Socio-economic Impacts—Forestry and Agriculture

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Abstract
Climate change affects the vulnerability and productivity of forestry and agricultural systems, predominantly by changes in precipitation and temperature patterns. Indirect impacts are altered risk of damage, for example, by longer periods of drought stress and other biotic and abiotic disturbances. While southern and eastern parts of the Baltic Sea basin are likely to experience a net impact of climate change that is negative for production, northern and western regions are likely to experience a general increase in production. As a result, land-use potentials will change and will foster adaptation and mitigation measures. In the northern region, forest management adaptation may lead to substantial yield increases, while in the south management, adaptation may be required to counter deteriorating conditions. Comparable conclusions can be drawn for agricultural management: if adaptation potentials are fully exploited, substantial yield increases can be expected for certain crop species. In the southern areas and for certain species, deteriorating conditions and possibly increasing climatic variability are projected. Both climate change impacts and human responses will affect socio-economic conditions in the Baltic Sea basin.

21.1 Introduction

Climate change affects the vulnerability and productivity of agricultural and forestry systems predominantly through changes in precipitation and temperature patterns and by changes in the frequency and intensity of risk factors for damage such as droughts, floods, storms and biotic disturbances such as pest infestations. In addition to changes in environmental factors, changing energy policies may influence agricultural and forestry systems through changes in demand for biomass for use as a biofuel. While southern and eastern Europe are likely face a net effect of climate change that is negative for production, northern and western regions are likely to see a general increase in production (EEA 2006). As a consequence, land-use potentials will change and will foster the need for adaptation and mitigation measures. Both climate change impacts and human responses will affect socio-economic conditions in the region.

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This chapter focuses on managed forest land and agricultural land, while the effects of current and future climate change on forest growth in general are covered in Chap. 16.

21.2 Climate Change and Forest Management

21.2.1 Forest Management in the Baltic Sea Basin

The main forest types in the Baltic Sea basin are boreal coniferous forests north of 60°N and temperate deciduous forests south of 60°N (EEA 2007). Climatic conditions in boreal forests are characterised by a growing season of 3–6 months with a mean temperature of about 5 °C and a water surplus (precipitation exceeds evapotranspiration, Otto 1994). There is a clear north–south gradient in temperature and an east–west gradient in humidity. A short growing season and low nitrogen supply are the main factors limiting forest growth in the boreal forests, whereas low water availability periodically limits forest growth over large areas in the temperate southern parts of the Baltic Sea basin (BACC Author Team 2008; Gundale et al. 2011). Information on the forests of the Baltic Sea basin is provided in the report on the status of forests in Europe 2011 (Forest Europe, UNECE and FAO 2011). Figure 21.1 and Table 21.1 indicate forest areas and their share of the land area by country (Forest Europe, UNECE and FAO 2011).

Table 21.1 Basic forest data for countries of the Baltic Sea basin (excluding Russia) in 2010 (Forest Europe, UNECE and FAO 2011)

Country	Total land area (1000 ha)	Forest[a] and OWL[b] (1000 ha)	Percentage of total land area	Forest and OWL per inhabitant (ha)
Denmark	4242	635	15	0.1
Estonia	4239	2337	55	1.7
Finland	30,408	23,116	76	4.3
Germany	34,877	11,076	32	0.1
Latvia	6229	3467	56	1.5
Lithuania	6268	2249	36	0.7
Poland	30633	9316	30	0.2
Sweden	41031	30,625	75	3.3

It should be noted that Forest Europe (2012) uses specific classifications of forest land and other wooded land that result in slightly different figures to those from the FAO used in Chap. 25

[a] Forests: Land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10 %, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use (FAO 2004)

[b] Other wooded land (OWL): Land not classified as forest, spanning more than 0.5 ha; with trees higher than 5 m and a canopy cover of 5–10 %, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 %. It does not include land that is predominantly under agricultural or urban land use (FAO 2004)

Most forests in the Baltic Sea basin are managed, and forestry is mainly based on native tree species that invaded the region after the last glaciation. However, many forests in the area have been cleared for agriculture, and forests still

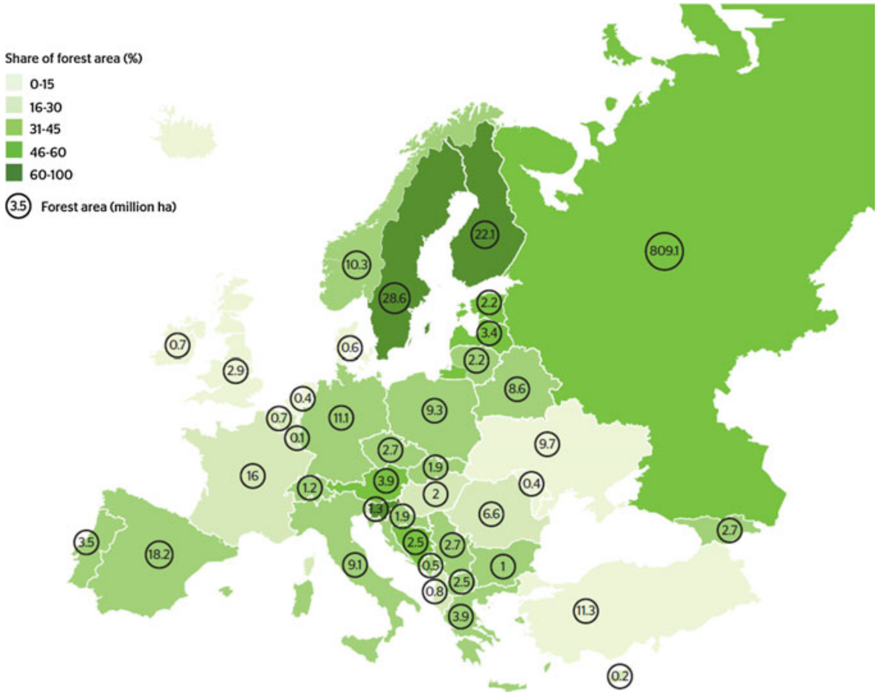

Fig. 21.1 Total and percentage forest area by country in 2010 (Forest Europe, UNECE and FAO 2011)

dominate the landscape only in northern Europe (e.g. Sweden, Finland and north-western Russia). In the temperate parts of the Baltic Sea basin, the current tree species composition is determined by past land use and management activities rather than by natural factors (Ellenberg 1986).

The total area of forest and other wooded land in the Baltic Sea basin (excluding Russia) is about 82 million ha. The total volume of stem wood is about 11,290 thousand m^3 and is dominated by the native tree species Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*). Together, these two species account for more than 70 % of the total stem volume, with smaller contributions by deciduous trees (mainly Birch, *Betula pendula*) (BACC Author Team 2008). The share of deciduous trees is greater in the temperate part of the Baltic Sea basin, which forms the transition from the temperate deciduous forest zone to the boreal coniferous forest. The role of exotic species is most important in the temperate zone, but even there their share is small. Forests in Finland and Sweden comprise about 43 % (by volume) of the total forest resources in the Baltic Sea basin (excluding Russia).

Table 21.2 provides an overview of the increment (net growth) and felling in 2010 (Forest Europe, UNECE and FAO 2011). These data indicate the productivity and utilisation rates of the forests. All countries of the Baltic Sea region manage their forests sustainably from a wood stock perspective, that is, felling does not exceed increment. However, sustainable forest management usually includes ecological and social aspects (Forest Europe 2012). In regions where biodiversity is being lost, sustainability criteria are not being met.

According to Forest Europe, UNECE and FAO (2011) the value of roundwood removals from forests in 2010 was almost EUR 10,000 million in Estonia, Finland, Germany, Lithuania, Poland and Sweden, with a corresponding employment of roughly 180,000 FTE (full-time equivalents) in the forest sector and 591,000 FTE in the manufacturing of wood and paper. Throughout the region, increment exceeds felling through increased stocking and maturing of forest resources. In the near future, forest resources are expected to increase further due to afforestation of agricultural land and the projected increase in forest growth under a warmer climate.

21.2.2 Impacts on Forest Management

Model simulations indicate that rising temperatures could improve tree growth in the northern boreal zone, while changes in precipitation are not likely to have a major effect on growth at these latitudes (Bergh et al. 2003, 2007; Ge et al. 2011b). In the southern parts of the Baltic Sea basin, tree growth is strongly water limited (Lasch et al. 2002, 2005). Here, an increase in temperature but without an increase in precipitation could further exacerbate the water deficit and thus decrease growth. In general, the temperature response optimum (the ability of tree species to manage higher temperatures) is higher and the effect of rising temperature is more positive, if precipitation also increases, whereas the main effect of higher temperatures is negative and the temperature response optimum lower if precipitation is reduced (Lindner et al. 2010). For example, growth of Norway spruce in the southern boreal zone is projected to increase up to 2050, but then decline due to more frequent dry spells during the growing season (Kellomäki et al. 2008; Ge et al. 2011b; see also Chap. 16). In the continental temperate zone, forest growth in general is limited more by water than by temperature, but the effect of increased levels

Table 21.2 Increment (net growth) and felling in forests available for wood supply, 2010 (Forest Europe, UNECE and FAO 2011, excluding Russia)

Country	Net annual increment		Felling			Value of roundwood removals
	(1000 m^3)	(m^3 ha^{-1})	(1000 m^3)	(m^3 ha^{-1})	(Percentage of annual increment)	(million EUR)
Denmark	5176	9.5	2371	4.1	40.9	–
Estonia	11,201	5.6	5714	2.8	51.0	196
Finland	91,038	4.6	59,447	3.0	65.3	1858
Germany	107,000	10.3	59,610	5.6	55.7	3003
Latvia	16,500[a]	5.5[a]	12,421	4.0	–	–
Lithuania	10,750	5.7	8600	4.6	80.0	181
Poland	67,595[b]	8.0[b]	40,693	4.8	–	1291
Sweden	96,486	4.7	80,900	3.9	83.8	2656

[a] 2000
[b] 2005

of atmospheric carbon dioxide (CO_2) may partly offset the potential negative effects of climate change (Freeman et al. 2005; Lindner et al. 2005).

The human response to climate-related impacts on forest management is likely to concern deteriorating condition and the possibilities for adapting forest management practices to address, for example, increased water stress or higher temperatures. This could comprise changes in stand structure (e.g. wider spacing), thinning measures, potential underplanting or selection of more suitable tree species and provenances.

Across much of the Baltic Sea basin, climate change has the potential to improve site and growing conditions, such as by removing formerly limiting conditions through rising temperature or nitrogen availability in the northern latitudes and by extending growing periods (Linderholm 2006). Climate change effects on forest growth (see Chap. 16) may lead to changes in forest yield, but may also affect management practices. The changing conditions could potentially allow an intensification of management (e.g. a shortening of rotation length and adjustment of thinning schedules), possibly even on formerly marginal sites and the introduction of new tree species. However, an intensification of forest management may have consequences affecting other goals, such as carbon sequestration and biodiversity protection. Furthermore, and in terms of practical silviculture, warming could make forest resources in wet areas inaccessible, due to shorter periods of frozen ground, thus reducing the availability of such timber. This could increase harvesting and transport costs and threaten supply for the wood industry (Lindner et al. 2010).

21.2.2.1 Adaptive Forest Management May Support Higher Yields

In general, given adequate precipitation and accessibility, changes in management have the potential for effective adaption to climate change. Regardless of the future climate scenario, it was found that shifting from current practices to thinning regimes that allowed higher stocking of trees resulted in an increase of up to 11 % in carbon uptake by the forest ecosystem. It also increased the carbon content in timber yield by up to 14 % (Garcia-Gonzalo et al. 2007b). Briceño-Elizondo et al. (2008) supported this conclusion for a revision of forest management practices not only for timber production, but also for benefits such as carbon sequestration and other amenities including biodiversity.

Kellomäki et al. (1997) simulated the impact of higher CO_2 concentrations, temperature and precipitation on Scots pine in southern Finland (61°N). They reported an increase in timber yield of up to 30 % and through that a potential shortening of rotation periods by 9 years (for a temperature rise of 0.4 °C decade^{-1} and a precipitation increase of 9 mm decade^{-1}), 17 years (for a CO_2 elevation of 33 µmol mol^{-1} decade^{-1}) and 23 years when all three factors are increased. The authors concluded that increased timber supply and profitability of forest management could be expected under a future climate. Similar results were found by Karjalainen (1996) who reported that timber production could increase substantially for 30 mixed species on medium-fertility stands in southern Finland over a 300-year period. More recently, Garcia-Gonzalo et al. (2007a) simulated different management approaches for Finland. They found the greatest increase in timber yield and percentage of saw logs to occur for a thinning regime with high stocking over 100 years. A gradual rise in temperature and precipitation and an elevation in CO_2 enhanced growth by about 24 %, resulting in a 12–13 % increase in timber yield. Bergh et al. (2007) estimated that Swedish forest growth could increase 10–50 % by 2070–2100 under the SRES A2 scenario (IPCC 2000), more in the north and less in the south and central-west. Norway spruce would be favoured in the north and Scots pine in the south, suggesting a corresponding change in preferred species for regeneration at sites suitable for both species (Swedish Forest Agency 2007).

Other studies also project increased growth and underline the need for adaptive management practices. Kärkkäinen et al. (2008) estimated the recovery of industrial wood and raw material for wood energy (biofuel) under two different cutting scenarios, contrasting ‘current’ and ‘climate change’ conditions for the next 50 years. The results indicated an average increase of about 10 % for industrial wood and 12 % for wood energy under a sustainable cutting scenario for Finland. A maximum cutting scenario would give increases of 33 and 32 %, respectively.

Pussinen et al. (2002, 2009) also found evidence that future climate change is likely to increase harvest removals and economic profitability in Finnish forestry. For forest management, this would allow shorter optimum rotations based on mean annual yields, for example for Scots pine in southern Finland. The highest mean annual carbon stock in forests over a rotation period, however, was achieved with longer rotation periods and higher nitrogen deposition (Pussinen et al. 2002; De Vries et al. 2009). In contrast, further warming may lead to reduced forest carbon stocks mainly due to increased decomposition of soil organic matter and thus lower forest soil carbon stocks. However, at the centennial perspective, the rate of delivery of bioenergy, which is largely correlated to harvesting rates, might be more important for climate change mitigation than potential changes in carbon stocks. In Sweden, the share of harvested biomass largely used directly for energy production has increased from ~40 % to near 50 % (bark, sawdust, lignin, branches and tops, wood from early thinning, etc.) over recent decades. This could also be the case in other countries due to the adoption of energy policies that restrict the use of fossil fuels and/or nuclear power.

According to Kellomäki et al. (2008), forest growth may increase by 44 % in Finland with an increase of 82 % in the potential cutting drain (maximum sustainable removals under a given management). They stressed the need to choose appropriate species and rotation periods and to consider changing forest structures and the requirement to sustain the productivity of forest land under climate change. Garcia-Gonzalo et al. (2007a) stated that both the climate change scenario and management regime influenced the profitability of timber production for a process-based ecosystem model applied to analyse the effects of climate change and management on timber yield for a forest management unit in Finland (63°N). The authors indicated that choosing the 'wrong' management regime, instead of the best one, could lead to an average economic loss of EUR 166 ha^{-1}. The highest species-specific opportunity costs (as lost potential benefit) were found for Scots pine (EUR 227 ha^{-1}) and the lowest for silver birch (*Betula pendula*) (EUR 53 ha^{-1}). They concluded by stressing the need to adapt future management to utilise the increase in growth under climate change (see also Matala et al. 2009).

Further results on climate change implications for forest management were provided by Briceño-Elizondo et al. (2006a, b), who tested the effect of eight different thinning regimes on Scots pine, Norway spruce and silver birch stands in the southern and northern boreal areas of Finland for a 100-year simulation. Results indicated that thinning regimes that increased the stocking of the tree population increased the mean carbon stock in the forest and timber yield, compared to the current thinning guidelines, regardless of tree species and climate scenario. Climate change enhanced stocks more in the north than the south. The results indicated that carbon sequestration in the ecosystem may be enhanced with no loss in timber production (Briceño-Elizondo et al. 2006a). According to Briceño-Elizondo et al. (2006b), thinning regimes that increased mean stocking over the rotation all increased total growth and timber yield, regardless of tree species and site. The authors highlighted the potential to exploit the benefits that climate change seems to provide in the form of increased growth and timber yield in the boreal conditions and suggested that current management rules be revised.

These findings support the results provided by Karjalainen (1996) on the effect of forest management on carbon sequestration in a 300-year simulation for 30 mixed species stands in southern Finland. Karjalainen explained that the total carbon balance (vegetation, litter, soil organic matter and products) was higher in unmanaged stands during the first 100 years, but not in the second or third. Under climate change conditions, results projected substantially enhanced timber production and carbon sequestration. This is supported by Garcia-Gonzalo et al. (2007a) who reported a 12–13 % increase in timber yield for an adapted thinning regime with high stocking over a 100-year rotation period under climate change impact. Matala et al. (2009) described the effect of forest management on carbon sequestration and increased production potential due to climate change over a 50-year period (2003–2053) in the growing stock of trees in Finland compared to current values (an initial amount of carbon in the growing stock of 765 million tonnes). They found an increase of $\sim$17 % for growing stock without climate change, but an increase of about 38 % under sustainable production and assuming a gradually warming climate until 2053. Another simulated management strategy, the maximum net present value (NPV) of wood production, resulted in an increase of 18 and 34 %, respectively, compared to the initial growing stock. The results show that future development of carbon sequestration and growing stock is not only dependent on climate change scenarios but on forest management adapting to changing conditions (Matala et al. 2009). Similar conclusions were drawn by Köhl et al. (2010) for, among others, temperate regions in north-eastern Germany.

21.2.2.2 Adaptive Forest Management is Required to Counteract Negative Impacts

In the southern part of the Baltic Sea basin, reduced precipitation in combination with higher temperatures is likely to result in reduced growth and increased risk of fire and pest outbreaks (Kellomäki and Kolström 1994; Lasch et al. 2002, 2005; BACC Author Team 2008; Köhl et al. 2010). However, adaptive forest management may counteract these unfavourable conditions.

In southern Finland, reduced precipitation may lead to lower productivity of Norway spruce. Ge et al. (2011a, b) examined the potential for different thinning regimes to improve carbon uptake, stem growth and timber yield. Again, the necessity for adaptive management systems was highlighted. Similarly, based on an ecosystem model for southern Finland in 2010–2099, Alam et al. (2010) reported a stronger productivity effect on forest structure than changing climate.

Peltola et al. (2010) supported the need for adapted forest management when considering forest damage. They explained that changing forest structure, such as birch (*Betula* spp.) replacing Norway spruce in southern Finland, can reduce the risk of wind damage in winter but increase risk during periods of unfrozen soil. Increasing rotation length, for example by 20 years, can increase carbon stocks in the living biomass for Scots pine in southern Finland and north-eastern Germany, but would simultaneously lead to decreased timber harvests (Kaipainen et al. 2004), which in turn can reduce potential for bioenergy delivery.

Similar results were found for the southernmost part of the Baltic Sea Basin. Köhl et al. (2010) modelled different climate change scenarios and management types using the

German national forest inventory data and two climate change scenarios from the IPCC's Special Report on Emission Scenarios (IPCC 2000): A1B, rapid and successful economic growth; B1: high level of environmental and social consciousness combined with a globally coherent approach to a more sustainable development. Three management types were used—'maximum profit oriented', 'diameter limit cut' and 'maximum net annual forest rent'—to evaluate their effects on future productivity and species composition of German forests. The results were based on changing precipitation and temperature patterns and show clear north–south differences. Overall, Köhl et al. (2010) concluded that the effects of different climate change scenarios on the future productivity and species composition of German forests are minor compared to the effects of forest management. Garcio-Gonzalo et al. (2007b), Briceño-Elizondo et al. (2008a, b) and Alam et al. (2008) also reported increased benefits from management schemes adapted to climate change.

Adaptive management requires consideration given to changing the species composition, especially when lower precipitation is expected. Lasch et al. (2002, 2005) reported for north-eastern Germany (Federal State of Brandenburg) aims of increasing the share of deciduous and mixed forests as an adaptation to climate change. While climate change led to a reduction in groundwater recharge of about 40 %, more intensive management slightly increased groundwater recharge (Lasch et al. 2005). Simulation studies with three management scenarios indicated that the short- to mid-term effects of climatic change in terms of species composition were less severe than expected. However, comparing diversity measures indicated a decrease in species diversity in contrast to an increase in habitat diversity under climate warming (Lasch et al. 2002).

Lasch et al. (2005) concluded that the potential for adaptive management based on changes in rotation length and thinning is very limited in the Federal State of Brandenburg, which is characterised by poor sites and dry conditions. They also concluded that it is necessary to include forest transformation strategies in management impact analyses for forest planning under global climate change. In contrast, Köhl et al. (2010) demonstrated for all the north-eastern Federal States of Germany that management matters more than climate change and concluded that the negative effects of climate change can be reduced by adaptive management.

The potential northwards shift in tree species is important with respective to adaptation potential. Birch (*Betula* spp.), already the main deciduous species in the boreal zone, shows a positive response to rising temperature and low sensitivity to precipitation (Truon et al. 2007; Lindner et al. 2010). In contrast, oak (*Quercus* spp.) and beech (*Fagus sylvatica*) respond strongly to changes in precipitation in temperate zones. While temperature increase was generally negative for the growth of beech, oak showed a weak positive response (Lindner et al. 2010). With sufficient precipitation, both species seem capable of a northwards shift in abundance (Kramer et al. 2010). On this basis, the BACC Author Team (2008) recommended that consideration be given to incorporating other indigenous tree species, currently of minor importance in forestry, but with high potential for timber production or carbon sequestration under climate change. Further recommendations included an increased share of those broadleaved trees species considered to perform better under climate change, substitution of sensitive species by better adapted provenances and replacement of low-productivity tree populations (BACC Author Team 2008). The importance of choosing suitable tree provenances was emphasised by Kellomäki et al. (2008), who showed that southern provenances of Norway spruce would be less sensitive to climate change in southern Finland.

21.2.3 Concluding Comments on Management Implications

Considering the long time scales of forestry (rotation lengths of 40–140 years depending on species and region), it is clear that major climate change impacts could occur within the lifetime of existing tree stands. To a certain extent, this would limit the adaptive capacity of tree species to the variability of the existing generation (Köhl et al. 2010). However, the genetic variability of most common tree species is probably large enough to accommodate the mean changes in temperature and precipitation (Beuker et al. 1996; Persson and Beuker 1997).

For the Baltic Sea basin as a whole, there are likely to be shorter winters, longer growing seasons, changes in precipitation (Forest Europe 2012) and, potentially, changes in storm patterns (see also Chap. 11). Conditions for pest outbreaks and tree damage will change under a warmer climate, more often for the worse. In Fennoscandia, some of the economically most damaging pests could be favoured: spruce beetle (*Ips typographus*), pine weevil (*Hylobius abietis*) and root rot fungus (*Heterobasidion annosum*) (Swedish Forest Agency 2007). The likely effects of climate change on insect damage and major pest outbreaks are still largely unknown. Nevertheless, many damaging fungi and insects may expand their occurrence from Central Europe and further south to the Baltic Sea basin (Parry 2000). On the other hand, there is empirical evidence to suggest that elevated CO_2 and higher temperatures may increase the resistance of deciduous species to herbivore browsing and thus reduce the risk of forest damage (Mattson et al. 2004).

Wind felling may increase as winter soils are frozen for shorter periods, and water tables are higher. The species most sensitive to wind, Norway spruce, would be favoured if deer populations survived winters better and browsed more than today on other plant species. Unless hunting increased, this would increase the sensitivity of Fennoscandian forests to wind felling (Swedish Forest Agency 2007). There is also a risk that pathogens and insects having marginal impacts under present-day conditions could become more important and that new insect pests could move in from the south.

To maintain resilience, in terms of production, biodiversity and other forest uses, adaptive strategies should be considered at regeneration. For example, planting more tree species and favouring a higher number of species when cleaning and thinning than is usual today (Swedish Forest Agency 2007).

Problems may also be encountered due to the higher frequency and intensity of extreme events, such as droughts, storms and spring and summer freezing (CCIRG 1996; Nikulin et al. 2011), with consequent damage to forests. The Baltic Sea basin has only a few tree species of economic importance in forestry, such as Scots pine, Norway spruce, birch and oak. However, changing tree species composition may be an appropriate adaptive management strategy (Ge et al. 2011a). The following changes in tree species composition are possible adaptive management strategies:

- A shift from mono-species to mixed species stands (see Kolström et al. 2011).
- Incorporating other indigenous tree species, currently of minor importance in forestry, but with high potential for timber production or carbon sequestration under climate change.
- Increasing the share of broadleaved species assumed to perform better under climate change.
- Substituting species sensitive to drought and late spring frosts by drought-tolerant and frost-resistant tree species or provenances.
- Replacing low-productivity tree populations with high productivity ones when the current population does not make full use of the potential productivity of a site.

Changing tree species can be an appropriate adaptive management strategy for improving productivity, which also includes the adjustment of thinning (intensity, interval, pattern: from above/below). In this context, adjusting the rotation period is an effective means of managing timber production and the carbon budget of forests. Over the rotation, the timing and intensity of thinning determine the growth rate and stocking, which control the rate of carbon sequestration and the amount of carbon retained in trees and soils. In most European countries, growing stock is still increasing, because timber harvest (thinning, final felling) is less than the increment. This means that the total carbon storage in the forest is increasing. On the other hand, the age-class distribution of the forests in the Baltic Sea basin is shifting towards the older age classes, and the overall length of rotation is increasing. This means that the rate of carbon sequestration is declining, even though the carbon stores are large. Harvesting of over-mature old forests with subsequent regeneration with productive stands would make better use of the substitution potential of the forest, even though average carbon stocks are reduced. However, to meet the overall criteria for sustainable forest management (Forest Europe 2012), a sufficient area of old forest for conserving biodiversity must be retained in all countries.

21.3 Climate Change and Agricultural Ecosystems

21.3.1 Agricultural Production in Europe

Agriculture is the most important force driving land use globally. Nearly half of the total EU-27 land area is devoted to agriculture (Green et al. 2005; Stoate et al. 2009) and the productivity of European agriculture is among the highest in the world (Olesen et al. 2011). Despite a wide range of climatic conditions, soils, urbanisation, land use, infrastructure, economic and political conditions across Europe, rapid modernisation and intensification of farming systems have led to an unprecedented increase in agricultural productivity after the Second World War, particularly in western Europe (Bouma et al. 1998; Olesen et al. 2011). For example, Europe accounts for about one-fifth of global meat and cereal production, and average cereal yields in EU countries are more than 60 % above the world average (Olesen et al. 2011). Such agricultural intensification has dramatically simplified landscapes, affected carbon and nutrient cycling, facilitated species invasions, decreased native biodiversity and increased herbicide, pesticide and fertiliser use in recent decades (Matson et al. 1997; Tscharntke et al. 2005; Stoate et al. 2009; Flohre et al. 2011). These changes have had profound and far-reaching effects on ecosystem functions and services, also extending to terrestrial and aquatic ecosystems outside agro-ecosystems (Green et al. 2005; Stoate et al. 2009).

Environmental and socio-economic conditions largely determine agriculture in Europe (e.g. Olesen and Bindi 2002). Climatic and soil conditions of the great European plain extending from south-east England through France, Benelux, Germany, Poland, Hungary, Ukraine and Belarus to Russia provide the most productive conditions in Europe. Agricultural policies and socio-economic conditions have hampered production in eastern Europe, however. In northern Europe, agriculture is mainly limited by climatic and soil conditions. Consequently, less than 10 % of land is cultivated in the Nordic countries (Olesen and Bindi 2002). It is noteworthy, however, that agriculture extends exceptionally far north in the Nordic countries because the Gulf Stream comparable climatic zones are present at higher latitudes in western Europe than in North America (Saikkonen et al. 2012). Seasonal variation in day length, length of the growing season, late spring and early autumn frosts and cold winters are the main climatic constraints on agriculture in the northern Baltic Sea area.

21.3.2 Agricultural Management in the Baltic Sea Basin

Agriculture in the Baltic Sea basin is characterised by different types of land use in the countries surrounding the Baltic Sea, with Germany, Poland and Denmark having the highest proportion of utilised agricultural area (UAA) (see Table 21.3). In all countries, especially Denmark and Finland, the share of UAA that is cropping land (used mainly for the production of cereals) is higher than that of grassland. The composition of land use is crucial regarding the likely effect of climate change and the management implications (see also Chaps. 17 and 25).

21.3.3 Impacts on Agricultural Production

In general, assuming no adaptation, Alcamo et al. (2007) saw the likely effect of climate change on agriculture in northern Europe as positive, both for summer and winter crops. A positive effect of climate change is also expected for the cultivation of bioenergy crops. For livestock, the effect may be either positive or negative. The influence of climate change on crop yield depends on crop species and regional characteristics. Thus, effects must be considered separately for regions, winter and summer crops, and particular crop species. Supit et al. (2012) evaluated the effect of climate change on crop yields without regard to adaptation strategies and found that winter wheat and all other winter and autumn crops may show increased yield under higher temperatures and elevated CO_2 levels until 2050. Crops planted in summer, especially maize and other C4 plants, may also show increased yield as water efficiency is improved by higher CO_2 concentrations. In contrast, Ewert et al. (2005) indicated that in some regions, technological improvements may have greater effects on crop yield than climate change and CO_2 increase.

Table 21.3 Utilised agricultural area (UAA) in 2010 in Baltic Sea coastal states of the EU (Eurostat 2011)

Country	Total land area (1000 ha)	UAA (1000 ha and as % of total land area)	Grassland of UAA (%)	Cereal land of UAA (%)
Denmark	4242	2676 (63)	8	55
Estonia	4239	948 (22)	31	39
Finland	30,408	2291 (8)	1	29
Germany	34,877	16,704 (48)	28	30
Latvia	6229	1805 (29)	35	38
Lithuania	6268	2772 (44)	22	54
Poland	30,633	15,709 (51)	20	44
Sweden	41,031	3073 (7)	15	31

21.3.4 Management Implication for Agricultural Production in the Baltic Sea Basin

Future climate change, especially increased climate variability, poses challenges for agricultural management in the Baltic Sea basin. Adaptation strategies, such as the adoption of agro-ecological techniques, diversified production to increase crop resilience, improvements in crop water-use efficiency and promotion of drought and flood insurance, are options to consider (Trnka et al. 2011). More frequent summer droughts may necessitate additional irrigation in order to take advantage of the potential for increased crop yields created by higher temperatures and increased CO_2 concentration (Supit et al. 2012). Additional adaptation strategies include soil conservation, changes in the timing of sowing and crop rotation, cultivation of different species or different crops and changes in the use of fertilisers and pesticides. Research in plant breeding for increased heat and drought tolerance is another option (Schaller and Weigel 2007).

21.4 Conclusion

This chapter reviews the changes in growing conditions likely to result from climate change in the Baltic Sea basin and related consequences for forest management and agricultural production. Effects differ with location, with growing conditions tending to improve in the northern boreal zone, with reduced precipitation and higher temperatures tending to result in deteriorating growing conditions in the southern temperate zone. Changing growing conditions are likely to cause shifts in forest structure and diversity. The importance of adapting management practices to altered conditions is clear and may allow increased yields and economic benefits as well as climate mitigation through substitution of fossil fuel energy with bioenergy. Evidence suggests that this is particularly the case for the northern parts of the Baltic Sea basin, while in the south, the potential for improved growing conditions might be counteracted by water stress and reduced growth in sensitive species, such as Norway spruce. The need for management adaptation is especially clear in the south, in terms of change in thinning regimes, rotation periods and species selection.

Conclusions on socio-economic impacts cannot be generalised, as potential yield increases as well as loss risks from more unfavourable conditions must be considered. On the other hand, investment in better transport infrastructure in the north and the higher risk of storm damage, with market distortion, risk of species die back, and more frequent bark beetle damage necessitating costly salvage cuttings, would be a considerable burden to forest management, increasing the need for planting where natural regeneration of current species is no longer suitable. A general decrease in tree age at harvesting may also decrease risk, irrespective of whether clear-cutting or selective cutting is practised.

Overall, the results highlight the importance of adaptive forest management strategies in the Baltic Sea basin and show positive benefits for forest management and conserving biodiversity. This could be of particular importance as management practises become more intensive, increasing the need to consider other aims (such as biodiversity and carbon mitigation.).

This chapter also outlines the likely effects of climate change on agricultural production in the Baltic Sea basin. It is clear from several studies that climate change is likely to have mainly positive effects on crop yield, especially for winter crops. However, increasing climate variability will lead to a need for adaptation measures. These are manifold and will differ among region and crop species.

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