# ECOLOGICAL RESEARCH IN SUPPORT OF SUSTAINABLE FORESTRY

**JOSEF FANTA**

Department of Physical Geography and Soil Science, University of Amsterdam;
Alterra Green Research Centre, Wageningen, The Netherlands

**ABSTRACT**

At the beginning of the 21st century, the political, economic, societal and ecological situation in Europe is undergoing rapid change. Forestry is included in these developments. European foresters face the challenge of re-considering the principles of forestry, formulating a European forestry policy and reshaping the forestry sector in certain European countries. The new paradigm of the future European forestry will be based on two principles: sustainability and multifunctionality, which, integrated and co-ordinated, will give rise to a modern system of forest management that will be economically feasible, ecologically sound and will fully cover the needs of contemporary society. A general assumption is that sustainable and multifunctional forestry can best be achieved by a close-to-nature management system; it is believed that this form of management best complies with the above principles.

The change in the scope of European forestry has direct consequences for forest research. To support developments, new scientific information is necessary. From the ecological point of view the following main research fields deserve particular attention: global change and its impact on forests, including $CO_2$ sequestration; forest ecosystem functioning and natural forest dynamics; the ecological functions of forests in a broader landscape context, in relation to biodiversity protection and nature conservation; the ecological risks, both natural and anthropogenic; and the restoration of deteriorated forests and sites.

In certain European countries the above-mentioned change in the scope of forest management and research is already under way. Broad international contact and active collaboration in research and practice ease the process of change and adaptation of the forestry sector to the new political, economic, ecological and societal situation.

**Keywords:** **c**hange in forestry concept, important fields of ecological research in support of sustainable forest management.

## Historical roots of European forestry

European forestry was born in the first decades of the 18th century and from the outset developed as an activity to solve the most urgent problem of that time: the acute shortage of wood and timber for energy and construction. Its very roots lay in the Middle Ages of France and Germany: the French Forest Ordinance issued in 1318; the first artificial establishment of forests in the Nürnburger Reichswald in 1368 by sowing Scots pine seeds. Within the concepts and principles developed in the course of the 18th century (Von Carlowitz: Sylvicultura Oeconomica, 1713; Duhamel de Monceau: De l'exploitation des bois, 1764; and others), the goal of the emerging forestry was accomplished by: re-afforesting the huge area of waste and derelict land unsuitable for agriculture; and improving the timber production of existing but often severely degraded forests.

In the course of the 19th century the Normalwald concept (age-classes of forest) was formulated and became the leading concept according to which man-made forests in Europe have been managed. European forestry developed into a rational commercial activity oriented towards wood and timber production, with its own consolidated organisation, forestry education and research, and management rules and skills. The approach was very successful. Over the centuries, European forestry has succeeded in producing huge amounts of wood and timber in restored forests and in continuing to increase the area of forested land.

## European forestry in the second half of the 20th century

In the second half of the 20th century the above concept of European forestry came under pressure when, after World War II the political, economic, environmental and social situation changed. The advancement of democracy accelerated societal development. Industrial production grew rapidly and along with it the standard of living of Europeans rose. Industrial methods changed the character of agriculture. Within the EC/EU favourable conditions were created for international trade and for an unprecedented mobility of products and commodities (including wood and timber) throughout the continent. Iron and cement replaced timber as construction material. Oil and gas became the main sources of energy.

These developments had repercussions on European forests and forestry. As a sector working with long-living organisms and long production periods, forestry could not keep pace with the above-mentioned rapid changes. The contribution of forestry to the BNP fell, together with the sector's economic relevance in certain countries. Even the large-scale switch to fast-growing conifer and exotic tree species did not help to improve the economic position of forestry for a long time. Today, however, the situation on timber markets is quite different to what it was 50 years ago. The surplus of wood and timber in Europe (including imports from the tropics and Siberia) means that prices are unlikely to rise in the near future - with the possible exception of the prices for best quality timber.

One phenomenon accompanying the increased industrialisation in the past century was environmental deterioration, destruction of nature and impoverishment of landscapes in all industrial countries and areas. European forests and forestry did not escape this. In some parts of Europe, e.g. the Black Triangle along the borders of the Czech Republic, Germany and Poland, the environmental deterioration turned into an ecological disaster: forest die-back on thousands of hectares, decrease of vitality of trees in a large area, and chemically changed soils.

The internal development of man-made forests and the application of age-class forestry revealed some shortcomings. The high expectations of the profitability of commercial coniferous monocultures resulted in a big decrease in the biodiversity of forests and in their overall ecological destabilisation. Insect plagues and frequent climate-related events deregulated planning and management and led to financial setbacks.

Along with this situation, and often as a result of the above developments, new economic, ecological and social demands have been posed on forests and forestry. It has been realised that the functions of forests must be broadened, and so must the tasks of forestry. Forests, of course, will continue to produce wood and timber; if possible at low management costs. But at the same time, forests have been accorded an indispensable role in maintaining a healthy human environment and in the restoration of deteriorated rural landscapes, including their water regimes. As part of nature, forests have an important place in nature conservation and the protection of biological diversity. Recreation in forests and forested landscapes has a high priority among the ever growing urban populations.

This short overview shows that the situation in and around forestry has become much more complex than it used to be. The combination of internal factors operating within forestry and on regional and local levels (e.g. instability of forests, management costs) and external factors operating at the supranational and even global levels (e.g. global warming, environmental deterioration) is bringing great uncertainty about future developments in the forestry sector. Analyses show that the concept on which European forestry is based must be modernised in order to meet the rapidly changing poli-tical, economic and environmental situation. Also, the scope of forest management must be broadened: forestry must be understood as the management of (renewable) na-tural resources.

## Forest management at the beginning of the 21st century

According to the present state of knowledge, the best response to the societal, economic and environmental criteria and situation in Europe is to combine the principles of sustainability and multifunctionality in forestry (cf. Liaison Unit, 1998).

Sustainability refers to the use of resources (human, natural and man-made) in ways that allow current generations to satisfy their needs without jeopardising the capacity of future generations to meet theirs. As such, sustainability is a resource-oriented, long-term and global concept. It is resource-oriented because we do not know what use future generations will make of the resources, or which economic activities they will engage in; it is, by definition, long-term as it involves the interests of future generations, and it is inherently global as it is difficult to achieve long-term sustainable resource use in a sector, country or a region if resource use in other sectors, countries or regions is not sustainable (OECD, 2001).

Multifunctionality refers to the fact that an economic activity may have multiple outputs and, by virtue of this, may contribute to several societal objectives simultaneously. Multifunctionality is thus an activity-oriented concept that refers to specific properties of the production process and its multiple outputs (OECD, 2001).

A general assumption at the present level of scientific information is that sustainable and multifunctional forestry can best be achieved in a close-to-nature management system; such a system is believed to comply best with the above principles. It enables a reasonable integration of ecological and economic goals, is flexible enough to be applied under various economic, environmental and forest conditions; gives rise, in the long term, to self-sustaining forest ecosystems; makes it possible to carry out forestry as sustainable management of natural resources.

A close-to-nature management concept is not new to European forestry. Various forms have been developed and applied since the beginning of the 20th century (e.g. naturgemässe and/or naturnahe Waldwirtschaft; integrated forest management; Pro Silva approach; etc.). Examples on a small scale can be found all over Europe. A more extensive application is currently being debated (Angelidis, Rey & Hermeline, 1997; Liason Unit, 1998).

This new concept of European forestry means that much has to change in forestry soon, at all levels. Expressed in forestry terms, it means that the forest restoration period of the past is drawing to a close; a period of restructuring of European forests must be started to adapt forests and forestry to the new situation (Von Teuffel & Krebs, 1999).

## Main ecological research fields and strategies in support of sustainable management

This transition towards sustainable forest management has consequences for forest research. Sustainable forest management requires a different approach to research and needs different scientific information to support the management.

Figure 1 gives a simple scheme of the main circumstances influencing contemporary forestry. Each of the items given in the three complexes deserves specific attention. I will concentrate on the complex of ecological circumstances and discuss several strategic aspects of ecological forest research closely related to the concept of sustainable

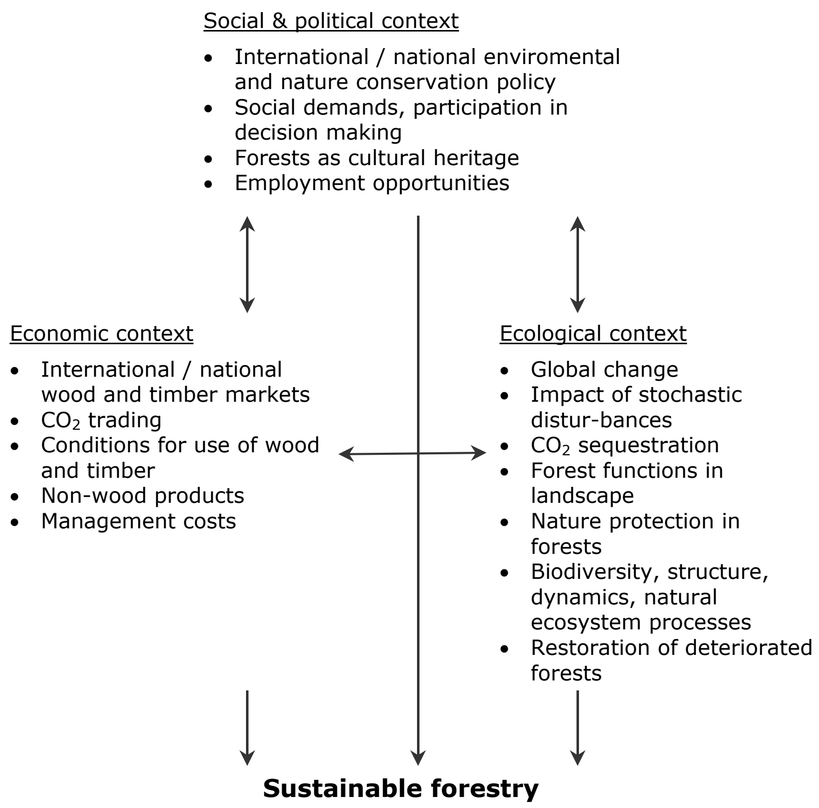


**Figure 1** - Sustainable forestry in its multifunctional context

forest management. The scope of ecological research in support of sustainable forest management is very broad. A range of aspects and research themes is related to or initiated by external factors and conditions. Others are related to new forest functions. And many themes are inherent to the management concept itself.

## Global change

Climate warming is obviously the most important external factor to be reckoned with in European forestry. Analyses show that rising temperatures and $CO_2$ levels (both largely anthropogenic in origin), and changes in precipitation have a long-term character (Houghton et al., 1990; Schönwiese, 1995; and many others), with profound impact on site conditions and forest growth. The main aspects involve: changes in tree growth and vitality, with both positive (especially in the boreal and temperate zones) and negative (Mediterranean, SE Europe) impact on tree growth and health; shifts in longitudinal and altitudinal vegetation zonation; vulnerability of commercial plantations grown outside the species natural range; change in natural processes in forest ecosystems (regeneration, succession, competition); weed infestations and insect plagues; frequent occurrence of extreme climatic fluctuations (drought, flooding); increased risk of forest fires (especially in the Mediterranean and SE Europe).

Today, a reliable regional prognosis of climate development is still not possible. The best possible forestry strategy to respond to the situation is to spread and minimise potential risks instead of aiming at maximum yields. Growing structure-rich mixed forests of indigenous species will support the flexibility of forest management (Lindner, 1999). More flexible methods of forestry planning and ecological methods of forest management should be broadly applied to support the stability of forests and their ecological functions in landscapes (Fanta, 1992). In the immediate future, the impact of global change in forestry offers a broad field for collaborative research with specialist institutions and represents an inexhaustible source of scientific information.

## Impact of large-scale stochastic disturbances

Storms, drought and excessive precipitation have been more frequent in recent decades and pose a considerable risk to forests and forestry, with major economic consequences. Severe gales afflicted NW European lowlands in 1972 and 1973, Switzerland and S Germany in 1990 and again in 1999, SE France in 2002. In thousands of hectares of forest the trees were blown down, millions of cubic metres of wood destroyed, financial and field management were disrupted and timber markets ruined. A disaster - at least in the eye of a decent and careful forester who likes order in his planted and carefully managed forest.

We cannot avoid these events and no forest can withstand a gale of 200 km per hour. And foresters are not able to convert even-aged monocultures into more resistant uneven-aged and structured forests within a few years. This requires consistent conversion planning and management over several decades, to which such exceptional storm events can and should give an impetus. A storm is always an unexpected event, but it need not necessarily mean a catastrophe with only negative effects. Economic and ecological analyses of the recent storms both show a more differentiated picture. When the damage is seen as the main issue, then clearing it up and restoring the previous situation stay in the foreground, sometimes even at any cost. Perceiving the situation as a natural phenomenon leads in most cases to another approach. Not all the thrown timber needs to be cleared and not always is restoration to the previous situation desirable and advisable. Within this approach, there is room for spontaneous regeneration with only minor management interventions at low cost, and for a shift to a close-to-nature forestry concept with a low-cost - high diversity management (Fischer, 1998; BUWAL, 2000; Willig, 2002). Outbreaks of insect plagues in man-made forests must always be reckoned with, but here too a differentiated approach should be applied. GIS and scenario analyses are appropriate tools for obtaining more insight into prevention, corrective measures and for developing a flexible, adaptive approach.

## $CO_2$ sequestration

European forests extend over more than 150 million hectares (excluding the European part of Russia), which represents a forest cover of 34 % of the total land area (FAO, 1997). The most recent estimates (1990 data ) of the $CO_2$ sequestration for 27 European countries (Karjalainen et al., 2003) are: total carbon stock nearly 13,000 Tg, of which 47 % in the biomass, 47 % in the soil and 6 % in wood products in use. Net biomass production was the highest in the British Islands, and in Central and SE Europe. Forests and wood products were able to sequester 7-8 % of the carbon emissions from fossil fuel combustion.

With this capacity, European forests are an active agent in global change and related environmental issues. It is expected that this function of forests will increase in the future, due to the absence of large-scale deforestation in Europe and to the expected expansion of the forested area that will result from restructuring the agricultural use of landscapes. Other supporting factors are the increasing volume increment observed in the last 50 years (probably the result of the synergy of increased temperature, precipitation, $CO_2$, and nitrogen content), and increasing age and standing biomass volume per hectare (Spiecker et al., 1996).

It seems clear that carbon sequestration (and, in the near future, carbon trade) will be an important agent in future forest management. This issue deserves to be a focus of forest research, both fundamental and applied, to support forest management with adequate information that can be used to underpin adaptive decision making.

## Ecological functions of forests in the landscape context

Forests are specific structural elements of landscapes, which contribute much to landscape stability. Their functions in landscape context are many-sided and extend far beyond the forested area. Forests are instrumental in erosion control in mountain and hilly areas, in water retention and flood prevention (Gastescu, 1990). The water cycle involves processes operating at large to small scales. Together with geomorphological conditions, the factors determining the water regime at the landscape/catchment level are different forest types (species composition, structure, age distribution, and methods of forest harvesting; MÍrell et al., 2003).

The restructuring of agriculture in Europe is underway, bringing big changes in land use Europe-wide. In marginal agricultural areas a considerable expansion of forested land can be expected, to counteract the degradation of abandoned land (Hanousková et al., 1999). In areas of intensive agriculture, an ecological network of landscape must be established to mitigate the impact of intensive agricultural use on the landscape system.

Forests will play an important role in this as core areas, corridors and stepping stones supporting biological diversity of landscape. The development of appropriate scientific information in this field is of high importance for landscape planning and management.

## Nature protection and nature management in forests

Forest management and the protection and management of nature are allies in renewable natural resource management. In some European countries, however, the relations between nature conservation and forestry are far from satisfactory. Forests have a high potential as a source of biological diversity (Donita & Ivan, 1998). The full development of this potential is one of the tasks of ecologically motivated forest management. In this way, European forestry has the capacity to solve problems of nature protection and management at least in the 34 % of European land covered with forests. It should be taken for granted that specific biotopes and endangered species will be protected by forest management.

The interests of nature conservation and forestry are identical in national parks and, to a lesser degree, in areas of protected landscape. One important type of area in which the interests of sustainable forestry and nature protection converge is natural/virgin forest. Such forest is very rare in large parts of Central and W Europe. It is seen as an important benchmark for man-made forests (Schnitzler & Borlea, 1998). Its protection and monitoring have a high priority in all European countries. Research on natural/virgin forest reveals unique scientific information about: the scale and frequency of natural disturbances; structural characteristics as source of biodiversity; stand dynamics (including processes of regeneration and competition).

It is of the utmost importance for sustainable forestry (at both national and European level) to protect existing virgin forests over the largest possible area and over the whole range of site and forest conditions. Protection of virgin forests should be the cornerstone of co-operation between forest and nature management (Turnock, 2002). Countries rich in natural forests have the opportunity to develop excellent expert know-ledge in this field.

## Ecologically motivated forest management

The central points in the development of methods and techniques of close-to-nature, sustainable forest management are biodiversity, the mimicking of natural dynamics (including natural disturbances), rich structures, and maximum use of natural processes (regeneration, succession, competition, selection). What underlies the difference in ecosystem functioning at particular sites is the huge variety of local site and forest conditions (cf. Donita, 1990; Pauca-Comanescu, 1989). The fundamental knowledge of ecosystem functioning is of immense value for decision making: each forest type needs a different approach to regeneration, thinning and other silvicultural treatment of stands. A uniform approach is inappropriate. Natural processes show how man-made forests should and can be managed with minimum costs and manpower. Such an approach must be based upon the full involvement of qualified people. Good cooperation between researchers and forest managers is essential. Problem-solving research facilitates the field management and contributes to its good results. It deserves the full attention of management bodies at all levels.

### Restoration of deteriorated forests and sites

The vitality and ecological stability of man-made forests have decreased considerably in some parts of Europe, not only due to severe and ruthless environmental deterioration in the second half of the 20th century (cf. Puhe & Ulrich, 2000), but also due to repeated rotations of conifers on the same spot and far outside their natural range (Kilian & Fanta, 1998; Hasenauer & Sterba, 2000). In both cases, the resulting changes in soil biology and soil nutrient status are seriously limiting today's forestry (Killham et al., 1983; Lettl, 1984; Hruška & Cienciala, 2003). Until recently, technical restoration using costly artificial means and measures used to be the usual alternative. Recent research has shown that allowing natural processes to run their course, though slower, is much more effective, especially in a more complex way (Lettl & Hýsek, 1994; Emmer et al, 1998). Pioneer tree species - often seen as worthless weeds by commercially oriented foresters - and spontaneous succession are reliable low-costs means for accomplishing the rehabilitation of degraded sites under very different conditions (Prach, 1994; Emmer et al., 1998). Here too, the main prerequisite for successful management is scientific insight into spontaneous development dynamics of forest sites and communities.

### Research methods and techniques

In recent times, ecological research has made tremendous progress. The application of new experimental and mathematical methods and computer technology is giving a strong impetus to innovation. The technique of GIS offers possibilities for the storage, combination and evaluation of geographically based data that were not possible a few years ago. New analytical methods in evolutionary genetics, palynology, microbiology, soil science and other disciplines are yielding new scientific information suitable for ecological interpretation.

Forest ecology, as an applied branch of ecology, is lagging somewhat behind in these developments. An acceleration in forest ecological research is very necessary: gaps in knowledge are many and research needs are high (Hüttl et al., 2000). Much can be achieved in collaborative forestry research involving research institutions and scientists from other disciplines and sectors. Complex research questions are best tackled by teamwork.

Collaboration within the sector deserves specific attention at the leadership level. Some European countries have reported good experience with specific reference units, sited within policy, research and practice with the aim of disseminating and interpreting scientific information, practical questions and experience and political decisions throughout the sector. A streamlined information flow is the basis on which good collaboration between sector bodies can be developed.

## CONCLUSIONS

Multifunctional, sustainable forestry is the answer of European foresters to the political, economic and ecological questions and demands of our time. The new concept is bringing about much change. But it is also an essential challenge to every forester, whether working in research or practice. Future European forestry will not be explicitly a sector of primary production, but a service sector to society.

In common with every deep-going change, this one also brings problems. The task of research in this transformation is twofold: (1) to reveal and deliver scientific information to underpin managerial decision making; and (2) to maintain and feed a professional platform, where new development trends and ideas in the forestry sector can be discussed and where scientific information can be disseminated to forestry practice, co-operating partners from other sectors, and to policy and society, with no bias and in an atmosphere of mutual trust and co-operation.

## REFERENCES

Buwal, 2000. Entscheidungshilfe nach Sturmschäden im Wald. Bundesamt Umwelt, Wald und Landschaft, Bern

Donita, N., Chirita, C. & Stanescu, V. (eds.), 1990. Tipuri de ecosisteme forestiere din Romania. Centrul de material didactic si propaganda agricola, Bucuresti

Donita N. & Ivan D., 1998. Sur la biodiversité des Carpates de la Roumanie. Ecologie 29:155-157

Emmer I.M., Fanta J., Kobus A.Th., Kooiman A. & Sevink J., 1998. Reversing borealisation as a means to restore biodiversity in Central-European mountain forests - an example from the Krkonoše Mountains, Czech Republic. Biodiversity and Conservation 7: 229-247

Fanta J., 1992. Possible impact of climatic change on forested landscapes in Central Europe: A review. Catena Supplement 22: 133-151

FAO, 1997. State of world’s forests. FAO, Rome

Fischer A. (ed.), 1998. Die Entwicklung von Waldbiozönosen nach Sturmwurf. Ecomed, Landsberg

Gastescu P., 1990. Water resources of the Romanian Carpathians and their management. Revue Roumaine de Geographie 34: 85-92

Hanousková I., Sullivan P.E. & Witkowski Z., 1999. Perspectives in the sustainable land use of marginal areas: land abandonment and restoration. In: Farina A. (ed.), Perspectives in ecology. Backhuys, Leiden, p. 295-308

Hasenauer H. & Sterba H., 2000. The research program for the restoration of forest ecosystems in Austria. In: Klimo E., Hager H. & Kulhavý J., Spruce monocultures in Central Europe - problems and prospects. EFI Proceedings No. 33. EFI, Joensuu, p. 43-52

Houghton J.T., Jenkins G.J. & Ephraums J.J. (eds.), 1990. Climate change, the IPCC scientific assessment. Cambridge University Press, Cambridge

Hruška J. & Cienciala E. (eds.), 2003. Long-term acidification and nutrient degradation of forest soils - limiting factor of forestry today. Czech Ministry of Environment, Prague

Hüttl R.F., Schneider B.U. & Farell E.P., 2000. Forests of the temperate region: gaps in knowledge and research needs. Forest Ecology and Management 132: 83-96

Karjalainen T., Pussinen A., Liski J., Nabuurs G.-J., Eggers T., Lapvetelainen T. & Kaipainen T., 2003. Scenario analysis of the impacts of forest management and climate change on the European forest sector carbon budget. Forest Policy and Economics 5: 141-155

Kilian W. & Fanta J. (eds.), 1998. Degradation and restoration of forests. Ecological Engineering 10: 1-107

Killham K., Firestone M.K. & McColl J.C., 1983. Acid rain and soil microbial activity: Effects and their mechanisms. Journal Envir. Quality, 12: 133-137

Lettl A, 1984. The effect of atmospheric SO2 pollution on the microflora of forest soils. Folia Microbiol. 29: 455-475

Liaison Unit in Lisbon (ed.), 1998. Sustainable Forest Management in Europe. Special Report on the Follow-up on the implementation of Resolutions H1 and H2 of the Helsinki Ministerial Conference. Ministry of Agriculture, Rural Development and Fisheries in Portugal, Lisbon.

Lindner M., 1999. Waldbaustrategien im Kontext möglicher Klimaänderungen. Forstwiss. Centralblatt 118: 1-13

MÍrell A. et al., 2003. Scientific issues related to sustainable forest management in an ecosystem and landscape perspective. Technical Report 1, COST Action E25. ECOFOR. Paris

OECD, 2001. Multifunctionality: Towards an analytical framework. OECD, Paris

Pauca-Comanescu (ed.), 1989. Fagetele din România. Cercetari ecologice. Editura Academiei, Bucuresti

Prach K., 1994. Succession of woody species in derelict sites in Central Europe. In: Fanta J. (ed.), Forest ecosystem development on degraded and reclaimed sites. Ecological Engineering 3, 1: 49-56

Puhe J. & Ulrich B., 2000. Global climate change and human impacts on forest ecosystems. Ecological Studies, Vol. 143. Springer, Berlin - Heidelberg - New York

Schönwiese C.-D., 1995. Klimaänderungen, Daten, Analysen, Prognosen. Ulmer, Stuttgart

Schnitzler A. & Borlea F., 1998. Lessons from natural forests as keys for sustainable management and the improvement of naturalness in managed broad-leaved forests. Forest Ecology and Management 109, 1-3: 293-303

Spiecker H., Mielikainen K., Kohl M. & Skovsgaard J.P., 1996. Growth trends in European forests. EFI Research Report 5. Springer, Heidelberg

Teuffel K. von & Krebs M., 1999. Forsteinrichtung im Wandel. AFZ/Der Wald, 16: 858-864

Turnock D., 2002. Ecoregion-based conservation in the Carpathians and the land-use implications. Land Use Policy 19: 47-63

Willig J., 2002. Natürliche Entwicklung von Wäldern nach Sturmwurf - 10 Jahre Forschung im Naturreservat Weiherkopf. Mitteil. Hess. Landesforstverwaltung Hessen, B. 38