Country Report "Germany"

In the frame of COST Action FP0703 ECHOES:

Expected Climate cHange and Options for European Silviculture

E.C.D. van der Maaten[1], P. Spathelf[2], M. Köthke[3], P. Schall[4], S. Taeger[5], S., A. Menzel[5], A. Bolte[6], Ch. Ammer[4], H. Spiecker[1].

[1] Institute for Forest Growth, University of Freiburg
[2] Institute of Silviculture, University of Applied Sciences Eberswalde
[3] Institute of Forest Based Sector Economics, Johann Heinrich von Thünen-Institut Braunschweig
[4] Silviculture and Forest Ecology of the Temp. Zones, University of Göttingen
[5] Chair of Ecoclimatology, Technical University of Munich (Freising)
[6] Institute for Forest Ecology and forest Inventory, Johann Heinrich von Thünen-Institut Eberswalde

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Introduction

This country report for Germany on climate change impacts, adaptation and mitigation-measures is written in the frame of the COST Action FP0703 ECHOES (Expected Climate cHange and Options for European Silviculture). The aim of the report is to exchange information with other partner-countries within ECHOES on objective facts, research studies and strategic processes that link up with the activities and foci of the ECHOES Working Groups on Impacts (WG-1), Adaptation (WG-2) and Mitigation (WG-3).

The report gives an overview on observed and expected climate change impacts in Germany, on impact monitoring and impact management. Regarding adaptation, forest vulnerability, adaptation strategies, measures and research are discussed. In the mitigation-section carbon accounts, bioenergy-potentials, research and strategic processes are elaborated.

Part I: Impacts

Authors: *E.C.D. van der Maaten, P. Schall, S. Taeger, A. Menzel* and *H. Spiecker*

I.1 Observed Impacts

For the temperate biogeographical region to which Germany belongs, climate change scenarios predict annual mean **temperature** increases within the next 100 years in the order of 3 to 4 °C, that are associated with summer extremes that will increase even more than the average summer temperatures. Mean annual **precipitation** is predicted to increase in the same time with maximally 10%, depending upon the area. But, as the seasonality of precipitation-events is likely to change, more frequent rainfall during winter time [e.g. Klein Tank and Können, 2003; Haylock and Goodess, 2004; Schmidli and Frei, 2005] and reductions in summer precipitation are projected. [IPCC, 2007; Green-Paper, 2007]. The combined temperature- and precipitation-trends will result in, e.g., more frequent **floods**, **summer droughts** (and associated forest fires), and prolongation of **growing seasons**, with a major impact on forest ecosystems [e.g. Rennenberg et al., 2004]. The impacts of climate warming are expected to be especially negative for the Alpine region (warming above average), the Southwest (greatest warming), and Northeastern Germany [DAS: Deutsche Anpassungsstrategie 2008].

A reduction of forest growth is predicted for Northeastern Germany, where changing water balances will lead to increased drought stress [Lasch et al., 2002]. Locally and temporarily, summer droughts also drastically increase forest fire risks. Especially the Bundesland of Brandenburg is concerned.

Wind climate tendencies are less clear. However, regarding projected future storm performance, there are several coherent model simulation outputs that point to a slightly increased frequency of intensive storm events in Europe with a focus on north-western and northern Central Europe [Parry, 2000; Christensen et al., 2002; Leckebusch and Ulbrich, 2004; Fuhrer et al., 2006; Leckebusch et al., 2006].

Correspondingly, the severe 2003 summer drought had negative implications for forest productivity and vitality in Central Europe [Ciais et al., 2005]. A sharp decrease in forest productivity after the drought could, however, not been substantiated by all studies and for all tree species. Dendrochronological studies on common beech for example, indicated that wood formation ceased in beech during drought, but recovered quickly after the drought [e.g. Dittmar et al., 2003; Kahle et al., 2007; van der Werf et al., 2007]. In a study by Spiecker [2005] on Norway spruce however, a sudden growth stop could be detected in the summer of 2003. After the extreme drought stress no late wood was formed anymore in 2003, and also early wood production in 2004 was highly influenced (see figure I.1)

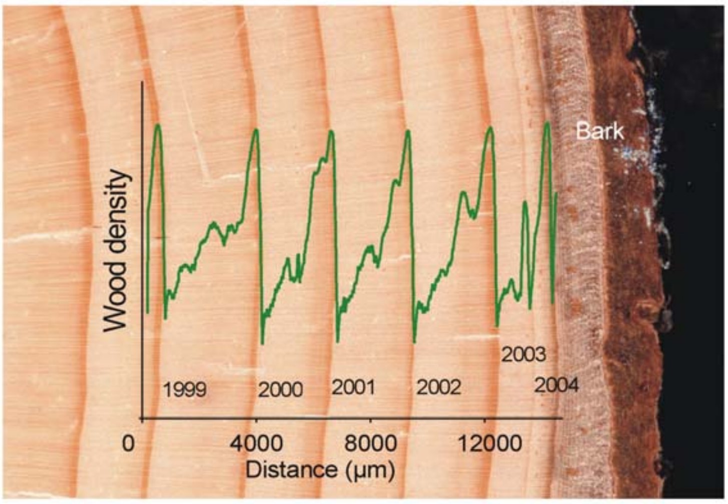

Fig I.1 *Wood density variation in Norway spruce.*

Wind climate tendencies, though some devastating storm events like Lothar (Central Europe, 1999), Gudrun (Southern Sweden, 2005) and Kyrill (Germany and Slovakia, 2007) have caused an increased loss of standing wood volume in the last twenty years [Schelhaas et al., 2003; Dobbertin and de Vries, 2008], are less clear and can not be associated to climate change per se or solely. Namely, the storm damages were fuelled by an historically high standing volume in European forests [MCPFE 2007], producing immense storm damage potential.

There is a coherent and significant footprint of these observed climate changes in nature, on the global scale [Rosenzweig et al., 2008] as well as on the European scale [Walther et al., 2002]. The reported abiotic impact factors, like summer droughts, are accompanied or followed by indirect biotic effects like changing pathogen and pest regimes of known species as well as of new species. Resulting altered disturbance regimes might strongly impact the forests in Germany [Dale et al., 2001]. In Central Europe, an increased occurrence of insect damages [Krehan and Steyrer, 2004; Ammer et al., 2006; Dobbertin and DeVries, 2008] and latitudinal range shifts of biotic disturbance agents [Battisti et al., 2005] could already be observed. For the case of Germany, this susceptibility is increased furthermore by forest structure and composition.

In this respect especially the European spruce bark beetle (*Ips typographus*) is concerned. There is a high share of monoculture, even-aged Norway spruce stands, that were often planted outside their natural distribution area [website BWI²]. Massive outbreaks of bark beetle were already observed and are likely to increase furthermore in the future, due to more frequent and more severe summer drought stress conditions. Similar trends can be seen in Germany for other insects, for example gypsy moth (*Lymantria dispar*) and oak processionary (*Thaumetopoea processionea*).

Observed impacts of climate change on German forests are both positive as well as negative. Inreased CO2 concentrations and prolongation of the growing season might result in increased productivities, whereas heat waves, summer drought, forest fire risk (especially in the Bundesland of Brandenburg), disturbance agents and storm events might void these positive influences [Presentation Waldstrategie 2020]. Phenological observations on bud burst and bud set over the period 1951-1999, reveal a pattern in which major tree species like beech and oak increase their total growing period with 8 to 11 days [Schaber and Badeck, 2003]. This is in accordance with earlier results indicating a Europe wide prolongation of the growing season by about 11 days [Menzel and Fabian, 1999], species specific information on trees in Germany (lengthening by 12 days for Birch and Oak, 9 for Beech and Horse Chestnut, 1951-1996) [Menzel et al., 2001] and a pan-European study revealing a pronounced earlier starting of spring [Menzel et al., 2006]. Also changing distribution areas are reported [Presentation Waldstrategie 2020].

As in large areas of western and central Europe (Maracchi et al., 2005; Koca et al., 2006), temperature increases support the creation of mixed stands and the replacement of natural conifers with more competitive deciduous trees. However, the drought susceptibility of one of the major deciduous tree species that was used in forest conversion over the recent past, common beech, is unclear [see e.g. Rennenberg et al., 2004; Kölling and Zimmermann, 2007]. As it is documented for various tree species, varying reactions are observed for different provenances of beech [Kriebitzsch et al., 2008; Konnert, 2007].

As climate change impact assessments are often based on *climate projections*, also the scientific field of climate modeling and simulation deserves attention. In Germany, intensive efforts are and have been made to contribute to the international challenge of global climate change modeling. General (or: Global) Circulation Models (GCMs) are, e.g., developed by the Max Planck Institute for Meteorology in Hamburg within the so-called ECHAM-model series, and by the Meteorological Institute for Meteorology (University of Bonn) with its ECHO-G model. ECHAM5, the most recent model-release of the ECHAM-models, was even used as important background data for the IPCC 2007 report [website IPCC-data].

Besides global climate change modeling, *regionalization* of the models is also aimed at within the mentioned, and other German institutions. Downscaling of GCMs to the European and national scale is done by numerous models, which are sometimes especially developed and applied for specific German Bundeslaender. Examples are:

- REMO model: a regional climate change model that is dynamically linked to GCMs to increase the spatial resolution of the simulation results [website REMO model].
- WETTREG model: a statistical model that scales down GCM output data based on types of large-scale weather patterns [Umweltbundesamt, 2007].
- STAR model: a downscaling model based on daily mean air temperatures [website STAR model].
- CLM model: a nonhydrostatic operational ‘community’ model with a resolution of 18km² that was developed from a small scale weather prediction model. It is driven by ECHAM5/MPIOM global model [website: http://clm.gkss.de].

I.2 Expected Impacts

Although observed impacts of climate change on German forests are reported to be both positive as well as negative, e.g. prolongation of the growing season versus severe summer droughts, expected impacts are associated with high uncertainty. For example, it remains unclear how common beech will be respond to the projected summer droughts. Consequently, predictions are often generalizations for large areas or biogeographical regions. This emphasizes the need for more detailed scientific research on individual species performance with preferably a regional approach.
An example of such a regionalization attempt is provided by the EU INTERREG IVB research project 'Transnational Forestry Management Strategies in Response to Regional Climate Change Impacts' (ForeSTClim). However, already now expected impacts can be formulated.

The projected temperature rise will result in accelerated development and lowered mortality rates for various pest species, allowing for massive attacks more frequently [Lindner et al., 2009]. While the increased temperatures will be associated with changed precipitation patterns, initiating more frequent and sever summer droughts, drought stress in trees will furthermore increase, making them more susceptible for insect attacks. In Germany this rationale is likely to be especially catastrophic for Norway spruce. This drought-sensitive tree species, planted even outside its natural range, will face big problems with the spruce bark beetle (*Ips typographus*) under drought stress conditions. It may be concluded that potentially devastating negative impacts may occur due to extreme climatic events and enhanced disturbances (both biotic and abiotic) [Lindner et al., 2009].

Besides this negative climate change impact, German forests may partially benefit from increased growth rates and wood production, when water-availability is not limiting. Lasch et al. (2002) modeled the productivity for Norway spruce, Scots pine, common beech and oak in Germany under climate change, using two different scenarios (ECHAM4 and HadCM2). Under higher simulated precipitation, an increase of around 7% for Norway spruce and Scots pine, and smaller increases for beech (2%) and even a decrease in oak production (7%) was projected.

The drier scenario resulted in productivity decreases for all species (respectively -4%, -7%, -16% and -12%). Due to these species-individual responses changes in competition as well as range shifts are expected to alter forest composition (Rigling et al., 2006; Lenoir et al., 2008).

Existing studies on the shifting of tree species distributions often rely on an environmental envelop approach which suggests shifts from coniferous towards deciduous species on the basis of potential natural vegetation, while not taking into account extreme events or genetic differences between different provenances. In addition to that, forests in Germany and Europe are highly managed, so the decisions at this level will alter the natural processes.

Linked to forest productivity is the carbon sequestration. A study by Vetter et al. [2005] in coniferous forests in Germany, reported that environmental changes induced an increase in biomass C-accumulation for all age classes over the period 1982-2001. Carbon is furthermore sequestered in the soil [Prietzel et al., 2006]. However, there are numerous factors impacting carbon sequestration. These factors should be taken into account when C-sequestration is estimated.

An overview of forest responses to change in Central Europe that are also of crucial importance for Germany, is provided in table I.1.

Table I.1 *Forest response to change impacts in Central Europe* [Bolte et al., in press]

Impacts	Pressure	Response / risk
Warming	Higher mean temperatures	Higher evaporation (loss of water resources)
		Increased mobilization and losses of carbon in forest soils (humus/peat decomposition)
		Improved conditions for reproduction of damaging insects
	Frequent heat waves	Damaging of leave/needle tissues
		Increased mortality, losses of regeneration options
		Forest fire
	Shortening of cold and frost periods	Reduction of carbon gains due to winter mobilization of carbohydrate reserves
		Wind throw by winter storms
	Extension of the growing season	Higher productivity (in case of sufficient water and nutrient availability)
		Early and late frost damages

Changed precipitation	Drought	Decreased productivity, higher mortality, higher susceptibility towards biotic threats
	heavy precipitation	Flooding damages (oxygen shortage)
		Increased mortality due to high variation of soil water regime
Changed wind climate	Storm	Wind throw / wind break
	Higher mean wind speed	Increased evapotranspiration
Changed biotic interactions	Variation of intra- and interspecific competition	Changed productivity and vitality, increased mortality, changed community structure
	Change of symbiotic conditions (e.g. pollination systems, mycorrhiza)	Changed productivity and reproduction conditions
	Attacks of biotic agents (insects, funghi, bacteria)	Decreased productivity, higher mortality, higher susceptibility towards abiotic threats

I.3 Impact Monitoring

In Germany impact monitoring takes place over national forest inventories (BWI), permanent research plots of the state forestry services of the individual Bundeslaender, and at a wider spatial scale within monitoring networks like the German National Soil Survey (BZE, ca. 2000 plots) and the ICP Forest Plots Level I (Crown condition survey, WZE; 450-2000 plots) and Level II (process monitoring; 86 plots) [Wellbrock and Bolte, 2008]. Also an International Phenological Garden Network, with 78 phenological gardens in Central Europe [website IPG], provide very valuable information on climate change impacts on, e.g., bud burst and set.

Although numerous climate change impact monitoring initiatives are running in Germany at different spatial and temporal levels, an integration of those initiatives shows to be difficult. Especially at the forest management unit more information on climate change impacts is needed to come up with adequate, adaptive forest management measures.

I.4 Impact Management

In Germany some first efforts have been made to develop national and regional strategies to adapt to climate change. In 2005, Schröter et al. published the „Climate Change in Germany Vulnerability and Adaptation Strategies of Climate-Sensitive Sectors"-report, followed by a regional strategy for North Rhine-Westphalia [Ministry for Environment and Nature protection, Agriculture and Consumer protection of North Rhine-Westphalia, 2007]. These documents propose adaptation-measures under climate change. The documents are backed-up by integrated assessments of climate change impacts on forests and the forest sector, like the one coordinated by PIK-Potsdam [website integrated CC impact assessment].

In addition to that single Bundeslaender begin to adapt forest management by giving forest owners state of the art information like risk evaluations and recommendations for the use of tree species under climate change (Bavaria, North Rhine-Westphalia).

Also from science, a need to formulate adaptive forest management strategies is recognized, illustrated by the recently started and EU FP7-funded project 'Models for Adaptive forest Management' (MOTIVE) or by the BMBF-DLR-funded project DSS-WuK (Decision Support System – Forest and Climate) with a national focus [Jansen et al., 2008].

Part II: Adaptation

Authors: *P. Spathelf, P. Schall, Ch. Ammer* and *A. Bolte*

II.1 Vulnerability of Forests and Forestry

Determinants of vulnerability and assessment methods

Vulnerability (biophysical or social v.) is ‘the extent to which a natural or social system is susceptible to sustaining damage from climate change’ [IPCC, 2007]. A system’s vulnerability is closely linked with its adaptive capacity, the greater a system’s adaptation capacity the less its vulnerability. For the present report, a complete assessment of the vulnerability of German forests and forestry can not be provided [for a systematic approach see concepts and methodologies in FAO, 2005]. For a brief overview the following determinants are being considered.

- Drought stress / lack of water availability
- Storms and other weather extremes such as heat waves
- Pests
- Fire
- Stand characteristics (age).

The information base revised/screened to give a first appraisal of forest vulnerability in Germany comprises, among others:

- Forest health / pest statistics
- Forest growth records
- Bioclimatic envelope analyses.

Tree species and forest types/ecosystems

Among the most important tree species in Germany with economic relevance, Norway spruce is mostly affected by climate change. Due to its preference for humid and cold sites N. spruce is very susceptible against drought and higher temperatures / heat. During the restoration phase of German forestry Norway spruce was planted far in excess of its natural range. Therefore, in many regions this species is already beyond the limits of its tolerance range, especially in Southern Germany. Moreover, Norway spruce is very susceptible against bark beetle attacks, thus suffering in many warmer regions of Germany (Tab. II.1).

Table II.1 *Salvage cutting in the forests of the German federal state of Baden-Württemberg (all forest ownerships) in the year 2005*

Region	salvage cutting due to insects	salvage cutting due to drought	share of salvage cutting at allowable cut	total volume salvage cutting
	[m³]	[m³]	[%]	[m³]
Baden-Württemberg	**2008244**	**176528**	**31**	**2184772**

European beech, however, is seen to be less susceptible to climate change because, in general, beech is restricted to sites where the species is natural and better adapted. Even less affected is Scots pine, Douglas fir and the valuable broadleaved tree species such as maple, ash[7] or alder. Species with a more sub-Mediterranean distribution such as downy oak (*Quercus pubescens*) will extend their range [Kölling & Zimmermann, 2007].

Although Scots pine is judged to be a robust species, it is affected significantly by forest fires, especially in Northeastern Germany (see Figure I.1). E.g. in the period between 1992 and 2005 in the federal state of Brandenburg 267 ha of forests were burnt annually which corresponded with more than 500 fires a year. Moreover, there are doubts about the future vitality of Scots pine at its southern range margin e.g. in Valais (Switzerland) where the drought and/or warmth tolerance may be exceeded [Bigler et al., 2006]

An additional concern is the fact that Germany's forests are getting more and more older. In Baden-Württemberg, the area of the forests older than 80 years has increased by nearly 20 % in the recent two decades. There are hints that older trees are more susceptible to environmental stresses (e.g. drought, emissions) than younger trees. Additionally it becomes evident that the sensitivity of tree species such as Norway spruce to climate variation has increased too [Spiecker, 2003].

[7] The health of European ash in Germany since several years is increasingly negatively affected by a complex disease with the involvement of the fungi *Hymenoscyphus albidus (Chalara fraxinea).*

A first overall assessment of the species vulnerability makes evident, that more than 50 % of the forest cover in Germany is composed of ‘vulnerable’ species (especially Scots pine and Norway spruce, see National Forest Inventory BWI II).

Regions

The most affected regions in Germany concerning climate change are those which will suffer significantly from increasing temperatures and decreasing water availability. According to current climate projections four regions in Germany will be in the focus of interest (Tab. II.2): Northeastern Germany, the southeastern basin and hill landscape, the valley of the river Rhine and the Pre-Alps. Many of these regions are characterized by the dominance of Norway spruce or Scots pine in the forest composition.

Table II.2 *Categories of climate risk regions in Germany (CRAMER et al., 2005, www.waldundklima.net)*

high	**moderate**	**low**
• Northeastern Germany • Southeastern basin and hill landscape • Valley of the river Rhine • Pre-Alps	• West German lowland basins • Central mountain ranges and Harz • Erzgebirge, Thüringen and Bavarian forest • Mountain ranges left and right of the river Rhine • Alps • Bavarian hill landscape	• Northwest German lowlands

In eastern Germany, for instance, the still mostly pure pine stands are frequently damaged after the mass propagation of needle-eating insects. And in many of the low and warm regions of South Germany several consecutive bark beetle attacks have significantly reduced the occurrence of Norway spruce.

Forest decline

A good indicator of tree species vulnerability in Germany is the damage level in the national survey of forest health [Waldzustandsbericht, BMELV 2008]. One of the core characteristics in forest health assessment is crown transparency. In 2008 26 % of all the trees are categorized into the section with ‘significant damages’ (i.e. needle/leaf loss > 25 %). All of the main species with economic relevance in Germany are affected, being oak (*Quercus robur* and *Quercus petraea*) with > 50 % significant damage at the first rank (Tab. II.3). Although oak in general is seen to be a robust species, there is evidence that oak is susceptible to the impacts of climate change. The reason for the low vigor of oak stands in Germany in many cases is due to a complex of site preconditions (dry sites, soil compaction etc.) and so-called triggering factors such as drought and subsequent foliage loss through moth caterpillars. E. g. the year 2003 with its extraordinary heatwaves and drought revealed a heavy impact on tree growth, vitality and insect damages [Forstwissenschaftliche Fakultät der Universität Freiburg & Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg, 2004].

Table II.3 *Excerpt of German forest health statistics 2007-2008*

	Norway spruce	Oak	European beech	Scots pine
Crown transparency	[%]			
2007	28	49	39	13
2008	30	52	30	18

Institutions and socioeconomic framework

Vulnerability to environmental change does not exist in isolation from the wider political economy of resource use [Adger, 2006]. From a forest government perspective German forestry has a long tradition and well-established institutions concerning forest conservation, forest management and research. The key players here are the state forest administrations who manage the state owned forests in different organizations. Despite the budget reductions and frequent reorganizations in the last years it is assumed that a rather low susceptibility to climate change related issues prevails.

Additionally to state forest administrations forest governance processes such as MCPFE, National Forest Programmes or Certification improve the transfer of knowledge on forests between the policy, economy, society and science [Krott, 2008]. Thus these networks can help to solve conflicts. Nevertheless in this field much research still has to be done.

To summarize, German forestry with its consolidated institutional framework can be characterized ‘moderately’ vulnerable to climate change. Nevertheless a few identified regions are highly vulnerable and soon require adequate adaptation measures.

II.2 General Adaptation Strategy or Policy

Adaptive forest management does not primarily aim at preserving and developing forest composition and structures, but the functionality of forests under conditions of climate change as a prerequisite for fulfilling the future needs of forest ecosystem services [Wagner 2004]. Adaptive management implies a large variety of different measures that support and assist forest ecosystems’ stress resistance, resilience and dynamic response, representing a set of target responses to climate change impacts.
In the following we present potential adaptation strategies [cf. Bolte et al., in press]. However the actual use of these possible measures is known. This is why our interpretation of the importance of a given strategy has to be seen as an assumption.
(1) Perpetuation of forest structures: This option tries to maintain the structural constancy of a forest even against an increasing successional pressure due to climate and site quality change. This can increase the risk of a catastrophic loss of forest, but may enable the manager to achieve the original management targets. Criteria for a positive application of the conservation option are (i) low local impact of climate change, (ii) high stand resistance to climatic stress, (iii) high stand age and (iv) high importance of the existing stand structure and forest composition for forest functioning (e.g. high economic value), (iv) high likelihood that silvicultural interventions improve the stability and/or vitality of the stand. This strategy seems to be applied on the majority of sites throughout Germany. It relies on a realistic guess of the tree specific stress tolerance.

However, while forest experts agree in the future suitability of species such as oak (Quercus spec.), lime (Tilia cordata), wild service tree (Sorbus torminalis), chestnut (Castanea sativa) others are under debate. Thus the potential of some other frequent Central European species such as European beech (Fagus sylvatica) or Scotch pine (Pinus sylvestris) is less clear. Whereas for example Ammer et al. [2005] and Kölling and Zimmermann [2007] argue that beech has a high potential to grow under relatively warm and dry conditions [see also Felbermeier 1994, Felbermeier and Burschel 1994, Kölling et al. 2007] others recommend to restrict beech on moist sites [Rennenberg et al. 2004, Geßler et al. 2007]. One probable explanation of these contradictory assessments may be due to the fact that different beech provenances show a varying adaptive potential to drought by regarding their origin in the center or margin of beech range (e.g. Czajkowski and Bolte, 2006; Rose et al., 2009).

(2) Active adaptation: This includes the active forest transformation in order to replace tree species and/or tree individuals sensitive to climate change by trees of native or introduced species and/or species' provenances that are potentially better adapted to future climate conditions. Another option is the active change of silvicultural systems like the shortage of rotation age in order to prevent wind throw. Criteria for the application of this concept are (i) a significant decrease of stand and species stress tolerance to climate/site change and (ii) considerable positive effects on forest functioning after active adaptation and (iii) high hazard risk for adjacent forest (e.g. bark beetle attacks). Examples for this strategy are the ongoing conversion of pure conifer forests, namely Norway spruce stands, into mixed stands or silvicutural measures aiming at replacing species such as Norway spruce by other species of comparable economic value (e. g. Douglas fir). In Germany, the Bavarian State Department of Environment, Health and Consumer Protection published a regional climate program in November 2007 that includes an example for the application of the 'active adaptation' concepts on species level. It is planned to transform until 2020 about 100,000 ha of pure Norway spruce forests in areas where a high risk of drought damages is assumed into less sensitive mixed forests, predominantly with European beech [StUGV, 2007].

Beside conversion there are two other options which are presently discussed in Germany. First, some authors have recommended integrating early successional species which seem to be more adapted to the drier site conditions into regular stand management [Lüpke 2009]. Second a debate has recently started whether or not (heavy) thinning may help to reduce the water stress of target trees during dry periods. However, hitherto the results reported in literature are not consistent and corresponding experiments have only recently been started.

The introduction of new tree species is in discussion as well. Presently only few woodland owners have started to plant non native tree species other than Douglas fir, Red oak and Grand fir on a larger scale. However, some research institutes have started to identify potentially suitable tree species matching ecological conditions and economic requirements. Existing trials with non native species are presently evaluated. In general for the incorporation of new, exotic tree species and provenances it is recommended to proceed according to the following: (1) species already adapted on larger scale in the planting region and tested non-autochthonous provenances, followed by (2) new species with knowledge on their behavior but no adaptation yet, and finally (3) completely new species.

(3) Passive adaptation: The third option addresses the active decision to stop measures maintaining forest structures or to actively adapting it to environmental changes. This should not be confused with a definition of 'passive adaptation' in terms of an observing and viewless, passive behaviour. The idea is to deliberately use spontaneous adaption processes in terms of natural succession and species migration, respectively. This minimises drastically the input efforts, but eliminate rather all possibilities to control the stand dynamics that are indicative for future forest composition, stand structure and forest functioning. Criteria for the use of this option are (i) low importance of the forest stand for economic and ecological functioning, (ii) no adequate measures for active adaptation, (iii) low cost-benefit ratio of conservation and active adaptation measures. For forest enterprises in Germany passive adaption seems to be not really an option. In contrast to forest enterprises several small (urban) woodland owners may choose this potion because they are often not interested in active forest management.

II.3 Forest Adaptation Measures

Forest adaptation measures in Germany show a large variety in terms of (i) status of implementation, ongoing, planned or proposed, (ii) scale, from stand level to regional and national level, and (iii) objective. Measures already in progress mainly focus on research and development and information dissemination, while concrete measures on the stand level are confined to coniferous stands in specific regions. Table II.4 gives an overview of ongoing, planned and proposed forest adaptation measures within Germany.

Table II.4 *Overview on ongoing, planned and proposed Forest Adaptation Measure (Numbering of forest type and measure according to presettings of the WG2 "Adaptation" data collection tool)*

Forest type	Measure
2. hemiboreal forest and nemoral coniferous and mixed broadleaved-coniferous forest	• 3.1.3. apply small scale cutting to increase spatial heterogeneity in forest structures • Early (pre-mature) regeneration of vulnerable stands • 2.3.1. modify thinning regime to improve stand water balance & decrease competition for available water • Government plan for conversion of highly vulnerable Norway spruce forests to mixed forests (includes material incentives) • 8.1.2. Development and dissemination of improved forestry guidelines • Conversion of pure pine dominated forests into mixed forests with beech and oak
6. beech forest	• Increase site variability (light and moisture) during forest regeneration by modified cutting
14. plantations and self sown exotic forest	• 1.2.5. reduction in the establishment of monocultures with vulnerable species • 4.1.1. reducing the rotation length in order to decrease mean standing stock • 6.4.1. Logistic support for forest owners in the case of large-scale disturbances
various forest types (unspecific)	• Increase share of mixed coniferous deciduous forests and deciduous forests • Increase tending efforts to promote species mixtures • Research on adaptive types of species

	mixtures/mixed forests • Implement adaptive forest management • Integrate forest adaptation into national/regional climate impact research programmes • 1.1.1. Selecting suitable species/ provenances better adapted to future conditions • 1.1.3. Favoring drought resistant species • 1.2.2. Use of natural regeneration with enrichment planting of species which are robust against climate change • 1.3.1. Using natural regeneration for the main forest tree species • 1.5.1. promote the use of (alternative) methods for protection of seedlings against browsing and grazing • 2.2.1. Modify thinning regime to promote species mixtures • 3.1.7. promote close-to-nature silviculture • 4.1.6. increase diversity of forest types/specis/provenances and stand level management regimes within management units • 8.1.4. Conferences and workshops about adaptation measures to climate change for forest owners and stakeholders • 8.4.15. Analysis of results from provenance trials to evaluate the response to climate • 8.4.16. Search for species or varieties better adapted to new environments based on phenotypic and molecular characterization • Classification of site and stand sensitivity to climate change • (Re-) assessment of drought resistance of tree species • 4.3.2. Decision Support Systems (DSS) to evaluate impacts of climate change and management and to identify suitable options • Improved methods to control seed sources and to track FRM trade

II.4 Research Studies on Forest Adaptation

Experimental study: Can thinnings improve the drought tolerance of Norway spruce stands?

Scope: As a silvicultural adaptation measure to more frequent and more severe drought periods an increased intensity of thinning operations in forest stands is proposed, since stand density has been found to influence water yield. However, the results of experimental studies are inconclusive. It remains rather unclear whether the lowering of stand density - and thus of the canopy leaf area - by thinning is compensated or even overcompensated for by higher leaf-level transpiration or transpiration from ground vegetation.

Research design: The effect of different thinning regimes on transpiration, growth and vigor of individual trees and forest stands, as well as on soil and ecosystem water balance is studied on an experimental site in Southern Bavaria near Landshut. The experiment includes measurements of (i) water flux and water content measurements on the tree and the ecosystem level, (ii) above and belowground productivity and (iii) other relevant tree physiological signals. The experiment consists of two replications of three thinning intensities, resulting in 6 research plots, 25 m x 50 m in size each. Before the start of the experiment the 26 years old stand has not been thinning. The initial stem number was between 2575 and 3500 stems ha-1. On each plot around 400 target trees ha-1 were selected. The thinning treatments were: no intervention (control), removal of 2 to 3 competitors around each target tree, removal of all trees except the target trees. This resulted in stem numbers between 416 (heavy thinning and 2785 (control) trees per ha. The measurements have been started in spring 2008, whereas the thinnings were carried out in January 2009.

Investigators: Department of Silviculture and Forest Ecology of the Temperate Zones, Georg-August University Göttingen; Chair of plant ecopysiology , TU München; Bavarian Forest Institute (LWF)

http://www.uni-goettingen.de/en/71591.html

Experimental study: Can we use introduced provenances of European beech for beech forest adaptation?

Scope: Since European beech forests are the major natural forest vegetation type in Central Europe, the German close-to-nature forestry demands for information about future adaptability of European beech (Fagus sylvatica L.). Recently, several studies revealed the varying adaptation potential to drought of different provenances of European beech [Czajkowski et al., 2005, Czajkowski and Bolte, 2006, Rose et al., 2009]. Thus, four different beech provenances, originating from the center and the margin of the beech range, will be tested regarding the effects of drought on the growth and vitality of young forest trees in the open under largely controlled conditions in an open-field laboratory. [Müller and Bolte, 2009].

Research design: Eight lysimeters with a surface area of 2m² and standardized soil substrate were installed in the open at ground level in isolation from the surrounding soil, and fitted with an automatic retractable roof to eliminate precipitation from the site. Soil moisture sensors, together with equipment fitted for measuring soil water discharge and precipitation, enable accurate determinations of evapotranspiration as well as observations of soil moisture development in the soil column. In 2009, each lysimeter is planted with 20 beech seedling originating from beech provenances of Northwest Germany (humid conditions), Northeast Germany (semi humid conditions) and of two location in Poland near to the beech range margin (continental conditions). One focus of the research is the investigation of fine root development using mini-rhizotrones. The results shall be used for evaluations on the use of introduced beech provenances to raise the future adaptation of beech forest to drought.

Investigators: Johann Heinrich von Thünen-Institute (vTI), Institutes of Forest Ecology and Forest Inventory of the Johann Heinrich von Thünen-Institute and Forest Genetics Waldsieversdorf/Großhansdorf together with future research partners.

http://www.vti.bund.de/de/institute/woi/forschung/versuchseinrichtungen.htm

Integrated research program: Lower Saxony climate impact research program – Part Forest

Scope: Quantification of expected climate change on the regional level (Bundesland Lower Saxony), integrated assessment of climate change impacts on agriculture, forestry and fresh water resources and development of adaptation strategies.

Research design: Methods for regional climate projection will be used to increase the spatial resolution of GCM simulation results. The actual response of forests comprised of European beech and Norway spruce to climatical gradients in temperature and precipitation is investigated within two study areas, the Harz Mountains and the Lüneburg Heath. It is intended to link the results of climate projections and invariant physical site properties by GIS-based modeling to determine future site characteristics and, hence, options for adaptation. The research program includes subprojects from soil science, forest genetics, tree physiology, molecular physiology of trees, silviculture and nature conservation.

Investigators: Several departments of Georg-August University Göttingen and Leibniz University Hannover; Nordwestdeutsche Forstliche Versuchsanstalt, Göttingen

http://www.kliff-niedersachsen.de.vweb5-test.gwdg.de/?page_id=26

Experimantal study: Species competitiveness under climate change.

Scope: Tree species cultivated in Germany comprise distinct ecological niches with respect to light availability during forest regeneration. This property is commonly used to control the composition of forest regeneration in combined objective and close to nature forestry by silvicultural means. However, it is likely that species competitiveness is sensitive to changing water availability due to climate change.

Research design: In the experiment 6 treatments are realized: 3 light intensities combined with a dry and a “normal” reference soil water regime. In total 360 young trees of Norway spruce and European beech were cultivated for 3 consecutive growing seasons. Measurements include height growth, above and below ground production, leaf mass, fine root length and branching pattern.

Investigators: Department of Silviculture and Forest Ecology of the Temperate Zones, Georg-August University Göttingen

http://www.uni-goettingen.de/en/71591.html

Research and development project: Decision Support System "Forest and climate change" (DSS-WuK)

Scope: The project 'Adaptation Strategies for Sustainable Forest Management under Changing Climatic Conditions – Decision Support System 'Forest and Climate Change' (DSS-WuK)' develops models and methods on the national scale to assist stakeholders within the German forestry and environment sectors to find adequate forest adaptation measures to climate change. The project aims to to evaluate impacts of climate change in terms of site changes and impacts of abiotic and biotic stress factors (drought, pests and wind) on a regional scale for major tree species, to estimate the changes in forest growth and economic utility, and to identify suitable silvicultural adaptation strategies.

Research design: These assessments are based on a compiled existing knowledge about climate change impacts and their effects on the economic and ecological services of forests within a user-friendly decision support system (DSS). The DSS reflects site variation at a regional scale due to wind climate, drought and climate-induced biotic agents based on regionalized projections (CLM – Climate Local Model, REMO – Regional Model) for the above- mentioned IPCC SRES A1B and B1 scenarios. High-resolution maps showing projected climate variation as well as model outputs (including abiotic and biotic risk level, site-growth development and economic indicators) for major tree species (European beech, Peduculate/Sessile oak, Norway spruce, Scots pine and Douglas fir) provide decision support to the individual stakeholder [Jansen et al., 2008].

Investigators: Forest Ecosystems Research Center, Georg-August University Göttingen; Northwest German Forest Research Station (NW-FVA), Göttingen; Johann-Heinrich von Thünen-Institute (vTI, Forest Ecology and Forest Inventory)

http://www.dss-wuk.de

Part III: Mitigation

Author: *M. Köthke*

III.1 Carbon Accounts

Germany committed itself to a reduction of greenhouse gases of 21% in the first commitment period (CP) of the Kyoto Protocol 2008-2012 against the 1990 level. The target will be set to 40% emission reductions in 2020, if the EU commits itself to a target of 30% (Deutscher Bundestag 2005).

The Kyoto Protocol (KP) commitments include the reporting of changes in the carbon stock caused by conversion of forest land to other land uses and vice versa (KP Article 3.3). The voluntary accounting of emissions and removals from existing forest land related to KP Article 3.4 was chosen by Germany as well (Winkler 2007).

The carbon removals by forests may contribute to the national emission reduction targets only up to a certain level. For Germany the accounting of emission removals from forest land is capped at 1.24 Mt C per year in the first CP. If the carbon balance caused by land-use changes related to KP 3.3 turns out to be a source of carbon, additional emission removals from forest management (Art. 3.4) may be credited against it, but only up to a maximum of 9 Mt C/yr (UNFCCC 16/CMP.1 2005). The national carbon balance will be assessed at the end of the CP 2012 (Winkler 2007). For the post Kyoto period beyond 2012 the rules are not yet agreed.

The annual carbon stock change related to land-use changes (afforestation and deforestation) and to forest management (forest land remaining forest land) reported in the national inventory report (NIR) is shown in table III.1 (website UNFCCC). For 2007 the total uptake of CO_2 from forest land was reported with 79.4 Mt CO_2 (21.6 Mt C) (UBA 2009). The average net increment of the forest carbon stock between 1987 and 2002 was calculated to be 1.52 t C/ha/yr for the old *Bundeslaender* and 2.32 t C/ha/yr for the new *Bundeslaender* (UBA 2009).

Table III.1 *Annual carbon stock change for Germany from land-use change and forest management (net emissions/removals in Gg CO_2) (website UNFCCC).*

	1990	1995	2000	2005	2006
Carbon uptake	**-74,399.45**	**-75,588.37**	**-77,196.57**	**-78,726.45**	**-79,049.74**
• land-use change: land converted to forest land	-335.94	-1,524.86	-3,133.06	-4,662.94	-4,986.23
• forest land remaining forest land	-74,063.51	-74,063.51	-74,063.51	-74,063.51	-74,063.51
Carbon emissions • land-use change: forest land converted to other land	**986.37**	**986.37**	**986.37**	**986.37**	**986.37**

The data for the NIR is based on data from two national forest inventories 1987 and 2002 (BWI 1 and 2) and an extrapolation of the trend. The currently available NIR data may soon be updated by data from an intermediate inventory 2008 (BMELV 2009). In comparison to the next national forest inventory 2012 (BWI 3) the carbon uptake of the first commitment period will finally be calculated (UBA 2009).

Between 1987 and 2002 the wood stock of the German forest increased on average 55 m³/ha (website BWI2). This trend is expected to slow down in the future and turn into a stock decrease referring to timber stock prognosis by WEHAM[8] (see Table III.2). The prognosis is based on the fact that the German forests are getting older on average due to the unequal age class structure and at the same time the felling volume is expected to increase due to an increasing wood demand (see Table III.3) (website BWI2).

Table III.2 *National wood stock (million m³) (website BWI2, outlook based on WEHAM).*

	2002	**2007**	**2012**	**2017**	**2022**	**2027**	**2032**	**2037**	**2042**
Wood stock	3,231	3,304	3,337	3,391	3,411	3,422	3,416	3,402	3,383

Table III.3 *Annual increment and felling volume for Germany (million m³/yr) (data 2001-2004: Bormann et al. 2006, data 2003-2042: website BWI2, outlook based on WEHAM).*

	historical data					outlook							
	2001	**2002**	**2003**	**2004**		**2003 - 2007**	**2008 - 2012**	**2013 - 2017**	**2018 - 2022**	**2023 - 2027**	**2028 - 2032**	**2033 - 2037**	**2038 - 2042**
annual increment	124.0	124.3	113.6	113.8		107.5	106.3	106.7	103.4	101.7	100.4	99.1	98.1
annual felling volume	58.8	60.7	65.8	73.9		70.9	78.4	75.8	78.7	78.9	80.7	81.1	81.0

In accordance with the Integrated Environmental and Economic Accounting for Forests (IEEAF) Bormann et al. (2006) complemented the forest inventory data with data from annual data collections. Referring to this data already nowadays one can see the decreasing annual carbon uptake of the German forest ecosystem (see Figure III.1).

[8] WEHAM: Waldentwicklungs- und Holzaufkommensmodellierung. Prognosis of the forest management, potential felling volume and forest development in the next 40 years (Website BWI2).

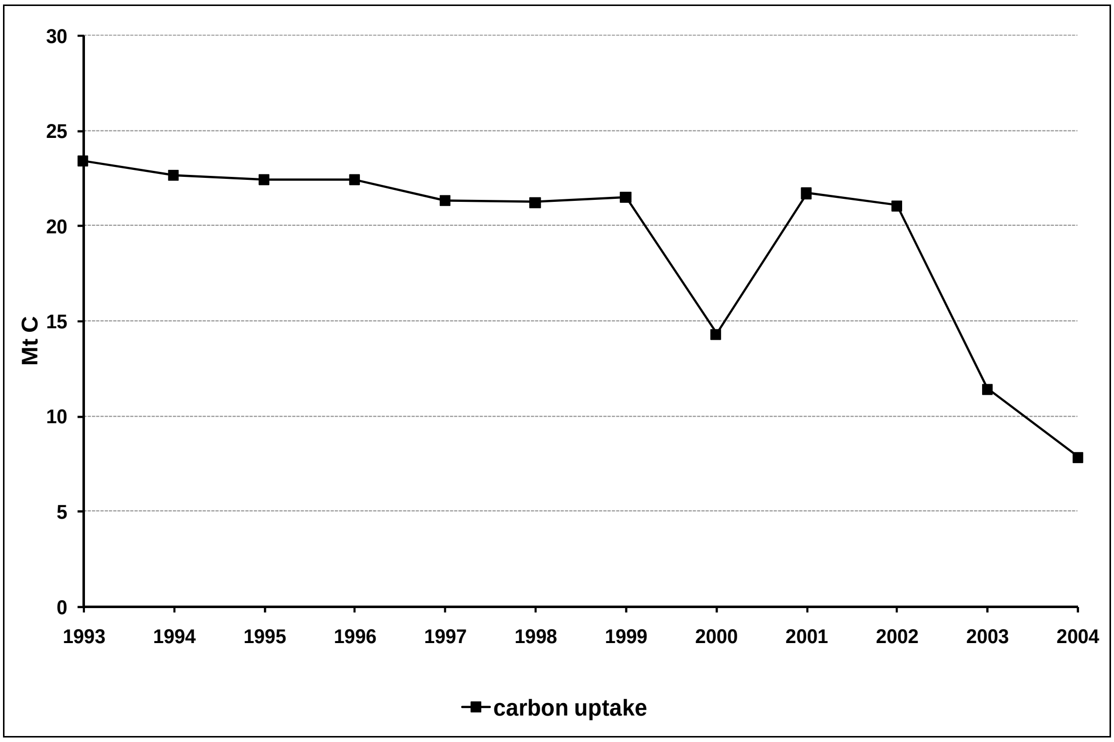

Figure III.1 *Annual carbon uptake of the German forest ecosystem (Mt C) (Bormann et al. 2006).*

III.2 Forestry as a Source of Bioenergy

The national objectives – referring to the National Climate Protection Programme 2000 – include the support of wood use for bioenergy and harvested wood products. The government's objective to increase the use of wood for energy and products is stated in the Wood Charta 2004. The use of wood and wood products should be increased for 20% from 2002 to 2012 with the aim to increase the carbon store in long living wood products and the effects of energy and product substitution (BMELV 2004). Table III.4 shows the annual use of wood for products and energy in Germany, including a scenario assumption for the wood use in 2012 (related to Mantau 2008).

Table III.4 *The annual use of wood for products and energy in Germany (million m³/yr) (Mantau 2008, the data include also the reuse of wood, the use of by-products and residues).*

	2003	**2007**	**2008**	**2012**
products	56.3	73.9	72.0	74.1
energy	31.3	52.0	54.0	58.0

The government aims at increasing the share of renewable energies to the targets of 30% of electricity consumption till 2020, 14% of heat supply till 2020 as well as 12% of motor fuels till 2020 (Deutscher Bundestag 2005, BMU 2008). The most important source of renewable energy in Germany is wood. Germany's energy production of solid biomass in 2007 was 9.112 million tons of oil equivalent (Mtoe), this is equivalent to 0.111 toe per inhabitant. The gross electricity production of solid biomass in 2007 was 7.39 TWh (EUROPSERV'ER 2008). 2007 biomass (mainly wood) had a share of 94% on the heat supply from renewables in Germany (94 TWh) (BMU 2008).

Within four years the share of renewable energies of the total final energy consumption has doubled (9.8% in 2007). Hence former targets had been adjusted upwards (BMU 2008).

Incentives: With the EEG Law 2000 an incentive feed-in tariff for renewable energy was established. For energy from wood a bonus is paid; eligible are thinning wood, logging residues, bark and wood from short rotation coppice. Since 2009 the law on the promotion of renewable energies in the heat sector (EEGWärmeG 2008) obliges house owners of new buildings to use renewable energy for part of their heating (EUROPSERV'ER 2008).

III.3 Processes, Instruments and Strategies

Related to the WEHAM prognosis the German forest will become a source of carbon around the year 2028 (see Figure III.2). The eligible carbon removal from forest management in the first CP of the Kyoto Protocol (cap of 1.24 Mt C/yr) will probably be reached and exceeded (see Figure III.2). In the likely case, that the carbon sequestration service of the national forests will generate revenues for the state in the first CP, the responsible federal ministry BMELV plans to transfer the benefit in some way to the forest sector (BMELV 2006). But so far it is not yet defined how this will be done.

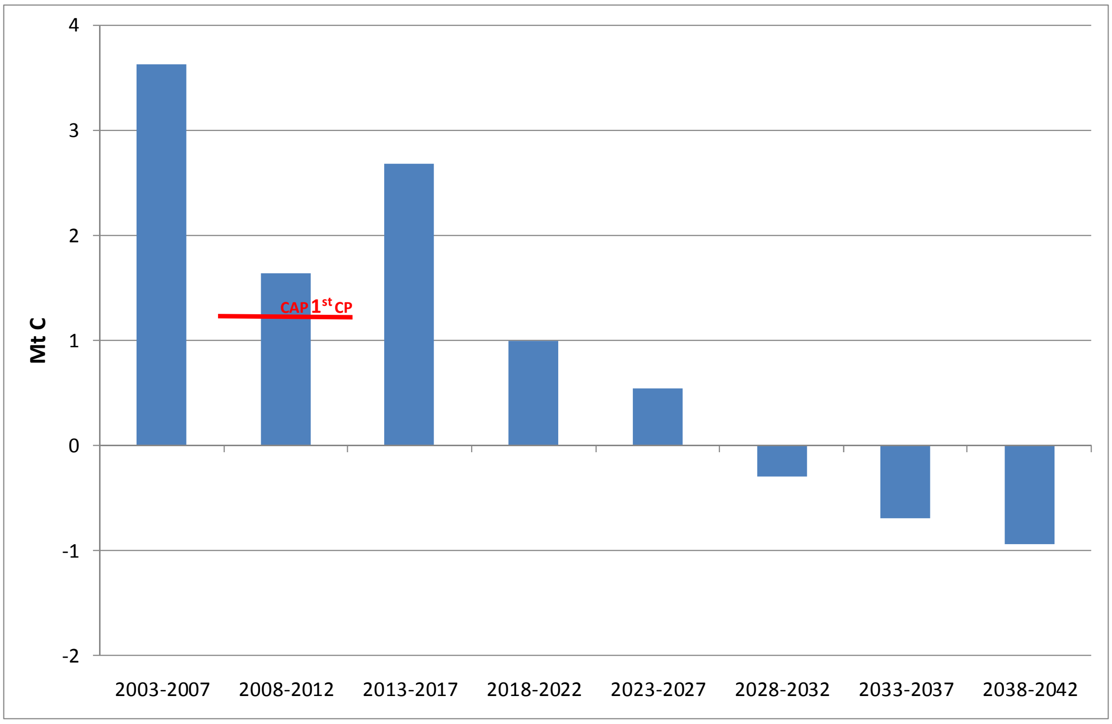

Figure III.2 *Net carbon removal of the national forest (Mt C/yr) (based on WEHAM data, website BWI2).*

- Land-use change (afforestation, reforestation, deforestation)

In Germany the conversion of forest land to other land uses is only permitted with official approval due to land use regulations, forestry laws on the national and *Länder* level as well as the law on environmental impact assessment and related regulations. Therefore deforestation has to be compensated by a comparable afforestation (BMU 2000, Deutscher Bundestag 2005). In addition afforestation is subsidised by the *Länder* and the EU (BMELV 2007).

Figure III.3 shows the annual area of afforestation and deforestation in Germany from 1993 till 2004.

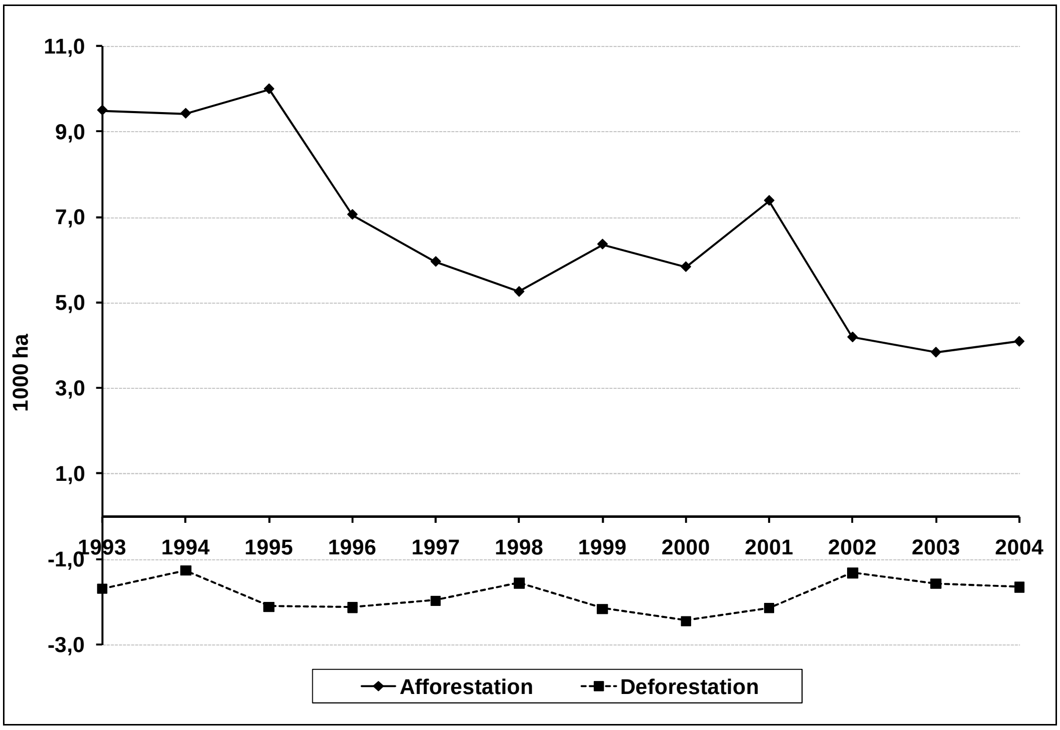

Figure III.3 *Land-use change: annual area of afforestation and deforestation in Germany (1000 ha) (Bormann et al. 2006).*

- Forest management

The National Climate Protection Programme 2000 pursues the strategy to improve the adaptability of the forests to climate change and to improve the vitality and stability of the forests. For the minimization of risks the conversion of forests and nature-orientated forest management are supported by the GAK (Gemeinschaftsaufgabe zur Verbesserung der Agrarstruktur und des Küstenschutzes) (BMU 2000, BMELV 2007).

- CDM- and JI-projects related to forestry

Possible project types for CDM- and JI- forestry projects are related to afforestation and reforestation. Till first of June 2009 Germany was no buyer of any CDM- or JI-forestry project nor was any in the pipeline by this date (website UNEPRISOE providing lists of projects and project pipelines). The possibility to run JI-projects in the field of land use, land-use change and forestry (LULUCF) is not admitted in Germany beeing a JI-host country (DEHSt 2008).

III.4 Research Studies on Mitigation

On behalf of the BMU the **Leitstudie 2008** was elaborated by Nitsch 2008. The study provides scenarios for the future energy supply structure according to the current national and European objectives for the protection of climate change and renewable energies (Nitsch 2008).

Different national research projects on mitigation are funded by the National Research Program "**Substainable Forestry**" (2004 to 2010). This program is incorporated in the framework program “Research for Sustainability” (FONA) of the Federal Ministry of Education and Research (BMBF) and is part of the European network WoodWisdom-Net (Era-Net) (the following project descriptions are taken from the Website of the National Research Program "Substainable Forestry”, further information on the projects is available on this website as well).

<u>Projects:</u>

Potential and Dynamic of Carbon Sequestration in Forests and Timber (CSWH)

> Quantification and assessment of the potential contribution of the forest and timber sector to the reduction and stabilization of CO_2 concentration in the atmosphere.

Dendrom – future resource dendromass

> Systemic analysis, guiding principles and scenarios for the sustainable energy recovery and the material use of dendromass from forest trees and coppice.

AGROWOOD

> Cultivation, harvest and utilisation of fast growing tree species on agricultural crops in the Freiberg region (Saxony) and in the Schradenland (South Brandenburg). Agrowood is an associated project of the agriculture promotion sector.

Ökopot

> Promoting the environment friendly use of timber products through an analysis of the ecological potentials of the timber and wood value chain. Providing a scientifically sound method and information on ecological benefits of wood products and on how to improve them.

Other projects:

Rohholz zur Energieerzeugung

Mobilization and economic use of wood from the forest and the landscape for energetic utilization. Estimation of biomass potentials for the production of bioenergy in the forest as well as in open landscapes.

University of Freiburg, Institut für Forstbenutzung und Forstliche Arbeitswissenschaft, funded by the DBU (Website DBU). 2004-2007.

Part IV: Case studies

IV.1 Case Study I

At this moment we do not elaborate on case studies. These will be developed at a later stage during the COST Action ECHOES.

IV.2 Case Study 2

Idem.

IV.3 Case Study 3

Idem.

Part V: Appendices

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