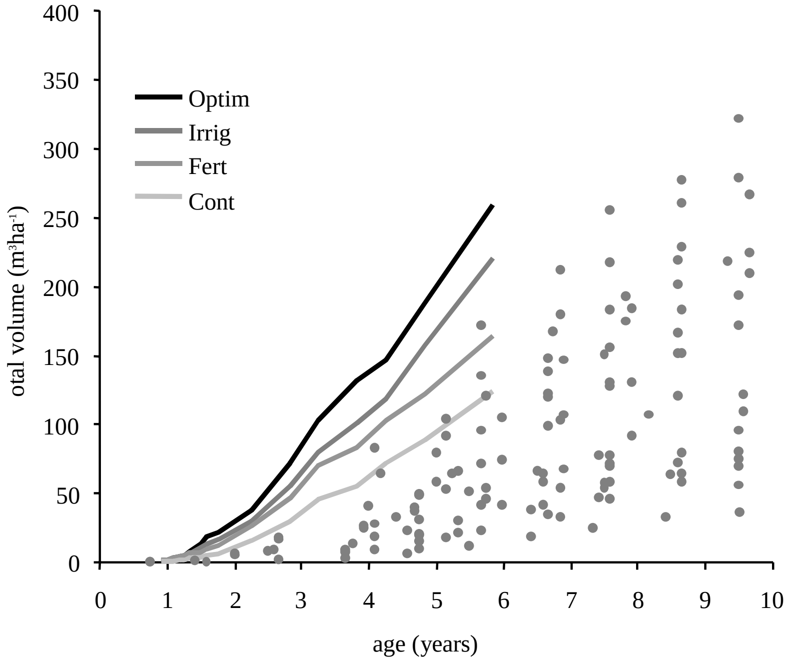

Figure 5. Increase in volume production induced by irrigation and fertilisation treatments in eucalypt plantations in Portugal. Dots represent total volume of industrial stands from the same region.

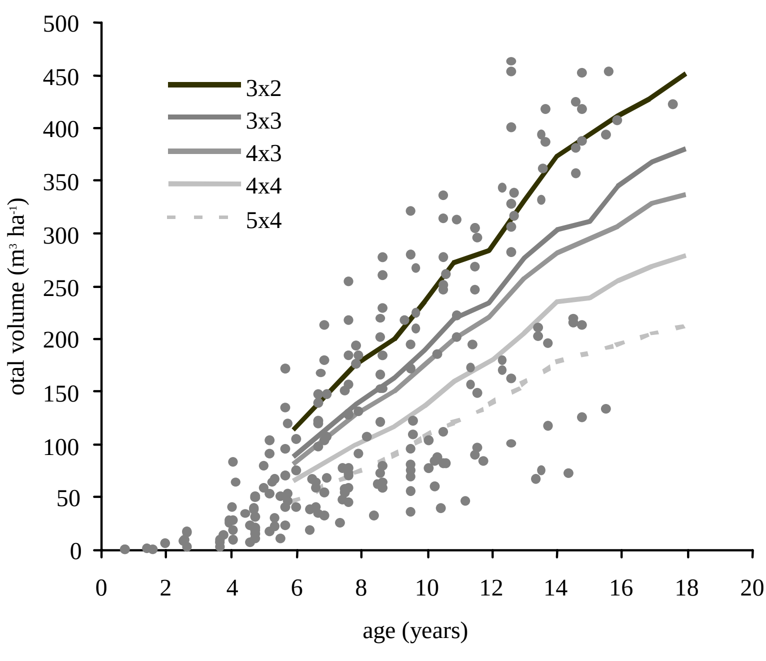

Figure 6. Effect of initial stocking in total volume production in eucalypt plantations in Portugal. Dots represent total volume of industrial stands from the same region.

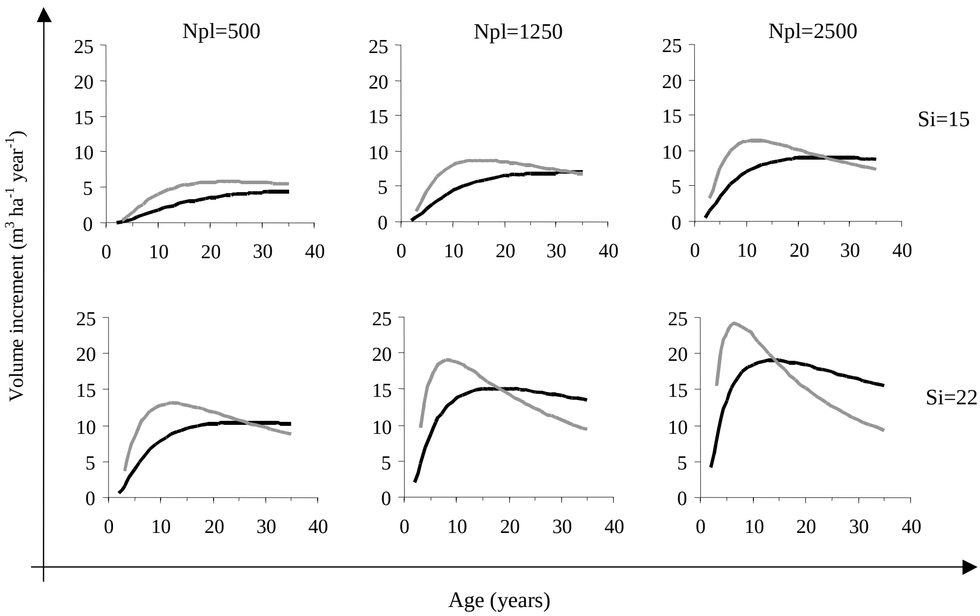

Figure 7. Manipulation of the age of volume productivity (current annual increment, in grey) through initial stocking and its interaction with site productivity. Mean annual increment is also shown, in black.

manipulate the age of culmination of volume production (maximum current annual increment) by stocking as well as its interaction with site productivity is shown in Figure 7 which was obtained with the GLOBULUS 2.0 model, a growth and yield model available for eucalypt plantations in Portugal (Tomé et al., 1998; Tomé and Soares, 1998; Tomé, 1999). Maximum current annual increment occurs at earlier ages and is higher for high initial stockings and for better sites.

All of the above examples show techniques that the forest manager may use in order to manage site productivity. Managers should also try to concentrate NPP on trees and particularly on the desired product. The concentration of NPP on trees implies the elimination or at least the reduction of non-tree components. Weeding and reduction of leaf consumption (or of the desired product, for instance fruits) may have a strong impact on the productivity attained by the plantation. Allocation of carbon to different tree components is known to vary with site conditions (*e.g.* Landsberg and Hingston, 1996) as well as with management (*e.g.* Reed and Tomé, 1998; Delgado and Tomé, 1997). The objective of management is to increase productivity, but at the same time, to concentrate it on the tree component that is going to be harvested. Foresters must be aware of the impact that management practices aimed to increase productivity may have on harvest index. For instance, there is a limit to the increase of stocking if the objective is to harvest wood for pulp. Very high stockings may produce higher yield in terms of total volume. However, the optimum stocking level in terms of merchantable volume may be at some intermediate stocking. Another opportunity for management is the direct intervention on the desired vegetation itself, for example, through pruning to increase wood quality, thinning to concentrate growth on the most promising trees, or application of uniform cuttings to promote regeneration and guarantee the transition to a new stand.

Final Remarks

Forest plantations are a reality in today's society. The present extent of planted forests worldwide probably exceeds 150 million ha (Evans 1999). Along this paper, the wood and non-wood products that can be obtained from planted forests were reviewed and linked with the objective for which the forests were established. As shown with the Portuguese example, forest may be artificially established for many purposes. Species and silvicultural systems as well as forest management may be quite diverse and are related to the ultimate use of forests. The need for high yield, wood-oriented plantations to complement the wood production that can be harvested from natural forest in a sustainable way, in order to satisfy the increasing wood demand, was also emphasised. A large proportion of new plantations is therefore established as even-aged monocultures with the primary purpose of producing wood. Kanowsky (1997) estimates that 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.

As explained before, when the objective of establishing a plantation is wood production there is a need to guarantee high growth rates for economic reasons (decrease wood cost) and also in order to use less area. High growth rates are usually associated with forests made up of monospecific and even-aged stands and with intensive management, implying manipulation of site productivity. When applied without the comprehensive analysis of the impacts that such management practices may have on the forest ecosystem, some disasters may occur as a consequence of ecosystem instability. As emphasised by Powers (1999), incorrect management practices can lead to soil erosion, compaction or nutrient drain, altering the site's potential so that long-term productivity is degraded. Management practices aimed to increase forest productivity must be compatible with a high level of biodiversity and forest tree genetic diversity, in order to maintain the adaptive potential of the forest ecosystem. At the same time it has to be guaranteed that the impact of plantation forests – whether they are more intensively managed or more close-to-nature – on water and nutrient cycles are not harmful. The establishment of a plantation causes disturbance and changes in the ecosystem. As managers, we must insure that we manage the system in a way that the soil basis is protected and the disruptions of ecological processes are within the boundary of resilience of the system.

So far, few experimental studies have been done that explicitly compare close-to-nature forestry with more intensive conventional silvicultural methods. The analysis of the few studies that are available or the extrapolation from studies on other issues that are partly relevant (harvesting or fertilisation experiments, mixed-species experiments) show that we cannot make generalisations about the impacts of close-to-nature and plantation forestry systems. Evans (1999) analysed the problem of the 'narrow-sense' sustainability of forest plantations, comparing the yield in successive crops and over time, and concluded that, so far, there is no significant or widespread evidence that plantation forestry is unsustainable. Where yield decline has been reported poor silvicultural practices appear to be largely responsible. He also reported the evidence from several countries (documented, for instance, in Spiecker et al. 1996; Cannell et al. 1998) that current rates of tree growth, including in forest plantations, exceed those of 50 to 100 years ago. This increase in growth, which has been attributed to rises in atmospheric CO_2 and nitrogen input in rainfall, better planting stock and cessation of harmful practices such as litter raking, indicates that yield decline in successive plantations may not be important. Based on recent reviews, Powers (1999) also concludes that direct evidence of productivity decline is rare, whereas the reverse seems common. According to this author, most records suggest that potential productivity may be sustained, although most findings reported in literature are short term and narrowly focused, many being confounded by factors that add ambiguity to the conclusions. He presents some rare instances in which true declines seem to have occurred, associated with biologically significant losses either in soil porosity or in site organic matter, and argues that they can offer clues to help us adjust forest practices and guide research programs.

One major conclusion from the discussion of such problems is that more research leading to the understanding of the ecosystem processes and how they are affected by the disturbances and changes induced by management practices is needed. This research implies the establishment of long-term experiments designed to study the results of site manipulation on short-term yield of the tree components with economical value. At the same time, these trials must be maintained and used to study the long-term effects of such management practices on long-term potential site productivity.

To conclude, I will summarise some of the most important points that were discussed throughout this paper:

- Plantations can perform many functions and provide multiple goods and services. High-yield, wood-oriented plantations, maybe the most abundant type of plantation, play an important role in satisfying the increasing wood demand.
- Integrated, multiple-use forest management and high-yield wood-oriented plantations should not be seen as alternative, but rather as complementary concepts. Total integration is not attainable, as some forest uses are contradictory. In its turn, total segregation does not exist; any forest provides, to a certain extent, multiple services. Between the two extremes there is a range of forest conditions leading to a more or less rich mix of products. The maximum value for society, at a global scale, may be achieved by an optimal combination of both concepts.
- Wood production, in quantity, is usually higher if the growing environment is manipulated to maximise site productivity, to anticipate peak NPP and to concentrate it in the desired product (merchantable wood). Site manipulation is limited in close-to-nature forestry, and therefore high wood production implies some level of segregation. Non-wood production, depending on the desired product, may also benefit from some level of segregation.
- Wood production and quality may be greatly influenced by appropriate genetic improvement programs that are more difficult to implement in complex production systems.
- On a worldwide scale, there is a place for every type of forest, provided that it is managed under sound sustainable management principles. The debate of sustainability should move from plantations towards management.

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Production and Resources in Close-to-Nature Forestry in Terms of Quality and Quantity

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Abstract

Close-to-nature forestry has a long tradition in Central Europe. The basic hypothesis is: if a forest on a given site is composed by the same species that are also part of the natural composition of species, and if the structure and the dynamic of development of this forest reflects the natural development under the given circumstances, this forest will have a greater stability against physical and biological risks and – at least in the long-term – will also have the highest possible productivity on this site, achieved with a minimum of cost-intensive human management activities. Furthermore this type of forest is supposed to provide a maximum biodiversity and other ecological and social benefits. The forests of Central Europe have been influenced by human activities for thousands of years. Therefore in many cases it is far from certain how the 'natural' composition and structure of our forests originally looked. Nevertheless many foresters tend to approach this tentative ideal objective by various management activities, using adequate regeneration-techniques, regimes of thinnings and patterns of final cuts. The objective is to create mixed, uneven forests with a maximum of variety in horizontal and vertical structure and extended production cycles. This 'modern silvicultural management' can have medium- and long-term effects on the forest resource. The species distribution, the dimension of the trees and the external and internal quality of the wood that will be harvested is likely to change significantly during this decade-long conversion process.

Species: For Central Europe there is evidence that close-to-nature forestry means a substantial shift from the conifers of today's man-made forests to broadleaves. Natural regeneration and long production cycles favour beech versus spruce in many cases. On drier sites oak species will replace pine forests. Broadleaved species (such as, ash, maples, birch and others), which were less important in the past, will increase in importance. All this will have consequences for the raw material supply of the existing forest products industry in the region and will influence their global competitive power.

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Tree dimensions: Modern silviculture regimes usually combine early and heavy thinnings with long rotation cycles. As a consequence a quantity of small-sized (and less valuable) timber, especially broadleaves, will reach the markets. On the other hand, the mature crop-trees will be of older age and consequently of larger dimensions. This can be an advantage for the next step of industrial conversion in terms of productivity and conversion factor, if the wood quality of these larger trees is ‘normal’ or better. However, too often, larger and older trees show an increase in secondary defects (rot, discolorations, etc.), which means a substantial decrease of their market value.

Log-quality: Uneven, horizontal and vertical structures within the stand means for a given tree changing competition situations within time. An asymmetric shape of the stem (ovality, eccentricity) as well as of the crown including big branches are a likely consequence. Early and heavy thinnings also tend to create trees with larger crowns and shorter logs and a greater taper within the log. All these features usually have a negative influence on the external quality of a log with consequences for its industrial utilization and market value.

Internal quality, wood structure: Changing competition patterns over time also very often mean a variation in radial growth. The effect is an uneven structure of growth rings. In addition to this, there are various types of variations and irregularities in the microstructure of the wood (reaction wood, juvenile wood, slope of grain, etc.). In general these quality features tend to influence the industrial value of the wood negatively.

Over all our first research results in the field of ‘silvicultural and wood quality’ suggest, that there might be negative impacts not only on log quality, but also effects on the processing and the quality of the final product. Because the shift of the silvicultural and management practices towards a close-to-nature-philosophy happened only recently, it is still not clear if these tentative consequences for the quality of the resource will be really significant. Furthermore, there are various concepts of silvicultural practices under discussion with different impacts on the wood quality of the forest resource. Therefore, more research is needed to assess and specify these impacts and consequently allow foresters to adjust their management activities to avoid or at least minimize these effects. In addition to this the wood industry has time to develop strategies and options to adjust their processes and products to a possibly changing resource, because the process of conversion of today’s forests into the close-to-nature forestry of tomorrow will take several decades.

Societal Aspects and Landscape Values of Plantation Forests

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Abstract

In highly humanized environments, forests are a socially constructed reality. That means that their evolution directly depends on our value and norm systems, which are connected to our social needs. The greater the social differences between countries or groups, the greater will be their forest social representations, and also their forest.

Social awareness of the forest is a rather recent phenomenon, growing with the awareness that quality of individual life and collective survival are connected to this endangered resource. Even if in most countries, forests represent backwardness, they are also undergoing post-industrial pressures, namely an increasing post-materialist (particularly ecological or green) view, and the services' fast growing demand that seems to override material products. Nevertheless, there is a general lack of empirical research on such market 'insolvent', but socially over-preached, demands. In any case, and even if social scientists tend to ignore it, in cross/national analysis, per capita annual wood consumption is one of best indicators to estimate comparative level and quality of life.

Surprisingly, the discourse on forest issues seems to suffer from a high cognitive dissonance. On one hand, abducted leadership shows a lack of professional expertise, and on the other, political authorities willing to counterbalance its pressure, have higher expectancies than they are ready to finance or support. The result is an inflationary social demand that results in high social tensions.

To solve such tensions, and to offer a reliable answer to real social needs, three main determinants seem to require our attention: forest culture, market and politics. As a new strategic sector, forests need a high professional corporate culture, able to overcome cognitive dissonance and prejudice. The notion of *cultivated forest* intends to make a key contribution in this direction. Landscape and green values can perfectly act as a very attractive corporate image. The particular challenge they pose to the forest sector can become an opportunity and a source of new business. As for any other strategic sector, marked orientation and economic efficiency are survival and success conditions. High fire risk is a

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good indicator of unsolved socioeconomic issues, and that old and new demands are in conflict. The general tension between business and ecological demands show a unique virulence in the forest sector that requires the particular attention of large forest corporations, particularly pulp and paper industries, which, according to public opinion, are prime beneficiaries.

The changes demanded from the forest sector cannot be managed with the indirect public measures that are oriented to solve problems of other sectors. New problems will be created if defining a forest policy is avoided. As far as the forest is a socially constructed reality – a more or less cultivated land – upon which social demands are growing and getting more complex, there is an urgent need to define a public policy and to allocate the necessary funds to implement the policy.

Social Indicators to Assess Landscape Values

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Abstract

Social change is reflected in its various representations in landscape and nature. Societal values shape the face of towns, peri-urban areas and the countryside reflecting the society's dominating rationale and taste at a given time. The perception and acceptance of shaping the landscape as spaces according to social needs and preferences in and around cities and in rural areas are an important dimension of identification and well-being of the local population. The assessment of the elements as core themes in landscape planning is fundamental to meet the expectations of various sections of society in the future. Globalisation, working with virtual media and a predominantly indoors life style on the one hand, and life quality in green surroundings on the other hand, where people feel comfortable, have both to be considered in planning processes. Thus, indicators to assess landscape values from a social scientific point of view may take the following dimensions into account:

- What do landscapes indicate?
- Landscape valuation as an integrated concept;
- Close-to-nature landscapes as social constructions;
- Managed and unmanaged landscapes;
- Plantation forestry as economic valuation of landscapes;
- Plantation forests enabled outdoor recreation; and
- Similarly, it should be considered whether landscapes can be defined in societal terms, especially with respect to:
  – well-being;
  – linking urban amenities with healthy surroundings;
  – strengthening of the local community and neighbourhood cohesion;
  – perceiving landscape as a cultural metaphor; and
  – landscape preferences and perceptions.

These indicators may be incorporated into close-to-nature-forestry as guidelines for participatory planning and implementation reflecting individual needs and social preferences. The aim of this contribution is to identify locally meaningful social indicators for landscape

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value assessment and to discuss ways and means how close-to-nature-forestry may make use of them.

Keywords: close-to-nature forestry, plantation forestry, social indicators, landscape

Introduction

Wherever humans live, they appropriate nature as culture, i.e. people are inevitably shaping landscapes in the wake of developing their culture. This process is as practical as symbolic. A landscape that is perceived as beautiful is a representation of societal values in a symbolic way. Perceptions, beliefs and values find their expressions in the material and immaterial world. It is a process of encoding and enciphering culture into landscape and its use and management. Without a key they cannot be read. Furthermore there are individual perceptions, tastes and preferences which are modifying these cultural keys at the personal level adding a very individual, and sometimes artistic, note to it.

Forests and forest landscapes are thus entire life-worlds for those cultures who live in and with them. For others they are predominantly sources of timber and other products. Each of these cultural views reveals that natural surroundings can only be understood by deciphering the social essence, which is represented in them. Therefore, it requires social indicators as keys to read and, if required, to assess the various cultural landscapes of the world.

What are Social Indicators and What Do They Measure?

Social indicators measure to what degree a stage of a society's development is reflected in its norms, symbols, institutions, values or any other form of perceiving and expressing itself. Social indicators measure the output of the assets a society is able to produce at a given time at the level of the individual. The achievement of social welfare objectives, for instance, if this has been the declared development target of a society, is to be measured by social indicators. Whether they are singular and quantitative, in the form of statistical figures, or multiple and qualitative, such as in the case of social well-being and quality of livelihood assessments, is up to the theory of an investigation. In other words, in whatever state of development a society is, the individual is a scale to measure it against. The individual is so to say an aggregation of social indicator outputs and thus a social indicator itself.

What Do Landscapes Indicate?

Landscapes are phenomena that include the natural, the social and the built environment in a state of constant shaping and re-shaping. Landscapes are dynamic configurations of many interests, actors working on and in a space with a certain power and economic potential. This potential is more or less equivalent to a range of cultural and biological diversity within the climatic limits of the area in which it occurs. Landscapes indicate the political history as well as the history of the material culture, and the characteristic staple products of a region such as wine, wheat, potatoes, milk or olives, etc. They indicate the economic potential as well as temperament of their indigenous inhabitants, their humour, aesthetic taste and preferred life-style.

There are no landscapes without people, and strictly speaking there are no *natural landscapes*, because every spot on earth has been either shaped or so far spared from human intervention. Landscapes are always cultural landscapes exposed to economic energies and soci-cultural performance. Out of these the fabric of any landscape is woven and each has its own distinct pattern and thus its own unique value.

Everything which is culturally relevant and a milestone in social history, leaves its mark on the landscape. Many phases of social history are synchronised and become an integrated present construction of phenomena from various temporal contexts. This is what the observer generally looks at when he is exposed to a particular landscape. However, there are short-term and long-term aspects in every landscape, which are more or less subject to change over a time-scale of three or four generations living together in the same era. Landscapes are very much connected to biographies with the people of the area, their memories and what the area stands for or stood for in a wider historical or geographical context. The legacy of a landscape is its natural potential and the history of its use.

Landscape Valuation as an Integrated Whole

Generally, landscape valuation does not start from a well-defined point of view or interest by experts, but it is the common observer who is exposed to a landscape in the broadest sense, perceiving it as an integrated whole. Prominent attractions within different aspects of a landscape are, however, particularly valued, yet it is the entire character of the landscape that ultimately matters. Monuments in a landscape, for instance, belong to it as the landscape underlines their uniqueness. The whole of a landscape is a configuration, if not amalgamation, of elements that have an influence on each other and have mostly grown organically or historically over a longer period of time. As we learn from history, generally there was very rarely a planning intention to shape a landscape as such, but the typical way a cultural landscape developed over centuries was for functional or aesthetic reasons. Today and in the recent past, the landscape planning attempts to give a certain direction to the development of a landscape and a spin that is derived from a politically induced landscape planning programme. Generally, the lack of organic development, the restricted time frame and, most of all, the different interests involved in planning are restraints of an organic development comparable to that of the distant past.

Organically grown valuation processes based on individual assessments and ‘taste’ are led by aesthetics and inclinations of how the landscape is experienced by individuals or distinct social groups (youth, elderly people, workers, academics, housewives, etc.). Valuation as an emotional process is a response to the environment with all senses and as natural process rarely has explicit objectives. It generally depends on how people do actively interact with particular landscapes and whether the respective landscape is embedded into their social activities or *vice versa*. If there is an attitude of passive consumption of landscapes, which are perhaps perceived as beautiful, is more a pleasing generalisation than a serious valuation. It can be taken as a visual appropriation and appreciation of an appealing scenery by those who do not use or manage land or the products derived from it.

Landscape valuation and the identification of social indicators for landscape planning as a professional undertaking has to be determined by development objectives. Plachter (1995, p. 393), who emphasises the distinction between a material and functional valuation of a landscape, denies the appropriateness of a holistic valuation of a landscape:

> *In view of the complexity, variability and dynamic change of landscapes a holistic approach to describe and evaluate landscapes is not appropriate. Indicators are necessary which reflect specific characteristics or values of distinct landscapes.*

He argues that there is no common ground of understanding of what a particular landscape means to whom. For the same reason one could say, landscape always remains something opaque which is impossible to grasp with indicators. Whether to use indicators would be more appropriate or a holistic appreciation, landscape always transcends a simple technical assessment. A contemporary landscape is a 'we-museum' of what matters for the generations living together.

Societal being, represented by social values and aesthetics is exposed in landmarks of intrinsic quality which are reflected in the mood of the landscape and the national character of the people, where social norms of what is generally accepted and favoured have been transformed. The so-called 'natural' is what a society perceives as nature at a particular moment in time. Any landscape is, therefore, a socio-cultural definition, a process by which landscape phenomena are related to phenomena of a particularly appreciated human life style and a code of conduct with phenomena perceived as natural.

Close-to-Nature Landscapes as Social Constructions

Landscapes are social interpretations of nature and constructions of the human mind to define the position of man towards it. In this sense a landscape always denotes a social relationship between the landscape and the observer. Such as the landscape painter who develops an affection towards the landscape he is painting; like the peasant has 'his landscape' in mind when talking about the landscape in general, and the ecologist and the green activist may have an idea of how it was or should be for future generations. Landscape is the experience of surroundings which may physically be the same, but which may be perceived by people in a different way.

How close to nature can people really get? How are their ideas of nature reflected in reality? Or how do ideas shape reality? Since the age of Enlightenment, when J.J. Rousseau, being a lonesome walker in the forests himself, invented one of the ideals of his era, the 'noble savage', who is supposed to be living in the wilderness as the prototype of a free and independent personality, naturalness and wilderness has become a topic in societal discourse that has a strong impact on environmental perception in modern societies (Willers 1999). The outdoor and camping movement, as well as hiking and trekking in the remaining wilderness areas amidst a paramount civilisation, have become concepts of a free and independent life. Scepticism against progress prevails among these sections of society, which perceive it as suspect and sometimes criticise it as anti-human and directed against a natural way of life. Where industrial mass production pushes aside small farmers and artisans, where city-life-styles become usual phenomena, wherever the insignia of civilisation spreads, nature is claimed to be threatened. Technical progress and this point of view is almost taken for granted, goes along with phenomena of de-naturalisation of the environment. The more the standard-of-living improves, and this has as well become a well established common sense notion, the poorer nature becomes. This may be seen, for example, in an example of the development of North America. J.B. Jackson (1979, p. 154) interprets the making of the USA landscape in the following way:

> *Let us consider the decades of the mid-eighteenth century, a point in the history of the man-made environment of America when a new and rationalist landscape was about to replace the old medieval, traditional landscape inherited from Europe. It was a time when many relationships in colonial America were changing: relationships between individual members of the family and of society, between individuals and their work, between individuals and their natural environment, and perhaps most significant of all,*

though hardest to define, a time when the individual was becoming aware of him/herself, and questioning traditional definitions of man. The time was thus approaching when the visible world, especially the man-made world, would begin to reveal those shifts in relationships. For relationships among men and women usually imply spaces, and new relationships produce new ideas of spatial size and location and change or growth. The look of land, even the look of the house, inevitably reflects those ideas.

What does social construction mean in this context? Similar to social change, which denotes the totality of continuous social action and development, social construction means the confirmation of what is generally claimed as social reality by all those who participate in public everyday life. Norms such as aesthetics and nature and cultural heritage conservation are agreed upon in laws and regulations, referring to tradition and social conventions. These norms are based on assumptions and implicit meanings, which are taken for granted. It can thus be widely taken as generally accepted today that in economically advanced societies that closeness to nature is a common value in most societies across the world, whereas anything being far from nature is perceived as inferior or less desirable. Whether they are productive or protected landscapes, whether managed or not, they had to look as if they were natural landscapes. This obviously applies to the current notions of landscape and nature in economically developed countries; Developing Countries may have a completely different point of view in this respect.

For instance, in communist China during the Cultural Revolution, landscape painting is characterised by emphasising industrial buildings and machinery and predominantly shows hard working people (Gesellschaft… 1977, p. 61), but the general aesthetics is still that of 15th century (Grosse 1923, p. 63) brush paintings (see Figure 1).

One can easily read the political message in the landscape. In the latter contemplation and observation is highlighted whereas the former stresses domination over nature by the overwhelming power of communism. In Figure 2, a painting by Liu Zhong-Ping, an aeroplane is shown spraying chemicals over a freshly planted landscape (Gesellschaft… 1977, p. 45) with the title “Awakening springtime on the shores of River Huai”. It is full of enthusiasm for an expected bumper harvest. The use of pesticides in agriculture is an icon to praise the victory of social progress over nature. This example may show how the landscape is a symbol constructed by social forces in order to achieve political goals.

Managed and Unmanaged Landscapes

We started from the assumption that every landscape is a cultural landscape shaped by human interventions. In this perspective, the management of landscapes is an activity that is guided by the use of certain resources for a particular period of time. Surface coal-mining, agriculture or large scale logging is a specific mode of economic valuation of land and has a severe impact on the landscape. To get a surplus value from whatever use of land is the ultimate goal of its management. Unmanaged land is a resource which is either left aside and spared from being productive or is not yet taken into consideration to be managed. Unmanaged landscapes are usually perceived as ‘natural landscapes’ although they are not natural at all (Lewis 1979). It is more the fact that human intervention and landscape management is taken as an inevitable necessity on the one hand, and on the other hand, there has to be space that provides people with the illusion of being close to nature or still having access to untouched nature (Willers 1999). This illusion is a necessary complement to satisfy the human imagination that there is space left for animals, rare and endangered plants, for silence, recreation, future generations, etc. The imagined natural landscapes suit an important

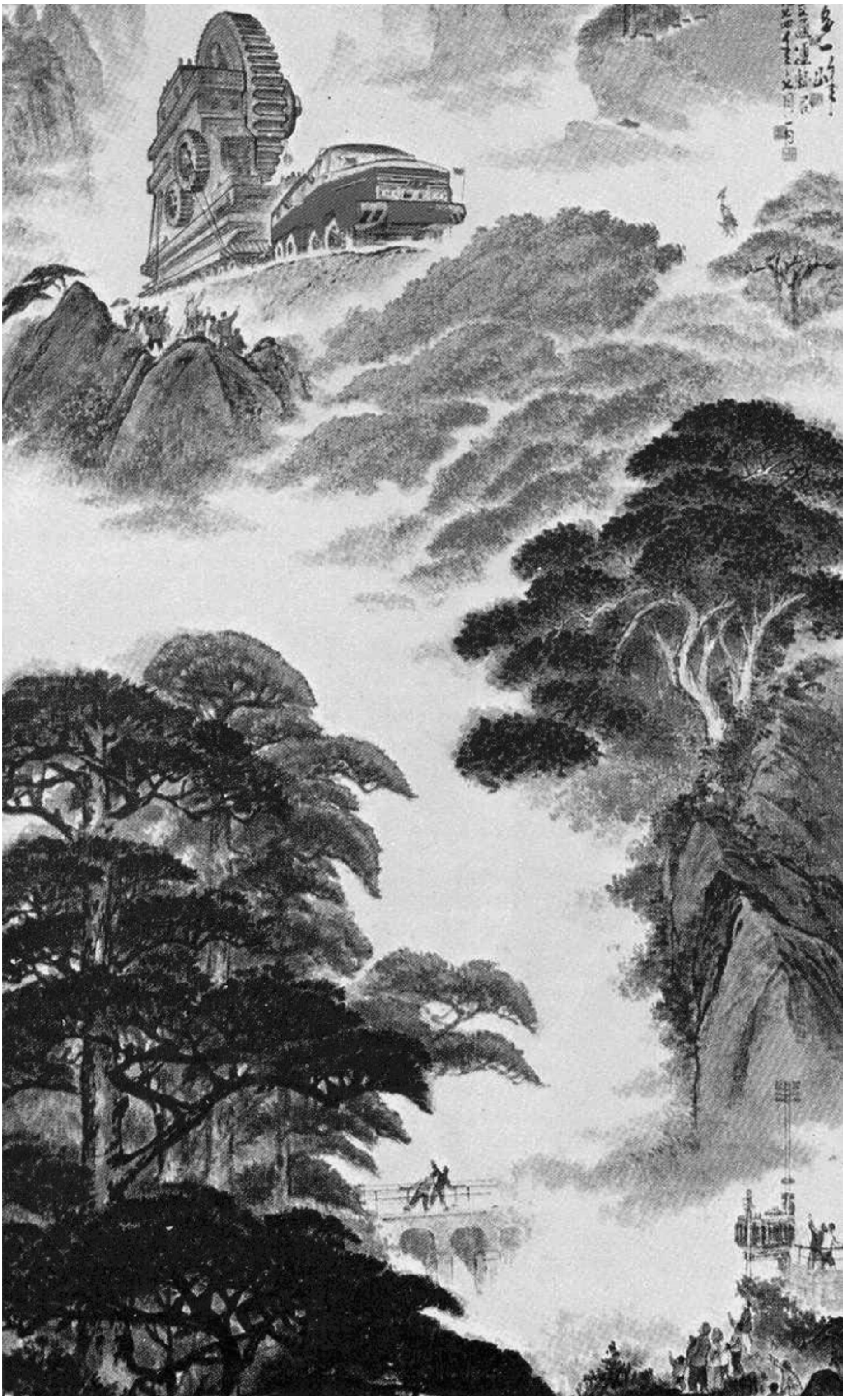

Figure 1. An example of a landscape painting from China during the cultural revolution.

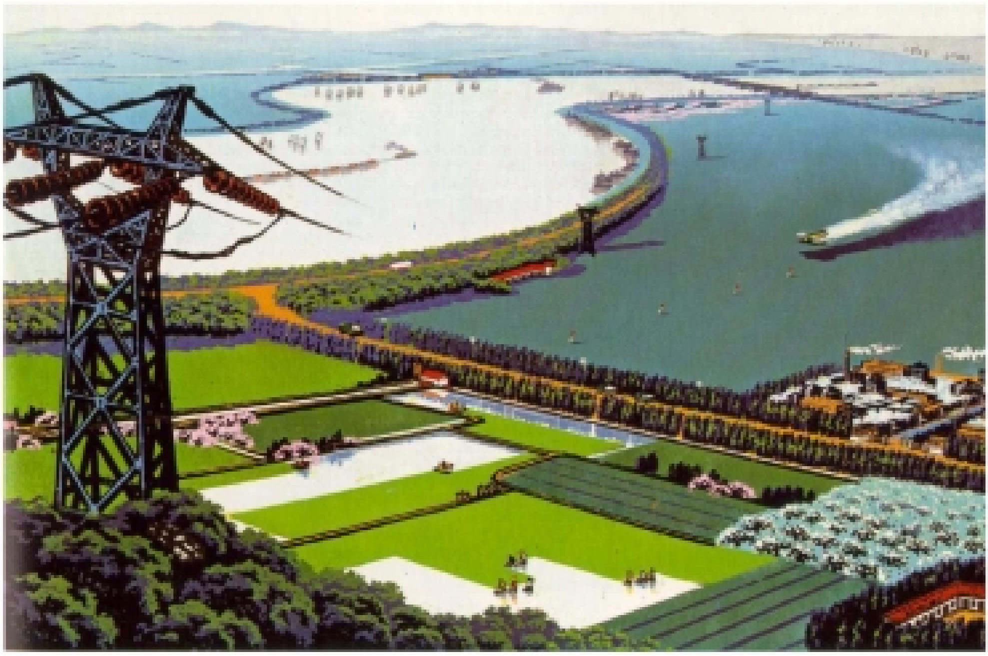

Figure 2. Landscape painting by Liu Zhong-Ping.

purpose by pretending that human penetration is not all pervading and omnipresent. Nature conservation, protected areas and sanctuaries, for instance, are psychological strongholds reassuring fast developing societies that nature is allowed to persist. Survival of the modern economy is no longer dependent on nature's grace, and yet the natural roots of mankind will not be allowed to be lost in the wake of this development. These psychological aspects of landscape and nature conservation are the foundations of modern conservation policy: unmanaged landscapes are generally perceived to be more valuable than managed ones. Aesthetic value is implicitly rated higher than economic surplus value. Once nature conservation or land use policy rates and assesses landscapes it has to develop economic and social indicators to measure the appropriateness of policy decisions.

Economy has developed its own methods, for instance, to assess non-market benefits of forests by using contingent valuation methods, travel cost method and hedonic pricing (Roper and Park 1999). Social indicators can reveal values, which are more or less hidden in landscapes. They are more hidden for those who have a predominantly technical view of landscapes, and less hidden for those who try to look below the surface of landscape as a resource in order to grasp some of its many aspects of meaning. These values are:

- integration value
- acceptance value
- frequentation value
- functional value
- illusion value

This selection of values, which, of course is non-exhaustive, is suggested as a non-monetary method to take social values into account that matter in any landscape and are thus relevant for theoretical reasoning.

Integration value: the integration value of landscapes measures the extent to which social groups, and marginal groups in particular, are actively using outdoor surroundings. The indicator is, how important people think landscapes are for their social life, i.e. how often people meet each other in green public spaces and interact in it in a way that is meaningful and important for them.

Acceptance value: the acceptance value of landscapes takes into account to what degree particular segments of a landscape are accepted by what section within a society and why. The indicators are the reasons for a positive or negative assessment of certain phenomena and their ranking and preference in political decision making.

Frequentation value: the frequentation value of a landscape is closely connected with the primarily accepted and favoured outdoor green space. Its indicator is the frequency of visits by the number of people with a particular socio-demographic profile per time unit.

Functional value: the functional value of landscape use and management indicates how many of its vital inherent factors have been taken into account for its assessment, such as: biodiversity, technical aspects of soil fertility, traditional cultural values, ethics, aesthetics, sustainability, etc.

Illusion Value: the illusion value stands for the degree of hiding inappropriate elements in the landscape, or the attempt to represent something other than that which is perceived on the surface. The indicator is the cost of covering undesired phenomena in the landscape by either putting them underground or camouflaging them with forest. For example, forest plantations could be thought of being surrounded by close-to-nature forests if public opinion supports this illusion as desirable.

The valuation of landscapes according to the application of these value categories shows the multiple dimensions of societal aspects that matter with such highly aggregated phenomena. In forestry, the valuation of landscapes is an inherent element, because forests make up a substantial part of the landscapes and are thus important aspects of landscape planning, nature conservation and social policy. For plantations and close-to-nature forests the above mentioned forms of valuation apply, and we can say that they are all as important for forests as for landscapes. The next section will have a closer look into the difference between plantation forestry and close-to-nature forests with respect to their social dimensions.

Plantation Forestry as Economic Valuation of Landscapes

Natural forests have become scarce over the last centuries in Europe as in other areas of the world (Ballée 1989). In the wake of this process, planted forest had to take over various functions that were previously provided by natural forests (e.g. wood production, supply of non-timber forest products, micro-climatic stability, watershed and soil protection, biodiversity, a shelter for wildlife, provision of recreation amenities, and more recently as sinks for carbon sequestration) (Boyle 1999). Plantations were used to replace natural forests because yields of selected commercial species were greater, and harvesting was less expensive. The economic valuation of land is the prominent objective of a purely economic rationale to maximise profits by optimising the use of marginal land in many regions. Natural forests are clear felled and replaced by plantations for productive rotation. Trees become crops with a scientifically defined productive life span and forests are predominantly technically perceived as tree stands.

Any economic valuation is a social valuation as well, because economic reasoning is related to social actors who favour a certain use of a resource because of an expected higher rate of return or other non-material benefits or amenities. Economic valuation determines the management strategies that shape a landscape with all the costs and benefits derived from it. It is a question of capital investment or investment of social energy, how close to nature a forest plantation is going to be managed and both aspects have to be taken into account for forest landscape valuation. The inclusiveness of social and economic values in forest landscape valuation has led to a specific multipurpose approach to meet the wide variety of objectives contemporary forestry is confronted with. This approach is called landscape forestry, which, according to Boyce (1995, p. 4), is:

> *... an art based on personal experiences, results of managerial actions, research results, and understanding of the dynamics of biological systems. The art is following and adjusting, step by step, courses of action found by experience to result in acceptable productions of desired benefits.*

One may add that these “acceptable productions of desired benefits” are defined by the value concepts or environmental strategies that are prevailing in a society at a particular time.

In this perspective it is of secondary importance whether forests are planted and perceived as natural or whether they are really virgin forests as long as they meet a social concern for forested landscapes and cover a substantial number of different demands of various political actors and interest groups.

Both forest types are highly valuable for society, because they provide it with a wide range of required products and services. Plantations can, for instance, relieve the economic pressure on natural or close-to-nature forests and the latter are more appropriate to serve recreation purposes, as habitat for animals and rare plants, for scenic beauty etc. The most important aspect of being perceived as inadequate or lacking acceptance for forest plantations is the mental or physical distance of the mostly urban and suburban observers to these secondary forests. Located close to the cities, there were once upon a time highly appreciated for supplying fuelwood and timber. During recent decades the use of and the preferences for particular functions of forests have generally changed (Boyce 1995, p. 9) in technically and economically developed countries. The basic problem with plantation forestry is its one-sidedness and lack of sensitivity towards other societal values, which have emerged with social and economic change. Being perceived as a fragment of an imagined natural forest it will always be second best and at times when ideals of wilderness and untamed nature are praised, they make a negative model of what was thought to be the ultimate socio-economic achievement generations ago. It is a parallel phenomenon as to the ugly face of industrial production: its benefits are welcome, but smoke, dust and pollution have to be kept out of sight.

Plantation Forests Enabled Outdoor Recreation

Large-scale and industrial wood production in 19th century Europe was to serve the needs and demands of an increasing population and a tremendous economic growth. Since the making of an urban working class during the latter decades of the 18th and throughout the 19th century, a rising demand for recreation evolved. After a 12 to 14 hour workday, the workers wanted to relax outside the cities, in the fresh air, and in a green and quiet environment. A social demand developed amongst the urban dwellers who had become disconnected from the countryside, to escape from the filth and smoke of the cities, at least on Sundays. Only two or three generations ago, the landless poor had fled the countryside that could hardly feed them, looking for a more secure living and income from employment in a factory. The opening up of large forest areas, due to political events as the expropriation of the aristocracy in some European countries after the French revolution, and in the aftermath of the Napoleonic wars on the Continent, or the establishment of large scale plantations by the state, facilitated recreation for the wider public. The forests, which were previously known as areas of restricted access or places of hard work for the village paupers, became attractive for recreation at low cost. A new demand was met by a new outlook on forests; hitherto unknown leisure time was now partly spent in forests that were perceived as healthy and convenient places (Seeland 1993).

The majority of the European forests, and not only in accessible lowland areas, were already secondary forests for a long time when the demand for forest recreation arose. Therefore it is obvious that predominantly forests in the vicinity of urban areas with a well-established road infrastructure were taken into consideration for that purpose. And these forests were far from being natural, and certainly not virgin forests. The latter would (even if there had been any) have been perceived as inaccessible and unsuitable for picnics and leisure walks. Plantation forests were probably found to be natural enough to meet the demand for recreation. And in those days, we must not forget, recreation was neither acknowledged as a product nor a by-product of forestry. It was a free benefit for those who could afford it.

Can Landscapes be Defined in Societal Terms?

During the last decade well-being has become an indicator of wealth and quality of life, where the average standard of living is high as compared to other countries, definitely much higher than in the developing and transitory societies of the South and the East. Rising expectations among the well-to-do mean that they expect to be better off than others. The legitimacy of this demand is backed up by a commonly accepted righteousness of hedonism for those who can economically afford affluence. To achieve a state of maximum amenities for those who claim to deserve them has become a core message in modern consumerist societies with high economic growth rates. The strong and still increasing trend towards urbanisation meets the challenge to link urban upper middle class notions of what is perceived to be an appropriate life-style pattern for themselves with the amenities of high value peri-urban recreation areas, with a variety of sports facilities and entertainment parks, country restaurants etc. Good health and beauty is an important nexus between one's own body and mind and the landscape which promises to provide these values to its visitors. These values are communicated very much among the peer groups of the same or similar social strata, they are important criteria for one's social self-esteem and an indicator to define one's social rank.

The regional identity and community ties are also derived from landscape characteristics providing those who live there with advantages (i.e. marvellous views, less noise, less smog or fog, etc.) and respective admiration by others who live in less favoured areas. The prominent position of certain landscapes in comparison with others is a quality-of-life standard of high value. And forests are high ranking among lakes and mountains, seashores and other value adding landscape elements (Tyrväinen 1999).

The fact that there is a socially relevant ranking of landscape qualities underlines the importance of perceptions and preferences related to them for forestry and landscape planning. Perceiving landscapes as a cultural metaphor for regional and national identity means that, for example, in the case of Switzerland that a high density of lakes, mountains, forests and wealthy cities makes up the unique blend of highly appreciated landscapes combined with other amenities in this country which attracts many foreign tourists. The social cohesion with the landscape among the native population is strong, and the foreign tourists appreciate this, because it is based on the conviction that there is an exclusiveness of having experienced these places, where others cannot afford to go. High standards of approved landscape beauty represent a high standard of management that becomes visible in the landscape. And this again is an indicator of the degree of well working processes among the administration and the social and political institutions. It can be read and seen in the landscape whether the political system of a society is in accord with the landscape and develops its inherent qualities or not.

Conclusion

Landscapes are manifestations where social relationships meet with natural phenomena, and both shape configurations which indicate cultural identity. Naturalness of the habitat and human interventions into it are constant processes of interaction. The use and management of highly aggregate amalgamations such as landscapes decide upon how these are reflected and perceived in social, environmental and policy discourses. Landscapes at a given moment in time are projections of social aspirations and purposeful interventions into the sphere of natural phenomena led by particular objectives that have emerged from these discourses. Social life styles and political power, negotiation and compromise, all keep the landscape in a state of constant change which again reflects social dynamics. Whenever a landscape is analysed with regards to its economy and history, it turns out to be a reminiscence of past forms of social life that made itself a particular environment or looked for suitable surroundings according to its needs. In order to decipher the messages in a landscape, one ultimately detects social life in a historical perspective. To make social relations visible and to understand the comprehensive network of nature-culture configurations, indicators are a valuable help. To assess the degree of integration, acceptance, frequentation, the functions of and the illusions which are encapsulated in landscapes, distinctions and interpretations are possible, how and in what way landscapes may be ranked, turned into protected areas or industrial building sites, or to be put on the world heritage list, for instance. As far as forestry is concerned, social indicators can be useful to distinguish and rate the response of various social strata within a society towards what forests people prefer and why. Future professional forest and landscape management will have to integrate social assessments in order to democratise policy processes to shape the landscape as the largest unit of socio-cultural identity.

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Economic Accessibility of Russian Forests for the European Market

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Abstract

The Russian Federation possesses a vast wealth of forest resources which, if used sustainably, can make a significant contribution to the global, and first of all, European economy and ecology. The forest and timber resources in Russia, and the markets for Russian timber are described. A method to assess the economic accessibility of timber resources is presented, and the implications for Russian forest policy are discussed.

Keywords: Russia, forest economics, forest resources, timber resources, forest policy, markets, mathematical models

Introduction

The Russian Federation possesses a vast wealth of forest resources which, if used sustainably, can make a significant contribution to the global, and first of all, the European economy and ecology.

The total area of Russian stocked forests is 770 million ha. The total growing stock is 81.9 billion m^3, including 61.5 billion m^3 of coniferous species. The share of mature and overmature forests is estimated at 43.8 billion m^3. These stands are largely found in reserved forests, which are technically inaccessible today and will remain inaccessible unless large investments are made. A potential European market may, most of all, be interested in forest resources concentrated in European Russia. These resources have the following characteristics:

- stocked forest area: 167 million ha;
- total growing stock: 22.0 billion m^3;
- total coniferous stock: 13.2 billion m^3;

- growing stock of mature and overmature stands: 9.6 billion m^3;
- annual increment: 380 million m^3; and
- In European Russia, the annual allowable cut (AAC) for final felling is 208 million m^3.

The 1999 actual final cut in European Russia amounted to about 70 million m^3, versus 105 million m^3 in the Russian Federation as a whole. Thus, in European Russia, around 35% of the AAC is actually used. Timber from final cutting may be complemented with that from thinning to increase timber outputs by 25–30%.

Table 1. Forest Resources in the Russian Federation, 1998.

Data	Measure	Total	Including European Russia and the Urals	Asian Russia
Forested (stocked) area	million ha	770	167	603
Total growing stock	billion m^3	81.9	22.0	59.9
Including: Coniferous stands	billion m^3	61.5	13.2	48.3
Growing stock of mature and overmature stands	billion m^3	43.8	9.6	34.2
Including: Coniferous stands	billion m^3	34.4	6.4	28.0
Annual growth	million m^3	980	380	600
Allowable cut	million m^3	542	208	334

The low level of forest utilisation is accounted for by a drastic decline in domestic demand for timber products due to low effective demand of the population (the 1999 average per capita annual income was as low as US$ 700) as well as insufficient processing capacities which had been erroneously concentrated in Asian Russia (Eastern Siberia) under the centrally planned economy.

Table 2. Timber industries' outputs in the Russian Federation in 1990–1998.

Products	Measure	1990	1995	1998	1998 % vs. 1990
Timber removal	million m^3	304	115.0	83.2	27.4
Industrial timber	million m^3	256	92.0	67.0	26.2
Sawnwood	million m^3	75	26.4	19.5	26.0
Plywood	thousand m^3	1597	930	968	60.6
Particle board	thousand m^3	5568	2210	1463	26.3
Fibre board	thousand m^2	483	234	197	40.8
Pulp (after cooking)	thousand tons	7525	4200	3168	42.1
Paper	thousand tons	5240	3270	2230	42.5
Paper board	thousand tons	3085	1300	1102	35.7

Table 3. Exports of primary timber and paper products (from the Russian Federation to countries outside the former USSR).

Timber Products	Measure	1990	1998	1998 vs. 1990, %	Share of Exports in Industrial Outputs	
					1990	1998
Roundwood	million m^3	15.0	17.5	116.7	5.6	26.1
Sawnwood	million m^3	7.1	4.2	59.1	9.5	21.5
Plywood	thousand m^3	324	615	189.8	20.3	63.5
Particle board	thousand m^3	115	170	147.8	2.1	11.6
Fibre board	thousand m^2	139	170	123.2	8.9	26.9
Pulp	thousand tons	389	971	250	5.2	30.7
Paper and paper board	thousand tons	906	1434	158.3	10.9	43.0

Whereas under the centrally planned economy, the State had covered the transportation costs of timber – on average transported to a distance of 1800 km – the market economy has made the Siberian forest resource economically inaccessible for the market in European Russia, home to 80% of the country's population.

A market-driven forest economy allows assessment of the actual forest resource accessibility for both domestic and international markets, including European ones, by resource type. To this end, the Government should address a rather important issue (i.e. forest revenue management). It may be accomplished through investment in the development of forest industries, and first of all, in the establishment of industries for chemical and chemical-mechanical wood processing.

The Russian forest legislation has set up a financial system which implies that stumpage price is established by decree in the form of tax rates. Because of the decree-wise established stumpage rates, the 1999 stumpage charges averaged US$ 0.6 per m^3, which is far lower than in all economically developed European countries.

A timber product cost-benefit analysis shows that the share of stumpage charges in the price of end products is very small. When roundwood is exported from Russia, stumpage charges account

Table 4. Forest rent revenue (forest resource charges) in US$/$m^3$.

Indicator	Roundwood exports	Domestic market
1. Free to the border (Finland)	30.0	–
2. Free to the customer	–	20.0
3. Railway tariff	12.0*	4.0**
4. Loggers' profits, including taxes and stock accumulation	4.0	4.0
5. Prime cost of forest logging – free to low landing	8.0	8.0
6. Forest rent revenue (stumpage price)	6.0	4.0

*The tariffs have been raised by 3 times.
**To distances up to 1200 km.

for, at most, 3% of the CIF prices while operating costs (including transportation) account for 30–40%. The remaining share of the price (over 50%) belongs to private timber business, and, to a great extent, to the intermediaries who do nothing to add value to the products. The virtual situation with forest revenue generation in the Russian Federation is summarised in Table 4.

The situation outlined above results from the absence of public forest revenue management under the monopoly of public ownership of forests. Forest revenue should go to the forest resource owner, but a large proportion is leaking from the country where the forest sector's investment needs in European Russia alone are estimated minimum at US$10–15 billion. To ensure forest rent capture and management by the Government, the most urgent step is to identify economically accessible forests (i.e. forests which are internationally classified as 'commercial forests', capable of generating forest revenue).

Under the centrally planned economy, this approach to forest resource assessment was never practised in Russia, and this has resulted in major miscalculations of the forest resource base in the former USSR, and therefore, major financial losses.

A Method to Assess Economic Accessibility of Forest Resources

We have developed a model to assess economic accessibility of forests for various scenarios of forest use. The methods to assess the economic accessibility of forest resources are described below:

In the first stage, the actual available resources are assessed through forest surveys (mensuration) and inventory. Each regional forest use scenario should include the following outcome indicators:

- forest cuts to be estimated by optimisation calculations with the use of growth and yield models;
- resource classification by species, size and quality group;
- resource location over the region with indication of public transportation routes (railways, roads, waterways).

For the purposes of economic accessibility assessment of forest resources, allocated for harvesting on the basis of biological and silvicultural criteria, the following characteristics of timber resource in each area of its concentration should be available:

$$Q_i(X1, X2, X3, X4, X5, X6) \quad (1)$$

where: Q_i is timber cut in area *i*;
X1 is stem volume;
X2 is growing stock per ha;
X3 is species composition;
X4 is soil and ground conditions;
X5 is terrain; and
X6 is the distance from the resource concentration area to a public transportation route.

If there are *n* areas of resource concentration, the aggregate regional cut would amount to:

$$Q_0 = \sum_{l}^{n} Q_i \quad (2)$$

In its turn, in each resource concentration area, the timber cut is expressed as the sum of timber cuts in individual species, size and quality groups:

$$Q_i = \sum_{l}^{k} Q_j \quad (3)$$

where: *l...,j...,k...* are the number of species, size, and quality groups of timber, respectively.

The forest resource characteristics (Equation 1) are provided by forest management planning and inventory for different forest use scenarios, and they underlie software-based econometric models to estimate inputs (capital, labour) required to harvest the allocated forest in each resource concentration area as well as the costs of its harvesting.

The multivariate approach to the identified problem is based on various technologies of forest resource utilisation with different assumptions of inputs. In each resource concentration area, economic indicators of forest use would be:

1. Capital inputs (aggregate and specific) into resource use

$$K_i = f(X1 - X6) \quad (4)$$

2. Labour inputs (aggregate and specific)

$$L_i = f(X1 - X6) \quad (5)$$

3. Resource utilisation costs

$$C_i = f(X1 - X6) \quad (6)$$

4. Gross revenue and average market sale price for 1 m^3 of timber products

$$P_i = f(Q_{ij}) \quad (7)$$

The average selling price would be a function of the species – size – quality composition of harvested resources (*j*).

To model the gross revenue and hence average sale price for roundwood, it is necessary to undertake a regional timber market survey. Mathematically, this problem can be identified and solved on a multivariate basis. The significance of thus estimated economic parameters of forest resource utilisation (Equations 4–7) depends on the quality of relevant regulations, including norm-based inputs (unit capital costs, labour, energy and material inputs). Based on the economic description of forest resources in each resource concentration area, a strategy for forest utilisation would be developed through resource selection, guided by the criterion of maximum profit per resource unit ($P_i - C_i$).

In this way, the economic priority would be established in resource exploitation to secure economic interests of the resource owner (the State). According to this approach, the first resources to be harvested are those with the most economically attractive characteristics (large-sized stands with a large proportion of conifers, close to transportation routes). The strategy of forest resource utilisation (from the best to the worst) would ensure significant savings of investment funds at the initial stages, and provide funds for reinvestment of the generated profit, which could be used to allow utilisation of the resources with less economically attractive characteristics. The strategy of forest resource use is shown in Figure 1.

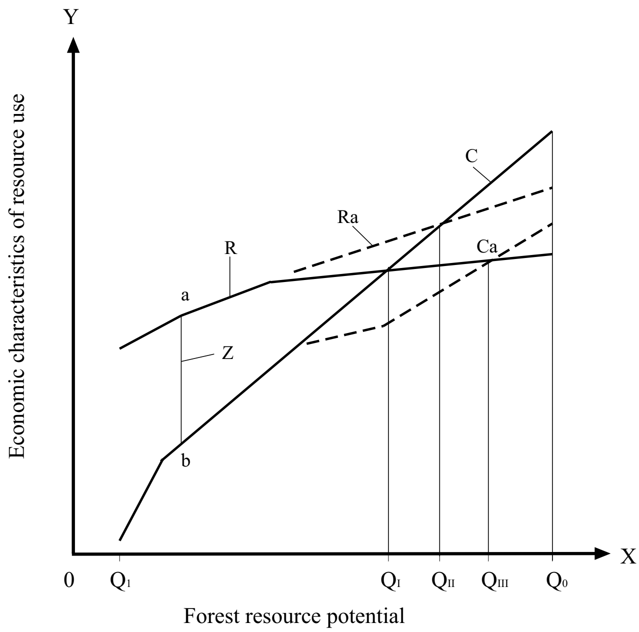

Figure 1. The process to shape a regional forest use strategy. The labels are explained in the following text.

Axis X denotes the forest resource potential. This potential is estimated for different scenarios of forest use while the resource stock (Q_0) defines the maximum value of the potential (allowable cut in the case of standing timber). Axis Y demonstrates economic characteristics of resource use. Line *C* is a cumulative curve of cost up-building as a function of changing volumes of exploited forest resources. Cumulative costs are calculated through adding volumes of forest resource:

$$Q_1 + Q_2 + Q_3 + \dots Q_n = Q_0 \qquad (8)$$

thereby, the selection of resource concentration areas is based on the following criterion:

$$C_1 < C_2 < C_3 + \dots < C_n \qquad (9)$$

where: C_1, C_2 ...C_n are unit operating costs of forest resource use in resource concentration areas. *R* describes the cumulative revenue, equal to:

$$R_1 + R_2 + R_3 + \cdots R_n \qquad (10)$$

where: $R_1 = P_1 Q_1$ (11)

The distance between *R* and *C*, measured along axis Y, represents the forest revenue affecting the amount of forest resource charges (segment $ab = Z$). Under the assumed forest use strategy, the unit forest revenue decreases with increasing volumes of exploited forest resource, and at volume Q_I it becomes zero (at the crossing of *R* and *C*), after which point any further increase in volumes of exploited resources would bring about negative values of forest revenue. Resources within Q_I are referred to as 'economically accessible resources, generating forest revenue through exploitation'.

The identification of economically accessible resources is a principal objective for the development of regional investment programmes in the forest sector. At the first stages of forest use, the public forest rent capture (forest revenue, captured by the state through a system of forest rentals) should be channelled, on the one hand, to reforestation and forest protection, and on the other hand, to investment in the forest sector restructuring and technical retrofitting of forest logging. In its turn, investment in timber industries would allow a significant increase in the amount of economically accessible resources. Such an increase may result from either reduced costs of production in timber industries (dotted line *Ca*) as an outcome of their retrofitting, or higher prices for roundwood (dotted line *Ra*) as an outcome of restructuring in wood processing industries where there are enormous reserves to reduce prices. Under the first scenario, the volume of economically accessible resources is measured by segment OQ_{III} along axis X, while under the second scenario – by segment OQ_{II}.

There may also be another scenario when the situation is affected simultaneously by two factors, expanding the resource accessibility: (i) reduced costs of logging; and (ii) higher prices for roundwood.

Discussion and Conclusions

The above concept of forest resource economic assessment allows the following goals to be met:

1. To practice routine planning, to produce mid-term and long-term forecasts for forest resource use and reproduction at the regional level;
2. To work out investment programmes of regional forest sector development based on economic priorities in forest resource utilisation;
3. To ensure efficient location of forest industries;
4. To shape an efficient financial system in the forest sector on the basis of forest revenue and transparent flows of funds, sufficient to cover both reforestation costs and economic growth in the forest industry.

In European Russia, a pre-assessment of forest resource accessibility allows the following conclusions to be made:

- The forest resource development priority should be given, first of all, to vast deciduous forests, represented by mature and over-mature stands of environmentally unsatisfactory sanitary conditions.
- Annual harvests could be increased up to 30–40 million m^3 in these forests to create an appropriate wood supply base for pulp and paper industries. Investment into the establishment of deciduous wood processing industries can be repaid under stumpage charges of about US$10 if the State is capable of investing this revenue in the forest sector.
- Forest-rich areas in the Russian European North have vast coniferous forests which can satisfy the European market demand for high quality coniferous sawnwood.
- A cost-benefit analysis shows that coniferous sawnwood from the Arkhangelsk Region, Komi Republic, Vologda and other regions can compete with similar products from

Scandinavian countries, and in addition, owing to the resource abundance (or even excess), forest felling would have milder adverse environmental impacts in such forest-rich areas in the Russian Federation.

- The Russian Federation is not and will not be (for a long time to come) facing the problem of old-age forests and the problem of national park establishment. All these problems should be addressed on an economic basis: only a *sound* economy will create a *healthy* ecology in the forest sector, and both of them will provide social benefits not only for the Russian Federation, but also for the entire European community.
- To meet the identified objectives, the Russian Federation needs a new forest policy, based on the principles of sustainable forest management and on market approaches. Table 5 shows the process of forest policy reform in the current decade.

Table 5. National forest policy development in Russia.

National forest policy elements	Soviet period: up to 1993, Centrally planned economy	Transition: 1993-1997, Basic Principles of Forest Legislation	Transition: 1997-present time, Forest Code	Prospects
Forest ownership	National	Not declared	Public federal	Diverse
Forest management decision-making levels	All-Union, and later – federal centre	Districts - municipal entities	Regions (Sub-national entities)	All federal forest management institutions
Forest use arrangements	Allocation of forest areas by decree	Incipient element of contract arrangements	Forest lease, timber sales	Various contract arrangements
Financial system	Financing from the budget	Budget financing + internal earnings	Enhanced role of forest revenue (rentals) + budget funds	Forest revenue is the major source of financing

A new national forest policy should rely upon:

1. A variety of forest ownership patterns, including private ownership;
2. Forest management decision-making by managers with relevant professional education and skills, pursuing interests of forest resource owners;
3. Market-driven forest use and reproduction arrangements;
4. Forest revenue management to benefit the national forest sector development.

The European community would also benefit from the integration of Russian forest policies, and first of all economic policy, into activities of the European Union, whose policies should be influenced by the European Forest Institute. That is my vision of a major objective of this conference.

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Programme

Scientific Seminar
Ecological and Socio-Economic Impacts of Close-to-Nature Forestry and Plantation Forestry: A Comparative Analysis

3 September 2000 • Instituto Superior de Agronomia – ISA • Lisbon, Portugal

Moderator: *David Burdekin, Member of the EFI Scientific Advisory Board, UK*

9.00 – 9.10 Opening words

9.10 – 10.20 **Topic A: Ecological impacts: biodiversity and genetic diversity**

- Ecological impacts of plantation forests on biodiversity and genetic diversity. *Michel Arbez, IEFC – European Institute for Cultivated Forests, France*
- Ecological impacts of close-to-nature forestry on biodiversity and genetic diversity. *Spyros Dafis, EKBY – Greek Biotope / Wetland Center, Greece*

10.50 – 12.00 **Topic B: Ecological impacts: water and nutrient cycles, ecosystem stability**

- Ecological impacts of plantation forests on water and nutrient cycles and ecosystems stability. *E.P. Farrell, University College of Dublin, Ireland*
- Ecological impacts of close-to-nature forestry on water and nutrient cycles and ecosystems stability. *Heléne Lundkvist, Swedish University of Agricultural Sciences, Sweden*

12.00 – 13.10 **Topic C: Wood production and resources in terms of quantity and quality**

- Wood and non-wood production from plantation forests. *Margarida Tomé, Instituto Superior de Agronomia, Portugal*
- Wood production and resources in close-to-nature forestry in terms of quantity and quality. *Gero Becker, Albert Ludwig University Freiburg, Germany*

Moderator: *Konstantin von Teuffel, Forest Research Institute of Baden-Württemberg, Germany*

15.00 – 16.30 **Topic D: Political and socio-economic aspects**

- Societal aspects and landscape values of plantation forests. *José Pérez-Vilariño, University of Santiago de Compostela, Spain*
- Social indicators to assess landscape values. *Klaus Seeland, Swiss Federal Institute of Technology, Switzerland*
- Economic accessibility of Russian forests for the European market. *Anatoly Petrov, Russian Institute of Forest Specialists, Education and Training, Russia*

16.30 – 17.30 Discussion and conclusions

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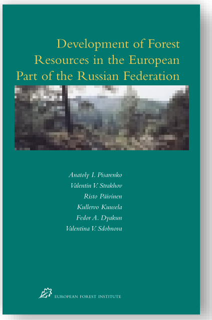

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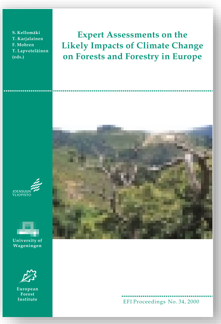

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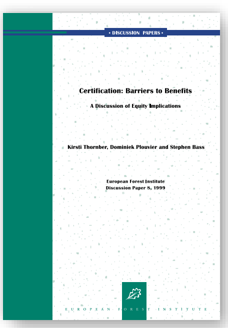

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