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Introduction to this issue

This is the first issue of the *Allgemeine Forst- und Jagdzeitung* featuring a complete set of contributions in the English language. It contains refereed versions of the invited papers to subplenary session 141 which convened during the last IUFRO World Congress, August 2005 in Brisbane/Australia. The session was entitled *Integrating approaches to achieve multiple goals – Intensive management, extensive management or preservation?* This theme examined recent developments in forest management approaches, and included a range of topics such as the various new models of forest design that are being developed, the problems associated with balancing forest production against preservation and the adoption of natural disturbance as a model for forest management.

Integrating approaches are needed to achieve multiple goals in forest management. This often requires some kind of "balancing act". Multiple demands of society have to be met simultaneously, but this ideal is difficult to achieve since economic and environmental conditions are not constant. The demands of society are changing and the cycles in which forest policies are modified, are usually shorter than the lifespan of the trees. The challenge thus, is to find a compromise between theoretical ideal and reality, to buffer the effects of the "political pendulum".

There are four invited presentations. Dr. CHRIS GOULDING from the New Zealand Forest Research Institute in Rotorua gives an example of Forest Stewardship Council (FSC) Certification of Industrial Plantation Forests. An increasing number of forest companies in New Zealand have had their management practices certified under FSC. Initially, environmental issues dominated the evaluation and monitoring for FSC certification resulting in changes to management policy and practice. Recently, fluctuating profitability has placed increased emphasis on how companies manage the social aspect of their industry. Dr. MARTINA MUND from the Max Planck Institute for Biogeochemistry in Jena, Germany relates some new findings about the impacts of forest management on the carbon budget of European beech (*Fagus sylvatica*) forests managed in a shelterwood system and a selection system. The impacts of the investigated moderate silvicultural practices on the carbon budget of European beech forests were lower than those reported for clear cuttings in temperate forests and this finding is useful for forest managers. The contribution by Dr. JUAN-MANUEL TORRES ROJO from the Centre for Research and Teaching of Economics in México deals with the important topic of managing community forests with timber production objectives. Neoclassical approaches are not completely suitable in Community Forest Management where the decision making process is under the control of a local community that owns the property rights of the land and the timber. Finally, Dr. TUULA NUUTINEN from the Finnish Forest Research Institute (METLA) in Joensuu shows how different objectives can be achieved simultaneously using the multiple path theory of forest design. The Multiple Path model is based on the understanding that not only one, but a variety of treatment schedules or "management paths" may be potentially suitable for each individual land parcel within a forested landscape.

The four contributions demonstrate various aspects of forest management under different environmental and social conditions. They show how multiple demands can be balanced, how spatial objectives can be coordinated, and how varied forms of expertise can be integrated in the design of a forested landscape.

KLAUS V. GADOW
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NIELS ELERS KOCH
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Vorwort zu diesem Heft

Dieses Themenheft der *Allgemeinen Forst- und Jagdzeitung* enthält zum ersten Mal eine vollständige Ausgabe mit englischsprachigen Beiträgen. Es handelt sich um die überarbeiteten und referierten Versionen der Vorträge für die Sub-Plenarkonferenz 141 des letzten IUFRO-Weltkongresses in Brisbane/Australien. Der Titel der Konferenz lautete *Integrating approaches to achieve multiple goals – Intensive management, extensive management or preservation?* Unter diesem Titel befassten sich die Vorträge mit neuen Entwicklungen im Bereich der Forsteinrichtung, also der mittel- und langfristigen Steuerung und Analyse der Waldentwicklung. Zu den speziellen Problembereichen gehören neue Konzepte und Methoden, die sich mit dem räumlich orientierten Entwurf der Waldentwicklung befassen, Fragestellungen im Zusammenhang mit der Berücksichtigung unterschiedlicher Zielsetzungen und die Bewertung unterschiedlicher Waldbauverfahren im Hinblick auf die Kohlenstoffbilanz der Wälder.

Der Wunsch nach gleichzeitiger Berücksichtigung unterschiedlicher Zielsetzungen erfordert integrierte Ansätze der Forsteinrichtung. Die notwendige Integration ist ein schwieriger „Balance-Akt", denn es kommt nicht nur darauf an, dass verschiedene Anforderungen der Gesellschaft gleichzeitig berücksichtigt werden. Erfahrungsgemäß sind die ökonomischen und ökologischen Bedingungen nicht konstant. Die Ansprüche der Gesellschaft ändern sich, und die Zyklen, in denen sich die forstpolitischen Vorgaben ändern, sind gewöhnlich sehr viel kürzer als die Lebensdauer der Bäume. Die Herausforderung für die Forsteinrichtung besteht also darin, Kompromisse zwischen theoretischem Ideal und der Realität zu finden, bzw. die unerwünschten Auswirkungen des „Politikpendels" abzupuffern anstatt sie zu verstärken.

Dieses Heft enthält vier Beiträge aus vier verschiedenen Ländern. Dr. CHRIS GOULDING von der Forstlichen Versuchsanstalt in Rotorua/Neuseeland analysiert die *Forest Stewardship Council* (FSC) Zertifizierung am Beispiel kommerzieller Plantagenwälder in der südlichen Hemisphäre. Eine zunehmende Anzahl von Privatwaldbesitzern in Neuseeland haben sich unter FSC zertifizieren lassen. Anfangs wurde die Begutachtung vorwiegend durch Umweltkriterien bestimmt. Gegenwärtig allerdings werden die sozialen Aspekte der Plantagenwirtschaft immer wichtiger für die Zertifizierung, u.a. bedingt durch Fluktuationen der Rentabilität. Dr. MARTINA MUND vom Max Planck Institut für Biogeochemie in Jena präsentiert neue Ergebnisse zur Auswirkung unterschiedlicher waldbaulicher Behandlungen auf den Kohlenstoffhaushalt von Buchenbeständen (*Fagus sylvatica*). Eine Fallstudie ergab, dass die sukzessive Entnahme von Bäumen im Schirmschlagbetrieb und im Plenterwaldbetrieb die Kohlenstoff-Vorräte in der Bestandesbiomasse gegenüber einem unbewirtschafteten, naturnahen Wald um rund 30% reduziert. Der Beitrag von Herrn Dr. JUAN-MANUEL TORRES ROJO aus dem Zentrum für ökonomische Forschung und Lehre in Mexiko befasst sich mit dem derzeit politisch relevanten Thema der Holznutzung durch Waldbauerngemeinschaften. Es wird gezeigt, dass dort, wo die Nutzungsentscheidungen durch eine lokale Gemeinschaft von Landeigentümern gefällt werden, herkömmliche neoklassische Ansätze der Bewertung und Entscheidungsfindung sich nicht als zutreffend erweisen. Dr. TUULA NUUTINEN vom Finnischen Forstlichen Forschungsinstitut (METLA) in Joensuu zeigt schliesslich beispielhaft, wie unterschiedliche Ziele der Landnutzung mit Hilfe spezieller Verfahren der Optimierung erreicht werden können. Die theoretische Basis bildet das sog. „Mehrpfadprinzip", das die Bestandesebene mit der Landschaftsebene verknüpft.

Die vier Beiträge demonstrieren unterschiedliche Aspekte der modernen Forsteinrichtung mit Beispielen aus verschiedenen Regionen der Erde. Sie zeigen, wie räumliche Zielsetzungen koordiniert und unterschiedliche Erfahrungen beim Entwurf einer Waldlandschaft integriert werden können.

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Forest Stewardship Council Certification of Industrial Plantation Forests

New Zealand Forest Research Institute Limited

(With 1 Table)

By C. J. GOULDING[1)]

(Received October 2005)

KEY WORDS – SCHLAGWORTER

Forest certification; Forest Stewardship Council; plantations; intensively managed.

Zertifizierung; Forest Stewardship Council (FSC); Plantagenwälder; intensive Waldnutzung.

1. INTRODUCTION

Sustainable management of forests has always been carried out to achieve multiple goals, to a greater or lesser extent. Admittedly, some forests have been actively managed almost exclusively for their timber but even with those forests, long term, sustainable management has had to accommodate use for non-timber values, even if such management has been low key and low cost. Recently, sustainable forest management and what constitutes "well-managed" forests have become critical issues throughout the world, with multiple use and benefits to a wide range of stakeholders being core components of forest policy, goals and management practice. Since the early 1990's, a driving force behind these issues has been the formal certification of forest management. Environmental concerns, including concerns about the effects of illegal and indiscriminate logging resulting in forest degradation, have been translated into market signals requiring wood product companies to provide evidence that they are meeting a set of standards of good forest management as set out by a certification programme. Markets are becoming more demanding for "green" and "sustainable" products and certification is seen as permitting access to those markets. The international trade in wood products is increasing. Over the course of one rotation in New Zealand, between 1972 and 2002 it increased from US$ 15 billion to US$ 135 billion[2], (by 75% in real terms since 1970, Rytkonen, 2003). Forest management standards set under the influence of concerned consumers and stakeholders in one part of the world are affecting foresters in another.

A large number of certification schemes have been established around the world. The major certification initiatives that are internationally recognised include the Forest Stewardship Council (FSC)[3], the Programme for the Endorsement of Forest Certification Schemes (PEFC)[4] and the ISO Environmental Management Systems – 14001 series. The North American based Sustainable Forestry Initiative (SFI) and the Canadian Standards Association (CSA) are significant in terms of the size of the wood production certified by those schemes. To ensure that the "certified" label can be passed along the processing chain from forest to the customer, each forest management certification scheme has an associated Chain of Custody certification to ensure verification of product claims. Often wood product from non-certified forests must be produced in the same facilities as is certified wood or incorporated with it in the final retail product. Chain of Custody is specifying increasingly stringent conditions as to the source of such non-certified wood (FSC defines this as "controlled" wood, see FSC standard FSC-STD-40-005, 1 October 2004). Hence, certification is influencing the wood products trade beyond the immediate sphere of forest owners prepared to undergo auditing for certification.

FSC was created in 1993, after discussions arising from the first meeting in 1990 by a *"group of timber users, traders and representatives of environmental and human-rights organizations who had identified the need for an honest and credible system for identifying well-managed forests as acceptable sources of forest products"*. FSC itself does not certify forest management but awards certificates based on audits carried out by FSC accredited independent bodies to a world-wide defined set of 10 principles and associated criteria. PEFC, founded in Europe in 1999, on the other hand provides a global umbrella organisation for the mutual recognition of national forest certification schemes. Each national scheme defines its own methods of determining accreditation, subject to overall approval by the PEFC members, the General Assembly.

FSC proffers an ideal of multi-goal, multi-stakeholder, natural forest management. It is also applicable to intensively-managed exotic plantations where the primary objective is timber production for profit. By the middle of 2005, more than 6 million hectares of plantations and 17 million hectares of mixed forest (forests that include planted trees) have been certified to FSC standards. However, FSC certification of plantations is subject to continuing debate. Of the 10 FSC principles, principle 10 is specific to plantations and was added two years after the adoption of the previous nine. The implementation of the FSC Principles and Criteria for plantation management is open to a range of interpretations and is sometimes controversial.

The New Zealand forest and timber industry is now almost entirely based on exotic plantations, 90% of the area of which are established with a single species, *Pinus radiata* that is intensively managed to an even-aged regime with clearfelling at a rotation of about 28 years. This paper discusses the New Zealand experience of FSC certification and the research that has been commissioned as a consequence of certification pressure in order to justify the claim that these forests are "well managed".

2. FOREST CERTIFICATION AND MARKETS

Some of the earlier market research studies suggested that consumers were prepared to pay a price premium for environmentally certified wood products, OZANNE and SMITH (1995), OZANNE and VLOSKY (1997), FORSYTH et al. (1999). This willingness to pay has been the subject of some discussion. OZANNE et al. (1999) reviewed a number of international studies that reported a proportion of environmentally aware consumers were willing to pay anything between an additional 1% to 20% for certified products. In New Zealand it was suggested that a high degree of concern for environmental issues was already present, inferring that a market for certified wood existed. A mail survey sent to New Zealand architects, retailers and consumers found that consumers were prepared to pay a premium of 16 to 22%. The corporate respondents represented by the architects and retailers had less favourable perceptions and certification would progress due to consumer demand or "pull" rather than a promotional advertising strategy or "push". BIGSBY and

1) Lead New Zealand auditor, on subcontract to Scientific Certification Systems, Forest Stewardship Council accredited certifying body.

2) FAOSTATS www.faostat.fao.org

3) www.fsc.org

4) www.pefc.org

OZANNE (2002) defined four segments of the New Zealand market for wooden outdoor furniture characterising these as "quality environmentalist", "implicit certification", "buy local" and "value for money" consumers. The first two categories that desired some form of certification constituted 58% of the sample and placed price low down on their list of key product attributes.

Several other researchers have found that consumers are unwilling to actually pay a significant price premium, despite indicating they would do when queried in market surveys. VEISTEN (2002) estimated that the UK and Norwegian consumer on average was only prepared to pay a price premium of 1.6% and 1% respectively. However, the study found that 39% and 32% respectively were prepared to select a certified labelled alternative provided the price premium was no more than 5%.

These results amongst others have led many forest companies to view environmental marketing as an opportunity to promote their business. Over the last decade the environmentally aware consumer group has rapidly grown in numbers. HANSEN (1997) studied the role of certification in marketing strategic planning where it has a role for effectively communicating with consumers. Widespread eco-labelling of products indicates that this is an effective method of influencing consumer purchasing, with consumers wishing to be assured of forest sustainability, even though environmental issues were not the primary concern when purchasing wood products, TEISL et al. (2002). Environmental marketing is now becoming the norm driven by this consumer pressure. KARNA et al. (2003) studied four European countries concluding that most forest companies saw certification as a necessary tool for marketing their products. They suggested that marketing strategy decisions around certification could impact strongly on forestry operations.

3. CERTIFICATION OF INDUSTRIAL PLANTATIONS IN NEW ZEALAND

New Zealand has nearly 700,000 hectares of plantation forests certified as "well managed" under the FSC principles and criteria[5]. This represents 38% of the total New Zealand plantation estate of 1.82 million hectares (MAF, 2005). 16 companies have one or more FSC certificates for the management of their plantation forests (there is a further one company with a certificate for the management of indigenous forests). 55 FSC Chain of Custody certificates are active. There is no FSC approved national standard, certification has been carried out to certifying bodies' interim standards in accordance with FSC procedures.

New Zealand is unusual in that 99% of its timber production now originates from its exotic plantations; the 6.4 million hectares of indigenous high forest are now largely protected from logging and are managed for conservation. The principal reason companies required certification was to obtain direct access to markets in the United States, driven by the demands of major retailers. A number of Asian companies purchase New Zealand certified wood, process it and then export the certified product. Europe, while also requiring imports to be certified, remains a minor market for New Zealand at this point in time. Conversely, Australia, New Zealand's largest export market for forest products, does not demand labelled certified products, nor does the New Zealand domestic market. Although OZANNE et al. (1999) suggested a high degree of environmental awareness, the perception by domestic consumers is that timber from New Zealand plantations is from "well managed" forests and there is no need for a certification scheme to tell them so. This has created the situation where higher value appearance grade timber products especially those obtained from pruned logs require certification, but structural and lesser grade timber products do not; neither do pulp, paper or composite boards. While the very first companies to be certified obtained a financial premium for their logs and timber when certified, this premium has largely disappeared.

The area of certified forests increased rapidly between 2000 and 2003 when the rate of increase slowed markedly. Part of the reason is that one third of the national estate is owned by small forest and woodlot owners. For these owners, the difficulties and costs of certification audits outweigh the perceived benefits. They have planted trees in significant amounts since 1990, usually on former pasture that is economically marginal for agriculture. The silvicultural operations of establishment, thinning and pruning are completed before mid-rotation. Many owners have a very uneven age class distribution with only a few blocks of even-aged trees where there is a long period with little activity and no yield that calls into question the reasons for certification during that period. Only a small proportion (estimated to be less than 20%) of this class of owners pay for continuous, professional forest management services.

3.1 Environmental Issues

Evaluation of social, economic and environmental issues form an integral part of the FSC certification, including consultation with stakeholders about a company's management. HOCK and HAY (2003) and HOCK et al. (2003) examined the publicly available FSC evaluation audit reports of 11 companies in New Zealand. These reports can be found on the relevant certifying bodies' websites. Changes to current management practices were required though no company had failed an audit. By far the most Corrective Action Requests (CARs) and Recommendations concerned environmental issues in Principle 6, with just under 9 such CARs per evaluation, along with a few additional CARs for environmental criteria contained in other principles. In general, the most common environmental CARs required managers to:

- minimise the use of chemicals
- improve the safeguarding of rare ecosystems and threatened and endangered species, including providing more information, with the establishment of protection areas within the plantation estate
- complete environmental impact assessments, particularly at the regional or landscape level
- assess and monitor flora and fauna more comprehensively
- understand the environmental consequences of current clearcut harvesting practice.

Specific issues raised in the audits were the lack of strategies for reducing or phasing out chemical usage and little support for research on alternatives. The control of competing woody weeds is frequently essential during establishment and the very early part of the rotation. This vegetation is usually of invasive alien species, for example blackberry, *Rubus fructicosus* and gorse *Ulex europaeus.* Control by manual methods is a slow, unpleasant job and consequently expensive; mechanical methods are impractical, thus the use of chemical control is widespread.

New Zealand companies have been certified in spite of using sodium fluoroacetate (1080) to control brushtail possum, *Trichosurus vulpecula*, imported from Australia in 1837 to establish a fur industry but now widespread throughout the country and considered a major pest with no natural predators. FSC certification would not normally be possible for companies using this compound which is on the FSC list of banned chemicals. An FSC derogation permits its use in New Zealand because of broad (though not unanimous) support from regulatory agencies and environmental groups due to the perceived benefits of pest control on adjacent natural forests and the current lack of any possible effective alternative

[5]) www.fsc.org, October 2005

despite considerable research into the problem. This highlights the importance of interpreting the FSC Principles and Criteria in the context to which they are applied and also the potential flexibility of the FSC process.

New Zealand makes a clear distinction between its conservation forest estate of indigenous species and its production forest of exotic plantations. Plantation forest management following the privatisation of state owned plantations after 1990 had increasingly concentrated management on the economic value of timber production at the expense of other potential values. At a national level, indigenous reserves constitute 6.4 million hectares or 78% of the 8.2 million hectares in total of high forest (indigenous and exotic forest combined). This percentage excludes the reserves contained within the plantations themselves. These reserves are comprised of small blocks or riparian strips and as a proportion of the gross plantation area is small by world standards and varies with the type of owner. For the small woodlot owner, the plantations are small blocks typically within a farm landscape and the block itself may contain no reserves, though the farm usually has patches of indigenous "bush". When the New Zealand Forest Service was disestablished in 1987, any manageable areas of indigenous forest owned by the state were excised from the plantation forests and placed under the control of the newly formed Department of Conservation. Thus those plantations that were formerly or are currently State owned often have a very small percentage of their total area in indigenous reserves. Prior to FSC certification the awareness of the need to protect ecosystems and natural vegetation within the plantation estate that are rare and representative of the wider landscape was lower than that required by the FSC.

Issues raised in the audits included the need for more information on the reserves, on these ecosystems and on rare and endangered species and their habitats. Plantation managers were required to implement protection and restoration strategies, with public and stakeholder consultation. High Conservation Value Forests (HCVF) are present rarely within New Zealand industrial plantations but can include special areas of planted exotic trees. There has been a growing awareness of the need to survey the plantations for potential areas of HCVF additional to those few high profile areas already in existence. For example, Kaingaroa Timberlands in 2004 designated small areas of geothermal ecosystem vegetation as a HCVF because of their unique characteristics, with a management plan to remove any encroaching pine trees.

In keeping with the above concerns, the audit reports also stated that there was a need to improve environmental impact assessments, including those at the wider landscape level, and to include such assessments when planning. Similarly, better information was required on flora and fauna, including improved documentation, better baseline information and maps.

The issue of clearcut size received prominence. Especially in the older established forests of the Central North Island, harvest coupes are very large by North American and European standards, sometime in excess of 1000 hectares, felled within a year. Furthermore, because of the timing and progress of afforestation, there are adjacent blocks with clearcuts in successive years. There are valid silvicultural reasons for this in some instances – the pooling of cold air out of season in the "frost flats" can result in failure at establishment if there are small areas surrounded by taller trees. There was, however, little past research and current scientific knowledge on the environmental effects of clear-cut size within a New Zealand plantation. Because of this, research results from elsewhere reported in the international literature lack local verification. An FSC CAR was issued to what was then a very large forest owner in the region to support research into the environmental effects of clear-cutting and coupe size within new Zealand. This research has been continued by companies that have subsequently purchased those forests.

3.2 Social Issues

During the evaluations for the initial certification awards, few CARs specific to social issues were requested, apart from the need to improve social impact assessment and integrate this with a company's routine monitoring procedures.

When the State plantation forests were proposed for privatisation, agreement was reached with New Zealand's indigenous people, Maori, regarding their outstanding claims for the return of land held by the state. Only the forest management and harvesting rights were offered for sale, with the land retained under State ("Crown") ownership and to be used to settle any justified claims. There is an established process[6] to resolve indigenous people's rights that is gradually returning the land ownership, so that it is widely expected that Maori will eventually be the largest group of plantation forest owners and managers. Companies will manage the forests under the terms of the licences, with perhaps continuation subject to agreement with the new landowners once the licences expire. This process is believed to be in accord with FSC principle 3.

In recent years, the New Zealand industrial forest sector has experienced some of its harshest economic times. Major changes in ownership have also occurred with consequent restructuring. This sometimes has resulted in substantial redundancies and particularly where small, local communities are dependent on forest employment and are vulnerable, the potential to significantly affect long-term social and economic welfare. For some forest managers in this situation who have held FSC certificates for some time and who have responded to requests to improve environmental issues, CARs dealing with social concerns are now the most significant issues. Attention is being focussed on social impact assessment and consultation with stakeholders consistent with the goal of achieving an adequate return on investment.

3.3 Benefits and Costs

In 2003, an informal telephone survey was made of the seven companies that had been certified for at least one year and had received at least one audit in order to ascertain the costs and benefits from achieving certification, Hay and Goulding (2003). A company employee with some connection to the certification process answered a prepared set of questions. *Table 1* summarises the responses.

All companies believed that certification had been worthwhile, though some expressed disappointment at the lack of price premium and the low marketing profile of the FSC. A qualitative observation was that those companies that had been certified the longest were those that valued the experience the most.

4. PLANTATIONS

The FAO global forest resource assessment of 2000, FRA2000 (FAO 2001) stated that industrial forest plantations account for less than 3% of the global forest cover but, in an indicative estimate only, supply 35% of the global roundwood. This is forecast to increase to 45% by 2020, Carle et al. (2002). Given that fast-grown plantations in the sub-tropics can have rotations much less than 10 years, this forecast must be problematic and could well be an under-estimate. Exactly what is defined as a plantation differs by organisation and in reality there is no clear delineation between "plantations" and "natural" forests. The current definition of a plantation by FSC is clearly judgemental, with negative pre-con-

[6]) www.waitangi-tribunal.govt.nz

Table 1

Realised Benefits and Costs of Certification from a 2003 Telephone Survey of Seven New Zealand Companies.

Nutzen und Kosten der Zertifizierung – nach einer im Jahr 2003 durchgeführten telefonischen Umfrage bei sieben neuseeländischen Firmen.

Benefits		
	Strategic market development	
		Forming customer relationships
		Entering new markets
		Winning orders
	Price Premium	
		Varied success
	Environmental management	
		Systemise and formalise practice
		'Prove' sound practice to stakeholders
		Improve relationships with environmental stakeholders
	Recognition of certification	
		Recognised by local authorities
		Reduced cost of compliance with regulations
	Public relations	
		Encourage trust within the local community
		Proactive contact with neighbours and environmental NGOs
		Obtain early information that is useful to the company
		Company pride
Costs		
	High indirect costs of compliance	
		Reserves – reduction in net stocked area
		Management time increased
	Evolving/changing standards	

ceptions *"forest areas lacking most of the principal characteristics and key elements of native ecosystems as defined by FSC-approved national and regional standards of forest stewardship, which result from the human activities of either planting, sowing or intensive silvicultural treatments"*.[7] FSC is now reviewing the implementation of its Principles and Criteria to plantations[8].

Poor forest management can be applied to any forest. Worst-case scenarios of plantation management include the replacement of the indigenous high forest and ecosystems by a uniform monoculture of an inappropriate species, the loss of biodiversity and the forced displacement of local communities from their traditional land and practices. When established as a large-scale investment by an outside company, plantations can be disruptive to the social values of the community due to the cyclic nature of markets or to the displacement of other diverse land uses and employment.

In New Zealand, plantations are more often established primarily for economic return. Maori, who already own some 25% of the New Zealand plantation area, expect financial gain from their use of the land. Following customary (and lengthy) debate by all members of the iwi (tribe), an agreed set of principles and constraints is formulated on how the forest land is to be managed that respects tradition and custom. Within these constraints, however, it is expected that plantation management will be carried out with maximum economic efficiency in much the same way as any corporate owner or Timber Investment Management Organisation to return the best financial dividend to the iwi. Management of their indigenous forest will by no means provide the same return, though remains important for non-timber values. In this situation there could be an inherent conflict between FSC principle 3 "Indigenous peoples' rights" and many of the criteria of the other FSC principles if they are applied rigidly.

There are conservation benefits when plantations do not replace indigenous high forests but have been established on human modified land that represents poor habitat for biodiversity. NORTON (1998) reviewed indigenous biodiversity in plantations and made recommendations for modifying forestry practice that could maximize both timber production and biodiversity. BROCKERHOFF et al. (2003) showed that New Zealand plantations can provide habitat for indigenous species. In a study of stands 5, 16 and 27 years old in four different biogeographic regions a total of 202 indigenous and 70 adventive vascular plant species were found, with considerable variation in species composition, richness and percentage of indigenous species. The forest environment of older stands sheltered a mostly indigenous forest understory community with considerable similarities to indigenous forests located nearby.

Little is known about the environmental effects of clearcutting exotic plantations from a "whole-of-forest", landscape viewpoint in New Zealand's developed but largely agricultural countryside. Internationally in developed countries where the population is largely urbanised, there is an increasing antipathy towards clearfelling, resulting in demand for and research into less intensive forest management practice and continuous cover silvicultural systems, MASON (2005). The FSC certification system reflects this antipathy. Conversely, large, clearcut coupes in industrial plantations are driven by economic factors in order to compete in the export market, and by practical necessity on steep slopes when employing cable harvesting systems.

As a consequence of requests from FSC audits, New Zealand research on bio-diversity and population dynamics in plantations is now being carried out. COLLIER and SMITH (2005) reported on the effects on stream invertebrates of progressive harvesting across catchments, while PAWSON (2005) is examining the distribution of native fauna and flora in a radiata pine plantation. The New Zealand Falcon (Karearea), *Falco novaeseelandiae*, one of New Zealand's endangered birds, is now being studied in its use of plantations. It is ground nesting, fast flying, feeding on small birds and insects. 20 nesting pairs were found in the plantations of Kaingaroa Forest, substantially more than would be expected in indigenous high forest of equivalent area[9]. Its preferred habitats are the margins of clear-cut areas, from the time shortly after planting following "green-up", the colonization by grass species with the attendant flocks of seed eating birds, through to early canopy closure.

5. CONCLUSIONS

OZINGA (2004) states that forest certification is at a cross-roads. It has brought together a range of concerned parties to discuss what constitutes well-managed, sustainable forests and has led to increased demand for certified wood products. It has improved management, but mainly in developed countries and not substantially. The problem is to implement the concept into real improvements worldwide.

Industrial plantations present especial challenges for certification. They can be a single, exotic species grown with intensive silviculture and use of chemicals, and with less biodiversity and fewer environmental or recreational values compared to old growth, indigenous forests in a conservation estate. Certification of the

[7]) FSC Principles and Criteria – glossary of terms.

[8]) www.fsc.org/plantations/

[9]) R Seaton. Ph D. study. Unpublished report on Kaingaroa Forest. See also www.wingspan.co.nz

(moderately) fast-grown, short-rotation plantations of New Zealand shares these challenges.

Plantations are predicted to supply 45% of the demand for world wood products by 2020 and if FSC wishes to continue to influence forest management then it must continue to include plantations in its certification scheme. Given the difficulty of defining what is a plantation, it may be advisable to not distinguish between "planted" and "natural" forests but concentrate on defining "outcome" rather than "prescriptive" based Principles and Criteria and associated performance indicators.

Plantations can be managed to achieve desired environmental characteristics. The "direct sawlog" silvicultural regime for New Zealand grown radiata pine with pruning and relatively low numbers of crop trees encourages biodiversity in the understorey, while the UK is researching the implementation of continuous cover forest management on the exotic plantations of Sitka spruce. At the forest level, clear-cutting can have its own environmental characteristics that are not necessarily negative, as illustrated by the NZ falcon and its supporting ecosystem.

Indigenous people can use plantations as a much needed source of economic wealth. They need to be allowed to participate in defining those characteristics of forest management that are essential to their culture. Both the indigenous land-owner and the owner of the forest management rights require a fair economic return from the plantations. When the indigenous people themselves are managing a plantation forest, within the constraints imposed by their culture their own forest management company and operational practices may be as economically efficient as and indistinguishable from an equivalent-sized multi-national, company.

The core principle is to manage the plantation forest as a whole, integrated within the wider landscape and social community.

Research is needed on the environmental effects of plantation silviculture, including clear-felling and how practice can be modified to achieve desired values of sustainability and biodiversity. Research is also needed to define what level of improved performance can be expected from the certification of management and how this can be measured. Better methods to value non timber products and services are needed. For certification to have the ability to influence undesirable forest management, there must be more market research to pro-actively encourage consumer demand and market "pull" for certified wood products.

6. ABSTRACTS

Retailers in North America and Europe are demanding forest products that have been certified as supplied from "well managed" forests. There are many certification schemes; that of the Forest Stewardship Council (FSC) is one of the most widespread worldwide. Although proffering an ideal of timber and non-timber products from uneven aged, natural forests, FSC is also applicable to intensively managed exotic forest plantations. As at October 2005, New Zealand has nearly 700,000 ha of its 1.8 million hectares of plantations certified and predictably, the most frequently issued corrective action requests concern environmental issues. Recently, social issues increased in prominence when an industry downturn impacted on employment in communities dependent on forestry. New Zealand's indigenous people are expected to become the major owners of plantation forest land, raising the profile of those criteria concerned with the rights of indigenous people to benefit from their forests. Certified logs now rarely command a financial premium, but certification compliance costs can be significant. Research could assist by designing modifications to plantation management systems that maintain profitability but enhance the social and environmental non-timber benefits, and by defining methods to more correctly value those benefits.

7. Zusammenfassung

Titel des Beitrages: *FSC-Zertifizierung der Plantagenwälder in Neuseeland.*

Der Handel in Nordamerika und Europa verlangt Holzprodukte, die zertifiziert sind, Produkte also, die aus Wäldern stammen, die unter bestimmten Vorgaben genutzt werden. Unter den zahlreichen Zertifizierungsschemas ist der Forest Stewardship Council (FSC) weltweit eines der verbreitetsten. Obwohl der FSC als Ideal Holz- und Nichtholzprodukte aus ungleichaltrigen naturnah bewirtschafteten Wäldern anpreist, sind Zertifizierungen auch in intensiv genutzten Plantagenwäldern möglich. In Neuseeland sind mehr als 650,000 ha der gesamten Plantagenwaldfläche von 1.8 Millionen ha zertifiziert. Wie erwartet, betrifft die häufigste Forderung nach korrektiven Maßnahmen Probleme des Umweltschutzes. In der jüngeren Vergangenheit hat der gesellschaftspolitische Aspekt dort an Bedeutung gewonnen, wo der Niedergang bzw. die Schwächung eines Industriezweiges sich auf die Beschäftigung auswirkte, besonders in Gegenden, wo die Bevölkerung von der Forstwirtschaft abhängig ist. Es wird erwartet, dass die Ureinwohner Neuseelands zukünftig die Haupteigentümer der Plantagenwälder werden. Damit nimmt die Bedeutung derjenigen Zertifizierungskriterien zu, deren Gegenstand das Recht indigener Völker zur Nutzung ihrer Wälder ist. Es ist selten, dass zertifiziertes Rundholz eine Sondervergütung bzw. einen Zusatzgewinn erzwingen kann. Die Kosten der Einhaltung der Zertifizierungskriterien können dagegen beträchtlich sein. In diesem Zusammenhang kann die Waldforschung helfen, modifizierte Plantagen-Managementsysteme zu entwickeln, die stets gewinnbringend, aber auch sozialverträglich und umweltfreundlich sind. Gleichzeitig sollte die Forschung neue methodische Grundlagen schaffen, die eine zutreffendere Bewertung der sozial- und umweltökonomischen Aspekte der Waldnutzung ermöglichen.

8. Résumé

Titre de l'article: *La certification FSC dans les forêts artificielles hautement productives.*

En Amérique Nord et en Europe le commerce exige que les produits ligneux soient certifiés, des produits donc en provenance de forêts qui sont mises en valeur selon certains principes. Parmi les très nombreux schémas de certification celui du Forest Stewardship Council (FSC) est, de loin, un des plus étendus. Bien que le FSC préconise comme idéal que les produits ligneux et non-ligneux proviennent de forêts inéquiennes avec traitement proche de la nature, les certifications sont également possibles dans les forêts artificielles exploitées intensivement. En Nouvelle-Zélande, ce sont plus de 650 000 ha qui sont certifiés sur les 1,8 millions d'ha de forêts vouées à la ligniculture. Comme prévu, les problèmes environnementaux exigèrent de plus en plus fréquemment des mesures correctives. Dans un passé assez récent l'aspect politico-social a gagné en importance là où l'affaiblissement ou le déclin d'une branche industrielle eurent des conséquences sur l'emploi, tout particulièrement dans les contrées où la population est dépendante de l'économie forestière. On s'attend à ce qu'à l'avenir les populations autochtones deviennent les propriétaires principaux des forêts vouées à la ligniculture. Cela étant, parmi tous les critères de certification, voient augmenter leur importance ceux qui traitent du droit des populations indigènes à l'usage de leurs forêts. Il est bien rare que du bois rond certifié puisse procurer une rémunération spéciale, autrement dit un gain supplémentaire. En revanche, les coûts entraînés par le respect des critères de certification peuvent être considérables. Dans un tel contexte la recherche forestière est à même d'aider à développer de nouveaux systèmes de management de la ligniculture qui soient toujours rentables, mais aussi socialement acceptables et respectueux de l'environnement. En même temps la recherche doit créer des bases méthodologiques qui don-

nent la possibilité d'évaluer avec exactitude les aspects socio-économiques et environnemento-économiques de l'exploitation des forêts. J.M.

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Impacts of forest management on the carbon budget of European beech (*Fagus sylvatica*) forests

(With 6 Figures and 3 Tables)

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KEY WORDS – SCHLAGWORTER

Silviculture; carbon budget; natural forests; shelterwood system; selection system; biomass; soil organic carbon; forest use history.

Waldbau; Kohlenstoffhaushalt; Naturwälder; Schirmschlagbetrieb; Plenterwaldbetrieb; Bodenkohlenstoffvorräte; Waldnutzungsgeschichte.

1. INTRODUCTION

In recent years the quantification of carbon sinks and sources of forest ecosystems have received increasing attention because of their role in the climate system (APPS and PRICE, 1996; IPCC, 2000, 2001). It is evident that losses or gains of carbon due to land-use change including deforestation, afforestation and reforestation affect the global carbon budget. Thus, these direct human-induced activities are explicitly included into Article 3.3 of the Kyoto Protocol (UNFCCC, 1997) as "accountable activities" in the national commitments to reduce net greenhouse gas emissions. In contrast, "additional human-induced activities" related to forest management of existing forests in Article 3.4 of the Kyoto Protocol are less obvious with respect to their impact on the global carbon budget.

Forests cover about 31% of European land area (excluding countries of the Commonwealth of Independent States (CIS)). Except for inaccessible areas (about 4% of forested area) all of these forests are subject to management of different intensities (MCPFE/UNECE/FAO, 2003). The net effect of repeated disturbances due to forest management on carbon losses and gain in forest ecosystems should be reflected in changes of carbon in tree biomass and in soils. Changes in timber production and biomass due to different silvicultural treatments are well known (e. g. HARMON *et al.,* 1990; CANNELL *et al.,* 1992; KARJALAINEN, 1996; FLEMING and FREEDMAN, 1998; TROFYMOW and BLACKWELL, 1998; WEBER, 2001; CROW *et al.,* 2002). In contrast, our knowledge about the effects of forest management, particularly of moderate silvicultural practices in hardwood forestry, on the amount of organic carbon in the mineral soil (SOC) is very limited.

Even less is known about the fate of harvested wood that contributes to carbon storage outside the ecosystem or that may reduce CO_2 emissions by substituting fossil fuel for energy production or

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by substituting for materials which have high fossil fuel emissions associated with their production. However, despite an increasing demand driven by population growth it is generally assumed that the pool of wood products will decrease rather than increase due to substitution of traditional wood products by other materials. Furthermore, because of the high proportion of short-lived wood products the mean residence time of carbon in the product pool (time after which 63% of the initial amount of wood products is converted to CO_2) is relatively short (about 10 to 20 years), shorter that the mean residence time of dead wood in temperate forest ecosystems (about 14 (broadleaved forests) to 34 years (coniferous forests), WIRTH *et al.,* 2003). Only if tree production focuses on trees with a large diameter and a high wood quality suitable for long-living wood products a lifetime similar to that of dead wood can be expected (PROFFT *et al.,* in prep.). A detailed analysis of potential changes in the pool of wood products and potential energy substitution would go beyond the scope of this study. The goal of this study is to analyse effects of moderate silvicultural practices on the carbon budget of European beech forests (*Fagus sylvatica*) at the ecosystem level, acknowledging that the product pool and potential substitution effects needs further attention.

The study started with the hypotheses that (1) the total amount of carbon stored in the forest ecosystem increase sequentially from a regular shelterwood system to a selection system to an unmanaged forest, (2) the investigated silvicultural treatments result in changes in the amount of carbon stored in tree biomass as well as in the mineral soil, and (3) soil organic carbon of the even-aged stands increase with increasing stand age.

2. MATERIAL AND METHODS

2.1. Terms and definitions

Terms that will be used in the following are sometimes used in forestry and forest ecology in different ways. These terms are explained in view of this study.

A regular (uniform) shelterwood system is a silvicultural system where the regeneration is initiated and supported by the removal of the harvestable ("mature") trees in two or more successive steps of cutting (e.g. preparatory- and seed-cutting, several successive cuttings to increase the light availability for the regeneration, and final-cutting). The temporarily remaining old trees (overstory, shelter) provide seeds and protect the natural regeneration from climatic extremes. The higher light available due to these cuttings also promotes the growth of the remaining old tress. Shelterwood cutting and later thinning produces an even-aged stand with a homogenous vertical and horizontal structure (by convention the age of even-aged tree communities does not differ by more than 20% of the intended rotation). Only at the regeneration stage, when the shelter of mature trees covers the seedlings and saplings, is the shelterwood system characterized by two, clear canopies.

A selection system is a silvicultural system that results in uneven-aged stands. Individual trees or small groups of trees are cut periodically to obtain the yield, to improve the forest structure and growth and to support (but not to force) the regeneration at the same time and at the same area. There are no defined cutting areas that are managed (e.g. thinned or harvested) at a specific time. The selection cutting shall result in (1) a multi-cohort stand, (2) a

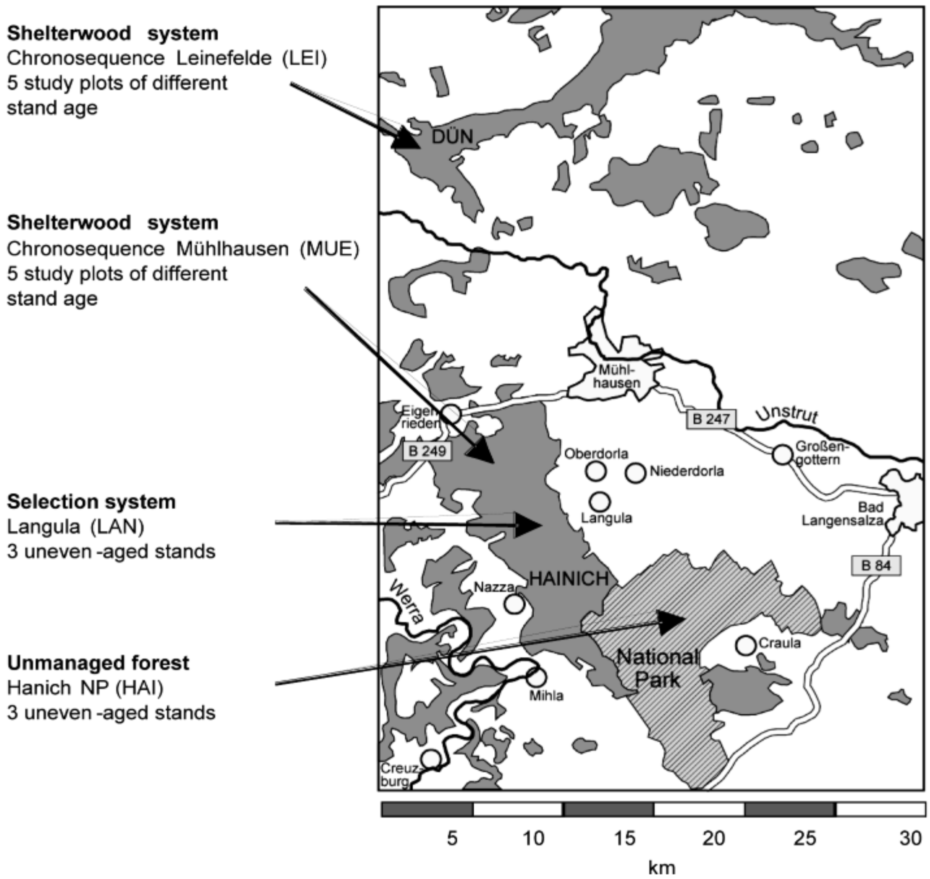


Fig. 1

Locations of the study sites at the Hainich-Dün region, Thuringia, Germany. Dark grey areas: forests.

Lage der Versuchsstandorte im Hainich-Dün Gebiet, Thüringen, Deutschland. Dunkelgraue Flächen: Wälder.

Table 1

General site characteristics of the study sites at the Hainich-Dün region, Thuringia, Germany.

Allgemeine Standortseigenschaften der Versuchsstandorte im Hainich-Dün Gebiet, Thüringen, Deutschland.

Climate	Subatlantic/submontane
Elevation	400 - 460 m a.s.l.
Topography	Plateau
Mean annual temperature	6.8 °C
Annual precipitation	750 -800 mm (growing season: 320-370 mm)
Parent material	Triassic limestone covered by a Pleistocene loess layer of variable thickness (ca. 10-50 cm)
Soil type	Depending on the thickness of the loess layer: Rendzic Leptisols to Cambisols and Cambisols to Luvisols (ISSS-ISRIC-FAO classification 1998)
Soil texture	silty clay /clayey silt
Humus form	Mull to F-Mull
Tree species	*Fagus sylvatica, Fraxinus excelsior, Acer pseudoplatanus, A. platanoides, Carpinus betulus, etc.*

reverse-J shape diameter distribution ("equilibrium distribution"), (3) a continuous vertical distribution of foliage, (4) a permanent, closed tree canopy, and (5) an equilibrium of harvest and regrowth of trees on a small spatial scale (BURSCHEL and HUSS, 1987; RÖHRIG and GUSSONE, 1990; MAYER, 1992; NYLAND, 1996; SCHÜTZ, 2001). For a more detailed description of the silvicultural systems see NYLAND (1996).

The term moderate silvicultural practices or moderate forest management refers to all treatments that exclude or do not cause (1) canopy openings that initiate a microclimate similar to that of open lands, (2) whole tree harvesting, (3) prescribed fire, (4) all kinds of mechanic soil preparation (e. g. scalping, bedding), and (5) fertilization, pesticide and herbicide application.

The amount of carbon stored in different compartments (pools) of the ecosystem is given in tons of carbon per hectare (tC ha^{-1}), and it is specified shortly as (living) tree biomass carbon (including stems, leaves, twigs, branches, and roots), dead wood carbon, organic layer carbon, and SOC (organic carbon in the mineral soil). It is stated explicitly when not the amount but the concentration of carbon is mentioned.

2.2. Study sites and historical forest use

The four study sites were located at the plateau of the lower mountain range „Hainich-Dün" (Thuringia, central Germany) within a maximum distance of about 30 km (*Figure 1*). The climate in combination with fertile soil conditions (*Table 1*) provides optimum growing conditions for beech forests. The four sites represented three silvicultural treatments: shelterwood system, selection system and unmanaged forest (*Table 2*). In total 10 forest stands of different stand age and 6 uneven-aged stands were investigated.

All study plots have definitely been forested with broadleaved forests since the early 1500s (MUND, 2004). Harvest and collection of fire wood was the most common forest use at the Hainich-Dün until the 18th century (and later on during the first and second world war). In the 16th to 18th century the forests of the central and southern Hainich (including the study sites Langula and the Hainich Nationalpark) were intensively used as a coppice with standards combined with forest grazing. Litter raking played a minor role in the Hainich-Dün region.

The chronosequences Leinefelde (LEI) and Mühlhausen (MUE) represent typical regular shelterwood systems of pure beech stands that were managed to maximise the annual increment of stem biomass and to get a uniform, high yield of beech timber. At both chronosequences the stands are thinned regularly every 5 to 10 years to reduce crowding within the main crown canopy. At LEI the oldest trees represent the first tree generation that did not grow up under a coppice with standards system, while the forests at MUE had been selectively cut high forests (since the 16th century) before they were transformed into shelterwood systems at the beginning of the 19th century.

The selection forests at Langula (LAN) are the private property of local forest cooperations (*Laubgenossenschaften*, LG). They are legal associations of local landowners who manage their property of forested land jointly. The study sites were managed according to modern understanding of selection systems since the 1930s. From the middle of the 18th century to the 1930s the sites were selectively cut and the forested area was still divided into "cutting areas" at which the harvest was carried out every 12 years. The present selection cutting of the stands executes the final harvest, tending, and regeneration cutting at the same time and on the same area. The selection cutting cycle is about 5–10 years. The canopies of all study plots of the selection system were clearly dominated by beech, but they also include some large valuable ash (*Fraxinus excelsior*) and maple trees (*Acer pseudoplatanus*).

The site Hainich NP (HAI) represented the unmanaged reference site in this study located within the most protected area (core zone I; in total about 600 ha) of the Hainich Nationalpark (7600 ha). However, it has to be kept in mind that the site is not a primary forest. The stands have not been harvested, thinned or used in any way since 1997. Between 1965 and 1997 the forest was part of a military training area (protection zone for a shooting range) and during this period there was no regular forest management, but a few single trees of high value were cut. Presently the forest is at an "advanced" stage of development, i.e. the old and tall trees start to top over or even break down, multiple canopies exists and gaps are rapidly filled by fast growing regeneration. The largest tree individuals still originate from coppice shoots or standards. In general, the forest can be characterized as an old-growth, uneven-aged (1–250 years) mixed deciduous forest. European beech (*Fagus sylvatica*) dominates the canopy. European ash (*Fraxinus excelsior*) and sycamore (*Acer pseudoplatanus*) are co-dominant tree species. Single trees of hornbeam (*Carpinus betulus*), Norway maple (*Acer platanoides*), wild cherry (*Prunus avium*), oak (*Quercus petraea, Q. robur*) and others are dispersed.

Further details on forest use history can be found in MUND (2004).

2.3. Tree biomass carbon

The structural stand characteristics of the study plots are given in *Table 2*. Within each study plot (100 m x 100 m) a squared inventory plot of variable size, depending on tree size and stand heterogeneity (500–10000 m^2), was established and tree girth at breast height (1.3 m above ground) and tree height of all trees higher than 1.3 m within the inventory plot were measured. Tree height was measured with an optical height meter (Suunto PM-5/1520P). At the oldest even-aged stands, which were characterised by two canopies built up by the residual shelter of old trees and the understory of saplings and poles, an additional small subplot

Table 2

General stand characteristics of the study plots.
Data are given for all trees with a dbh ≥ 7cm. The understory includes all tress with a dbh < 7 cm and above 1.3 m tree height. N: stand density, $\bar{D}$: arithmetic mean of stem diameters at breast height. $\bar{H}$: tree height calculated for $\bar{D}$. Do: dominant stand diameter = quadratic mean of stem diameters at breast height of the 20 % largest trees per subplot. Ho: dominant stand height = tree height calculated for Do. B: Basal area (1): The inventory data of the stands Lan-I and Lan-II were provided by GLEICHMAR (1996) and the University of Dresden, Lehrstuhl für Waldwachstums- und Holzmesskunde (pers. comm.), respectively.

Allgemeine Bestandeseigenschaften der Versuchsflächen.
Die dargestellten Werte beinhalten alle Bäume mit einem bhd ≥ 7 cm. Der Unterstand umfasst alle Bäume mit einem bhd < 7cm und einer Baumhöhe von über 1.3 m. N: Bestandesdichte, $\bar{D}$: Arithmetisches Mittel der Durchmesser in Brusthöhe. $\bar{H}$: Mittlere Baumhöhe berechnet für $\bar{D}$. Do: quadratisches Mittel der Brusthöhendurchmesser der 20 % größten Bäume pro Teilfläche. Ho: Weise'sche Oberhöhe; Baumhöhe berechnet für Do. B: Bestandesgrundfläche. (1): Die Inventurdaten der Bestände Lan-I und Lan-II wurden von GLEICHMAR (1996) bzw. der Universität Dresden, Lehrstuhl für Waldwachstums- und Holzmesskunde (pers. comm.) zur Verfügung gestellt.

A) Even-aged stands; Altersklassenwälder

Study site	Silvicultural system	Age (years)	Location	N (Trees ha^{-1})				$\bar{D}$ (m)			$\bar{H}$ (m)			B ($m^2 ha^{-1}$)	D_o (m)	H_o (m)
				Beech	Others	Total	Understory	Beech	Others	Total	Beech	Others	Total	All species	All species	All species
LEI (Leinefelde)	Shelterwood system	30	51°20´13´´N 10°22´07´´E	976	688	1664	3104	0.108	0.089	0.100	12.3	12.5	12.4	13.87	0.117	13.1
		62	51°19´48´´N 10°21´19´´E	624	0	624	0	0.249	0	0.249	24.2	0	24.2	34.01	0.367	28.5
		111	51°20´02´´N 10°22´07´´E	216	8	224	0	0.438	0.366	0.436	34.4	32.8	34.3	35.23	0.536	36.9
		141	51°19´41´´N 10°22´04´´E	100	0	100	564	0.570	0	0.570	37.5	0	37.5	24.25	0.676	38.3
		153+16	51°20´02´´N 10°22´07´´E	64	0	64	16680	0.596	0	0.596	38.2	0	38.2	18.17	0.706	39.8
MUE (Mühlhausen)	Shelterwood system	38	51°11´41´´N 10°18´20´´E	1616	432	2048	1440	0.106	0.094	0.104	11.5	11.9	11.6	18.58	0.137	12.4
		55	51°11´37´´N 10°18´36´´E	1120	200	1320	180	0.154	0.193	0.160	19.0	22.5	19.6	31.40	0.263	24.7
		85	51°11´53´´N 10°19´11´´E	552	8	560	0	0.240	0.250	0.240	23.0	28.2	23.1	31.40	0.406	29.8
		102	51°11´31´´N 10°19´13´´E	470	42	512	0	0.273	0.409	0.285	25.5	31.3	26.0	39.72	0.459	34.6
		171+10	51°11´24´´N 10°18´25´´E	80	4	84	23100	0.579	0.608	0.580	34.9	30.4	34.7	22.63	0.682	34.7

B) Uneven-aged stands; Ungleichaltrige Bestände

Study site	Silvicultural system	Plot No.	Location	N (Trees ha^{-1})				$\bar{D}$ (m)			$\bar{H}$ (m)			B ($m^2 ha^{-1}$)	D_o (m)	H_o (m)
				Beech	Others	Total	Understory	Beech	Others	Total	Beech	Others	Total	All species	All species	All species
LAN (Langula)	Selection system	Lan-I[1]	51°07´44´´N 10°22´14´´E	312	17	329	323	0.240	0.536	0.255	20.5	32.6	21.2	24.99	0.462	32.4
		Lan-II[1]	51°08´33´´N 10°22´16´´E	246	17	263	414	0.296	0.357	0.301	22.9	27.9	23.3	25.00	0.463	32.4
		Lan-III	51°10´33´´N 10°20´16´´E	212	4	216	56	0.366	0.307	0.365	26.3	25.7	26.3	31.79	0.683	36.9
		Average				269				0.307			23.6	27.26		
HAI (Hainich)	Unmanaged forest	Hai-I	51°04´48´´N 10°27´45´´E	150	37	187	373	0.442	0.368	0.427	28.0	29.1	28.2	34.00	0.592	34.8
		Hai-II	51°04´42´´N 10°27´14´´E	220	88	308	440	0.274	0.428	0.318	19.3	27.3	21.6	34.94	0.522	30.4
		Hai-III	51°04´45´´N 10°27´07´´E	257	87	344	150	0.288	0.512	0.345	22.2	33.2	25.0	43.67	0.623	35.1
		Average				293				0.350			24.5	36.69		

(25–500 m²) was fixed within the inventory plot to get an estimate on tree number and size of the very dense understory. All saplings (tree height > 0.2 m, dbh 0–0.05 m) and poles (dbh 0.05–0.15 m) within a subplot were grouped into five diameter and height classes, and the number of trees per size class was counted. At the study plot MUE-171+10 tree regeneration did not form a regular, closed understory but there were alternating, very dense groups of saplings, which cover about 55% of total stand area. Seedlings (tree height < 0.2 m) were neglected at all stands.

The estimates of stem, branch, twig and coarse root (> 2 cm in diameter) biomass of all tree species resulted from multiple regression models for European beech given by WIRTH *et al.* (2003). Comprehensive species-specific regression models for the biomass of *Fraxinus excelsior*, *Acer pseudoplatanus*, *Carpinus betulus* or other non-beech tree species of the study sites were not available. Fine root biomass was derived from CLAUS (2003) or was assumed to be equal to leaf biomass (average ratio between leaf biomass and fine root biomass, CLAUS, 2003; SCARASCIA-MUGNOZZA *et al.,* 2000). The biomass at stand level resulted from the sum of tree biomass within each inventory plot extrapolated to one hectare. For more details see MUND, 2004.

The integrated mean of one rotation period of the even-aged stands was calculated setting the starting point to stand age 12 years (LEI) and 18 years (MUE) and the end point to 155 or 173 years, respectively. These borders were derived from the fact, that the final cuttings of the oldest stands were carried out 2 years after the field work for this study and thus, when the understory of the study plots LEI-153+16M and MUE-171+10 was 12 or 18 years old and the overstory 155 or 173 years old, respectively. The biomass at the beginning and the end of the rotation period was linearly extrapolated from the youngest and the oldest stands of the chronosequences.

Leaf biomass and annual litter fall resulted from litter sampling (litter traps) over two years (1999/2000 or 2000/2001). The litter was collected every two weeks from October to November and every two months over the rest of the year. It was separated into leaves of different tree species, twigs, branches, and a "rest" including mainly beech nuts and a small fraction of other fruits and buds.

For the conversion of dry weight of woody biomass into the amount of carbon stored in woody biomass we assumed an average carbon concentration of 50% of dry weight (WIRTH *et al*., 2003). The carbon concentration of beech leaf litter was 0.494 g g^{-1} and that of non-beech leaf litter 0.463 g g^{-1}. For fine roots a carbon concentration of 0.408 g g^{-1} was used, measured by CLAUS (2003) at LEI and the HAI.

2.4. Organic layer carbon

The organic layer (all dead organic matter smaller than 5 cm in diameter resting on the mineral soil) was sampled at 15 random points within each study plot (100 m x 100 m) at the end of September 2001, a week before litter fall began. The sampling area of each sample was 50 cm x 50 cm, resulting in a total sampling area of 3.75 m² per study plot.

Because of the favourable site conditions the organic layer included only an L-layer (humus form Mull) or an L-Layer and a thin (< 2 cm), weakly developed F-Layer that partly included some mineral particles and that cannot be sampled separately from the L-Layer (humus form F-Mull). To homogenize the material for the determination of carbon, the air-dried samples of the organic layer were separated into (1) fine woody debris, (2) coarse leaf litter (only weakly decomposed leaves > 2 mm) and (3) fine leaf litter (fragmented and partly fermented leaves ≤ 2 mm). All fractions were dried at 70 °C and weighed. The C/N analyses resulted in carbon concentrations of 0.479 g g^{-1} for coarse leaf litter and 0.302 g g^{-1} for partly decomposed leaf litter. The low carbon concentration of the latter fraction resulted from mineral particles admixed with the well decomposed litter. After weighing and C/N-analysis the coarse and fine leaf litter were pooled to the fraction leaf litter.

2.5. Dead wood carbon

Coarse woody debris (CWD), defined as dead wood lying on the ground with a diameter of 5–20 cm and a length of more than 10 cm, was determined by the "line intersect method" (BAILY, 1970; RINGVALL and STÅHL, 1999; MARSHALL *et al.,* 2000). At the study plots (100 m x 100 m) six parallel lines, each 100 m long, were marked by a string (line transect). The diameter of all pieces of CWD, whose central axis cross the line transect, was measured at the point the line was crossed. Corrections for the angle of the wooden pieces from the horizontal were not needed, because all pieces either lay on the ground or the angle from the horizontal was smaller than 15 degrees (MARSHALL *et al.,* 2000). In order to get an average biomass of CWD that also considered the volume of different decay classes, the decay class and the length of all pieces were determined.

The classification into five decay classes was based on a combination of several descriptive and quantitative parameters such as remaining proportion of bark, infection by fungi and number and condition of fruit bodies, resistance to a knife blade that is pushed into the wood, texture (hard, soft, friable), shape and colour of the decaying wood (modified from GRAHAM and CROMACK, 1982; MCGEE *et al.,* 1999; PYLE and BROWN, 1999). The parameters were collected for all pieces of dead wood and compared with each other resulting in a relative scale of wood decay from fresh dead wood

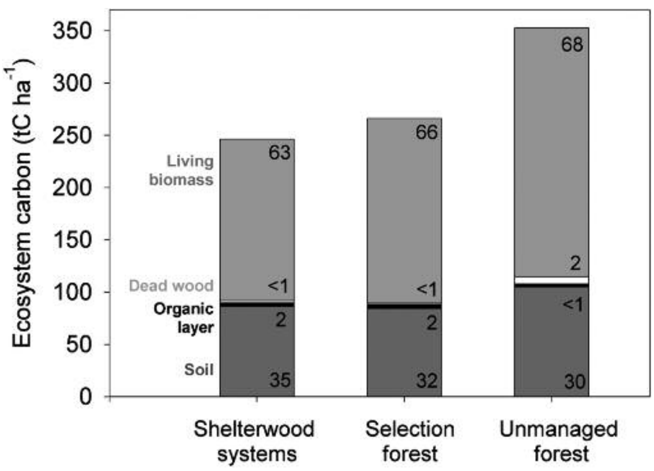


Fig. 2

Total amount of carbon stored in differently managed beech forest ecosystems (*Fagus sylvatica*) at the Hainich-Dün region, Germany. The numbers given at the right corner of the bars represent the proportion of carbon (%) stored in the different compartments. Total soil organic carbon includes the entire mineral soil down to the transition zone to the bedrock (C-horizon), and it is not corrected for site-specific variations in soil properties (e. g. clay content, C:N ratio, soil depth).

Gespeicherte Gesamtkohlenstoffmenge in unterschiedlich bewirtschafteten Buchenwäldern (*Fagus sylvatica*) des Hainich-Dün Gebietes, Deutschland. Die Werte in der rechten Ecke der Säulen geben den Anteil der einzelnen Kompartimente am Gesamt-Kohlenstoff (%) an. Der Gesamt-Bodenkohlenstoff beinhaltet den gesamten Mineralboden bis hin zur Übergangszone zum Ausgangsgestein (C-Horizont) und wurde nicht hinsichtlich standortspezifischer Unterschiede in den Bodeneigenschaften (z. B. Tongehalt, C:N Verhältnis, Bodentiefe) abgeglichen.

(decay class 1) to highly decayed dead wood (decay class 5). Large logs and snags of European beech often decay from their centre outwards to the youngest tree rings, resulting in hollow cylinders with a narrow shell of nearly un-decayed wood. To detect this "pseudo fresh dead wood", logs were knocked on in order to hear if inner parts were already decayed. Hollow logs were generally classified as decay class 4.

There are no available data on changes of wood density with a progressive decay of dead wood from European beech, ash or maple trees in situ. Thus, it was assumed that the basic density of dead wood declines linearly from 558 kg m^{-3} at decay class 1 to 62 kg m^{-3} at decay class 5. This assumption was based on several studies dealing with the decay of dead hardwood (e. g. ARTHUR *et al.,* 1993; STEWART and BURROWS, 1994; DUVALL and GRIGAL, 1999; WEBER, 2001; CLINTON *et al.,* 2002; MACKENSEN *et al.,* 2003), and on some specific properties of beech wood, which affect its decay rates (e.g. relatively low concentrations of tannin agents and the deposit of them in the cell lumen instead of the cell wall, sensitivity of beech wood to infection by white-root fungi, KUČERA, 1991; HAMMEL, 1997). The average amount of CWD per study plot resulted from the average of the six line transects per study plot.

Carbon concentration was assumed to be 50% of dry dead wood (STEWART and BURROWS, 1994; WEBER, 2001; CLINTON et al., 2002; KAHL, 2003).

Lying dead wood (logs) with a diameter of more than 20 cm and standing dead wood (snags; including stumps) with a dbh ≥ 7 cm were determined on a plot basis, which means that all logs and snags within the study plots (100 m x 100 m) were measured. The average diameter of a log resulted from the diameter in the middle and at both ends of the log. Snags were measured in the same way as living trees (dbh and height).

2.6. Soil sampling and analysis

Within the study plot (1 ha) of each study site 16 random soil samples (0–15 cm soil depth) were taken. Fifteen soil samples were taken with soil cylinders (PE-tubes) that were 20 cm high and had

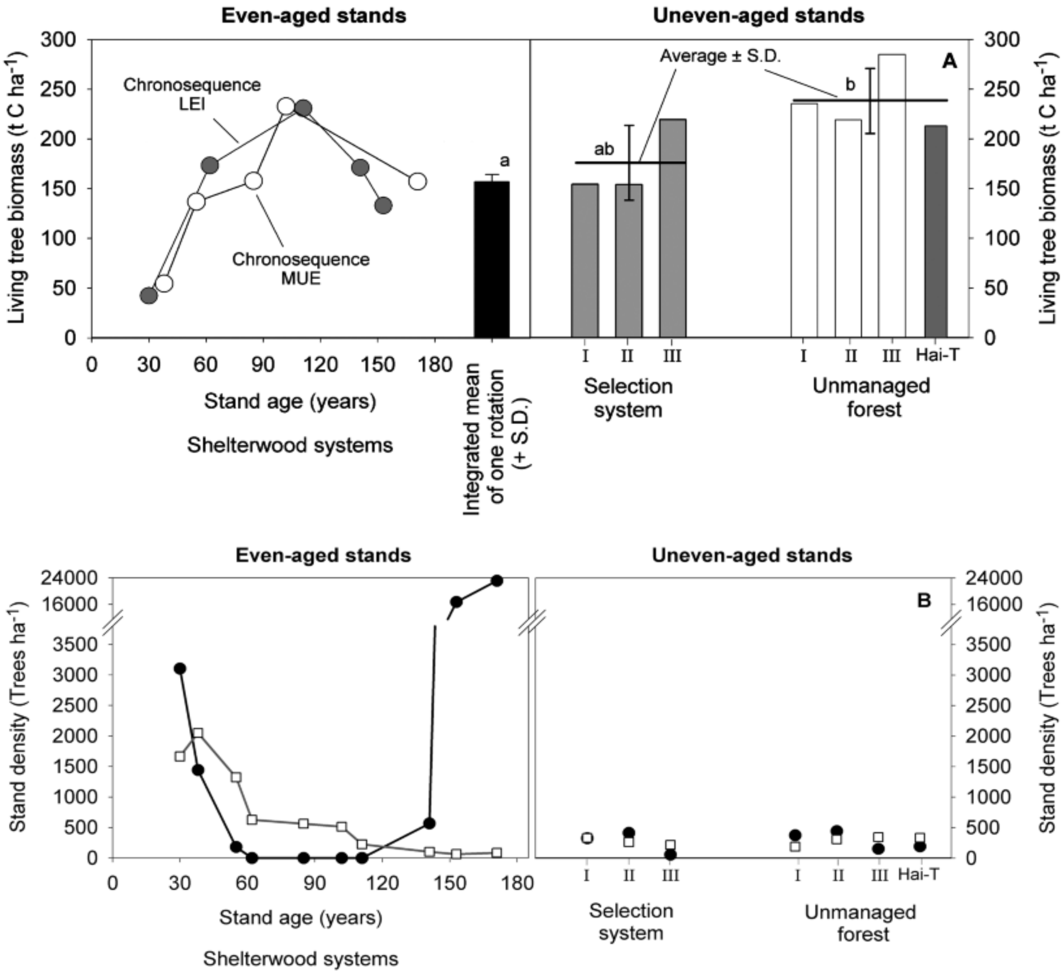
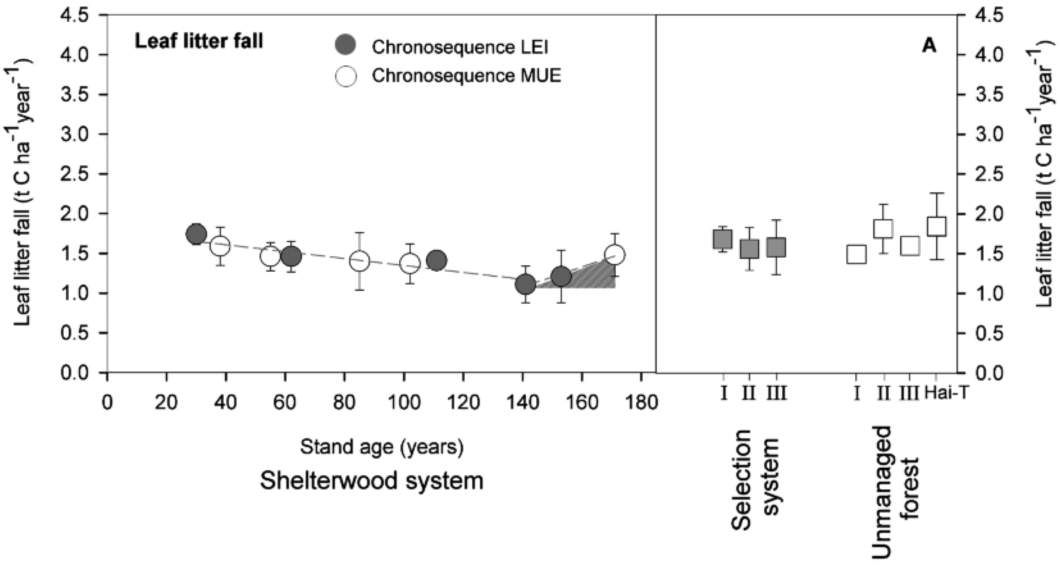


Fig. 3

(A) Amount of carbon stored in living tree biomass of differently managed beech forests (*Fagus sylvatica*) at the Hainich-Dün region, Germany. Different letters indicate significant differences between the silvicultural systems (ANOVA, P < 0.05). The study plot Hai-T represents the main catchment area of the Eddy-covariance tower at the study site HAI (MUND, 2004). (B) Stand density in relation to stand age of the even-aged stands and in the uneven-aged stands. Circles: dbh < 7 cm, Squares: dbh ≥ 7 cm.

(A) Menge an Kohlenstoff, die in der Biomasse lebender Bäume unterschiedlich bewirtschafteter Buchenwälder (*Fagus sylvatica*) im Hainich-Dün Gebiet, Deutschland, gespeichert wurde. Unterschiedliche Buchstaben kennzeichnen signifikante Unterschiede zwischen den Waldbausystemen (ANOVA, P < 0,05). Die Versuchsfläche Hai-T repräsentiert das Haupteinzugsgebiet des Eddy-Kovarianz-Turmes auf dem Versuchsstandort HAI (MUND, 2004). (B) Bestandesdichte in Abhängigkeit vom Alter der Altersklassenwälder und in den ungleichaltrigen Beständen. Kreise: bhd < 7 cm, Quadrate: bhd ≥ 7 cm.



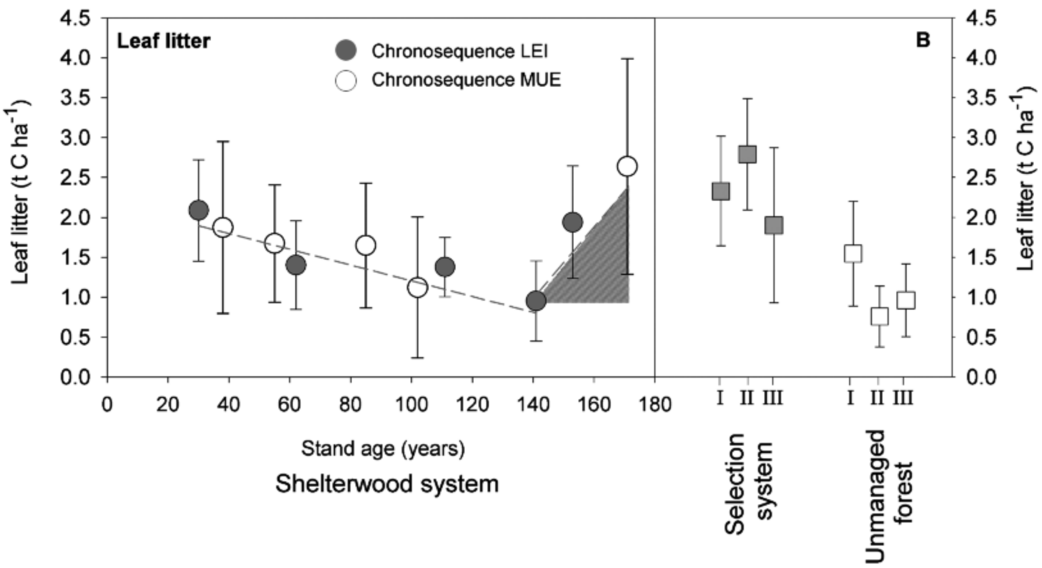


Fig. 4

(A) Annual leaf litter fall (means ± standard deviation) in relation to stand age and silvicultural system. (B) Leaf litter fraction of the organic layer at the end of the growing season before litter fall begun in relation to stand age and silvicultural system. The data represent the means ± standard deviation of 15 random samples per study plot. The shadowed area in *Figure A* and *B* indicates the amount of litter that was likely produced by the understory of the older stands. The study plot Hai-T represents the main catchment area of the Eddy-covariance tower at the study site HAI (COTRUFO, 2003).

(A) Jährlicher Blattstreufall (Mittelwert ± Standardabweichung) in Abhängigkeit von Bestandesalter und Waldbausystem. (B) Fraktion der Blattstreu in der organischen Auflage am Ende der Vegetationsperiode und vor erneutem Streufall in Abhängigkeit von Bestandesalter und Waldbausystem. Dargestellt sind die Mittelwerte ± Standardabweichung von 15 zufälligen Proben pro Versuchsfläche. Die schraffierte Fläche in *Abb. 4 A* und *B* kennzeichnet die Menge an Streu, die wahrscheinlich durch den Unterstand in den älteren Beständen produziert wurde. Die Versuchsfläche Hai-T repräsentiert das Haupteinzugsgebiet des Eddy-Kovarianz-Turmes auf dem Versuchsstandort HAI (COTRUFO, 2003).

an inner diameter of 10.5 cm, and one sample was taken from a soil pit (top of the mineral soil down to the transition zone to the bedrock, excavation method, 30 cm*30 cm*5 cm).

The soil samples were divided by depth into three fractions: 0–5 cm, 5–10 cm and 10–15 cm (soil pits: 5 cm steps down to 30 cm soil depth, 10 cm steps from 30-50 cm depth, and 20 cm steps down to the bedrock). Dead and living roots, plant and animal residues (> 1 mm) and large stones were picked out. Two subsamples of each fine soil sample (≤ 2 mm) were taken with an automatic subsampler (Labor-Probenteiler Typ PT 100, Retsch GmbH & Co. KG, Haan, Germany, 1998) to determine: (1) the residual water content of the air-dried samples (drying at 105 °C) and (2) the C and N concentrations. The samples for C and N analysis were ground with a mixer mill (type MM 200, 1998, Retsch, Haan, Germany), and then the element concentrations were determined via total combustion by the elemental analyzer VarioEL II (1998) or VarioMax (2000) (“Elementar Analysen Systeme GmbH”, Hanau). Total inorganic carbon was quantified by ignition of the air-dried and grounded soil samples at 450 °C for at least 8 h to oxidize all organic matter, followed by a determination of the inorganic C with the elemental analyzer VarioMax, 2000 ("Elementar Analysen Systeme GmbH", Hanau, Germany). The organic carbon was calculated from the difference of total organic carbon and inorganic carbon. All elemental analyses were corrected for the residual water content (difference between air-dried samples and samples dried at 105 °C). SOC resulted from the product of fine soil mass and carbon concentrations.

Soil pit samples were analysed also for particle size distribution (combined sieving and sedimentation method according to the DIN ISO 11277 norm, AUA GmbH, Jena). The strong relationship between clay content and residual water content ($R^2 = 0.67$, $P < 0.001$) was used as an estimate for the clay content of the samples taken with a soil cylinder. For more details see MUND, 2004.

2.7. Statistical analysis and software

The main statistical analysis was based on a generalization of the linear regression model (General Linear Model) that included procedures to test for effects of categorical and continuous predictor variables. The most relevant procedures were multiple regression analysis and the "separate slopes model" (SSM) analysis. All these statistical procedures were provided by the *Visual GLM module* of the Software STATISTICA for Windows, StatSoft, Inc. 2000. Graphical presentations were carried out with SigmaPlot for Windows 2000 (version 6.0). The integrated mean of one rotation period of the even-aged stands was calculated with the software "Xact" (XactPro Version 7.22, SciLab GmbH). For data management and simple mathematical operations Microsoft Excel 2002 was used.

3. RESULTS

3.1. Total and biomass carbon

The total amount of carbon stored in living and dead tree biomass, the organic layer and in soil (mineral soil down to the transition zone to the bedrock) of the study sites increased with decreasing intensity of management from about 246 tC ha^{-1} at the shelterwood systems to 266 tC ha^{-1} at the selection system to 352 tC ha^{-1} at the unmanaged site (*Figure 2*). Carbon in tree biomass accounted on average for about 65% of total carbon in the forest ecosystems (excluding ground vegetation).

At the even-aged stands carbon in living tree biomass showed a clear age-related curve that increased until a stand age of about 100 years and then decreased rapidly at the older stands (*Figure 3a*). This pattern is not a function of stand or tree age as a physiological parameter, but it reflects changes in stand density due to thinning and, in particular, preparatory- and seed-cutting at a stand age of about 130–140 years (*Figure 3b*).

Dead wood carbon ranged between 1.7 tC ha^{-1} (~ 9 m^3 ha^{-1}) in the managed forests and 6.4 tC ha^{-1} (~ 41 m^3 ha^{-1}) in the unmanaged forest (*Figure 2*). Thus, it accounted for only 0.6 and 1.8%, respectively, of total carbon stored in the forest ecosystems.

3.2. Carbon in annual litter fall and in the organic layer

Mean annual litter fall of all the study sites did not differ significantly (range 2.1-2.8 tC ha^{-1} $year^{-1}$). Age-related differences were found along the chronosequences only for leaf litter fall (*Figure 4A*). This stand-age effect was most likely associated with changes in the stand density due to thinning (*Figure 3b*).

Mean carbon in the organic layer (including leaves, fruits and fine woody debris at the end of the growing season but before litter fall) of the study sites were relatively low (range 3.0–4.1 tC ha^{-1}), which reflected the favorable site conditions and high biological activity in soil. The differences between mean organic layer carbon of the study sites were statistically not significant. The leaf litter fraction of the organic layer, which ranged from 0.8 tC ha^{-1} to 2.8 tC ha^{-1} (*Figure 4B*), was positively correlated with litter fall of beech leaves of the previous year and negatively correlated with the basal area of the stands (multiple regression model, $R^2 = 0.67$, $P < 0.001$). The negative relationship between the leaf litter fraction of the organic layer and the basal area of the stands indicates higher decomposition rates due to a more constant and humid microclimate in stands with a higher basal area compared to stands with a lower basal area. The age related pattern of leaf litter in the organic layer was similar to that of annual leaf litter fall (*Figure 4A, B*), but the spatial variation within each study plot was much larger.

3.3. Soil organic carbon

In the mineral soil (from the upper soil layer down to the transition zone to the bedrock) at LEI and MUE 75 ± 13 tC ha^{-1} (mean ± standard deviation) and 98 ± 9 tC ha^{-1}, respectively, were found. At LAN about 85 ± 11 tC ha^{-1} and at HAI about 105 ± 16 tC ha^{-1} were stored in the mineral soil. The differences between the study sites were caused mainly by a small-scaled variability in soil texture (varying between clayey silt and silty clay) and soil depth (varying between 36 and 78 cm). On average total SOC accounted for about 32% of total carbon stored in the ecosystem (*Figure 2*).

SOC in the upper mineral soil (0–15 cm soil depth; SOC_{0-15}) at LEI (36 ± 6 tC ha^{-1}) and LAN (39 ± 6 tC ha^{-1}) were significantly lower than the SOC_{0-15} at MUE (42 ± 5 tC ha^{-1}) (ANOVA, $P < 0.05$). The highest amount of SOC_{0-15} was found at HAI with 53 ± 2 tC ha^{-1}. However, the SOC_{0-15} was significantly controlled by the clay content (estimated by the residual water content of the air-dried cylinder samples) and the C:N ratio of the soil. After excluding the effect of site-specific variation in the clay content

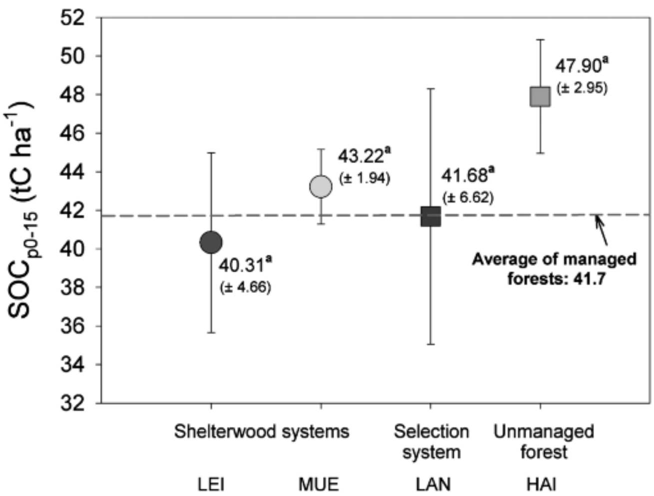


Fig. 5

"Processed" SOC in 0–15 cm soil depth (means ± standard deviation; SOC_{p0-15}) of the silvicultural systems. Processed SOC_{0-15} represent the mean SOC_{0-15} per study site for the case that all study plots had the same clay content and the same C:N ratio (separate slopes model analysis). The letter "a" indicates that the means per study site did not differ significantly (ANOVA, P = 0.07, data were transformed with $y = x^{3.5}$ prior to analysis).

Bodenkohlenstoffvorräte der Waldbausysteme in 0–15 cm Bodentiefe (Mittelwert ± Standardabweichung; $Boden_{p0-15}$-C). Der „bereinigte" $Boden_{0-15}$-C repräsentiert den mittleren $Boden_{0-15}$-C der Versuchsstandorte für den Fall, dass der Boden in allen Versuchsflächen den gleichen Iongehalt und das gleiche C:N-Verhältnis aufweist („separate slopes model"-Analyse). Der Buchstabe „a" gibt an, dass die Mittelwerte der Standorte sich nicht signifikant voneinander unterscheiden (ANOVA, P = 0,07, die Daten wurden vor der statistischen Analyse mit $y = x^{3,5}$ transformiert).

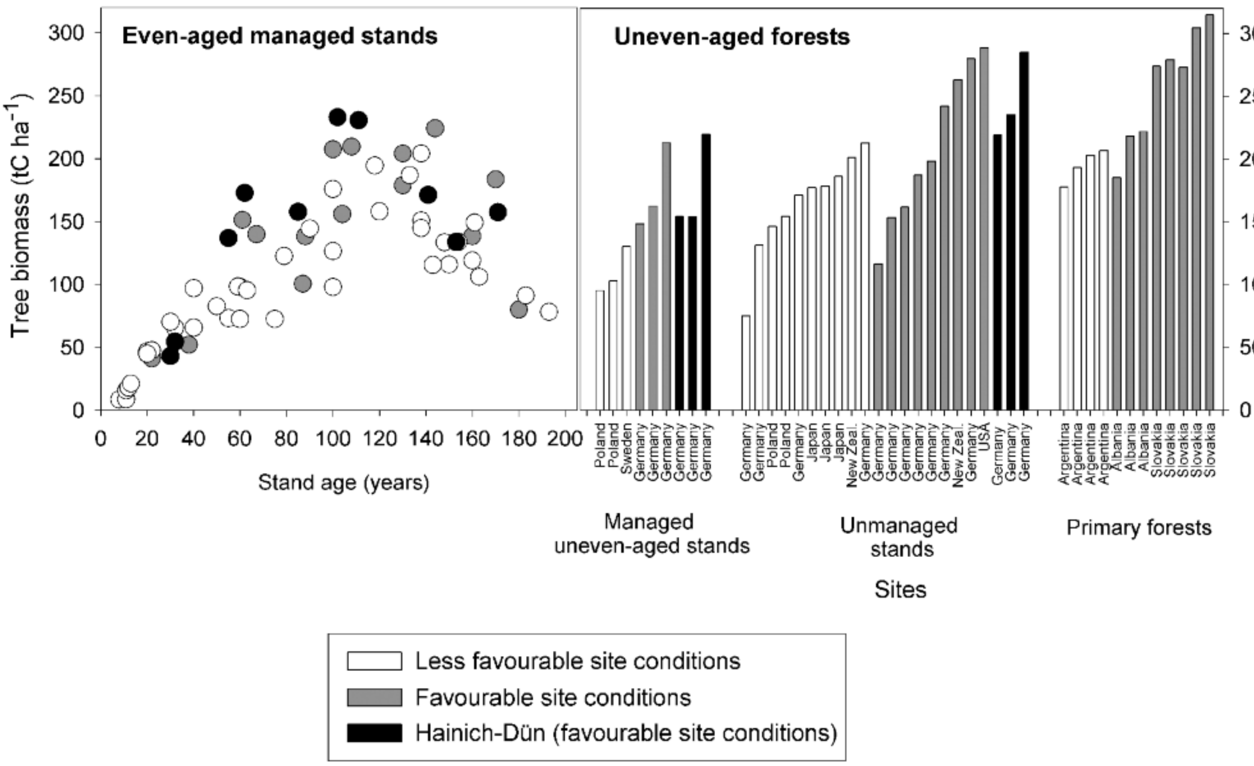


Fig. 6

Carbon in living tree biomass of differently managed, beech dominated broadleaved forests under different growing conditions. The unmanaged forests include very old forest reserves as well as recently protected forests. The primary forests can naturally be disturbed. Data of the managed, even-aged stands origin from Italy, Denmark, France, Belgium, Netherlands, Sweden, Czech Republic, Japan, Argentina, Bulgaria, USA, Canada, and Germany. To convert timber volume per hectare reported in most studies into the amount of carbon in total tree biomass per hectare, the conversion-expansion factors for even-aged beech forests by WIRTH *et al.* 2003 and a conversion-expansion factor of 0.39 for uneven-aged stands (MUND, 2004) were used.

Kohlenstoff in der Biomasse lebender Bäume unterschiedlich bewirtschafteter, buchendominierter Laubwälder und unter unterschiedlichen Wuchsbedingungen. Die nicht bewirtschafteten Wälder umfassen sehr alte Waldschutzgebiete ebenso wie erst seit wenigen Jahren unter Schutz gestellte Wälder. Die Primärwälder können natürlichen Störungen unterliegen. Die Daten der bewirtschafteten Altersklassenwälder stammen aus Italien, Dänemark, Frankreich, Belgien, Niederlande, Schweden, Tschechische Republik, Japan, Argentinien, Bulgarien, USA, Kanada und Deutschland. Um das Derbholzvolumen pro Hektar, welches in den meisten Studien angegeben ist, in Kohlenstoff der gesamten Baumbiomasse pro Hektar umzurechnen, wurden Konversions-Expansionsfaktoren für gleichaltrige Buchenbestände nach WIRTH *et al.* 2003 und ein Konversions-Expansionsfaktor für ungleichaltrige Bestände von 0,39 (MUND, 2004) verwendet.

and the C:N ratio via statistical analysis (separate slope model analysis) the differences between the resulting, "processed" $SOC_{0–15}$ ($SOC_{p0–15}$) of the study sites decreased (*Figure 5*). Mean $SOC_{p0–15}$ varied between 42 tC ha^{-1} at the managed sites LEI, MUE and LAN and 48 tC ha^{-1} at the unmanaged HAI. An effect of stand age on $SOC_{p0–15}$ at the even-aged stands was not found. Also stand density, basal area or living tree biomass did not affect $SOC_{p0–15}$ significantly.

The difference in $SOC_{p0–15}$ between the managed and the unmanaged sites of about 6 tC ha^{-1} was not significant (ANOVA, $P = 0.07$, data were transformed with $y = x^{3.5}$ prior to analysis), but it may be possible that the observed trend to higher $SOC_{p0–15}$ in the unmanaged forest is associated with the cessation of timber use about 35 years ago.

4. DISCUSSION

The first hypothesis of the Hainich-Dün case study, that the total amount of carbon increase sequentially from the regular shelterwood system to the selection system to the unmanaged forest was confirmed. However, the differences between the regular shelterwood system (even-aged forests) and the selection system (uneven-aged forest) were very small and were dominated by carbon stored in living tree biomass. Also the higher amount of carbon found at the unmanaged forest was caused mainly by higher tree biomass. In contrast to the second and third hypothesis, only a trend of higher $SOC_{p0–15}$ at the unmanaged forest compared to the managed forests were found, and $SOC_{p0–15}$ did not show an age-related increase at the even-aged stands.

It is clear that this study is an observational case study, which should be interpreted under the constraint that site-specific properties and historical management may significantly affect current carbon budgets. To generalize the observed impact of moderate silvicultural practices on the carbon budget of beech forests and to compare them with the impacts of intensive management practices the results of this case study are discussed in the context of other case studies in differently managed broadleaved forests, and partly also coniferous forests, which are often managed in a clear-cutting system.

4.1. Tree biomass carbon

A selection of case studies on temperate broadleaved forests that include information about climate, silvicultural treatments, stand age, and living and dead aboveground biomass allows a more general interpretation of the present results (*Figure 6* and *Table 3*). The

Table 3

Dead wood carbon of temperate broadleaved forests.
Dead wood volume was converted to dead wood carbon assuming a mean basic wood density of 310 kg m^{-3} (~ decay class 3, *Fagus sylvatica,* MUND, 2004) and a carbon concentration of 50%. Dominant tree species: 1 *Abies alba*, 2 *Acer platanoides*, 3 *Acer pseudoplatanus*, 5 *Acer saccharum*, 6 *Betula alba*, 7 *Betula lutea*, 9 *Carpinus betulus*, 11 *Fagus grandifolia*, 12 *Fagus sylvatica*, 13 *Fraxinus excelsior*, 14 *Nothofagus fusca*, 15 *Nothofagus menziesii*, 16 *Nothofagus pumilio*, 17 *Nothofagus solandri*, 18 *Nothofagus truncata*, 19 *Quercus montana*, 20 *Quercus petraea*, 21 *Tilia cordata.*

Totholz-Kohlenstoff in temperaten Laubwäldern. Zur Umrechnung des Totholzvolumens in Totholz-Kohlenstoff wurde eine mittlere Raumdichte von 310 kg m^{-3} (~ Zersetzungsklasse 3, *Fagus sylvatica,* MUND, 2004) und eine Kohlenstoffkonzentration von 50 % angenommen. Dominierende Baumarten: 1 *Abies alba*, 2 *Acer platanoides*, 3 *Acer pseudoplatanus*, 5 *Acer saccharum*, 6 *Betula alba*, 7 *Betula lutea*, 9 *Carpinus betulus*, 11 *Fagus grandifolia*, 12 *Fagus sylvatica*, 13 *Fraxinus excelsior*, 14 *Nothofagus fusca*, 15 *Nothofagus menziesii*, 16 *Nothofagus pumilio*, 17 *Nothofagus solandri*, 18 *Nothofagus truncata*, 19 *Quercus montana*, 20 *Quercus petraea*, 21 *Tilia cordata.*

Sources; Datenquellen: (1) ERDMANN and WILKE 1997, (2) OHLAND 2000, (3) BASCIETTO 2003, COTRUFO 2003, (4) GRANIER *et al.* 2000, COTRUFO 2003, (5) BOBIEC 2002, (6) STRUCK 2001 in WIRTH *et al.* 2003, (7) MEYER 1999, (8) BOBIEC 2002, (9) HARMON *et al.* 1986, (10) MULLER 2003, (11) WHITTACKER *et al.* 1979; BORMANN and LIKENS 1979, (12) HART *et al.* 2003, (13) STEWART and BURROWS 1994, (14) WEBER 2001, (15) DAVIS *et al.* 2003, (16) MEYER *et al.* 2003, (17) KORPEL' 1995, (18) TABAKU 1999, (19) MÜLLER-USING and BARTSCH 2003.

Site	Dominant tree species	Management	Dead wood tC ha^{-1}	Source
Managed stands				
Schiefergebirge, Hessen, Germany	12	managed beech stands	1.4	1
Mühlhausen, Thuringia, Germany	12	Selection system	0.8	2
Bleicherode, Thuringia, Germany	12 (3, 2)	Selection system	0.4	18
Soroe, Denmark	12	Natural regeneration	4.9	3
Hesse, France	12 (20, 24, 6)	Natural regeneration	2.8	4
Biaowieza, Poland	9, 21, 2 etc.	Selection cutting	0.5	
-"-	9, 21, 2 etc.	Selection cutting	0.5	5
Median			**0.8**	
Unmanaged stands and old-growth forests				
Brandesbachtal, Thuringia, Germany	12	Forest reserve	4.1	6
Northwestern Germany	12, 20	Forest reserve	1.4	7
-"-	12	Forest reserve	4.2	7
-"-	12, 20	Forest reserve	12.2	7
-"-	12	Forest reserve	6.4	7
Solling, Germany	12	Forest reserve, 1994	4.4	19
-"-	12	Forest reserve, 2000	7.9	19
"Heilige Hallen", Germany	12	Forest reserve	30.8	18
Limker Strang, Germany	12	Forest reserve	2.3	18
Biaowieza, Poland	9, 21, 2 etc.	Forest reserve	15.4	8
-"-	9, 21, 2 etc.	Forest reserve	21.9	8

selected sites were classified as (A) even-aged managed forests, (B) uneven-aged managed forests, (C) recently unmanaged/protected forests, which were used by humans in the past, and (D) primary forests that are not influenced by historical or recent forest use. Each of these categories were subdivided into forests growing under (1) favourable conditions or (2) less favourable conditions.

Broadleaved forests containing a substantial proportion of coniferous trees are explicitly excluded from this summary, because these mixed forests showed a clear tendency to higher living and dead wood biomass than pure broadleaved forests.

Despite the wide geographical range of the selected case studies (e. g. Japan, central Europe, Canada) living biomass C of the managed even-aged broadleaved stands showed a trend of a maximum-curve that peaks at a stand age of about 100 to 120 years (*Figure 6*), similar to the stand age pattern of the Hainich-Dün case study (*Figure 6*, black circles). At favourable site conditions tree carbon tend to be higher than at less favourable site conditions (on average about 146 tC ha^{-1} and 114 tC ha^{-1}, respectively, excluding stands

Table 3: **continued**

Site	Dominant tree species	Management	Dead wood tC ha^{-1}	Source
Unmanaged stands and old-growth forests (continued)				
Hardwood forests, northern America	5, 11 etc.	*not reported*	10.4	9
-"-	5, 11 etc.	*not reported*	11.6	9
-"-	5, 11 etc.	*not reported*	24.7	9
-"-	11, 5, 19 etc.	*not reported*	14.5	9
Southeastern Kentucky, USA	11, 5, 19	*not reported*	14.8	10
Hubbard Brook Forest, USA	5, 11, 7	unmanaged natural succession after clear cutting	14	11
Big Bush, Nelson, New Zealand	18, 17, 15	*not reported*	27.9	12
Station Creek, New Zealand	15, 14	undisturbed old-growth forest	65.6	13
Fergies Bush, New Zealand	15, 14	undisturbed old-growth forest	148.9	13
Rough Creek, New Zealand	15, 14	undisturbed old-growth forest	73.2	13
Tierra del Fuego, Argentina	16	natural succession after windthrow	37.9	14
-"-	16	-"-	31.3	14
-"-	16	-"-	25.4	14
-"-	16	-"-	28.7	14
-"-	16	-"-	35.4	14
-"-	16	natural succession after clear cutting without slash removal	60.5	14
Central South Island, New Zealand	17	natural succession after wind throw	11.9	15
Median			**15.1**	
Undisturbed primary forests				
Tierra del Fuego, Argentina	16	primary forest	34.4	14
Mirdita, Munellagebirge, Albania	12, 3	primary forest	6.2	15
Puka, Munellagebirge, Albania	12 (1)	primary forest	4.7	16
Rajca, Eastern Albania	12, 21, 6	primary forest	13.2	16
SNr Vihorlat, Western Carpathians, Slovakia	12 (3, 13)	primary forest	10.0	17
SNr Rozok, Western Carpathians, Slovakia	12	primary forest	29.4	17
SNr Havesova, Western Carpathians, Slovakia	12	primary forest	21.9	17
Median			**13.2**	

younger than 20 years as they are not represented on favourable site conditions), but the age trend is similar at both site conditions. The lower living biomass of stands older than 120 years is very likely not an effect of stand age or tree senescence per se, but it may be related to decreasing stand densities as a result of increased commercial thinning and preparatory cuttings, which are typical for regularly managed even-aged broadleaved forests growing over relatively long rotation periods. Unfortunately, detailed data on the thinning regime and stand densities are missing in most available case studies.

The described age-trend in managed, even-aged, temperate broadleaved forests contrasts recent findings by the meta-analysis of PREGITZER and EUSKIRCHEN (2004), who show a steady increase of biomass in temperate forests. The main reason for this discrepancy may be that in the meta-analysis of PREGITZER and EUSKIRCHEN (2004) the data set was stratified by biomes only, but not by coniferous and broadleaved/deciduous forests and not by management (managed or unmanaged stands). Broadleaved stands in Europe were not included in that meta-analysis. Also in Europe undisturbed, old-growth broadleaved forests (> 200 years old) have higher biomass than younger, regular managed stands (*Figure 6*). However, in Europe old-growth broadleaved forests are usually not even-aged stands, because rotation lengths over 200 years are relatively unprofitable (exceptions are veneer oak forests), and natural even-aged broadleaved stands are rare as large scale stand-replacing disturbances are rare in natural broadleaved forests of Europe (ELLENBERG, 1996). If even-aged stands would be grown in longer rotations without a successive commercial thinning before the final harvest, stand biomass would increase with stand age. In conclusion, to understand stand-age effects on biomass in forests it is necessary to separate between the stand-age effect in forests developing unaffected by management activities after a stand replacing disturbance (continuous increase of biomass with stand age), and the stand age effect of regularly managed stands that represent mainly the time frame for distinct management activities such as precommercial and commercial thinning, and final cutting.

Carbon in living tree biomass of all sites of this study were at the upper range found in other beech or temperate broadleaved forests (*Figure 6*), which confirms the favourable growing conditions of the study sites. Very low tree biomass in some unmanaged forests may reflect impacts of historical forest use (VON LOCHOW, 1987; CHRISTENSEN *et al.,* 2005). The highest tree biomass was reported for primary beech stands under favourable conditions in Albania and Slovakia (about 300 tC ha^{-1}, KORPEL', 1995; MEYER *et al.,* 2003).

In managed pure broadleaved stands dead wood carbon usually did not exceed 5 tC ha^{-1} (*Table 3*, KIRBY *et al.,* 1998), because harvest residuals are collected for fire wood. Thus, the low amount of dead wood in the managed forests of this study (less than 2 tC ha^{-1}) is just typical for managed temperate broadleaved forests.

Dead wood carbon in pure unmanaged and primary broadleaved forests cover a wide range from less than 5 tC ha^{-1} to more than 60 tC ha^{-1} (*Table 3*). Dead wood carbon in the unmanaged forest of this study were about two times smaller than that reported for primary European beech forests in the western Carpathian and Albania (~14 tC ha^{-1}; KORPEL', 1995; MEYER *et al.,* 2003). This may reflect differences in the disturbance regime and decay rates compared to the sites in Slovakia and Albania (partly higher elevation and partly higher precipitation), but most likely they are the result of historical forest use by local people for fire wood. The highest amount of dead wood (more than 35 tC ha^{-1}) was not found in uneven-aged primary broadleaved forests, but in unmanaged broadleaved forests characterised by recent or repeated disturbances and/or a history that resulted in even-aged stands with a single canopy of old trees (e. g. natural succession after clear-cutting, windthrow in a former forest pasture; TABAKU, 1999; WEBER, 2001; KIRBY *et al.,* 1989) (*Table 3*).

Maximum dead wood given for pure primary broadleaved forests in Table 3 (34 tC ha^{-1}) is lower than that reported for montane beech forest reserves in Europe including also beech-fir-spruce forests (CHRISTENSEN *et al.,* 2005, 250–552 m^3 ha^{-1} ~ 39–86 tC ha^{-1}). The need for a strict separation between broadleaved, mixed and coniferous forests become apparent when the amount of carbon stored in dead wood of pure broadleaved forests is compared with that of primary coniferous forests ranging between 15 and 250 tC ha^{-1} (GRIER and LOGAN, 1977; HARMON *et al.,* 1986; HARMON *et al.,* 1990; KIRBY *et al.,* 1998; LEIBUNDGUT, 1993; DUVALL and GRIGAL, 1999; KRANKINA *et al.,* 2002; PEDLAR *et al.,* 2002). It is assumed that the main reasons for the strong effect of the vegetation type on dead wood carbon, at least in Central Europe, are: (1) relatively high decay rates of beech wood compared to wood of many coniferous species (MUND, 2004), and (2) montane forests with a high proportion of conifers are often less affected by historical forest use, particularly fire wood sampling, than lowland or submontane pure beech forests (CHRISTENSEN *et al.,* 2005).

4.2. Organic layer and soil organic carbon

Vegetation type and site conditions are important factors that interact and covariate with the impacts of forest management on SOC (MUND and SCHULZE, 2005). However, to discuss the effects of forest management on SOC it is reasonable to consider broadleaved and coniferous forests, because there are more data available for coniferous than for broadleaved forests, and general patterns of management effects observed in coniferous forests may be valid also in broadleaved forests.

Evaluating the effects of forest management on soils it is important to separate clearly between the organic layer (or forest floor) resting on the mineral soil, and organic carbon in the mineral soil (SOC), because the organic layer is more sensitive to disturbances than the mineral soil (YANAI, 2004). Very high carbon losses after clear-cutting were restricted to the organic layer and to coniferous forests which are characterised by relatively high amounts of carbon stored in the organic layer (e. g. COVINGTON, 1981 (50% after 15 years), JOHNSON *et al.,* 1995 (25% after 8 years), HEINSDORF, 1986 (23% after 20 years), MATTSON and SMITH, 1993 (35% within 23 years)). Here, cumulative losses from the organic layer can sum up to 20–50 tC ha^{-1} (COVINGTON, 1981; HEINSDORF, 1986; JURGENSEN *et al.,* 1997). A high susceptibility of the organic layer can even be assumed for less intensive disturbances as it was shown in the Hainich-Dün study (*Figure 4B*) and for gradual environmental changes (BMELF 1997, VESTERDAL *et al.,* 1995; MEIWES et al., 2002; PRESCOTT, 2002; BERG, 2000).

In contrast, significant carbon losses from the mineral soil occur mainly after intensive disturbances such as stand replacing fires (BHATTI *et al.,* 2002; WIRTH *et al.,* 2002) and land-use changes from forests to agriculture (MATSON *et al.,* 1997) and from primary forests into plantations (GUO and GIFFORD, 2002). Land-use changes in the opposite direction (afforestation of croplands or grasslands) result in an increase or decrease of SOC, and thus in a clear stand-age effect on SOC in the regrowing forests (THUILLE and SCHULZE, 2005; TURNER and LAMBERT, 2000; BERTHOLD and BEESE, 2002; GUO and GIFFORD, 2002; PAUL *et al.,* 2002; VESTERDAL *et al.,* 2002). Also clear cutting combined with whole-tree harvesting, mechanic soil preparation (e. g. scalping, bedding) or prescribed fires can lead to a substantial reduction of carbon in the mineral soil (EDWARDS and ROSS-TODD, 1983; BLACK and HARDEN, 1995; WORRELL and HAMPSON, 1997; QUESNEL and CURRAN, 2000; BLOCK *et al.,* 2002; JURGENSEN *et al.,* 1997; JOHNSON and TODD, 1998, PRESCOTT *et al.,* 2000; JOHNSON and CURTIS, 2001; LATTY *et al.,* 2004). Soil compaction caused by heavy harvesting and extraction machines may indirectly affect the carbon balance of the mineral soil (JOHNSON *et al.,* 1991; JURGENSEN *et al.,* 1997; WORRELL and HAMPSON, 1997).

However, there are also many case studies that reported an increase of SOC in the upper mineral soil after tree harvesting and it is most likely that this increase was caused by transport processes (DOC, soil fauna, mechanically incorporation by heavy harvesting and extraction machines) from the organic layer and harvest residuals to the mineral soil (EDWARDS and ROSS-TODD, 1983; MATTSON *et al.,* 1987; HUNTINGTON and RYAN, 1990; MATTSON and SMITH, 1993; BLACK and HARDEN, 1995; JOHNSON *et al.,* 1995; OLSSON *et al.,* 1996; JURGENSEN *et al.,* 1997; DAI *et al.,* 2001; JOHNSON and CURTIS, 2001; YANAI *et al.,* 2003). The duration of this positive effect on SOC is unclear (JOHNSON and CURTIS, 2001), and it has to be emphasized that this effect refers only to net carbon gains in the mineral soil due to a translocation process. An increase of SOC after harvesting does not balance net carbon losses from the ecosystem due to the removal of tree biomass and the accelerated decomposition of dead organic matter after tree harvesting.

In contrast to the clear effects of intensive disturbance on SOC, the moderate disturbances studied at the Hainich-Dün resulted only in a trend towards higher SOC at the protected forest compared to the managed sites. A stand-age effect on SOC was not observed within a single rotation period, and SOC was not affected differently by shelterwood or selection cuttings. The lacking evidence for significant effects of moderate silvicultural practises on SOC can be interpreted with respect to the dominating effects of (1) soil-specific factors and their high spatial variability, (2) the favourable growing conditions at the Hainich-Dün, which allow for a rapid closure of canopy gaps, and (3) historical forest use.

The effects of varying soil texture and C:N ratio were excluded in this study statistically, but the remaining large variability of SOC within the study sites (*Figure 5*), reduces the strength of statistical tests for significant differences.

At the fertile sites of the Hainich-Dün the growth of the remaining trees and the natural regeneration recover the forest soil within a few years after canopy opening, and thus the time span of reduced litter input and increased decomposition rates is also relatively short. There are many studies that showed substantial effects of partial cuttings on air and soil temperature (MITSCHERLICH, 1981; LIECHTY *et al.,* 1992; BAUHUS and BARTSCH, 1995; BRUMME, 1995; CHEN *et al.,* 1995; REYNOLDS *et al.,* 1997; FLEMING *et al.,* 1998; BARG and EDMONDS, 1999; GRAY *et al.,* 2002; LAPORTE *et al.,* 2003) and on mineralization rates and cation losses (CLAYTON and KENNEDY, 1985; BAUHUS, 1994; VESTERDAL *et al.,* 1995; MESSINA *et al.,* 1997; BRADLEY *et al.,* 2001; PRESCOTT, 2002; RITTER *et al.,* 2005). However, these studies did not consider the duration of these changes, and they did not study changes of SOC.

Because of the historical forest use at HAI (see chapter "material and methods") $SOC_{0–15}$ may be lower than it would be without forest use. Thus, current $SOC_{0–15}$ at HAI does not reflect the entire potential for carbon storage in primary beech forests. Nevertheless, the observed trend to higher $SOC_{0–15}$ at the unmanaged site HAI may be related to the permanent dense canopy, which is opened only for relatively short periods of time (less than a decade) when single senescent trees break down, and which provides a stable and humid microclimate that in turn may promote the incorporation and stabilization of organic matter by the soil fauna. Large scale destructions of the forests at the Hainich Nationalpark by fire or windthrow are very unlikely. In addition, the production and decomposition of dead wood at the unmanaged site may substantially contribute to carbon inputs to the mineral soil. In the unmanaged forest dead wood is an additional carbon pool that was not available or at least only in very small amounts since humans have colonized the Hainich-Dün region. When these effects cumulate over time, it may be possible that the unmanaged forest will accumulate carbon in the mineral soil even though an equilibrium in tree biomass is reached.

Assuming that the observed difference in $SOC_{0–15}$ of about 6 tC ha^{-1} between the managed and the unmanaged sites was induced by the cessation of regular timber use 35 years ago, about 0.17 tC ha^{-1} $year^{-1}$ (= 6 tC ha^{-1}/35 years) have been accumulated in the mineral soil at the unmanaged site. This rate can be interpreted as a management-related carbon sink resulting from historical forest use followed by forest protection, and it may remain when tree biomass will have reached a steady state. In the past it was generally assumed that old-growth forests or primary forests are at or near a steady state with respect to the net carbon exchange between the forest and the atmosphere due to equilibrium between tree growth and heterotrophic respiration (e. g. ODUM, 1963; JARVIS, 1989; MELILLO *et al.,* 1996; RYAN *et al.,* 1997). In opposite, SCHULZE *et al.* (2000) and CAREY *et al.* (2001) postulated a residual carbon sink in unmanaged, old-growth forests. This postulate is confirmed not only by the trend to higher SOC at HAI, but also by 3 years of net ecosystem CO_2-flux measurements at HAI (KNOHL *et al.,* 2003; ANTHONI *et al.,* 2003; WERNER KUTSCH pers. comm.) and by studies in a 500-year-old Pseudotsuga-Tsuga forest (Washington, USA; HARMON *et al.,* 2004; PAW *et al.,* 2004).

Summarizing it can be assumed that intensive silvicultural practices cause net carbon losses from the organic layer and the mineral soil, even though there may be a temporal transport of carbon from decomposing harvest residuals and organic layer to the mineral soil. Moderate silvicultural practices in well growing beech forests affect the organic layer, but the mineral soil is only slightly affected or the effects are overridden by site-specific effects and/or long-term effects of historical forest use. Thus, in the mineral soil effects of moderate practices may be detectable only if they have cumulated over several decades to centuries. The small difference in mean $SOC_{0–15}$ between the managed sites at the Hainich-Dün region and the unmanaged site may be such a cumulative effect of the cessation of timber use about 35 years ago. A major challenge of future research is to quantify the long-term effects of historical forest use on current SOC and to separate them from the effects of recent forest management. A crucial precondition for these investigations is the establishment of representative long-term, managed and unmanaged study sites.

5. ABSTRACT

Forests cover about 31% of European land area (excluding CIS countries). Except for some protected or inaccessible areas, all of these forests are used by humans. The influence of different silvicultural treatments on timber production and the amount of carbon in tree biomass is well known. In contrast, data on the impacts of forest management, particularly of moderate silvicultural practices in hardwood forestry, on the amount of organic carbon in the mineral soil (SOC) are very limited.

A case study on differently managed European beech (*Fagus sylvatica*) forests in Germany showed that the successive removal of trees in a shelterwood system and a selection system reduces the amount of carbon stored in tree biomass on average by about 30% compared to an unmanaged forest. Biomass carbon at the even-aged stands of the shelterwood system showed a clear age-related maximum curve (maximum at a stand age of about 100 years: 230 tC ha^{-1}). Leaf litter resting on the mineral soil at the end of September before litter fall began (0.8–2.8 tC ha^{-1}) was mainly affected by annual leaf litter fall of the previous year and the basal area ($R^2 = 0.67$). Excluding the effect of variations in the clay content and the C:N ratio via statistical analysis soil organic carbon in the upper mineral soil (0–15 cm soil depth, $SOC_{0–15}$) did not correlate with stand age, and mean $SOC_{0–15}$ of the study sites or silvicultural systems (ranging between 40 and 48 tC ha^{-1}) did not differ significantly. These results indicate that the effects of disturbances due to shelterwood cuttings or selection cuttings on $SOC_{0–15}$ are small compared to the high small-scaled variability of soils, the favourable growing conditions at the Hainich-Dün region that allow for a rapid canopy closure after tree harvesting, and potential long-term effects of historical forest use. However, there was a trend to lower mean $SOC_{0–15}$ at the managed sites (42 tC ha^{-1}) as compared to the unmanaged site (48 tC ha^{-1}). This trend may represent a cumulative effect of the cessation of timber use at the unmanaged forest for the last 35 years.

The impacts of the investigated moderate silvicultural practices on the carbon budget of European beech forests were lower than

those reported for clear cuttings in temperate forests. A major challenge of future research is to quantify the long-term effects of historical forest use on the current amount of SOC and to separate them from the effects of recent forest management. A crucial precondition for these investigations is the establishment of representative long-term, managed and unmanaged study sites.

6. Zusammenfassung

Titel des Beitrages: *Der Einfluss waldbaulicher Verfahren auf den Kohlenstoffhaushalt von Rotbuchenwäldern.*

Wälder bedecken rund 31% der Landoberfläche Europas (ohne die Länder der Gemeinschaft Unabhängiger Staaten (GUS)). Mit Ausnahme einiger streng geschützter oder unzugänglicher Flächen werden all diese Wälder vom Menschen genutzt. Der Einfluss unterschiedlicher waldbaulicher Behandlungen auf die Stammholzproduktion und die in der Bestandesbiomasse gespeicherte Kohlenstoffmenge ist umfassend untersucht worden. Daten zum Einfluss der forstlichen Bewirtschaftung, insbesondere moderater waldbaulicher Verfahren der Laubholzbewirtschaftung, auf Kohlenstoffvorräte im Mineralboden hingegen sind rar.

Eine Fallstudie in unterschiedlich bewirtschafteten Rotbuchenwäldern (*Fagus sylvatica*) in Deutschland ergab, dass die sukzessive Entnahme von Bäumen im Schirmschlagbetrieb und im Plenterwaldbetrieb die Kohlenstoff-Vorräte in der Bestandesbiomasse gegenüber einem unbewirtschafteten, naturnahen Wald um rund 30% reduziert. Die Bestandesbiomasse der gleichaltrigen Bestände des Schirmschlagbetriebes folgte zudem einer Maximumkurve in Abhängigkeit vom Bestandesalter (Maximum im Bestandesalter von rund 100 Jahren: 230 tC ha^{-1}). Die Ende September (vor dem herbstlichen Laubfall) in der Blattstreu gespeicherte Menge an Kohlenstoff (0,8-2,8 tC ha^{-1}) wurde vor allem durch den Laubfall des Vorjahres und die Bestandesgrundfläche beeinflusst ($R^2 = 0.67$). Nachdem die Effekte der Variabilität von Tongehalt und C:N-Verhältniss auf die Kohlenstoffvorräte im mineralischen Oberboden (0–15 cm Bodentiefe, $Boden_{0-15}$-C) mittels statistischer Analyse eliminiert worden waren, ergab sich keine Korrelation zwischen $Boden_{0-15}$C und dem Bestandesalter. Die mittleren $Boden_{0-15}$-C-Vorräte der Untersuchungsstandorte bzw. der waldbaulichen Behandlungen (40-48 tC ha^{-1}) unterschieden sich nicht signifikant voneinander. Dies weist darauf hin, dass die Effekte moderater Störungen durch den Schirmschlagbetrieb und den Plenterwaldbetrieb auf die $Boden_{0-15}$-C-Vorräte gering sind im Vergleich zu der hohen kleinräumigen Variabilität des Bodens, den günstigen Wuchsverhältnissen im Hainich-Dün Gebiet, welche einen raschen Bestandesschluss nach der Baumernte ermöglichen, und möglichen Langzeiteffekten historischer Waldnutzung. Es zeigte sich jedoch ein Trend zu geringeren mittleren $Boden_{0-15}$-C-Vorräten in den bewirtschafteten Standorten im Vergleich zu dem unbewirtschafteten Standort (42 tC ha^{-1} im Vergleich zu 48 tC ha^{-1}). Dieser Trend könnte auf kumulative Effekte seit der Aufgabe der Holznutzung in dem unbewirtschafteten Wald vor etwa 35 Jahren hinweisen.

Der Einfluss der untersuchten, moderaten waldbaulichen Verfahren auf den Kohlenstoffhaushalt von Rotbuchenwälder war geringer als der Einfluss, der von Kahlschlägen in temperaten Wäldern berichtet wurde. Eine große Herausforderung zukünftiger Forschung ist die Quantifizierung von Langzeiteffekten historischer Waldnutzung auf die derzeitigen Bodenkohlenstoffvorräte und die Trennung dieser Effekte von denen der derzeitigen Bewirtschaftung. Eine unabdingbare Voraussetzung für derartige wissenschaftliche Untersuchungen ist die Einrichtung repräsentativer Dauerversuchsflächen in bewirtschafteten und unbewirtschafteten Wäldern.

7. Résumé

Titre de l'article: *Effets de la gestion forestière sur les quantités de carbone stockées dans les hêtraies.*

Les forêts couvrent environ 31% de la surface de l'Europe (sans les pays de la CEI). Si l'on excepte quelques territoires strictement protéges ou inaccessibles, toutes ces forêts sont utilisées par les hommes. L'effet des différents traitements forestiers sur la production de bois d'œuvre et sur les quantités de carbone stockées dans la biomasse des peuplements a été le plus étudié. En revanche, des données sur les conséquences des modalités de la gestion forestière – en particulier des méthodes sylvicoles douces appliquées aux essences feuillues – sur les quantités de carbone dans le sol minéral sont rares.

Une étude particulière menée en Allemagne dans des forêts de hêtre (*Fagus sylvatica*) a montré que les prélèvements d'arbres effectués dans la cadre de la coupe d'abri ou du jardinage diminuaient la quantité de carbone de 30% environ par rapport à celle présente dans une forêt naturelle, sans traitement. La biomasse des peuplements équiennes traités par la méthode de la coupe d'abri suit par ailleurs une courbe liée à leur âge (maximum pour les peuplements âges d'une centaine d'années: 230 tC h^{-1}). La quantité de carbone stockée dans la litière de feuilles à la fin septembre (avant la chute automnale des feuilles) – soit 0,8 à 2,8 tC h^{-1} – dépend avant tout de la masse de feuilles tombées l'année précédente et de la surface terrière du peuplement ($R^2 = 0{,}67$). Après que furent éliminés les effets de la variabilité de la teneur en argile et de celle du rapport C:N sur les quantités de carbone dans le sol minéral (profondeur du sol 0–15 cm, sol_{0-15}-C) en procédant à une analyse statistique, aucune corrélation n'apparut entre «sol_{0-15}-C» et l'âge du peuplement. Les quantités de C dans le sol entre 0 et 15 cm de profondeur suivant les stations étudiées ou les traitements sylvicoles (40-48 tC h^{-1}) ne présentent pas de différences significatives. Cela montre que les effets des perturbations modérées provoquées par la méthode de la coupe d'abri ou par le jardinage sur la quantité de C dans le sol_{0-15} sont faibles par rapport à la grande variabilité du sol à petite échelle, aux conditions de croissance favorables de la région Hainich-Dün, qui permettent une rapide fermeture du peuplement après la récolte, et enfin aux conséquences possibles sur le long terme de l'utilisation historique de la forêt. Toute fois est apparue une tendance à une quantité moyenne plus faible de C dans le sol0-15 des stations gérées forestièrement que dans celles qui ne le sont pas (42 tC h^{-1} contre 48 tC h^{-1}). Cette tendance peut donner des indications sur les effets cumulatifs depuis l'abandon il y a 35 ans environ de la récolte de bois dans une forêt aujourd'hui non exploitée.

L'effet des méthodes sylvicoles douces étudiées sur les quantités de carbone dans les hêtraies était beaucoup plus faible que celui provoqué par des coupes à blanc dans les forêts tempérées. La recherche se doit à l'avenir de quantifier les effets à long terme de l'exploitation historique des forêts sur les quantités de carbone actuellement stockées dans le sol, puis de déterminer comment ceux-ci auront tendance à évoluer avec les méthodes de gestion actuelles. Un préalable incontournable à des recherches scientifiques de cet ordre est la création de placettes d'expériences permanentes représentatives dans des forêts exploitées et non-exploitées.

J. M.

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Management of Mexican Community Forests with Timber Production Objectives

(With 1 Figure and 2 Tables)

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1. INTRODUCTION

Forest Management is normally conceptualized as the process that produces multiple goods and services from forests. However, forest structure and composition are most commonly manipulated for the purposes of producing timber. Forest management for timber production usually assumes that the decision making process is conducted by a single owner or decision maker who wishes to maximize profits from forest production and where the production or maintenance of positive externalities is considered a cost for the forest owner. Hence, most of the classical and neoclassical forest management approaches at the stand, forest and landscape level include these assumptions. However, real life forest management often does not fit into this framework.

Community Forest Management (CFM) is one example of forest management where neoclassical approaches to forest management are not completely suitable. CFM may be defined as forest management where the decision making process is under the control of a local community that owns the property rights of the land and the timber. In this case the decision making process involves more actors than in traditional forest management. This set of community actors may additionally have multiple objectives which can not necessarily all be optimized. These objectives might vary not only according to the characteristics of the forest stands, as traditional forest management dictates, but principally according to the governance structure of the community, including the distribution of property rights among community members, the decision making process they follow and social and economic characteristics of the community. As noted by KELLERT et al. (2000), achieving the goals of CFM is a complicated and organizationally challenging task. Beyond technical constraints and challenges, CFM requires reconciliation of diverse and sometimes conflicting interests within the community (NYGREN, 2005), the alignment of community's governance's structure with an efficient decision making process of forest operations, the definition of an appropriate incentive mechanism for community participation, not only in forest related tasks, but also in the conservation of forest lands and the promotion of linked activities according the property rights distribution, as well as the blending of diverse levels of formal and informal institutions (KLOOSTER, 2000a). The recognition of this complexity makes CFM a problem much more difficult than the traditional forest management problem.

This type of forest management occurs in many regions where forests are owned collectively, particularly in the developing world where communities are frequently composed of indigenous people (BRAY et al., 2005). CFM has a long tradition in some countries such as Germany, Austria, the Scandinavian countries, Italy and France where some common property forests have been managed through contracts for centuries (PESONEN, 1995; CASARI and PLOTT., 2001; CASARI, 2002; HERBST, 2004). However the developing world offers the study of CFM where the management rests in the hands of poor communities in most of the cases in absence of explicit contracts, but under the presence of clear internal rules as well as a governance structure and social capital that make CFM a viable alternative to forest management. Examples in the Peten of Guatemala (GRETZINGER, 1998), Peru, Brazil, (LOAYZA VILLEGAS and CHOTA VALERA, 1996; D'OLIVEIRA et al., 1998), Bolivia (CRONKLETON, 2002), Honduras (NYGREN, 2005), many African countries (CAMPBELL and SHACKLETON, 2001) and Mexico (BRAY et al., 2003) show that this type of management may be both sustainable and possibly contribute to poverty alleviation.

This paper characterizes CFM in Mexico by using data from National Forestry Inventories for 1993 (DGPF, 1994) and 2000 (VELÁZQUEZ et al., 2002), locality and municipality data for 1990 and 2000 from the population census conducted by the National Institute of Statistics and Geography (INEGI), a survey of 450 forest communities conducted in 2002 by the Instituto Nacional de Ecología (INE), the University of California at Berkeley and the World Bank (INE, 2002) and a survey of 47 forest communities conducted by INE in 2004 (INE, 2004).

This paper emphasizes some basic elements of CFM and discusses to what extent certain physical and technical variables might be relevant to ensure that CFM might effectively mitigate forest degradation and fragmentation as well as rural poverty. The paper is divided as follows; the next section shows some descriptive statistics on Forest Communities, then section three characterizes only those communities with timber harvest activities, emphasizing their production system, forest management strategies and some relevant socioeconomic information. The fourth section deals with forest conservation in these communities introducing an econometric model that shows the relevance of variables related to the forest production system in defining forest land conservation. Finally, the last section presents some conclusions.

2. CHARACTERIZING FOREST COMMUNITIES (FC's)

The total forest area in Mexico covers close to 65 million hectares. About half of this area is occupied by tropical forests (49%) and the rest is dominated by temperate forest, mainly pine and pine-oak forests (VELÁZQUEZ et al., 2002). Forest areas are especially important for their diversity, resulting from the variety of climatic conditions, topography, and the connection of two biogeographic zones (neartic and neotropical) within the Mexican territory (CONABIO, 2000). Particularly important is the richness of the tropical forest areas, which concentrates most of the genetic diversity, estimated to include as much as 10% of global biodiversity (BENÍTEZ and GONZÁLEZ, 1997).

It is estimated that from 10–15 percent of the forests in the country are public property, mostly in the National System of Protected Areas (SINAP) where some private and communal properties are also included. Private owners hold between 15 to 20 percent of the forest lands, usually located in highly productive lands. The remainder of the forests, and the vast majority (65–70%), is in the hands of communities with collective land grants (in two categories known respectively as *ejidos* and *indigenous communities*) given as part of the agrarian reform programs stemming from the Mexican Revolution. These communities are currently organized as agrarian villages with the possibility of having full private property rights on agricultural land but where forests are required to be maintained as a common property. This is the result of 1992 agrarian reforms that exempt forests (temperate and tropical) from privatization. These FC's have different levels of organization as well as different history and cultural identity.

Mexico has a total of 29,932 *ejidos* and *indigenous communities* (TINOCO, 2001) and there exists information on basic statistics for 99.3% of them. This information suggests that almost 58% of the total forest area is under communal property (*Table 1*) with an average size of 2,324 ha. On average, these communities have 32% of their land covered by forests.

Some forest communities are composed of indigenous people with a long tradition of dependence on natural forest extraction, mainly in the form of non timber forest products. Indigenous villages living in forest areas account for almost 43% of the indigenous villages in the country[1]. These villages are usually very isolated, lacking most public services, with few opportunities for development, and representing the highest levels of poverty in the country. On the other hand, this type of FC struggles to keep their cultural and social traditions in spite the external pressure that jeopardizes their organization and production systems (LARSON y SARUKHÁN, 2003).

Indigenous forest villages are mostly located in the temperate forests and only 37% of them are located in tropical regions where a large percentage of the most biologically diverse regions of the country are found (TOLEDO et al., 1994). Approximately 20% of these communities are thought to have timber harvest activities (ESTEVA, 2004).

The remainder of FC's are composed of non-indigenous people who may have less historic forest dependence and who very often use forest resource availability either to increase direct income or to provide some lacking public services in the villages through timber harvest. Sometimes these FC's are not well organized, which may lead to strong negative impact on the forests due to illegal harvesting, intentional forest fires or the application of non sustainable forest practices. However, there exist some cases where these communities are well organized, showing an alternative way to make

[1]) Own estimate based on the distribution of indigenous localities (INEGI, 2000) and the National Forest Inventory (VELÁZQUEZ et al., 2002). Toledo (1998) estimates that as much as 90% of the indigenous people in Mexico lives in Forest areas.

Table 1

Distribution of forest communities in Mexico.

Verteilung der Waldbauern-Gemeinschaften in Mexiko.

Forest area (ha)	Number of Forest Communities	Average Forest area (ha)	Total area (ha)	Share (%)
Less than 20	962	9	8,344	0.02
From 21 to 100	1,843	58	106,478	0.29
From 101 to 500	4,511	263	1,185,592	3.22
From 501 to 1,000	2,427	723	1,755,409	4.76
From 1,001 to 5,000	4,544	2,263	10,285,281	27.90
From 5,001 to 10,000	884	6,960	6,152,963	16.69
From 10,001 to 100,000	675	21,828	14,733,903	39.97
More than 100,000	13	202,490	2,632,364	7.14
Total	**15,859**	**2,324 (av)**	**36,860,334**	**100.00**

Source INE, 2005

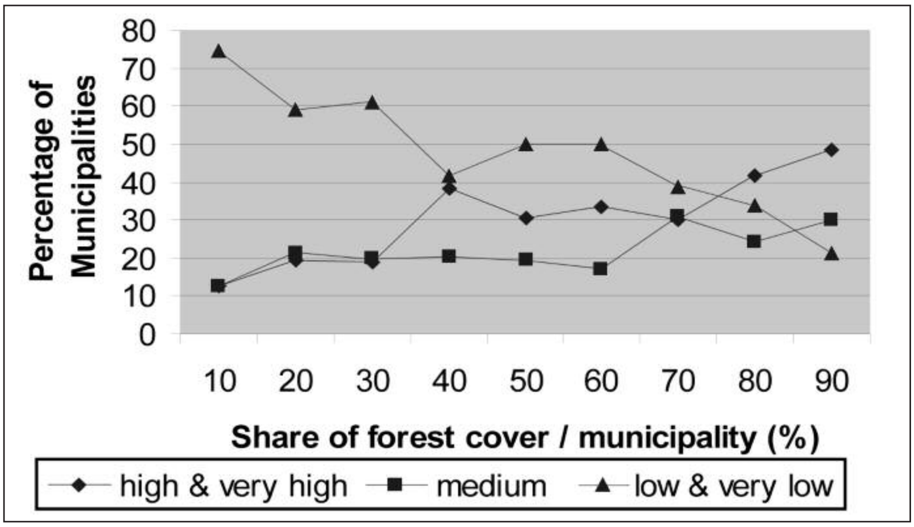

Fig. 1

Share of poverty classes (high poverty to very low poverty) by municipalities according to the their forest extension.

Anteil der Gemeinden mit geringem bis sehr geringem Einkommen in Bezug auf ihre relative Waldfläche.

the transition to market forest activities while taking new measures to maintain forest productivity, biodiversity, and forest cover in their communities. This last type of communities usually manages their forest as common property[2] and very often is organized for the commercial production of timber in vertically-integrated enterprises. The third and the largest group of these forest communities is composed of villages without commercial logging activity, high rates of poverty and few opportunities to develop alternative economic activities.

Poverty as well as land degradation and fragmentation is common in forest areas throughout the country. A simple graphical analysis by municipalities shows that most of the poorest areas (according to the *Consejo Nacional de Población* – CONAPO, 1998) are located in forest lands. *Figure 1* shows the share of low, medium and high poverty municipalities according to the amount of forest areas they have.

As can be observed, the larger the share of forest lands in the municipalities, the larger the proportion of poor and very poor communities. MUÑOZ et al. (2005), estimate that as much as 86% of FC's with more than 100 hectares of forest are located in areas of high and very high poverty indices.

3. CHARACTERIZING COMMUNITY FOREST ENTERPRISES (CFE's)

The sector of FC's with timber harvest operations is usually known as Community Forest Enterprieses (CFE's). The rise of this sector is due to combinations of institutional, social, economic and physical factors. BRAY et al. (2005), argue that the agrarian reform laws accompanied by the massive forest land redistribution occurring during the period 1958–1976, where much of the forest land was delivered to local communities, created the foundation for the rise of a large CFE's sector. The effects of some forest policies, a tradition of rural activism, and the social capital embedded in Mexico's traditional rural communities have been additional ingredients in the large size of this sector (BRAY et al., 1993).

An unpublished study shows that 2,417 communities in Mexico received government authorized harvest permits[3] in 2002 (ANTINORI et al., ms). The average size of these communities is around 8,734 ha with an average forest cover of 52%. In these communities the size distribution is very wide, ranging from a few hectares (20 hectares of forest land) to more than 240,000 ha, although almost 68% of the communities have a total area smaller than 5,000 ha.

Total forest size and commercial forest size are important elements to ensure technical and economic efficiency of forest operations. SUTTON (1968, 1969, 1973) determined that per acre overhead costs in New Zealand for relatively small forests (2,500 acres 1,000 ha) were about 5 times those of large forest (more than 150,000 acres). Moreover, he estimated that forest tracts of less 50 acres were very expensive to manage. CUBBAGE (1982) studied the efficiency of different tract sizes under different logging systems including manual harvesting. He found that tracts less than 40 acres were very expensive to harvest. A quick estimate of a minimum size to perform commercial forest management under an even-aged management system yields that for a 60 year rotation with stands (harvesting tracts) ranging from 15 to 20 ha (roughly 40–50 acres), the size of the forest must be of the order of 1,000 ha. This estimate is more optimistic than CHAPELA's (2000) who argues that successful CFEs happen to have forests of at least 2,000 ha. Size of the forest area is also important to ensure that CFEs can provide sustainable livelihoods for community members. A simple estimate of the economically sustainable size for members of a CFE[4] shows that it has to have in average 6,000 ha. Based on these estimates it can be argued that a large percentage of CFEs should not be technical and/or economically efficient either to be managed under an even-aged management system (< 1,000 ha.) or to maintain a minimum wage for the community members. However, as will be

[2]) There is a wide variability of forms how community members organize to manage and harvest common forest lands such as total fragmentation with parcelized forests, subcommunity-level working groups, community level enterprises, and even unions of communities organized to market their timber or forest products or share costs to reach economies of scale.

[3]) This estimate includes Communities with timber and nontimber forest products harvest in temperate and tropical forests as well as arid zones.

[4]) Assuming: i) one community member needs at least to earn the minimum wage for a year (2004), ii) the community sells standing trees at average price (2004) iii) the community has average number of ejido members with no additional transaction cost and iv) the forest tract has the average timber yield (ANTINORI et al., ms), then the minimum size of the forest tract is close to 6,000 ha to produce enough profit to meet community owner's requirements.

argued later, this does not mean that the CFE can not be well managed technically or that it can not provide economic support for the community members.

Economic sustainabilty of the CFEs has been discussed by several authors. They have found that it depends principally on both profitability and competitiveness. In the short run, the competitiveness is guaranteed for some CFEs because of the high quality of their forest resources (TORRES et al., 2005) or the scarcity of their products, as is the case of the tropical products (MOTA, 1985). However, for most of the CFEs timber quality is not that high (MERINO, 1997). In addition, the combined effect of high harvesting, logging and industrialization costs, which are very high compared with international standards (MOTA, 2002), plus the extremely low investment in the forest as well as other assets jeopardize the long term economic sustainability of these CFEs.

Profitability of CFEs has been discussed by some authors. It has also been argued that CFEs force a reconsideration of theories of the firm, and can not be treated in the same way as a profit maximizing firm (ANTINORI and BRAY, 2005). They also have tax exemptions and most of them have sunk cost which will never be considered, as a consequence, the opportunity costs of forest labor are often lower than official minimum wages and the true costs of management and the multitude of marketed and non-marketed benefits distort comparisons (PUTZ, 2000).

CFE's bookkeeping is in general not very clear since variables such as depreciation and many legal accounting obligations are not considered, which makes it more difficult to estimate profits. ANTINORI (2000) estimates gross margin levels (sales less labor and materials) in the state of Oaxaca ranging from 32 to 54%. However, other estimates show lower levels of profit and a high risk of going broke (CHAPELA, 1996; MOTA, 2002). In any case, most of the CFE's provide economic and social benefits, building the basis for community development, and meeting a set of multiple socioeconomic objectives such as generating employment, individual subsistence uses, provision of public goods, a sense of community solidarity, and social welfare purposes which are not aligned with a profit maximizing firm.

CFE's have usually additional sources of income such as harvesting of non timber forest products (NTFP) or the sale of environmental services. The INE's surveys (INE, 2002, 2004) show that 53% of CFEs have NTFP activities. These activities in general are seasonal and strongly dependent on market demand. They are normally performed by young and old people, community members with no property rights and the poorest community members (TORRES and ZAMUDIO, 2002). Selling environmental services has become another source of income; the INE (2002) survey shows that 7% of CFEs are engaged in different types of projects related to environmental services sales. Despite the diversity of forest related economic activities, for most of these communities off farm activities account for more than half of household incomes (DE JANVRY and SADOULET, 2001).

A review of 54 case studies in these communities has suggested that forest communities obtain up to 22% of their total household income from forest activities (VEDELD et al., 2004). The 75 CFE's sampled in both INE's surveys (INE, 2002, 2004) reveal that 35% of the households in these villages have been classified as living below the poverty line according to the Mexican government's human capital investment program OPORTUNIDADES[5]. This figure contrasts with the whole sample from both surveys (470 forest communities), where 43% of households are estimated to be living below the poverty line. Such a difference enforces the statements that extremely poor forest communities have limited access to timber harvest activities and that the CFEs might be a means of poverty alleviation. However, this poverty alleviation seems to be seasonal and in some regions is not enough to sustain a good living standard.

3.1. Production system of Forest Community Enterprises

Communities engaged in commercial logging have many different ways to organize themselves for production. Timber harvest implies the organization of the community at various levels to develop a wide variety of tasks in different seasons, from protection and conservation activities, to the marketing of forest products.

CFE's organize themselves at various levels of vertical as well as horizontal integration. Vertical integration has been widely documented (ANTINORI, 2000; ANTINORI and BRAY, 2005). It occurs when the community is engaged in all different activities of the forest production system, which can vary from selling timber on the stump through contracts with little direct community involvement, to communities with advanced processing such as moldings and furniture with export markets, and diversification into other forest products such as water bottling and ecotourism (BRAY et al., 2003).

Most of the CFE's in Mexico are not vertically integrated. Close to "54% of them sell standing trees with limited participation in logging activities; 35% sell logs with almost no value added labor (I1) and 11% sell sawn wood (I2) processed under different levels of quality (ANTINORI et al., ms). Community participation for Non Integrated CFE's (NI) is reached through conservation activities and seasonal or temporary labor force paid by the contractors. For the case of communities with First level of integration (I1), community participation can go from felling, logging and yarding activities up to log transportation. Finally, CFEs with a second level of integration (I2) include additional participation in the industrialization at different levels.

Vertical integration depends on many different factors such as the level of human capital skills in forest operations, education, organizational and social capital as well as the size and commercial quality of the forest. Asset ownership and road infrastructure availability promotes vertical integration especially when markets are not complete as it is the case in the log or stumpage markets (ANTINORI, 2000).

Horizontal integration has been less documented than vertical integration. It happens when communities selling similar products converge in one enterprise or association to reach economies of scale or additional market power. CFE's horizontally integrated vary in contracts and levels of integration. Some communities just agree on the location of sawmill that they will use year to year in order to reduce costs (CHAPELA, 2000). Others agree on the acquisition of equipment, infrastructure or services that are commonly used to reduce high fixed costs (MOTA, 2002; NASCIMENTO and MOTA, 2004), however, in spite of the fact they are integrated through some kind of arrangement, rarely act as a unique firm. In some regions, these communities agree on pricing products or services acting more than a cartel rather than a horizontally integrated enterprise (MOTA, 1985).

There are not that many cases of communities horizontally integrated. ANTINORI (2000) has suggested that local decision-makers' preferences for autonomy and avoid bargaining costs, even from other agrarian communities, may be a reason. Nascimento and MOTA (2004) have also suggested that the lack of inexpensive accountability mechanisms as well as the lost of rights to receive additional help from development and resource conservation programs are incentives to not to integrate. However, horizontal integration is expected to happen as large community sawmills with

5) This is a cash transfer program conditional on children's school attendance and health monitoring (JANVRY and SADOULET, 2005).

long idle time become too costly for the CFE. Some examples have been already documented where CFEs buy additional log volumes from their neighbor communities (MOTA, 2002; TORRES et al., 2005).

3.2. Community Forest Management

CFE's rose in the early 70's in northern Mexico. Most of the forest management, harvesting and industrialization techniques were inherited from concessionaire and large state owned companies (Merino y Segura, 2005). The forest management practices were limited to scarce thinnings, fire prevention and regeneration cuts through selective cutting. Forest regeneration has been done mostly natural with little reforestation, which are usually done in more vertically integrated CFE's. Data from INE (INE, 2002; 2004) reflects that 41% of CFE's do not reforest at all. Among those that reforest, the ratio of reforested area to forested area is in average as low as 0.2%[6] and the average survival rate of hectares reforested is only 62%. The most advanced CFEs concentrate reforestation efforts on burned areas as well as those affected by hurricanes. However, most of the reforestation efforts are done in degraded areas and accompanied by government subsidies either to acquire seedlings or equipment as well as to compensate labor.

Silvicultural activities have improved in some regions. Government has promoted silvicultural practices such as pre commercial and commercial thinnings and pruning through monetary incentives and equipment donations. Some CFEs have engaged in training and research programs, resulting in the development of their own best management practices to deal with problems such as: appropriate harvesting (VESTER and NAVARRO, 2005), forest regeneration (SNOOK et al., 2003; WALTER et al., 2005), pest management as well as strategies for forest fires prevention and control (RODRÍGUEZ and FULÉ, 2003).

Continuous cover forestry (CCF), involving selective harvesting (GADOW et al., 2002), was the official forest management strategy until the middle of the 70's for both tropical and temperate forests. In the late 70's rotation forestry (RF) was introduced in the northern part of the country for temperate forests and rapidly expanded to southern and central Mexico. Despite the system was tested in medium to large properties, it was also used in small to medium forests, which often caused rapid liquidation of the surplus growing stock which in some cases led to land use change. In recent years CFE's under RF systems have started to combine the treatments with CCF systems, which appear to be more efficient (CHAPELA, 2005). Tropical forest management in FC's is done under selective cuttings relatively well organized to regulate timber harvest. However, most of the harvesting is done in high value species and the inherent deficiencies of the method applied in tropical regions (FREDERICKSEN, 1998) jeopardize the sustainability of some communal tropical forest under timber management, especially when regeneration is not ensured or when the spatial distribution of timber harvests is not ecologically suitable (TORRES et al., 2003).

Techniques to optimize harvest schedules and monitor forest dynamics are used by a few CFE's; some of them with a long history of technical development particularly in northern Mexico. However, these tools are not available for most of the CFE's, which in addition present severe gaps on training in logging and harvest scheduling.

Mexico has 34 CFE's under certification (CCMSS, 2005) covering close to 612,000 ha. A large proportion of Certification has advanced because of subsidies from NGO promoters and government regulators not because of tangible economic benefits derived from markets (KLOOSTER, 2004). The apparent lack of a price premium for certified products has created a paradox, since this presumed market incentive for forest products based on good management practices is not generating the additional income that was supposed to be used to invest in sustainable management practices (GEREZ and ALATORRE, 2005). Hence, supposed benefits for communities from certification such as recognition as good forest managers, improvements to forest management plans, better forest management activities, and a reduction in the negative environmental impacts due to logging are not tangible (KLOOSTER, 2004) and there is a low incentive to maintain certification. The use of improved management practices is relatively low. In addition, such management practices are not clearly defined for the wide diverse conditions in the country and for the CFEs perceptions and traditions as noted by PURNOMO et al. (2004) in other regions.

Timber yield in most of commercial forests owned by CFE's is low. Some authors have argued that this is the result of years of selective management and lack of knowledge to improve forest practices (MERINO, 1997; ALIX et al., 2005). This is true in some regions, however, it must be recognized the low timber productivity of most of the Mexican forests. Average yield in tropical forests ranges from 1.3–1.6 $m^3ha^{-1}year^{-1}$ (TORRES et al., 2003) for only mahogany or red cedar, while in temperate forests it ranges from 1.6–1.9 $m^3ha^{-1}year^{-1}$ for only pines and firs (DGPF, 1994). Harvest yields as reported from the forest Government agency are very variable, ranging from less than 05 $m^3ha^{-1}year^{-1}$ to more than 12 $m^3ha^{-1}year^{-1}$ which shows not only the variability of the forest yield but also the likely low control by the agency, as some harvest yields are far beyond the average yield.

4. FOREST CONSERVATION BY CFE's

Forest conservation has been a topic widely studied in Mexico's forests. There are works at various geographical levels which explore the socioeconomic drivers of deforestation, from pixel level (MUÑOZ et al., 2004), to municipality (DEININGER and MINTEN, 1999) and state level (TORRES and FLORES, 2001). However few of them have taken the FC as the study unit (DURÁN et al., 2004; ALIX-GARCÍA et al., 2005). The study by MUÑOZ et al. (2004) showed that the main correlates for deforestation nationwide were proximity to cities and rural population centers, low slope and soils appropriate for agriculture. This suggests that the main driving force behind deforestation is the relative profitability of agricultural and pastoral activities versus forest. ALIX-GARCÍA et al. (2005), using INE's survey (INE, 2002) found evidence that FCEs have higher overall deforestation as well as higher deforestation per capita than FCs without commercial timber harvest activities. For these comparisons they used land cover maps in digital format on a scale 1:250,000 for years 1994 and 2000.

By using the same data base plus the second INE's survey (INE, 2004) the same conclusion can be reached in spite of the fact that the additional sample has larger CFE's, as well as a larger proportion of CFE's with second level of vertical integration (I2) than the first sample (INE, 2000). With this combined data an attempt to explain deforestation in CFE's with forest management variables was made without considering some socioeconomic variables that might be influencing the deforestation process[7]. Results for the

[6]) This average figure do not reflect the important efforts made in some tropical FCE's, where focalized reforestation has notably improved the survival rate and seedling's population of mahogany in natural forests (SNOOK, 2005)

[7]) The lack of a good set instrument variables to identify the model was the main reason to exclude socioeconomic variables directly (ANGELSEN y WUNDER, 2003). In addition the model was fitted by using the generalized method of moments to account for the lack of omitted important exogenous variables and the likely non orthogonality of the variable vertical integration. The instruments for this variable were: presence of profits (0,1), nontimber forest products harvest (0,1), level of education (continuous) and municipal road density (km/ha).

model fit are shown in *Table 2* along the goodness of fit statistics. Note that the rate of deforestation varies according to the extent to which the forestry business is vertically integrated. Stumpage CFE's have a low rate of deforestation. This rate increases as the CFE integrates forward and reduces at high levels of vertical integration. Simple t-tests show that CFEs which are more vertically integrated have considerably lower deforestation rates than those who sell standing trees or logs. The highest variability in deforestation rates can be found in CFEs with a first level of integration (I1). These FC's sell logs and have a wide variability of arrangements for timber harvest, ranging from individual harvesting up to allow contractors to come into the community to harvest. Such variability in the governance structure of the forest tracts as well as the likely mismanagement from the contractors generally induced to reduce logging costs might be the cause of such high deforestation rates in this type of communities. This behavior seems logical, as one would expect that communities that had made larger investments in the Community Enterprise would be more concerned with the sustainability of their forests, their most important input.

Another interesting result is the effect of the management system. Note that the more intensive the management system the larger the deforestation rate. This result has two implications; the first one suggests that RF systems[8] might be leading to excessive liquidation of surplus forest stock in the FCE's which might look as a degradation of the forest stock. In addition, the large openings caused by regeneration cuts might be accompanied by land use changes. It is common to find in the central part of Mexico naturally regenerated areas turned into corn fields before the time legally imposed to have regeneration (10 years) is reached. The second implication is that intensive RF systems are very likely to make regeneration areas look like deforested patches in the satellite images, causing misinterpretation of deforestation processes. In any case, more research is needed to define the real effect of timber management on deforestation. This research should focus on improving the model identification when socioeconomic variables are incorporated as well as the quality of the land use estimates through the use of improved cartographic material in scale and resolution.

The type of vegetation, as expected, is important for explaining the deforestation rate. Tropical areas have a larger deforestation rate than temperate areas as has been widely documented in Mexico (VELÁZQUEZ et al., 2002). However, the type of community did not have the expected sign as one would expect that FCs with larger proportion of indigenous people (as is the case of communities rather than ejidos) would have a greater forest conservation sense. This result might be explained with the fact that these communities are performing timber harvest operations and an improved management can be obtained only through training and education, which happen to be very low in these communities.

Some authors have demonstrated theoretically that under some economic conditions the extraction of nontimber forest products could be no help to reduce deforestation (BRAZEE and SOUTHGATE, 1992), while others have predicted that society will drive up the prices of such products, increasing the value of the forest relative to other uses over time, as these forests become scarcer. On the other extreme, some assessments (PETERS et al., 1989; GODOY and BAWA, 1993; SIMPSON et al., 1996; GODOY et al., 2000; SHEIL and WUNDER, 2002) have lowered the high expectations of the economic and conservation benefits of NTFP. What seems to be a reality is that the bulk of forest products derives from secondary successions or low value temperate forest not from high timber value forests as is the case of most FCE's. However, it is also true that communities seek and place values on these resources in ways that differ significantly from the valuation of outsiders (ARNOLD and RUIZ, 1998) and that perspective must not necessarily be aligned with conserving biodiversity or economic returns derived from NTFP harvest (SHEIL and WUNDER, 2002). In this context the significance of the variable harvesting non timber forest products can be explained, since it might reflect the presence of well defined rules for harvesting forest products, or some mechanism to redistribute benefits among community members not receiving benefits from timber harvests. Both mechanism are aligned with conservation of the forest stock.

The choice of how to divide up profits between dividends and public goods has been considered the main determinant of deforestation per community member (ALIX-GARCÍA et al., 2005). Interestingly such a variable turned out to be non significant to estimate the rate of deforestation in our analysis. In any case, deforestation in FCE's is an important issue, and even high level of dependency on forest resources might not be enough to reduce the problem. DURÁN et al. 2004 emphasizes this issue, pointing out that even in communities that are very interested in sustainable management of their forests, the lack of access to good technical assistance and poor administration of existing resources can lead to excessive deforestation.

5. CONCLUSIONS

This paper shows the main characteristics of the timber management systems applied in forest communities in Mexico and pro-

[8]) Recall that seed trees are the most used natural regeneration method, which it is known as MDS which means Silvicultural Development Method.

Table 2

Determinants of rate of deforestation (dependent variable = rate of deforestation 1994–2000).

Variablen, die die Entwaldungsrate beeinflussen (abhängige Variable = Entwaldungsrate 1994–2000).

Variable	Parameter Estimate	Approx. T Ratio	Approx. Prob > |T|
Intercept	-0.426199	-2.504	0.0156
Level of Vertical Integration	0.210920	1.929	0.0594
Level of Vertical Integration (square)	-0.041005	-2.052	0.0454
Management System (1=CCF; 2=Mixture CCF, RF, 3=RF)	0.102299	2.638	0.0111
Picking NTFP (Picking = 1)	-0.070131	-1.847	0.0706
Type of vegetation (Temperate =0, Tropical=1)	0.125294	3.545	0.0009
Type of community (Ejido=0; Community=1)	0.120603	2.410	0.0197

Shea partial R-square = 0.3551; number of observations = 76, and Model Prob > F = 0.0009.

vides revised estimates on the attributes of such communities. It shows that the size of the forest owned by the community is a very important feature to ensure not only the survival of the FCE, but also, to reduce the pressure on the selection of the most appropriate timber management system.

Competitiveness of FCEs in the international markets could be temporarily ensured in very few of them. The estimated timber yields for such communal forests are far below international standards and costs associated to logging activities are amongst the highest in the world. A large proportion of these FCEs is viable because they are enjoying the liquidation of timber surpluses with high quality timber. This last feature is the main reason it makes some of them temporarily appropriate for an international market. However, such a liquidation is temporal and could jeopardize the survival of small to medium FCEs, especially those applying intensive timber management systems. Particularly vulnerable are those communities in tropical areas with low training and educations levels. Such communities will be relegated to harvest sporadically without the possibility to integrate vertically and with a high risk of losing their forest stock through land use changes. For this large proportion of FCEs public policy should focus on organization at different levels, horizontal integration, development of special markets and the opening of other rural development alternatives not in conflict with forest. The treatment of these communal forests should follow CCF type of systems trying to design incentives to reduce fragmentations in adjacent communal forests and to reduce the cost of large scale forest practices which usually are not covered by small FCEs. It is notable that for these communities, timber harvest activities do not represent a large proportion of the community member's income, however, presumably a good governance structure aligned with forest and community characteristics must be present to reduce negative impacts to the forest.

Some medium and most of the large communities have the potential to develop a continuous timber harvest activity that ensures direct benefits for some members and some compensation to the rest of the community in the form of public goods or services. However, it is very difficult that such communities could compete in the international market given their long term timber yields and cost structure. Nevertheless, they might serve as promoters of economic activities inside the communities or as buffers in the case of economic contingencies. Research is needed to define which governance structure or social capital characteristics must be promoted in this type of communities such that the survival of those FCEs can be ensured.

6. Zusammenfassung

Titel des Beitrages: *Eine Analyse der Waldbauerngemeinschaften in Mexiko.*

Dieser Beitrag liefert neuere Angaben über die mexikanischen Waldbauerngemeinschaften (Forest Community Enterprises, FCE's). Die Untersuchung zeigt, dass die Größe des Waldeigentums ein entscheidender Faktor ist, der u.a. die Überlebenschancen der FCE's beeinflusst. Die Erträge sind vergleichsweise gering während im globalen Vergleich die Holzerntekosten als besonders hoch eingestuft werden. Dennoch sind zahlreiche FCE's derzeit rentabel, weil sie hohe Vorräte an hochwertigem Holz nutzen können. Die Liquidierung dieser Vorräte ist nicht immer im Einklang mit der Nachhaltigkeit. Dadurch werden die Überlebenschancen der kleinen bis mittelgroßen Gemeinschaften verringert, insbesondere dort, wo intensiver Waldbau betrieben wird. Die Waldbauerngemeinschaften in den tropischen Regionen mit niedrigen Ausbildungstandards sind besonders gefährdet. Die Holznutzung in diesen Gemeinschaften ist sporadisch und das Risiko, das Waldeigentum durch Änderungen der Landnutzung zu verlieren, ist hoch, daher ist eine vertikale Integration kaum möglich. Für diese relativ zahlreichen FCE's sind politische Maßnahmen erforderlich, die sich u.a. mit der horizontalen Integration, der Entwicklung spezieller Märkte und alternativer Landnutzungen befasst, die nicht mit dem Waldschutz konkurrieren. Die Autoren argumentieren, dass für die Nutzung der Wälder der Waldbauerngemeinschaften das Dauerwaldprinzip mit selektiver Einzelbaumnutzung (Continuous Cover Forestry, CCF) am besten geeignet ist. Dadurch können die Waldfragmentierung verhindert und die Kosten großflächiger Holznutzungen vermieden warden. Es ist bemerkenswert, dass die Holznutzungen in den Waldbauerngemeinschaften nur einen geringen Anteil am Einkommen der Mitglieder ausmachen. Negative Auswirkungen der Waldnutzung können durch klare, an die jeweiligen Eigenheiten der FCE's angepasste, Entscheidungsstrukturen reduziert werden. Einige der mittelgroßen und die meisten der großen Waldbauerngemeinschaften besitzen das Potential zur Entwicklung einer kontinuierlichen und nachhaltigen Waldnutzung, mit direktem Nutzen für einige Mitglieder sowie der Möglichkeit, öffentliche Güter und Dienstleistungen für den Rest der Gemeinschaft sozusagen als Kompensation bereitzustellen. Dennoch erscheint es wegen der langen Produktionszeiträume und Kostenstrukturen sehr schwierig, die FCE's international konkurrenzfähig zu machen. Allerdings können sie als „Motoren" ökonomischer Aktivität innerhalb der Gemeinschaft eine wichtige Rolle spielen. Zusätzliche Forschungen sind notwendig, um zu erkunden, welche Entscheidungsstrukturen und welche Merkmale des sozialen Kapitals gefördert werden müssen, um das Überleben der FCE's zu gewährleisten.

7. Résumé

Titre de l'article: *Etude sur les communautés de sylviculteurs au Mexique.*

Cette contribution livre de nouvelles informations sur les communautés mexicaines de sylviculteurs (Forest Community Enterprises, FCE's). Cette recherche montre que la taille des propriétés est un facteur déterminant qui, entre autres, conditionne les chances de survie des entreprises. Les revenus sont relativement faibles alors que, d'après une comparaison globale, les coûts d'exploitation des bois se classent parmi les plus élevés. Cependant de nombreuses FCE's sont actuellement rentables car elles peuvent exploiter un volume sur pied important et constitué d'essences de grande valeur. Une belle liquidation de ce capital n'est pas toujours harmonieusement accordé à la gestion durable. De ce fait les chances de survie des petites et moyennes communautés sont réduites, en particulier là ou l'on pratique une sylviculture intensive. Les groupements forestiers dans les zones tropicales où les standards de formation sont bas sont particulièrement menacés. Dans de telles communautés les récoltes de bois sont sporadiques et le risque est considérable de voir les forêts disparaître au bénéfice d'autres mises eu valeur du sol; dans ces conditions une intégration verticale est à peine possible. Pour ces FCE's relativement nombreuses des mesures politiques sont indispensables; elle devront, entre autres, concerner l'intégration horizontale, le développement de marchés spécialisés et les utilisations alternatives des sols n'entrant pas en concurrence avec la protection des forêts. Les auteurs défendent la thèse que pour l'exploitation des forêts de ces communautés c'est le principe de la durabilité qui convient le mieux, avec une exploitation sélective par arbres – du type jardinatoire (Continuous Cover Forestry, CCF). Ainsi on évitera la fragmentation des forêts et on limitera les coûts lies aux exploitations sur des grandes surfaces. Il est intéressant de remarquer que dans ces FCE's les récoltes de bois ne constituent qu'une faible partie des rentrées d'argent des membres des groupements. Des conséquences négatives de l'utilisation des forêts peuvent être diminuées par des structures de décisions transparentes, adaptées aux caracté-

ristiques propres à chacune des FCE's. Ces communautés de sylviculteurs ont le potentiel d'un développement continuel et durable de la production forestière avec une exploitation directe par certains de leurs membres et également la possibilité d'assurer des productions d'intérêt général et des services au reste de la communauté, à titre de compensation pourrait on dire. Cependant il apparaît très difficile de rendre ces FCE's concurrentielles au niveau international eu raison de la longueur des périodes de production et des structures des coûts. Néanmoins elles peuvent jouer un rôle important en tant que «moteurs» de l'activité économique au sein de la communauté. Des recherches complémentaires sont encore nécessaires pour déterminer quelles structures de décisions et quelles caractéristiques du capital social doivent être appuyées pour garantir la survie des FCE's. J. M.

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Balancing between set-aside and forest management activities of stands using integrated stand and forest level optimization

(With 3 Figures and 1 Table)

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Forsteinrichtung; Bestandesplanung; Naturschutz; Optimierung.

1. INTRODUCTION

Conventionally, there are two major conservation strategies in forestry: 1) the *segregation strategy* where protected areas (so-called set-asides) and production areas are spatially segregated and 2) *the multiple use strategy* which incorporates nature conservation into forest management for timber production. Traditionally, decisions on forest management strategies and corresponding rules for management practices are usually made at regional and national level by forest policy makers. Thus, set-asides are treated separately in land-use planning, they are not part of forest management planning.

A more practical approach is to offer greater freedom to forest owners to choose where, when and how they wish to implement the set-aside areas and the forest operations on their properties (see e.g. PARVIAINEN and FRANK, 2003). For example, in Finland silvicultural recommendations, which specify the rotations and the timing and intensity of thinning at stand level, give only minimum requirements such as the minimum regeneration age or the minimum amount of trees that should be left growing after thinning (YRJÖLÄ, 2002).

The multiple goals set for products and services including benefits from nature conservation vary between forest owners. In addition, the production potentials of different forest goods and services depend on available forest resources and their management. Therefore, the optimum combination of set-asides and stand level management activities should be identified separately for each individual forestry unit. In principle, the problem can be solved analytically through optimisation when the consequences of different management options in respect to the utility of decision maker are known (e.g. PUKKALA et al., 1995). However, it is not always easy for forest owners to define their overall utility without prior information on the production potentials of their forest resources.

The aim of this paper is to introduce a method for balancing between set-aside and forest management activities of stands to achieve multiple goals for a given forestry unit. The method is implemented in the Finnish MELA system (SIITONEN et al., 1996; REDSVEN et al., 2004) based on integrated stand and forest level optimization. In addition, a case study is presented to illustrate the method 1) in the analysis of production potentials under different management strategies and 2) in the simultaneous location of set-asides and management activities for a forest area in Finland.

2. METHOD

The MELA system is based on integrated stand and forest level optimisation where the management of stands is solved endogeneously based on forest level goals (for methodological details see LAPPI, 1992; GADOW and BREDENKAMP, 1992; SIITONEN, 1993; NUUTINEN et al., 2000; HOEN et al., 2001; CHEN and GADOW, 2002). In the MELA system, the potential range of stand management schedules or paths[1] over space and time is used as input for the optimisation. For this purpose, the MELA simulator automatically generates a number of alternative management paths over time for each stand. The alternative paths for a particular stand represent a decision tree (*Fig. 1*).

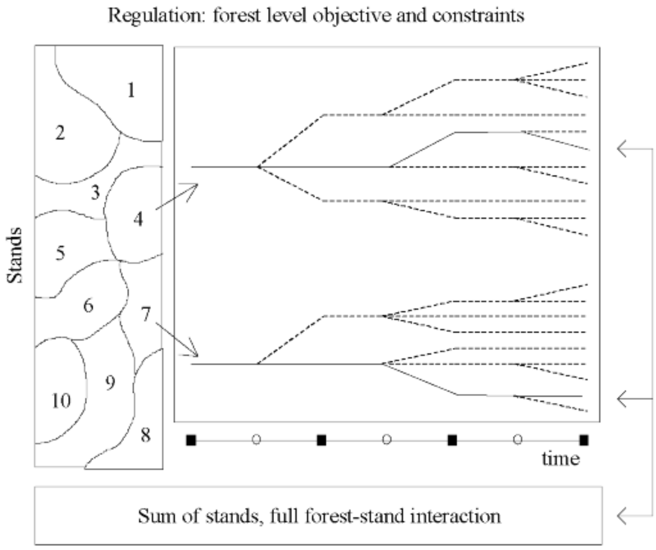

Fig. 1

Schematic representation illustrating the principle of integrated stand and forest level optimisation. Source: SIITONEN et al., 1996.

Schematische Darstellung zur Illustration der Verknüpfung von bestandesweiser und betrieblicher Optimierung. Quelle: SIITONEN et al., 1996.

The basic simulation elements of a particular management schedule are states and events. The events consist of natural processes and management activities defined by the built-in basic event routines. The task of the basic event routines is to evaluate the feasibility of the basic events for each state of the stand, to simulate the details of the basic events (such as the value of standing trees or the cost of harvesting), and to collect the summarised variables (such as income from timber sales and costs due to silvicultural, improvement and harvesting operations).

In the MELA system version 2002 (REDSVEN et al., 2004), the basic event routines for natural processes cover ingrowth, upgrowth and tree mortality. The development of the growing stock is predicted for the sample trees of the sample plots at five-year time steps, by using a set of individual-tree models based on empirical studies (HYNYNEN et al., 2002). The main simulation variables are the number of stems per hectare, tree species, diameter, height and age. In the MELA system only expected values of the models are used in the simulation, i.e. the stochastic variation in natural processes is not explicitly taken into account.

The basic event routines for management activities include artificial regeneration, clearing of regeneration areas, soil preparation, tending of young stands, tree felling operations, ditching, fertilisation, pruning of pine, and changing the values of stand variables. There are six cutting methods available for event definitions: thinning where instructions are based on basal area, thinning where instructions are based on number of stems, clearfellings, seed-tree cutting (for natural regeneration of pine, birch and aspen), shelterwood cutting (for natural regeneration of spruce) and removal of the overstorey. The event parameter of the MELA system makes it possible to define a set of optional events for each simulation application within the built-in event routines and their arguments. For example, the simulation of a thinning based on basal area specifications can be regulated using the parameters concerning thinning intensity, selection of tree size, selection of tree species and minimum removal per hectare. Correspondingly, the rotation period can be determined by the basal area weighted breast height diameter and/or stand age.

Logging costs are calculated as a function of time expenditure and unit costs. The time-consumption models of RUMMUKAINEN et al. (1995) and KUITTO et al. (1994) are used in the MELA system version 2002 (REDSVEN et al., 2004). In these models the most important factors affecting time consumption are stem size, number of removed trees, cutting method, the cutting drain and the off-road distance. In each cutting alternative for a stand, MELA uses the logging practice with the lowest total costs unless the user defines otherwise.

The value of standing trees is calculated based on the unit prices for wood assortments and the volume of those wood assortments derived separately for each stem. The prices in the MELA system are constant and exogenous and the capital markets are assumed to be perfect, i.e. money can be saved and borrowed in unlimited quantities at the same rate of interest.

The wood production process comprises a set of sequential actions, and the time interval between these actions can be very long. Therefore, the generally accepted way to handle time in forestry is the net present-value (NPV) method. In the MELA system version 2002 (REDSVEN et al., 2004), NPV is calculated for each management schedule applying the principles of the Faustmann formula and incorporating three components (see REDSVEN et al., 2004, p. 461–463). The first component includes the revenues from cuttings (gross income with roadside prices) and costs due to silviculture, forest improvement and harvesting during the user-defined analysis period. The second component represents the revenues and costs from the end of the analysis period until the end of the on-going rotation period. The simulation of each management schedule is continued by automatically selecting the first feasible

[1]) A management path is a unique succession of management activities.

event for each new state without alternatives until the regeneration criterion or the unconditional termination of the simulation period (typically 150 years) is met. In the latter case, the standing value of the stand is calculated instead of the regeneration of the forest. The third component covers the value of bare land representing the revenues and the costs from the rotation periods after the overall simulation period. The NPV of the whole forestry unit is the sum of the stand NPV's.

After the simulation, an optimal combination of management schedules for individual management units is selected (see *Fig. 1*) using the JLP optimization package (LAPPI, 1992). JLP is a linear programming (LP) software package designed especially for management planning systems based on integrated stand and forest level optimisation.

3. CASE STUDY

3.1 Material

The case study was carried out using simulation and optimization tools of an internet application of MELA (DemoMELA 2005). The summary results of DemoMELA were used to draw the production frontiers (*Fig. 2*) and to compare the alternative plans (*Table 1*). The stand level results were exported to a GIS (ArcMap) to draw thematic maps (*Fig. 3*).

The case study area (Project K127-152 at DemoMELA, see *Fig. 3*) consisting of 26 stands covers 70.2 hectares in timber production. Most sites represent the medium fertility class (*Myrtillus* and *Vaccinium* types). The dominant tree species is Scots pine (67 percent of standing volume), and the rest is Norway spruce (20 percent of standing volume) and different deciduous species. Only about 30 percent of the forested area is covered by stands more than 80 years old and could be regenerated during the forthcoming 10 year period.

Two different sets of management schedules corresponding to different management strategies were simulated for the period of 50 years. In the first set (referred to as Standard), all typical forest management operations (artificial regeneration, clearing of regeneration area, soil preparation, tending of young stands, different types and intensities of thinning and regeneration cuttings) were simulated as options where and when feasible (i.e. every time when the specific minimum requirements are met) according to current silvicultural recommendations (YRJÖLÄ, 2002). The regeneration options included clear cutting followed by planting or seeding, and natural regeneration with seed trees of pine and birch, or shelterwood of spruce. Natural regeneration was simulated for pine on less fertile sites and for spruce and birch on medium fertile or fertile sites. Planting was simulated for pine on medium fertile and less fertile sites, and for birch and spruce on medium fertile and fertile sites. Seeding was simulated for less fertile sites.

In the second set (here referred to as Nature-oriented and in DemoMELA as Less-intensive), no clearfellings were simulated. In addition, all operations were delayed and implemented as less intensive than in the Standard approach.

In both sets, the simulator produced for all stands one management path where stand was set-aside from timber production during the first 10 year period. Thereafter, only natural processes were simulated for the set-aside management schedules. NPV for those schedules was based on the cutting value (component 2) and land value (component 3) of stands. The total number of simulated schedules was 1237 in the first (Standard) set and 194 in the second (Nature-oriented) set.

3.2 Production frontiers

Two different production frontiers (*Fig. 2*) corresponding to the two different management strategies (Standard and Nature-oriented) were calculated using optimisation. For both, the objective function was to maximise NPV from timber production using a 4 percent interest rate. The particular interest rate corresponds to the current effective rate of interest on the capital market. In these calculations, compartments could be subdivided (see LAPPI, 1992, p. 13).

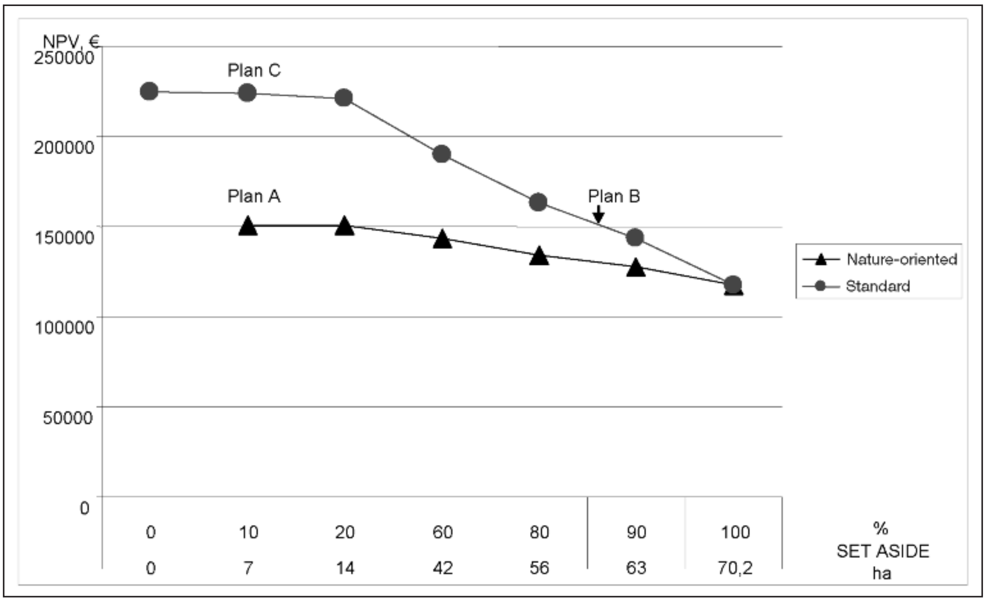

Fig. 2

Production frontiers (production possibility boundaries) between NPV and the area of set-aside under different management strategies in the case study area. The plans A, B and C marked as points on frontiers.

Produktionsmöglichkeitenkurve für den Nettogegenwartswert und die Naturschutzfläche bei unterschiedlichen Management-Strategien in der Fallstudie. Die Kombinationen A, B und C markieren Punkte auf der Produktionsmöglichkeitenkurve.

On the Standard frontier, the maximum value of NPV when all stands were in timber production was 224471 €. The value is decreasing gradually when stands are set aside until the area of set aside is 20 percent of the land. Thereafter, the decrease is more drastic.

On the Nature-oriented frontier, the maximum value of NPV was 151031 € (67 percent of Standard). To reach that value, some stands (131 and 145, see *Fig. 3* – upper right) were set aside from timber production. This was due to the change in feasible management practices. Because there were no feasible cutting operations for those stands according to the Nature-oriented silvicultural recommendations, no future income was expected from those stands during the analysis period. As a result they were set aside to avoid any costs. The additional increase of 10 percent (up to 20 percent) in set-aside areas causes only a moderate decrease in the value of NPV. Thereafter, the decrease due to increasing set-aside areas is more pronounced.

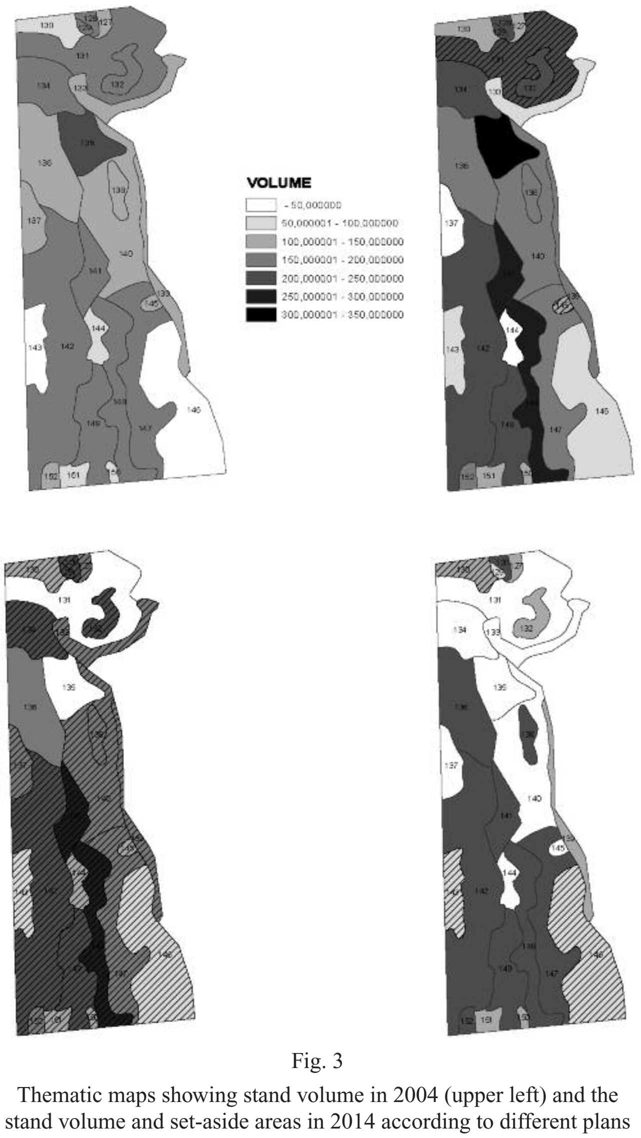

Fig. 3

Thematic maps showing stand volume in 2004 (upper left) and the stand volume and set-aside areas in 2014 according to different plans (Plan A – upper right, Plan B – lower left and Plan C – lower right). The darker the colour is the greater the stand volume. Stands set aside are marked with shading (see e.g. stand 134 on upper right).

Die thematischen Karten zeigen die Bestandesvorräte im Jahr 2014 (Plan A oben rechts; Plan B unten links; Plan C unten rechts). Je dunkler die Schattierung, desto höher der Bestandesvorrat. Naturreservate sind gestrichelt dargestellt (s. z. B. Bestand 134 oben rechts).

3.3 Alternative plans

Three points on the frontiers were selected as alternative plans (Plans A, B and C, see *Fig. 2*) for closer examination (*Table 1*, *Fig. 3*). The maximum point of NPV on the Nature-oriented production frontier was selected as Plan A. Both Plan B and Plan C were selected from the Standard frontier. Plan B was obtained by searching the point where the value of NPV was the same as in plan A, and Plan C by searching the point where the amount of set-aside areas was the same as in Plan A.

In Plan A, the removal varied between 43 and 243 m^3/a during 5 decades. During the same time period the volume of the growing stock nearly doubled. In plan B, the same value of NPV as in Plan A was attained even though the area of set-asides was 61 ha. In Plan B only three stands (131, 135 and 136, see *Fig. 3* – lower left) were kept in timber production. Two of these (131 and 135) were clear-cut during the first 10 year period. In Plan B, the volume of the growing stock more than doubled during the 50 year period.

In plan C, the value of NPV was 48 percent higher than in Plan A even if the same amount of land is set-aside. In Plan C, however, different stands were set-aside (130, 143 and 146 – poorly stocked stands growing on less fertile sites, see *Fig. 3* – lower right) compared to Plan A. In Plan C, removal varies between 76.5 and 566 m^3/a, and the volume of growing stock between 7341 and 10061 m^3 during 5 decades.

4. DISCUSSION

This study illustrates how integrated stand and forest level optimisation can be used to analyse production potentials, and simultaneously locating set-aside areas and management activities.

In the case study, production potentials were examined using production frontiers between net present value of timber production and the area of set-asides. Similar frontiers could be presented for any of the numerous other variables (e.g. biodiversity indicators such as the amount of old, large deciduous trees) produced by the MELA system.

Similarly, optimal path combinations could be obtained using more complex utility functions (e.g. PUKKALA et al., 1995). Nature values could be incorporated into the optimization in several ways. For example, the target values for specific biodiversity indicators or for the amount of set-asides by forest types could be pre-defined for the analysis. The target values for set-asides by forest types can

Table 1

Characteristics of alternative plans.

Merkmale der drei unterschiedlichen Pläne.

	Plan A	**Plan B**	**Plan C**
NPV0, 4 %, EUR	151 031	151 031	223717
Set-Aside, ha	7	61	7
Removal 2004-2013, m^3/a	43	215	566
Removal 2014-2023, m^3/a	177	0	138
Removal 2024-2033, m^3/a	59	0	76.5
Removal 2034-2043, m^3/a	243	0	481.2
Removal 2044-2053, m^3/a	140.4	75	348.3
Volume 2004, m^3	9988	9988	9988
Volume 2014, m^3	12738	10792	6870
Volume 2024, m^3	14033	13652	7796
Volume 2034, m^3	16527	16814	10061
Volume 2044, m^3	16989	20044	8312
Volume 2054, m^3	18373	22175	7341

be in the MELA optimization when and where they are available. When applicable biodiversity indicators – compatible also with Nature-oriented management practices – become available, they can also be incorporated into the MELA system as decision variables, and thereafter utilized as constraints – or even as an objective – in the optimization.

The calculation of net present value was based on the standard MELA models. Therefore, the net present value of timber production in stands that were the set aside value was equal to the cutting value and land value of stands. Therefore the positive value of NPV existed even if all stands were set aside. This assumption implies that the stands set-aside could be returned to timber production after the planning period. The assumption is in accordance with the new conservation policy where set-asides may be temporary. An improvement for the calculation of NPV would be the incorporation of a land rent into the calculation of income when markets for set-asides exist.

In the case study, two separate management strategies were defined, simulated separately, and illustrated using production frontiers. The comparison of two frontiers helps the decision maker to evaluate the loss in timber production if Standard management strategy is replaced with a Nature-oriented one. In principle, all feasible management schedules covering both Standard and Nature-oriented practices should be simulated simultaneously, and thereafter the optimal combination of stand management paths corresponding to the utility function of the forest owner could be selected. As a result, some stands could be managed as standard and some stands as nature-oriented.

In practice, however, forest owners usually face the situation where the target for set-aside areas is given exogeneously, and they want to search for the optimal combination of set-asides and stand management under different management strategies corresponding their own utility functions. For this kind of decision situation, the comparison of production frontiers is an intuitive tool.

In the case study, the difference between Standard and Nature-oriented management practices was not great: on the one hand, Standard recommendations were close to naturalistic (PARVIAINEN and FRANK, 2003), on the other hand, the simulation of Nature-oriented management practices was limited by current silvicultural recommendations which are based on expert knowledge on growth and yield under Finnish conditions. For example, management options corresponding to continuous cover forestry (CCF) were not simulated because they are not recommended for boreal coniferous forests (MIELIKÄINEN and HYNYNEN, 2003). The overall decision space in the Nature-oriented set was sparse and irregular: the number of feasible schedules in this set was only 16 percent of the corresponding number in the Standard set. This limited the options available e.g. for stand 131 which was therefore set-aside due to the lack of feasible cutting operations.

However, the difference in the value of NPV between Standard and Nature-oriented frontiers was greater than the losses due to giving up clear cuttings. The Nature-oriented recommendations aim at increasing the growing stock. At the initial stage, there was a lack of mature stands for any cuttings according to the Nature-oriented recommendations. Each change of a management practice requires an adaptation period during which the stands start reaching new criteria. The length of the adaptation period depends on the structure of the forest area and the changes in management practices. In the case study, the adaptation period for the Nature-oriented recommendations appeared to be longer than 50 years.

The objective function defines the ranking criteria for set-asides: the stands are set aside in order to minimize the economic losses. The amount of set-aside areas is specified as a constraint. This is a rather simple LP formulation which could be improved by using a stand optimization routine together with a ranking algorithm as a post-processor. However, the application of an integrated stand and forest level optimization makes it easier and faster to iterate different analyses for the whole forest area.

On the Standard frontier, approximately 20 percent can be set aside without economic losses. Thereafter, the negative effects are increasing.

In the case study, the allocation of set-asides for individual stands differed considerably between alternative plans. In Plan C set-asides were located to minimize the losses in timber production. Thus, the value of NPV was 48 percent higher than in Plan A even if the area of set-aside was the same. The optimal combination is very sensitive to the properties of the forest area and, therefore, the solution applies only for this particular case study. Generalisations are not possible, but the approach may be usefully employed in similar studies.

Because the adaptation period for the changes in management practices or the optimal allocation between set-aside and stand management varies according to the goals of the decision maker and the properties of the forest area in question, this type of analysis will be useful for forest owners when they consider changing their management strategy or offering stands for temporary protection.

5. ABSTRACT

Conventionally, there are two major conservation strategies in forestry: 1) to set areas aside from timber production and 2) to incorporate nature values into forest management practices. Typically, set-asides are designed in land-use planning process separate from forest management planning. Decisions on forest management strategies are usually made at regional and national level by forest policy makers. These decisions are then implemented into forest practice as recommendations, such as rotation periods and thinning rules. In practice, production potentials of different forest products and services depend on forest resources and their management. Both forest resources and the multiple goals set for products and services vary between forestry units. Therefore, the effective combination of set-asides and management activities of stands should be solved separately for each individual forestry unit. The aim of this paper is to introduce a method for balancing between set-aside and forest management activities of stands to achieve multiple goals set for a particular forest area. The method is implemented in the Finnish MELA system based on integrated stand and forest level optimization. In addition, a case study is presented to illustrate the method 1) in the analysis of production potentials and 2) in the simultaneous location of set-asides and management activities for a forest area in Finland.

6. Zusammenfassung

Titel des Beitrages: *Vereinbarkeit von Waldnutzung und Naturschutz. Verknüpfung der Bestandes- und Landschaftsebenen.*

Die Berücksichtigung der Naturschutzziele in der Waldnutzung orientiert sich an zwei unterschiedlichen Strategien. Die Segregationsstrategie strebt eine räumliche Trennung der Nutz- und Schutzgebiete an. Die Integrationsstrategie dagegen versucht, durch Anpassungen im Management, Naturschutzziele auf ganzer Fläche zu verwirklichen. In der Landschaftsplanung werden Schutzgebiete häufig gesondert ausgeschieden, und diese Entscheidungen sind nicht immer Teil der forstlichen Entwicklungsplanung von Waldlandschaften. Strategische Grundprinzipien der Waldnutzung betreffen die regionale und nationale, also die forstpolitische Ebene. Diese strategischen Vorgaben werden dann durch Managementanweisungen in Form spezieller Durchforstungsregeln und Umtriebszeiten realisiert. In der Praxis ist die Bereitstellung bestimmter Güter und Dienstleistungen direkt abhängig von den verfügbaren Vorräten und von der Art und dem Zeitpunkt der Nutzung. Sowohl die Holzvorräte als auch die Zielsetzungen und die Nachfrage nach bestimmten Produkten und Dienstleistungen unterscheiden sich in der räumlichen Dimension, unter Umständen sogar zwischen benachbarten Beständen. Diese räumliche Variation ist typisch für Waldlandschaften. Daher erfordert die effektive Kombination von Schutzflächen und genutzten Beständen gesonderte Lösungen für jeden Forstbetrieb. Dieser Beitrag beschreibt eine Methode zur Realisierung der Integrationsstrategie, also der gleichzeitigen Berücksichtigung von Zielen des Naturschutzes und der Holznutzung innerhalb einer definierten Waldregion. Der Ansatz ist im Finnischen MELA-System implementiert und basiert auf dem Mehrpfadprinzip, d.h. auf der optimierten Verknüpfung von Bestandes- und Landschaftszielen. In einer Fallstudie wird a) die Analyse des Produktionspotentials und b) die gleichzeitige Zuordnung von Schutz- und Nutzzielen in einem finnischen Waldgebiet demonstriert.

7. Résumé

Titre de l'article: *Compatibilité entre l'exploitation forestière et la protection de la nature. Combinaison des peuplements et des paysages.*

La prise en considération des objectifs de la protection de la nature dans l'exploitation forestière fait appel à deux stratégies différentes. La *stratégie de ségrégation* s'efforce de séparer sur le terrain les zones de production et les zones de protection. Au contraire la *stratégie d'intégration* cherche à agir sur la surface entière en harmonisant le management et les objectifs de la protection de la nature. Dans la planification portant sur les paysages les zones de protection sont très souvent mises totalement à part et de telles décisions ne constituent pas toujours une partie du plan de développement forestier des régions boisées. Les principes fondamentaux stratégiques concernent le territoire régional et national, et relèvent donc de la politique forestière. Ces objectifs stratégiques seront atteints grâce aux directives du management, sous forme de règles particulières concernant les éclaircies et la durée de la révolution. Dans la pratique la préparation de certains biens et la fourniture de services sont directement liés aux matériels sur pied disponibles ainsi qu'au type et à l'époque de la récolte. Aussi bien le volume de bois sur pied que la demande de produits ou de services déterminés se différencient dans leur dimension spatiale selon les circonstances, et voire même entre peuplements voisins. Cette variation spatiale est typique des régions de forêt. De ce fait une combinaison effective des zones de protection et des peuplements productifs impose des solutions particulières à chaque entreprise forestière. Dans cet article on décrit une méthode permettant d'appliquer la *stratégie d'intégration*, c'est à dire la prise en considération simultanée des objectifs de la protection de la nature et de ceux de la production de bois. Le programme est implémenté grâce au système finnois MELA et basé sur le principe des voies multiples c. à d. sur combinaison optimale des objectifs relatifs aux peuplements et aux paysage. Dans une étude spéciale on a exposé: a) l'analyse du potentiel de production b) la coordination simultanée des objectifs de production et de protection dans une région forestière de la Finlande. J.M.

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Der Schutz und die Erhaltung des Tropenwaldes sind eines der wichtigsten internationalen Anliegen der Umweltpolitik.

Aus ökonomischer Perspektive ist die Erhaltung des Tropenwaldes umso eher möglich, je vorteilhafter seine nachhaltige Nutzung für die örtliche Bevölkerung ist. Forschung, die zu einer Verbesserung der nachhaltigen Nutzungsmöglichkeiten der Tropenwälder beiträgt, dient daher auch der Erhaltung der vielfältigen Waldökosysteme in den tropischen Ländern.

Dies ist eine starke Motivation für eine auf die technische und wirtschaftliche Verwendung der Holzarten tropischer Wälder gerichtete Forschung.

Bolivien ist das ärmste Land Südamerikas, ungefähr die Hälfte seiner Fläche ist mit Tropenwald bedeckt. Bis zu diesem Zeitpunkt konzentriert sich die Holznutzung im Naturwald auf wenige bekannte Baumarten, deren Holzvorräte jedoch begrenzt sind.

Viele andere dort vorkommende Holzarten sind technisch und ästhetisch durchaus gleichwertig, werden aber bisher kaum genutzt. Ein Anstieg der Nachfrage nach diesen Holzarten würde nun die Nutzungsmöglichkeit des Naturwaldes verbessern und der einheimischen Bevölkerung zusätzliche Einkommensmöglichkeiten bieten.

Mit der vorliegenden empirischen Marktstudie wurde deshalb für eine Reihe der weniger bekannten Holzarten beispielhaft untersucht, ob die bolivianische Forstindustrie in der Lage wäre, die für eine industrielle Verwendung ausreichende Menge von Parkett-Vorprodukten aus diesen Hölzern zu exportieren.

An diese Studie anschließend zeigt eine Analyse des Parkettmarktes in Deutschland, wie die Chancen der Vermarktung dieser hierzulande eher unbekannten Holzarten als Parketthölzer auf dem deutschen Markt als einem wichtigen Exportmarkt einzuschätzen sind.

Dieses Buch enthält umfangreiche farbige Darstellungen und Beschreibungen der unbekannten Holzarten und wendet sich an ein breites Publikum wie Wissenschaftler, die in den Bereichen Holzmarkt und Tropenholz arbeiten, an die Unternehmen der Parkettindustrie, an Importeure von Tropenholz sowie an Entwicklungshelfer und Interessierte, welche die Entwicklung des Forstsektors in Bolivien unterstützen wollen.

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