ELEMENTS OF SUSTAINABLE FOREST MANAGEMENT

N. LUST
Laboratory of Forestry - University of Ghent

ABSTRACT

Elements of the modern day vision on sustainable forest management are discussed. Some aspects of the concept are analyzed, focusing on the natural definition in comparison with the ecosystem definition. The significance of ecological stability is emphasized. It is pointed out that perhaps the most important aspect of forest stability and sustainability is the ability to retain soil fertility. Attention is paid to the importance of species composition, the role of organic matter, the impact of forest use and the problems of forest engineering.

In order to reach sustainable forest management, a number of strategies can be applied, based either on the market or the state. There is a need for measurable criteria and indicators for the evaluation of sustainability. Therefore new programmes of scientific sampling or even basic research are still needed.

Forest sustainability provides still a dramatic lot of questions and efforts, a.o. on the potentiality of sustainable forestry.

1. INTRODUCTION

Sustainable development, as the central concept of "Our Common Future", has been defined in 1987 by the independent World Commission on Environment and Development as follows : "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987).

The objectives of sustainable forest management are described in the Statement of Forest Principles, adapted at the United Nations Conference on Environment and Development in Rio, 1992 : "Forest resources and forest lands should be sustainably managed to meet the social, economic, ecological, cultural and spiritual human needs of present and future generations (Anon., 1992).

A definition of sustainable forest management was given in the General Guidelines for the Sustainable Management of Forests in Europe, known as Resolution H_1 of Helsinki 1993 : "Sustainable management means the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national and global levels, and that does not cause damage to other ecosystems".

2. CONCEPT

The term "sustainability" has became very fashionable in and outside of forestry. Serious difficulties, however, arise, when putting this concept into practice. The term is so imprecise and ambiguous, that depending on varying interests and political intent, it can take on different meanings accordingly (Oesten, 1995).

2.1. Origin of concept

Twight (1983) pointed out, that the principle of sustainability dates from mercantilism which regarded the wealth of a nation in the autonomous disposal of natural resources. It is based on an obligation towards future generations. The idea of sustainability originates from the national interest of France and Germany to have enough timber for military ship-building and domestic consumption. The vision has led to the forest management plan as a technocratic approach of securing sustained timber production.

Sustained yield, sustainability and sustainable development are well known terms for forestry scientists and practicing foresters. Foresters have strived already for a long time for the introduction of the silvicultural principle of sustainability into the whole economic system. The concept was fully formulated in the classical period. Sustainability as a management goal has been developed in Germany during the 18th century (v. Carlowitz, v. Xanthier), aiming at sustained production of wood. It was developed in a pure form by Hundeshagen and Heyer, as a logical deduction from the "normal forest model". It became generally accepted and implemented as a guiding concept or economic principle in forestry at the turn of the last century. Since then, in close relation with the developing society, the concept has undergone manifold changes (Zürcher, 1965 ; Peters, 1984). Starting from a narrow definition, meaning only the yield of wood, it developed and expanded to cover, among others, wood production, monetary yield and the modern-day multiple-use interpretation. The expansion of the term to include each and every relation and function between people and forests within a complex totality, complicates the operational feasibility of the model. It is possible to clearly define a "sustained yield of wood", but for the socio-economic and ecological conception of sustainability, exact knowledge is necessary.
For each of these forest functions, the limits of the corresponding sustainability definition have to be redefined.

2.2. Natural versus socio-economic approach

Among the numerous definitions for silvicultural sustainability, it can be specifically referred to the natural definition (Speidel, 1984) and the socio-economic one (Plochmann, 1982). According to Speidel "Sustainability is the ability of forestry enterprise to obtain lasting and optimal forest cropping, infrastructural achievements and other goods for the benefit of present and following generations. Accordingly, those actions and achievements are "sustainable", which secure and/or maintain this ability for the forestry enterprise". Speidel's definition has in common with earlier ones the concept of forestry as a subsystem, which normally coexists with its natural and social environment in a state of equilibrium. It demands that forests are managed in such a way as to provide optimal multi-purpose benefits for future generations (Oesten, 1995). According to Speidel, the preconditions for a sustainable management are among others : the safeguarding of production, the continuation in performance of site conditions and the existance of a socio-economic framework.

Plochmann's sustainability definition relates to ecosystems, emphasizing the need to preserve functioning forest ecosystems. In this sense "forestry" can be defined as the development of the economic, social, cultural, aesthetic and natural potential of forests for mankind whilst preserving the natural sustainability. "Sustainability" on its side can be defined as the conservation of nature, as the long term and extensive protection of the natural base of production of the forest in both quantitative and qualitative terms. This "ecosystem-definition" goes far beyond previous concepts of natural sustainability like the sustained wood yield definition.
Among others, it can include energetic aspects of forestry or the debate on the "naturalness" of forest management (Brandl, 1989).

2.3. Moral aspects

Oesten (1995) stresses, that sustainability, above all, should be understood as a code of behaviour, a moral demand on the management and use of forest. Being a value judgement, it is neither true nor false, it cannot be objectively deducted nor scientifically proven. In the academic field of ethics, a distinction is made between ideal norms, which are principles valid for an idialized protagonist, and practical norms, which are directed towards "unidealized" and possibly more realistic protagonists.

Practical norms differ from ideal norms in three important ways :

- they have to reduce and simplify complex ideal norms ;
- they need to be connected to ideas and values that have a high motivating content of their own, i.e. consciousness, insight and conviction ;
- they are defined by their feasibility.

Practical norms require attention for a number of specific actions : self preservation, watchfulness and precaution, preservation, assistance and education. The question arises, however, how can we practically translate such norms into sustainable management in forestry and in the economy as a whole ? Where is the proper place for these kinds of moral, economic and ethical comtemplations, within the interaction of political science and forest economy actually to be found ?

2.4. Additional aspects

The debate on sustainability would not be complete, if the central role which the concept of sustainable forest management is currently playing in the context of the negociations of an international tropical timber agreement, was not mentioned.
Besides, we all know the large scale problems which our forests are facing today, e.g. in Europe. The most important of which are the loss of vitality and decline, mainly due to atmospheric pollution and adverse climatic conditions, forest fires, large scale storm and insect damage, and loss of economic interest. Forests have also to face the danger of potential climate changes and therefore strategies have also to be developed towards adapting forest management to these changes.
Kremer (1995) states, that the implementation and control of sustainable forest management in practice put a lot of questions on national, regional and local level :

- What actions must be taken to improve implementation ?
- Which criteria and or indicators are considered essential for monitoring sustainable development of forests ?
- Which of these criteria/indicators are already implemented and which require more scientific research ?
- What are the technical standards for data collection ?
- Can these standards be harmonized ?
- What improvements are needed or must be used by further scientific research ?

3. ASPECTS OF SUSTAINABLE SILVICULTURAL MANAGEMENT

3.1. Ecological stability

The traditional meaning of sustainability must be expanded within the general framework of ecological stability. Up to now silviculture was mainly based upon empirical knowledge, lacking an ecological basis of understanding. This has led to the development of management systems, which exceed the ecological carrying capacity and led to losses in sustainability and even to pronounced decline phenomena.

Stability, unfortunately, is also a very imprecise and ambiguous term. It refers to the ability of a system to remain near an equilibrium point (resistance component) or to return to it after a disturbance (resilience component). Stability within an ecosystem context can only be analyzed in relation to perturbations, either natural or anthropogenic of nature.

Larsen (1975) stresses on the importance of ecological stability within the framework of global stability. He mainly analyses stability and its components in respect of genetic variation, complexity and the biological cycle.

Populations respond to spatial and temporal environmental variation by selection and adaptation. Hence the most important aspect of genetic variation is the buffering it provides against varying environmental conditions. A reduction in the genetic resource base (diversity) may consequently have a profound effect on both ecosystem resistance and resilience. This is demonstrated by Larsen (1975) and confirmed by Bergmann et all. (1990) who explain the decline of central European silver fir as a result of genetic variation lost during the last glaciation.

Population ecology demonstrates that more inter-relationships in the food web provide greater stability. In nature, ecosystem resistance is apparently associated with diversity (= species richness). This suggests that ecosystem response to perturbation depends primarily on the adaptive characteristics of the populations in the system. Selection acts to maximize fitness of populations in the system and not directly on stability properties of the system as a whole.

As also emphasized by many other authors, e.g. Ulrich (1987), the long-term stability and productivity of forest ecosystems is closely linked with the nutrient cycle. Perhaps the most important aspect of stability in managed forest ecosystems is the ability to retain soil fertility, following management-induced perturbation (harvesting, recultivation) and pollution (soil acidification).Monitoring changes in nutrient losses provide a useful indication of ecosystem response to disturbance (Larsen, 1975).
Stability in this context is mainly due to resistance. Key features include nutrient and water storage capacity, the ability of the soil to buffer acidity formed during net-nitrification (acid pulse) and to prevent or diminish the leaching to nitrate and other nutrients. System resilience can be conferred by mineral weathering, which provides the system with nutrients. Further, natural and anthropogenic (pollution) air born sources of elements may contribute to nutrient supply and thereby to system resilience (Larsen, 1995).

Species composition contributes to system stability through the biogeochemical cycle, mainly due to species specific turnover and storage rates. Species with a rapid turnover and a low storage contribute to ecosystem resistance, whereas species characterized by slow turnover and high storage rates contribute more to resilience (Swank and Waide, 1980).
The forest floor vegetation plays an important role in the circulation and retention of nutrients (Bormann and Likens, 1979). Ground vegetation promotes the percolation of water, minimizes erosion and contributes to diversity and activity of heterotroph organisms, including decomposers, thus stabilizing the biogeochemical cycle by balancing production and mineralisation.

3.2. Organic matter

The importance of soil as a medium for supplying nutrients and water to trees is highlighted by Dighton (1995), especially the role of organic matter in modifying the soil physico-chemical and biotic characteristics. Not only may it contribute to the nutrient pools available for tree growth, but it may influence the retention of nutrients and water in soil, assist in the structural formation, as a focus for aggregate formation, and influence the nature and abundance of soil biota. The role of organic matter, silvicultural practices to retain it in soils and an understanding of the relationship between nutrient supply from soil, demand by the crop and effects of management are essential for the continuation of productive commercial and multi-use forest systems.

Where second rotation forestry is concerned, a considerable amount of nutrient resides in the residues from the previous crop in the form of leaf litter and woody debris, which is not exported from the site. This reservoir is often removed by burning, on the grounds that it is easier to replant a "clean" site and that during the early phases of decomposition of woody debris (with a high carbon/nutrient ratio) nutrient importation to that debris is in direct competition with the demands for the newly planted tree, often called "nutrient lock-up" (Raison et al., 1991). However, organic matter plays a pivotal role in both the fertility and stability of soils (Swift & Woomer, 1993). This is especially true in tropical and sub-tropical environments, where turnover rates of organic matter are high.
Eucalyptus forests, planted on abandoned agricultural soil or poor agricultural land, cause considerable losses of nutrients from the system by intensified harvesting of the crop (Raison et al., 1982). In poor soils maintenance of soil structure and fertility can be achieved by the addition of inorganic fertilizer (Jones and Dighton, 1993). As the cost of fertilizer increases, it becomes less economical and more environmentally unfavourable (causing pollution of water courses) to apply increasing higher rates of fertilizer to maintain productivity. This is especially true where soil structure has declined to a state where temporary binding sites for nutrient elements have been lost and applied fertilizer is rapidly leached from the rooting zone.

Dighton (1995) put some questions on the silvicultural management of organic matter.

- Can organic residues be maintained on site to act as long-term supplies of nutrients ?
- How can release of nutrients from these materials be optimized for crop use ?
- What site preparation protocols will optimize sustainability of forestry ?

3.3. Forestry impacts on sites

Management and forest use have strong impacts on woodlands and their sites (Green, 1984 ; Vos & Stortfelder, 1992 ; Vos, 1993 ; Vos et al., 1995). Several forestry attributes with compacts on site are recognized :

- tree products (stem, branches, twigs and leaves), other products (litter, mosses, mushrooms, game) and some "non-removable benefits" (soil protection, recreation suitability, etc.);
- inputs of labour ;
- technology : inputs of animal/mechanical power, fertilization, liming, use of herbicides, controlled burning, etc.;
- management : tree harvesting and felling system, coppicing system, pollarding system, grazing intensity, abandonment, etc.

Many impacts on sites result from promoting or inhibiting nutrient cycling by :

- changing the character and amount of litter impact ;
- coniferous plantations promote acidification and limit mineralization ;

- coppicing and pollarding, capturing of litter for agriculture and gardening, harvesting of leaves, twigs and bark for animal fodder, harvesting of mosses for florists empoverish sites by biomass extraction;
- dead wood on the forest floor contributes to the buffering of acidification ;
- controlled burning of understorey and forest floor contributes to N-fixation in humus forms ;
- changing the character and amount of chemical inputs : fertilization and liming promote mineralization of humus forms ;
- changing the factors that control decomposition :
- clearcutting promotes both mineralization and acidification as well as erosion of humus forms ;
- forest grazing may enrich the forest floor by manuring and pedoturbation ;
- open, high deciduous or mixed forests promote deep pedoturbation and therefore the buffering capacity, nutrient supply and water retention capacity ;
- coniferous plantations limit mineralization by shadowing.
- soil horizon disturbances :
  plowing and digging for tree planting, grubbing of boars and pigs and trampling and digging by forestry labourers and recreants promote mineralization of humus forms.

Habitat differentiation is strongly affected by forest management and forest use. If human impacts are dominant, biodiversity is strongly affected by :
- decline of "horizontal" habitat pattern diversity ;
- decline of "vertical" microhabitat diversity.

Abeels (1995) points out the important role of forest engineering for the improvements of forestry. Objective methods for the selection of appropriate equipment and techniques for given forest types and operating conditions must be suggested in order to keep negative impacts on forest soil to a minimum. Damages to the trees, to the soils and to the environment must be avoided or at least minimized.

The effect of compaction consists in a partial or total destruction of the soil profile. It can include many layers in the depth of the profile. Soil particles are squeezed together and the macroporosity is affected while soil density grows. In most of the cases, compaction effects are observed to a depth of about 60 cm. In planted areas the phenomena of compaction reduce air and water movements in the soft soil medium. At the same time, an increase of the mechanical strength may effect the growth of the roots and of the rootlets, or at least their distribution. The transfers of nutrients and minerals are slowed down. Due to various deficits, growth is compromised. Soil compaction affects also the horizontal water movement too. Effectively, some kinds of vertical internal "walls" may arise from the creation of ruts.

Appropiate tools and techniques are required for several silvicultural practices. Natural regeneration is one of the most sensitive conditions for any mechanical technique. Artificial means might be required to improve the site and the soil, for example by using heavy scarifiers hauled or actuated by tractors.
Competition between plants and species must be controlled. Mechanical tools are guided for

the reduction of the undesirable vegetation and trees. The forester must be a mechanic and a biologist to operate correctly.
Bouvarel (1995) explains that, in recent years, researchers and developers have paid special attention to the influence of the machines especially with respect to environmental harvesting techniques. At the moment there is no regulation on exhaust emissions from the engine for forestry machines. The use of biofuels, such as ethanol, methanol and rapeseed - based oil (diester) is tested. Hydraulic oils based on mineral oils are very slowly decomposed in the ground and may injure the operator's skin during maintenance works. Much research is done in order to reduce oil consumption. All these emissions and leakages can be reduced by using improved systems. The electronic and computer components introduced in the machines allow to optimize the efficiency of the engine, the transmission and hydraulic systems. The new harvesters or forwarders are already equipped with an integrated control of the engine.

The harvesting of timber involves large scale operations. The wood industry is putting constraints on the type of timber it requires. So forest harvesting techniques are placed between silvicultural biologic requirements and user demands. Log and wood transportation can leave spectacular ruts and soil disturbances in the soil. They raise conflicts between foresters and operators or harvester. The real damage is difficult to recognize. It must be underlined that the observable modifications to the soil have various repercussions. Some are revealed by the changes in the local flora. However, much more information about the relationship between soil condition and flora must be known (Abeel, 1995). Plant composition and dynamic reaction to soil content may be of the highest importance. Effectively, soil modifications due to scalping, sinkage, compaction, etc. are difficult to measure directly. Indirect evaluations arise from the measurements of the density, the porosity, the resistance to cone penetration, respiration or gaseous exchanges.

Abeels (1995) stresses also the significance of forest accessibility with regard to sustainable multiple-use forestry. A too wide opening of the forest will introduce too much intrusion possibilities. The forest environment is weak and the soils and the trees must be protected. Even trampling is likely inadvisable in most cases. Bicycling with mountainbikes must be avoided. All terrain motorcycles and 4 x 4 vehicles must keep their wheels out of forest soils and stands.

The increase of the number of passes will alter natural, spontaneous movement of water and nutrients in the soil, of small and large animals on and in the ground.

Vos et al. (1995) state that the significant impacts of forestry on sites (humus forms and soil) raise the question of the sustainability. They put two relevant questions :

- Do sites under man-controlled forests reach steady states of organic matter nutrient supply, etc. ?
- Are sites able to recover after disturbances ? This renewability may be interpreted as a measure of site sustainability.

According to Vos et al. (1995) the question whether a site is renewable depends only on the time needed to reach steady states. They mean that some trends are clear : the process is nonlinear and steady states are achieved in ca 100-150 years. It asks for a longer time on sites with environmental stresses for plant and animal life.
Therefore, it may be concluded that :

- Favorable forest sites that were managed for at least 50-100 years will in generally be in a steady state, whereas nutrient-poor and/or dry forest sites will in general not be in a steady state in this moment.
- Sites are in general non-renewable within a lifetime.

In secondary development, after abandonment of pastures and field, steady states of the uppermost horizons are achieved faster, within 100 years.

4. STRATEGIES TOWARDS SUSTAINABLE MANAGEMENT

4.1. General strategies

There is a continuous debate about the meaning of the term "sustainability". This is due partially to personel interests and partially to a lack of knowledge. The latter has led to the "trench-warfare" between the foresters and the environmentalists.
Moen (1995) identifies two ways to go in order to reach the premises for a sustainable forestry. One is to study the virgin forests. When "all" relevant aspects has been studied, one can use this knowledge by trying to "blueprint" the natural methods, using today's methods. The other approach is founded on the idea that it is no certainty that "nature knows best". It is possible that forest fires reduce the soil nutrients in such a way that productivity is reduced, but contributes towards the securing of the biodiversity which is an important element in sustainable managements. In this context it is possible that one may come closer to the relevant knowledge through focusing on smaller areas, and study these in detail.
Moen (1995) illustrates his statement with an example. The study of the boreal virgin forest areas indicates that 30 % of the area is covered by old trees (more than 150 years) and that 20 % of the standing volume are dead trees. Large game birds find their place in this ecological system and have their habitat in old forests. The woodpecker lives off (amongst other things) insects found in dead wood and finds thus its niche in such virgin-type forests. The advice to management directly concluded from such studies is : increase rotation and leave dead trees. Thorough detailed studies show, however, that large game birds can use the forests after 30-40 years and woodpeckers can just as well make use of harvest residue, low stumps and high stumps. Indeed, large game birds just need trees with branches strong enough to bear a weight of 5 kg, bilberry plants and insects in the bilberry plants. These are conditions which can just as well be created in a 30-50 year old forest as in "virgin forest copies". Another similar example is given for the famous White backer woodpecker (Dendrocopos leucotos).

On his side Glück (1995) states that, if society demands a greater quantity and quality of sustainable multiple use forestry, a great number of strategies can be applied. They are based either on the market (property and marketing strategies) or the state (forest incentives, regulations, planning and formation values). Presently the state strategies such as regulations and incentives are predominating in the policy mix. Financial incentives for improving the management of protection forests should improve the benefit-cost balance of the forest owner and stimulate him to provide more security than without incentives. Possible additional cost or diminished revenues in the present have at least to be compensated in the future by financial incentives and additional revenues. Otherwise the effect of incentives is small.

Furthermore, the classic management plan cannot be considered anymore as a suitable and complete tool for the realization of a sustainable management. Indeed, it mainly restricts itself to one dimension of forestry, i.e. timber production. If today not only timber but also protection against natural forces, valuable biotopes and recreation are to be supplied at a sustained yield basis, there is no specific planning instrument like the forest management plan. In spite of that, there are a number of political strategies which can be applied for securing sustainable multiple use forestry.

4.2. Criteria and indicators

The real challenge for the idea and movement of sustainable forest management is its implementation and control, together with its launching and supporting. The need to identify measurable criteria and indicators for the evaluation of how different countries have progressed in their efforts to follow the principles of sustainable forest management and conservation of biological diversity of Europen forests became the most pressing issue in the International follow-up of the Helsinki-Conference (Anon., 1995). Finally a Pan-European list of criteria and most suitable quantitative indicators, completed with descriptive indicators was identified in Geneva in June 1994 keeping in mind that the indicators should be :

- scientifically valid ;
- technically feasible ;
- cost-effective.

Due to the complexity of the objective a great number of criteria and indicators have been selected. Each of the 6 criteria is completed by several indicators, a total of twenty plus seven sub-indicators. The approved list is the toolbox for gathering and assessing information on how the signatory states have succeeded in implementing the general guidelines for sustainable forest management as described in the Helsinki Resolution H1 and H2. In the Helsinki process, sustainable forest management at the national scale can be viewed as the maintenance of a number of valuable features which, taken together or separately, keep the nation's forest land as a whole in a condition enabling a regular yield of those goods and services which society expects.
A criterion describes the different sides of sustainability on a conceptual level. It is a distinguishing element or set of conditions or processes by which a forest characteristic or management is judged. The indicators show changes over time for each criterion and demonstrate how well each criterion reaches the objective set for it.
The adapted european criteria are :

1. Maintenance and appropiate enhancement of forest resources and their contribution to global carbon cycles.
2. Maintenance of forest ecosystem health and vitality.
3. Maintenance and encouragement of productive functions of forest (wood and non-wood).
4. Maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems.
5. Maintenance and appropriate enhancements of protective functions in forest management (notably soil and water).
6. Maintenance of other socio-economic functions and conditions.

It was agreed upon that some aspects of the sustainability of forest management cannot be measured by a single quantitative indicator. They are too complicated or too expensive to measure. On the other hand, they can also be generally accepted conditions that should be fulfilled. These features can sometimes be described only by their existence and the extent to which they can reach the objectives or conditions set for them. The descriptive indicators are considered as indicators which describe the policy instruments used in order to enhance the sustainable management of forests and they are complementary to the agreed quantitative indicators. They are grouped into four classes :

1. The legal/regulatory framework
2. The institutional framework
3. The economic policy framework and financial instruments
4. The informational means to implement the policy framework.

Legal/regulatory framework comprises legal regulations (prohibitions, permissions and obligations) in the form of laws and decrees.
Institutional framework includes various legal and institutional arrangements for dealing with issues in question. These arrangements include a.o. the revision of action programmes, agreements, linking the activities of different organisations, enterprises and scientific communities, international cooperation, funds, etc. The capacity of an institutional framework guarantees the efficiency of legal/regulatory framework, economic policy framework and financial instruments and informational means used.
Financial instruments are monetary transfers by the state for certain modes of behaviour instead of market services. They comprise financial incentives for various proposes, financial disincentives (taxes) and licences. Economic policy framework contains also those activities related to the market mechanisms, which are not covered by financial incentives.
Informational means are based on the implication of information, knowledge, ratio and morale. They aim at convincing the respondents. There are many informational instruments, such as non-legally binding guidelines, land-use, planning, statistical surveys, public relations, education, research, rewards, extension service, etc.

When adapting the list of European criteria and most suitable indicators, the following features were stressed :

- The criteria are the same for all European countries. They are based on scientific information, and they are measurable, unambiguous, available to the public and open for discussion. They are intended for evaluation at national level, not at local forestry level.

- The criteria are defined in such a way that it is easy to follow their implementation.

- The list of criteria covers all major aspects, i.e. economic, social, ecological and cultural aspects.

- Since indicators translate the criteria into more direct operational tools, they support the reporting process and make the reporting internationally credible.

- The quantitative and descriptive indicators are interdependent and jointly provide a full picture of the state of forests and forest management in a country.

- The indicators are neither final nor totally comprehensive since forests have multiple functions. The work of defining indicators and their measurement schemes is a continuous process and new indicators will be added to the list as soon as new scientific information is obtained and common agreement is reached. Also, the already existing criteria and indicators will need to be revised over time to reflect new research and improved understanding of forest management.

- The need to identify the terms and definitions has also become an integral part of the Helsinki Process.

Next to the Pan-European concept of sustainable forest management several other processes and initiatives have taken place, e.g. the meetings in Kuala Lumpur, New Delhi, Olympi and Ottawa. In this context is must be referred to the thoroughly developed Canadian proposal with 6 criteria and an abundance of indicators and subindicators. The process involved the establishment of a Steering Committee composed of 30 members representing a wide-range of special interest groups such as the federal, provincial and territoral governments, industry, NGO's, Aboriginal groups, small woodlot owner associations and the academic community.
A science Panel and a Technical Committee were created to carry out specific tasks, to conduct consultations and research, and to draft a set of criteria and indicators for the consideration of the Steering Committee (Anon. 2, 1995).

The criteria and indicators for sustainable forest management are aimed to :

- characterize sustainable forest management and to provide a quantitative and qualitative basis to assess progress ;
- provide the basis for domestic policies on the conservation, management and sustainable development of forests ;
- contribute to the clarification of issues related to environment and trade, including product certification ;

- develop concepts and terms that would facilitate the going domestic and international dialogue on sustainable forest management.

The six criteria identified include :

1. Conservation of biological diversity : the variability among living organisms from all sources and the ecological complexes of which they are part.

2. Maintenance and enhancement of forest ecosystem condition and productivity : the health, vitality and rates of biological production in forest ecosystems.

3. Conservation of soil and water resources : the maintenance of soil and water quantity and quality.

4. Forest ecosystem contributions to global ecological cycles : the impact of the forests and forest activities on global ecosystem functions.

5. Multiple benefits to society : sustaining the flow of benefits from the forest for current and future generations.

6. Accepting society's responsability for sustainable development : fair, equitable and effective resource management choices.

Notwithstanding the different starting conditions and approach, there is a remarkable resemblance between the Pan-European and Canadian list. For example the six main themes of the European list, viz. forest resources, multiple functions of forests, health and vitality, biological diversity, soil and water conservation and other socio-economic benefits are found almost identically in the Canadian criteria. It appears, however, that Europe wants to stress more both the maintenance of forest resources and the importance of wood production, whereas the Canadians want to focus more on conservation of biological diversity. So it might be concluded that the Canadian list better corresponds to the original point of view of Rio de Janeiro, although it is to be expected that the Canadian forests will be managed on a less sustainable way, at least on a local scale. Indeed, the practice of the current management and exploitation systems reveal that the European forests are better treated and considered as ecosystems, although a major part of these forests are certainly not sustainably managed. Furthermore, the detailed description of indicators and sub-indicators in the Canadian List is striking. The six criteria comprise 22 indicators and 83 sub-indicators. But on the other hand there is no list of descriptive indicators, as there is an extented one added to the European quantitative list.

4.3. Gaps in knowledge

It is evident that a lot of data are required to establish the reports dealing with progress made in the implementation of sustainable forest management in relation with the conservation of biological diversity. Generally, measurements are already available for some of the indicators, while some others can barily be measured. Yet some indicators, especially the quantitative indicators under work, require a new programme of systematic sampling or even basic research.

A major remark in the whole discussion remains a correct definition and assessment of sustainable forest management. It is by far not sure that even a positive answer on the numerous subindicators will guarantee in practice forest sustainability. Several questions can be put.

1. Is sustainability a natural feature ? It is quite clear that nature does not assure sustainability as a rule. There is a natural evolution, dominated by local circumstances and activated by changing climatic factors. Many climax forests of the temperate regions lead to a spontaneous site degradation, observable by simple indicators such as acidity and nutrient balance (pH and CEC). Vast forest disturbances in tropical and subtropical areas provoke spontaneous and quickly evolving soil degradations.

2. Is it anyhow possible to measure sustainability ? An evaluation requires standards, of which a reliable majority is not available. Major changes, such as site productivity, can normally only be proved after long periods, significant losses can be hidden by artificial means. Changes in tree species and use of management techniques such as drainage, irrigation or fertilization, can seemingly indicate a higher production, whereas in reality the natural capacities have decreased.

3. In connection with standardization and control-assessments, also the question of the time scale arises. Management impact can often be detected almost immediately, e.g. by forest destruction or strong disturbances, whereas in other cases the detection period needs several hundreds of years. Herewith the question of reversibility has also to be considered. Loss of sustainability is mostly not a linear process yet exponential. Complete exhaustion of the site can be accelerated in subsequent generations.

4. The proposed criteria and indicators are intended for an evaluation on a national level. It is evident however, that sustainability must be judged also on the small local level. It might be thought at the stand level, as the level of e.g. ownership or enterprise can be very misleading.

5. How many and which indicators must be positive to arrive at a global positive evaluation ? It is evident that many indicators can show a good result, such as forest area, volume of growing stock, carbon storage, area of protection forests, etc. whereas at the same time others can reveal major problems, e.g. in the field of biological diversity, ecosystem vitality or nutrient balance.

6. To what extent should biological diversity be maintained ? It is clear, that forest management in all cases impacts biodiversity and that it does not go together with complete maintenance and/or conservation of biological diversity. Moreover it seems that maintenance of natural biodiversity is not needed for the maintenance of (a reasonable and

acceptable level of) sustainability. On the other hand enhancement of biological diversity in forest ecosystems is not difficult, certainly not in Europe, since forest management and use has led to a significant loss of the biological richness and diversity.

7. An important problem is the question to what extent, to what area, forest sustainability must be assured. It is thinkable, even normal, that the present forest area, will change. It seems reasonable that some tropical forests will be converted into other land uses. This is also acceptable, provided that in each region a sufficient area of sustainable (multiple-use) forest remains, depending on the natural and socio-economic situation of that region.

Next to the above mentioned remarks, a lot of other questions arise and gaps in knowledge can be identified. So at the end of a meeting on the scientific basis for sustainable multiple-use forestry in the European Community among others, the following gaps and promising topics for research have been listed, divided over several fields (Oesten et al., 1995).

1. **Forest policy and economics**

- analysis of concept of sustainable forestry, compared with other concepts such as sustainable development and ecological stability ;
- economic and social evaluation of non-wood benefits ;
- analysis of political strategies/instruments e.g. incentive systems and their effectiveness and efficiency ;
- analysis of planning process on the local, regional and national level.

2. **Forest environment and silviculture**

- Geochemical stability : site, soils and water, species and silviculture for biodiversity ;
- Genetic and ecophysiological aspects of adaptability.

3. **Forest operations and techniques**

- Optimization of machines (control of total emission ; prevent damages to the forest soil ; improve working conditions ; design new machines) ;
- Management of harvesting operations : planning of harvesting systems techniques for early thinnings and small scale forestry, programmes for forestry workers.

4. **Social aspects of forestry**

Analysis of the social values of forests and forestry ; red list of threatened old woodlands in Europe ; design and management of new forests ; network of reference systems ; methods for forestry decision-making ; marketing analysis.

5. **Sustainable multiple-use forestry in different regions and under different conditions.**

Instruments used in aiming at a sustainable multiple-use forestry in each country, how economic sustainability can be obtained in forestry at the EU scale ? at which scale is a certain sustainability reachable ? what is possible at the farm level ?

5. SUMMARY AND CONCLUSION

Sustainable management is a newly formulated objective of forestry. Although sustainable forestry is a well known term, already for a long time, it is not yet achieved and presently leads to huge discussions. This is mainly due to the different meanings given to the term. Starting from a narrow definition, only based on the yield of wood, it developed to the modern-day multiple use interpretation (natural definition against the ecosystem definition). Besides sustainability should be understood as a moral demand, characterized by ideal and practical norms. Meanwhile it is striking that the concept of sustainability is linked with the international tropical timber trade and the large scale problems, which the forests are faced with today.

Up to now silviculture was mainly based upon practical knowledge, lacking on ecological bases, which resulted in losses of sustainability and stability. This terms are strongly linked with each other. Mainly ecological stability, with its components genetic variation, complexity and the biological cycle, is worthwile to stress. The long-term stability and productivity of forest ecosystems is closely linked with the nutrient cycle. Perhaps the most important aspect of stability in managed forest ecosystems is the ability to retain soil fertility.

Species composition contributes to system stability. The importance of the soil must be highlighted. The role of organic matter is essential for the continuation of multi-use forest systems. It has a central function in both the fertility and stability of soils.
Management and forest use have strong impacts on woodlands and their sites. Variables involved are : forest products, inputs of labour, technology and management. Many impacts result from promoting or inhibiting nutrient cycling by changing the character and amount of litter impact, of chemical inputs, by changing decomposition and disturbances.

Forest engineering too has a significant meaning with respect to sustainability. Methods for the selection of appropriate equipment and techniques must be developed. Soil compaction must be avoided completely. Special attention to the influence of the machines, especially with respect to environmental harvesting techniques, must be paid. Meanwhile the significance of forest accessibility with regard to sustainable multiple-use forestry must be stressed.

A great number of strategies can be applied to support the implementation of a sustainable forest management. They are based either on the market or the state. The classic management plan cannot be considered anymore as a suitable tool for the realization of a sustainable management.

There is a need of measurable criteria and indicators for the evaluation of sustainability. A Pan-European list of criteria and most suitable quantitative indicators, completed with descriptive indicators, has been identified, keeping in mind that the indicators should be scientifically valid, technically feasible and cost-effective. The criteria are the same for all European countries and they are intended for evaluation at national level, not at local forestry level.
Measurement are already available for some of the indicators, while some others can easily be measured. Yet some indicators require a new programme of systematic sampling or even basic research.

It is not sure that a positive answer on the numerous indicators will guarantee forest sustainability. A lot of questions remain open, e.g. is sustainability a natural feature, is it anyhow possible to measure sustainability, on what time-scale must sustainability be measured, how can it be complemented and assessed on local level, what kind of standards can be accepted, to what extent must biological diversity be maintained or on what area must forest sustainability be assured. The implementation of sustainable forest management will require still a dramatic lot of efforts, on all possible foresty fields : forest policy and economics, forest environment and silviculture, forest operations and techniques, social aspects of forestry and local conditions.

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