Virgin forests as a knowledge source for central European silviculture: reality or myth?

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Abstract
In central Europe, the few remnants of virgin forest left have often been studied for reasons based on the following line of argument: Such studies increase our understanding of forest dynamics under a natural disturbance regime and are therefore an important basis for close-to-nature silviculture. This paper reviews the history of this idea, examines its merits and drawbacks focusing on selected silvicultural issues, and explores the potential for using virgin forest research as a source of ideas for developing silviculture in future.

Research on virgin forests has had important implications for managed forests in the case of maintaining nurse logs as a seedbed for tree seedlings, of knowing the maximum age and size of trees, and, to a minor extent, of identifying the habitat requirements of species which are found mainly in virgin forests. However, past research on virgin forests has not provided any major direct contributions to defining close-to-nature silviculture. The main obstacles to knowledge transfer seem to be: (i) the scarcity of virgin forest remnants in central Europe, (ii) differences between the stand histories and current stand structures in virgin and managed forests, and (iii) the better opportunities to study phenomena of interest directly in managed forests, with easier access and possibilities of using manipulative approaches (field experiments) with proper replication. Current trends in central European forests and silviculture, such as the creation of forest reserves, the increase in growing stock, the shift to continuous-cover forestry and the increasing importance of forests as habitats for endangered species, suggest there is still much to learn from virgin forest remnants, and to justify further research. However, virgin forests should only be studied when an issue can best be addressed by using them as the object of study. Otherwise, managed forests should be preferred, or a combination of virgin and managed forests.

Keywords: virgin forests, forest reserves, protected areas, close-to-nature silviculture, central Europe, forest dynamics, research history

1 Introduction
In 1905, Julius Fröhlich started his career as a trainee in the forestry department of Bosnia. At this time, about 50 % of the total forest area of Bosnia of two million ha was considered virgin forest (FROHLICH 1954, p. 9), i.e. forest that has not had any human-induced treatment (LUND 2002). Fröhlich surveyed these forests and planned their exploitation. Today, most of these forests have lost their virgin status. Twenty-seven “strict forest reserves” totalling 3125 ha in area remain in Bosnia (PARVIAINEN et al. 2000). Only five of these reserves can be considered as “virgin forest reserves” (PINTARIĆ 1999). The total area of virgin forest remnants in central Europe is difficult to estimate since this area depends on the definition of the notion “virgin forest” (LUND 2002). Strictly protected forest areas cover about 100 000 ha in Austria, Belgium, the Czech Republic, France, Germany, Hungary, The Netherlands, Poland, Slovakia and Switzerland (PARVIAINEN et al. 2000). However, only a minor part of these forests can be considered to be virgin forests. In Scandinavia and eastern Europe, larger patches with little human impact still exist (PARVIAINEN et al. 2000).
Forest scientists and managers have often stated that forest management could profit from a better understanding of virgin forest dynamics. For example, RUBNER (1920) claimed that we could learn three things from virgin forests: Whether stands are naturally mixed or mono-specific; whether they are uniform in structure or heterogeneous; and how natural regeneration occurs. Rubner was an early pioneer in promoting virgin forests as objects of study. Since about 1950, a large body of scientific studies and papers dealing with virgin forest remnants in Europe has developed. Indeed, the reserve status of many of these remnants was promoted and secured by forest managers and scientists.

This interest in virgin forests has often been justified by the following line of argument: These forests have not been subject to human impact, and studying them therefore offers us opportunities to advance our understanding of forest structure and dynamics (LEIBUNDGUT 1959). This is particularly interesting given the current trend towards a more nature-oriented silviculture, which largely relies on using natural processes to reach silvicultural goals (OTTO 1995; SCHÜTZ 1999, 2004). It is even possible to completely rely on natural processes, without any silvicultural interventions, which is appealing on steep-slope protection forests where interventions are costly (HILLGARTER 1978; BRANG et al. 2004b).

In this paper, I will first review the history of scientific interest in virgin forests in Europe. Second, I will examine the conceptual foundation of this interest, using examples in which research results obtained in virgin forests have been applied to forest management. Third, I will explore the potential for future contributions from research on virgin forests to designing silvicultural systems.

2 History of scientific interest in virgin forests

Interest in virgin forests is linked to the veneration of nature in general, as inspired by the Swiss-French philosopher Rousseau (1712–1778). In the 19th century, interest in natural forests increased partly as a counter-movement to a more and more rational and technical world, and also to man-made uniform forests which often rather resemble arable land. This emotional appeal of natural forests can be illustrated by a statement by WESSELY (1853), who described an expedition into a virgin forest in Austria: “... intruding into this wilderness where man had apparently not laid his foot had an unutterable appeal, which no one was able to withstand. It was a feeling which may have been the same as that of the great sailors when they discovered new continents1.” Also today, at least three different virgin forests are called “Cathedral Grove” (Internet search, 2 December 2004), which illustrates how these forests are valued.

GÖPPERT (1868) was one of the earliest foresters to study virgin forests in Europe. GAYER (1898), BIOLLEY (1901), GURNAUD (1886) and ENGLER (1900) promoted a type of naturalistic silviculture that was in contrast to the common practice of large-scale clearcutting. Their silvicultural thinking prepared the terrain for a new interest in virgin forests, which were, during their life, still being harvested and thus transformed into managed forests in eastern and south-eastern Europe (FRÖHLICH 1954).

CERMAK (1910), in his paper on “Silvicultural issues in virgin forests”, described the forest composition and structures as well as disturbance regimes in virgin forests in Bosnia-Herzegovina. By “silviculture”, he still meant the sustainable use of the remaining virgin forests. One of the early citations attributing a particular value to virgin forests for silviculture in managed forests can be found in a paper by RUBNER (1920), with the title “Silvicultural

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1 German citations have been translated by the author.
conclusions from virgin forests”: “With increasing culture and more sophisticated techniques, man will not detach himself from nature, but will increase his ties with it and govern it, by knowing it and subordinating himself to its restrictions”. BASELER (1932, p. 39) reviewed early research on virgin forests. According to him, the scientists investigating virgin forests thought that these forests “should become an educational aid for managing cultural forests in a close-to-nature manner”. Later, AUBRÉVILLE (1938) published a book on African rain forests. In his account of forest dynamics, he already developed the mosaic cycle theory, which was later refined by REMMERT (1991).

After World War II, the Iron Curtain made it difficult for scientists from western countries to study virgin forest remnants in eastern Europe. In spite of this, the uniqueness of these remnants and their scarcity in western Europe stimulated international cooperation. Several scientists had already started to study the structure and dynamics of virgin forests in the 1950s (and even 30s, ZLATNIK 1938). It is no coincidence that these scientists (PINTARIĆ 1959; MLINSEK 1978, 1993; LEIBUNDGUT 1982; MAYER et al. 1989; KORPEL’ 1995) advocated a type of silviculture which was partly in contrast to the contemporary practise. They were against schematic clearcutting and in favour of small-scale interventions taking the particularities of each stand, and even of each tree, into account. The title of a paper by VÉZINA (1959) clearly conveys the link between virgin forest studies and close-to-nature silviculture: “Contribution to the study of virgin forests as a basis for developing a silvicultural system which is more close-to-nature.” MLINSEK (1978) hoped to find the knowledge basis for close-to-nature silviculture in untouched forests. Research and observations in virgin forests were intended to stimulate the conversion of forests heavily influenced by humans into more natural forests.

The idea of conversion was actually present much earlier when the question of whether virgin forests more closely resemble even-aged or uneven-aged forests was first raised. In my opinion, it is not clear why this should matter so much since there is no need for managed forests to closely resemble virgin forests. At the beginning of the 20th century, however, this was a matter of debate. While some authors (WESSELY 1853; KOPEZKY 1895) compared virgin to single-tree selection forests (plenter forests, “Plenterwald” in German), others (CERMAK 1910; RUBNER 1920; GEHRHARDT 1923) claimed that they more closely resemble even-aged forests. BASELER (1932) provides a good overview of the different opinions. It becomes clear that the answers vary according to site conditions, which influence the occurrence of tree species.

Leibundgut advocated an approach to silviculture with a free conduction of cuts (“freie Hiebsführung” in German, SCHÜTZ 1994), which made full use of the silvicultural “toolbox”. He considered forests not as tree farms, but as dynamic ecosystems, although he clearly focused on the tree layer and not on the whole forest ecosystem. This viewpoint was therefore already ecosystem-based, although today it would still seem narrow. According to this ecosystem-based view, virgin forests are an interesting object of study. This argumentation continued with, e.g., FABIJANOWSKI (1978), PRUSA (1985), ZUKRIGL (1990), and BERNADZKI et al. (1998).

In spite of the apparent stress laid on the importance of studying virgin forests, interest in virgin forests at the time was of a rather general nature. The main agenda of the scientists mentioned above was strengthening the scientific basis of “close-to-nature” or “nature-oriented” silviculture. The real contributions of virgin forest studies to this agenda were not clear. It rather seems that virgin forests were a fascinating object of study on their own, and that these studies had, with “nature”, a common denominator with nature-oriented silviculture, but no direct link. Therefore, the conceptual justifications for research on virgin forests seem, in retrospect, to have been quite vague until about 1990. The statement of objectives of a monitoring program in forest reserves illustrates this vagueness: “Application to silvicul-
ture and forest management by deriving knowledge for treating production forests and for conservation of species and habitats in forests” (Albrecht 1988). Mayer et al. (1972) claimed that research on virgin forest remnants would deliver the basis for biological rationalisation: “A closer insight into the natural development dynamics will allow us to realize the combined productive and social functions in our managed forests with a minimum of regulating measures.” This is in line with the opinion of Leibundgut (1982, p. 16): “Virgin forest research should deepen our knowledge about the characteristics of our tree species and their coexistence in stands, and thus improve the fundamentals of a real close-to-nature silviculture, so that we can achieve objectives at minimum expense.” Korpel’ (1995, p. 1) had the same point of view: “A close-to-nature forest management will essentially involve considering the regular processes and characteristics which take place in natural forests, without human interference.”

Recently, these vague arguments favouring virgin forest studies have been augmented by the concept of mimicking natural forest dynamics to preserve biodiversity, which was developed in North America (Lertzman et al. 1996; Spies and Turner 1999; Franklin et al. 2002). This approach is also increasingly advocated in Europe (Angelstam 1998; Peterken 1999; Bengtsson et al. 2000). To implement such an approach, however, a better understanding of virgin forest dynamics is required. The following citation nicely illustrates both justifications for virgin forest research, the old vague justification and a recent more precise one: “It is generally accepted that natural forests are the basic model for the realisation of nature-oriented silviculture. In strict forest reserves the development cycle of natural forests can be observed, elucidated and understood, and these findings subsequently mimicked in production forests” (Parviainen et al. 2000).

A recent attempt to apply virgin forest research to silviculture is the establishment of paired plots in forest reserves and nearby managed forests (Meyer et al. 2004). If pairs have similar site conditions, developmental stages and stand histories, they can directly be compared, and the management influence on stand structure and habitat characteristics quantified.

In line with the idea of mimicking disturbance regimes of virgin forests in production forests, the interest in natural and virgin forests in Europe has considerably increased during the last two decades because of their importance as habitats for virgin forest dependent species (Schuck et al. 1994; Diaci 1999). In many countries, a network of forest reserves has been established, and the development of these reserves is being studied (Parviainen et al. 2000). In line with this interest in biodiversity, there is a clear shift away from pure studies of stand structure, stand dynamics and regeneration to studies of virgin forests as a habitat for diverse fauna and vegetation, including endangered species. The shift in research focus from stand dynamics to habitat characteristics is coupled with a shift in scale, from studies at the tree and stand levels to studies at the landscape level, according to the habitat requirements of the species in question.

In terms of research methods in virgin forests, the earliest accounts were based on descriptions of the stand structures in extended areas, although the exact area described is rarely given (Wesely 1853). Sometimes, stem distributions of a few temporary plots that were subjectively selected are presented to illustrate the key findings (Seidel 1848; Fröhlich 1954). Today, such an approach would not be scientifically acceptable anymore. It is fascinating, though, to read the purely descriptive account of Rubner (1920) on virgin forests, and to notice that most of his statements are in agreement with the results of recent research, which were gained with much more sophisticated and time-consuming methods.

Starting about in 1950, many permanent plots were established, and the developmental phases mapped (Korpel’ 1995). Recently, this still subjective approach has been complemented with representative inventories at the landscape scale (Projektgruppe Natur-
waldreservate 1993; Anonymus 2000), with paired plots of managed and unmanaged forest as described above (MEYER et al. 2004), and with modelling (RAEMACHER et al. 2001).

3 Knowledge transfer from virgin to managed forests

3.1 Methods and examples used

In this section, I will ask in what respects studying virgin forests, and extrapolating the silvicultural knowledge gained to managed forests, has been a successful approach. I will try to answer this question using examples focusing on the following selected aspects of silviculture:

- Long-term competitive interactions between tree species
- Natural regeneration under canopy cover
- Maximum age and size of trees
- Forest dynamics without management operations
- Natural disturbance regimes
- Effects of tending and thinning measures on stem quality
- Habitat requirements of species which depend on virgin forests

As extrapolations in time and space can be problematic (BRANG et al. 2004a; KOHL et al. 1995), I will first briefly review the conditions that should be met for valid extrapolations.

3.2 Extrapolation from virgin forests to managed forests

Forests vary greatly with respect to site factors (mainly climate, geology and soil), disturbance regimes (e.g., frequency and extent of windthrow and snow break) and forest history (e.g., current developmental stage, plant migration after the Ice Age). They are therefore also highly diverse in terms of species composition and stand structure. For instance, the mortality, establishment and growth rates of trees and disturbance regimes often depend on site factors. Therefore, such rates can only be extrapolated with caution from one site to another and should only be applied to a management context if the sites are sufficiently similar. If research on virgin forests and nature reserves, which are in most cases studied as single case studies, should result in silvicultural applications, this site-dependency could be a barrier to knowledge transfer.

Nevertheless, relatively static site factors such as climate, geology and soil may be quite similar, even with distant sites. This similarity often shows up in the occurrence of similar plant communities, of similar altitudinal sequences of plant communities, and in similar height-diameter relationships among the trees. If we find a similar herb layer in a Fagus sylvatica forest in the Ukrainian Transcarpathians and in Switzerland, and similar height growth-stem diameter relationships (COMMARMOT et al. this issue), we can safely assume a large similarity in site factors, and, since site factors are related to disturbance regimes, even in the latter.

Silvicultural decisions always have a long-term perspective and must therefore cope with large uncertainty with respect to, e.g., future social needs. In the light of this uncertainty, it seems unreasonable to set unrealistically high standards for knowledge transfer from unmanaged to managed forests on similar sites. In research, however, in which generally valid patterns are sought, similarity standards must be higher. For instance, for paired plots of managed and unmanaged forests, plot selection criteria for ensuring sufficient similarity must be strictly applied (MEYER et al. 2004).
Historically, the inference made from research in virgin forests decreased over time, paralleled by increasing knowledge about virgin forests and more strict standards in science in general. Pure observations and temporary plots were used in the 19th and at the beginning of the 20th century to draw general conclusions. Later, in the second half of the 20th century, longitudinal case studies on small permanent plots were the dominant method, and the conclusions were more site-specific. The case study character of this method, however, was not always considered, and conclusions were sometimes made without sufficient replication. Since about 1970, inventories in virgin forests with plots in systematic grids have increasingly been used. In central Europe, however, we have to accept that the virgin forest remnants are so scarce, and the establishment of many nature reserves so recent, that, for the majority of the sites, we will not be able to quantitatively describe natural disturbance regimes with satisfying certainty for several decades. The representativity gained with inventories remains representativity for case studies, and not for site types.

3.3 Long-term competitive interactions between tree species

Many of the early reports on virgin forests mention competitive interactions between and within tree species. For instance, the observed shade tolerance of seedlings and saplings of *Abies alba* Mill., *Picea abies* (L.) Karst. and *Fagus sylvatica* L. was used to explain their ability to outcompete light-demanding species (CERMÁK 1910; RUBNER 1920). Although the competition-induced mortality of light-demanding species in the presence of shade-tolerant species has not yet been demonstrated with longitudinal data from virgin forests, it is supported by practical experience and by evidence from pollen analysis (BURGA 1988). Accordingly, *Fagus sylvatica* virgin forests are often poor in other tree species (FROHLICH 1947; KORPEL’ 1995; MEYER et al. 2002; COMMARMOT et al. this issue). These facts were known to silviculturists, but could be confirmed in virgin forests, where stand structures often differ from those found in managed forests. However, even if we had ample scientific evidence about the competitive abilities of tree species from virgin forest remnants, it seems difficult to transfer general patterns to managed forests since such abilities heavily depend on site factors, or may be due to a particular stand history in the case studies. For instance, SCHÜTZ (2004) found, in contrast with other studies, a competitive advantage of *Fraxinus excelsior* L. over *Acer pseudoplatanus* L. in a small, man-made gap in a managed forest in the Swiss central Plateau.

3.4 Natural regeneration under canopy cover

The study of natural regeneration processes was often mentioned as a justification for research on virgin forests (HILGARTER 1978; LEIBUNGDUT 1959, 1982). Long-term suppression and release, the overlap between tree generations, the impact of browsing ungulates on regeneration, and regeneration on nurse logs were of particular interest.

The capacity of shade-tolerant tree species to grow vigorously after long-term suppression has been well documented in and outside of virgin forests (e.g., SCHÜTZ 1969; CROSSLEY 1976; SEIDEL 1977). In central Europe, there is a sufficient area of single-tree selection forests to study the phenomenon. Findings from virgin forests therefore only confirmed results from managed forests.

Many remnants owe their reserve status to their use as a hunting reserve (MAYER et al. 1989; e.g., Bialowieza: FABIJANOWSKI 1978; Neuwald: MAYER et al. 1972). Changes in tree species composition as a result of long-term browsing pressure are often assumed, but are
difficult to prove since longitudinal data on both species composition and browsing pressure are unavailable. Studies from virgin forests confirm the general patterns of browsing preference for particular tree species. However, the interactions among ungulate population densities, their feeding behaviour and seasonal migrations, and habitat suitability are complex. Establishing generally valid patterns is difficult in managed forests alone, and, therefore, extrapolations from virgin forests to managed forests are questionable as well.

The case of regeneration on nurse logs is different (Fig. 1). In a recent literature review, MAI (1998) summarizes 274 publications related to natural tree regeneration on dead wood. Some species, in particular Picea abies, depend strongly on this substrate in cool-wet environments such as many high-elevation forests. From MAI’s list, it becomes clear that early accounts of regeneration on nurse logs are mostly based on observations in virgin forests (GÖPPERT 1868; ENGLER 1904; CERMAK 1910; but see MOREILLON 1910). This phenomenon could rarely be observed outside virgin forests since virtually all timber was harvested in managed forests at that time, sometimes even including the stumps, and no nurse logs were normally left. Regenerating subalpine Picea abies forests using stumps (MOREILLON 1910) and nurse logs has often been proposed. At the beginning of the 20th century, however, while this phenomenon was known (PILLICHODY 1910), it was not yet translated into management recommendations (BAVIER 1910). We therefore know that some species regenerate on nurse logs because we can observe it in virgin forests. Even today, this phenomenon can rarely be observed outside forest reserves since the practice of purposefully leaving coarse woody debris in stands is too recent.

**Fig. 1.** Picea abies saplings on a downed log in the virgin forest remnant Scatlé, Brigels/Switzerland.

### 3.5 Maximum age and size of trees

Most of our knowledge about the maximum age and size that trees of different species can reach comes from virgin forests (e.g., KORPEL’ 1995). So far, this knowledge has not been directly applied in managed forests since most trees are cut many decades before their biological death would naturally occur. This knowledge has indirectly been used for modelling forest succession under the assumption of no management (BUGMANN and SOLOMON 2000), and for deriving minimum levels of regeneration in mountain forests based on the remaining lifespan that current stands are expected to have (BRANG and DUC 2002).
However, there is no hard evidence for the assumption that maximum tree and stand ages are identical in managed and unmanaged forests. In contrast to many virgin forests, only few trees exhibit an early suppression phase in many managed forests, which may reduce the maximum age of trees in the latter case. Predictions about the remaining lifespan of managed forests are therefore uncertain. Knowledge about maximum tree age has also been used to derive the duration of tree and whole stand generations, and to estimate the proportion of different stages of development (KORPEL’ 1995), which has implications for the habitats available historically for different organisms and thus for biodiversity.

3.6 Forest dynamics after abandonment of silvicultural operations

Our understanding of the dynamics of virgin forests has sometimes been used to assess the implications of a no-intervention silvicultural strategy in mountain forests. This would be an attractive option since silvicultural operations in protection forests (BACHOFEN and ZINGG 2001) on steep mountain slopes are costly. The difficulty is, however, that even if we conclude that natural forest dynamics are unlikely to impair the protective effect of such forests, this conclusion cannot be directly extrapolated to forests with a long history of human impact. The starting conditions are different. For instance, the stand structures are much more homogeneous in managed than in virgin forests under similar site conditions (BRANG 2003).

3.7 Natural disturbance regimes

Early virgin forest definitions excluded early developmental stages resulting from large-scale disturbances (BASELER 1932, p. 40), which are not likely to occur very often in central European virgin forests (FRÖHLICH 1954; ZUKRIGL 1990). Knowledge of the frequency, extent and intensity of natural disturbances of different types (e.g., windthrow) would be helpful for designing anthropogenic disturbances (silvicultural interventions) which either resemble natural disturbances, or minimize their occurrence (by enhancing resistance) or their impact (by enhancing elasticity, BRANG 2001). However, the small size of the remaining virgin forest remnants makes it very difficult to characterize natural disturbance regimes, especially if large-scale disturbances from agents such as storms prevail. Therefore, designing silvicultural operations to resemble natural disturbance regimes is not a promising approach in central Europe. Moreover, one effect of the long-term management of the European landscape has been an increase in overall species richness (WOHLGEMUTH et al. 2002). Therefore, restoring virgin forests and natural disturbance regimes would increase the overall species richness only if it were restricted to certain parts of the forest area.

3.8 Effects of tending and thinning measures on stem quality

Interestingly, studies of virgin forests have rarely been used for scientifically underpinning the need for tending and thinning measures in managed forests. If such measures are effective, the timber quality should be higher, and the species composition of the tree layer more diverse in managed than in virgin forests. There are, however, several obstacles to such comparisons. First, genetic differences can cause phenotypic variability among provenances, and thus between virgin forests and remote managed forests. Second, the suppression phase is usually much shorter in managed than in virgin forests. Therefore, the stem shape and
branchiness of young trees in central European virgin forests is strongly influenced by competition from overstory trees, while young trees in managed forests respond to competition from trees of the same cohort (MLINSEK 1967). For Fagus sylvatica and Quercus petraea (Matt.) Liebl., it has been observed that very long durations of suppression will impair the ability of the trees to successfully release (KORPEL’ 1995). This is much less the case with Abies alba and Picea abies (SCHÜTZ 1969).

The obvious influence of tending and thinning measures on species composition is difficult to separate from an influence of the patch sizes of young stands and thus light availability, which is usually greater in managed than in virgin forests. The early descriptions of virgin forests often compare them to a particular type of single-tree selection forest: They have a high growing stock and a closed canopy since gaps are filled with regeneration which has reached the upper canopy and are thus dark (BASELER 1932).

Thus, the potential for learning about tending and thinning from virgin forests is limited. This and the excellent returns from forestry during most of the 20th century, which created no need for reducing the costs in tending young stands, may explain the absence of comparative studies between tended young stands and virgin forests. The timber quality of virgin forests mainly became an issue when they were exploited (FRÖHLICH 1954).

3.9 Habitat requirements of species which depend on virgin forests

In comparison to managed forests, virgin forests usually contain a higher proportion of large trees (NILSSON et al. 2002; COMMARMOT et al. this issue) and larger volumes of dead wood (coarse woody debris, HARMON et al. 1986; KORPEL’ 1997; SANIGA and SCHÜTZ 2002). Some species depend on these characteristics, in particular birds (ANGELSTAM and MIKUSINSKI 1994; WESOŁOWSKI and TOMIAŁOJC 1995; BÜTLER et al. 2004) and saproxylic insects (GROVE 2002).

Much of our knowledge about the range in quantities of dead wood in forests comes from research on virgin forests or nature reserves. However, these levels and their fluctuations (SANIGA and SCHÜTZ 2002) cannot be directly used as standard levels for managed forests since the relationship between dead wood volumes (and quality) and habitat requirements needs further study. Moreover, our knowledge about the habitat requirements of species which appear to depend on virgin-forest type habitats originates less from virgin than from managed forests (SCHIEGG 2000; BÜTLER et al. 2004). The importance of large trees as nesting sites for rare birds was not first noted in remote virgin forests, but in the habitats of these birds in managed forests.

3.10 Summary: Examples of knowledge transfer

In this section, I will summarize the examples given in the sections 3.3 to 3.9. Research on virgin forests has had important implications for managed forests in the case of nurse logs as a seedbed for tree seedlings, the maximum age and size of trees, and, to a minor extent, habitat characteristics required for virgin forest dependent species. These topics concern objects which have partly or almost fully disappeared in managed forests, and could therefore be studied only in virgin forests. Research on virgin forests has been of minor importance for managed forests in the cases of competitive interactions between tree species, natural regeneration under canopy cover, forest dynamics after abandonment of silvicultural operations, natural disturbance regimes and the effects of tending and thinning measures on stem quality. The main obstacles to knowledge transfer seem to be: (i) the scarcity of virgin forest
remnants in central Europe, which restricts the potential for site-specific replication and thus generalisation, (ii) differences between the stand histories and current stand structures of virgin and managed forests, and (iii) the opportunity to study phenomena of interest directly in managed forests, with easier access and the possibility to use manipulative approaches (field experiments) with proper replication.

Past research on virgin forests did not, in contrast to earlier claims, provide direct contributions to defining important characteristics of close-to-nature silviculture, such as a prevalence of natural regeneration, reliance on tree species which naturally occur on a site, use of shade as a principle for regulating intra-specific competition, reliance on opportunity rather than deterministic decisions, and imitation of natural successional processes (SCHÜTZ 2004). These characteristics of close-to-nature silviculture were mainly developed in managed forests, based on failures of silvicultural techniques far removed from natural processes (OTTO 1995).

4 Outlook: Future silvicultural research in virgin forests

Virgin forests cannot be the unique reference point for managed forests. In landscapes with a dense human population, the local demand for diverse forest products and services should rather be the main guide to management.

However, there are indeed trends in central European forests and silviculture which might benefit from scientific findings from studying virgin forests since these trends make managed forests more like virgin forests. The first trend is the creation of forest reserves and national parks. Research on forest dynamics in virgin forests can help us predict the consequences of this trend in terms of stand structure, species composition, habitat characteristics, and corresponding influences on forest services such as protection against natural hazards on steep slopes. In particular, research on virgin forests could contribute to a better understanding of stand disintegration and reinitiation phases, which were in the past short-circuited by management. A second trend is the increase in growing stock, which has amounted to about 1% each year since about 1950 (Eidg. Forschungsanstalt WSL und Bundesamt für Umwelt, Wald und Landschaft 2001, p. 77), and its consequences for forest products and services. A similar increase can be observed in average stand age. A third trend is the trend to continuous-cover forestry (“Dauerwald” in German), which is likely to reduce the mosaic of developmental stages in central European forest landscapes, and will lead to stand structures with a finer grain, more similar to that of virgin forests. Moreover, this trend is also likely to favour shade-tolerant tree species (VON LÜPKE 2004), another characteristic of central European virgin forests. A fourth trend is the increasing importance of forests as habitats for endangered species. Large virgin forest remnants could help us to understand spatial patterns of habitat use on different scales.

In retrospect, there seems to be a gap in the history of research on central European virgin forests between a strong motivation and a less strong argumentation. The virgin forest label is appealing for research on silvicultural topics, but, on its own, insufficient as justification. Virgin forests should be studied when an issue can best be addressed by using them as objects of study. Otherwise, managed forests should be studied, or a combination of virgin and managed forests. This principle applies to all issues where studying virgin forests is an option.
Acknowledgements
I wish to thank Jean-Philippe Schütz and Andreas Zingg for helpful comments on an earlier version of this paper, and Silvia Dingwall for improving the English.

5 References


Projektgruppe Naturwaldreservate im Arbeitskreis Standortskartierung der Arbeitsgemeinschaft Forsteinrichtung., 1993: Empfehlungen für die Einrichtung und Betreuung von Naturwaldreservaten in Deutschland. Forstarchiv 64: 122–129.


Accepted May 23, 2005