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AN ANALYSIS OF FORESTRY POLICY WITH THE CONTEXT OF A CHANGING CLIMATE: COMPARISON OF THE CZECH REPUBLIC, ENGLAND AND SWEDEN

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ABSTRACT

Climate change is a burning topic globally and influences most aspects of humans' life. One of the tools that can be useful in tackling climate change is forest creation because trees convert carbon dioxide (CO_2) from the atmosphere into organic compounds during photosynthesis. At the same time, changing climate affects trees by more extreme weather conditions and higher concentrations of CO_2 in the atmosphere. It is necessary to consider the fact that trees and forests have various functions and climate change can affect all of them. The impacts are not only ecological but also social, cultural and economic. For this reason it is vital to have such policies that would protect forests and help with their adaptation for future weather conditions.

This research aims to analyse the effectiveness of current forestry policies in terms of supporting climate change adaptation in three European Union countries: England, Czech Republic and Sweden; representing three different forestry approaches and structure of their forests.

Policies in each country differ significantly. This may be a result of different the structure of forest and its use. While policy makers in the Czech Republic and Sweden are more concerned about the production function of their forest, the English approach is focused on afforestation. In general, there are two main groups of adaptation measures, those for short term (usually reducing stress which is not caused by climate change) and those for long term (changes in species composition). Although all of the countries have some short-term measures for climate change adaptation in place, none of them appears to be concerned about the long term horizon which will be (together with sustainable forest management) essential for future maintenance and development of strong, healthy and resilient stands.

Keywords: Climate change, Forests, Legislation, Grants, Adaptation measures

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1 INTRODUCTION

There are various studies addressing climate change adaptation and mitigation in connection with forestry, for example FAO (2011), Alcamo *et al.* (2007), Fischlin *et al.* (2007), Carina and Keskitalo (2011), Roberts (2008) and Salinger *et al.* (2005). However, these are very general and offer only proposals or reviews of particular measures to help forest adaptation to climate change and do not actually evaluate the effectiveness of policies including these measures in practice. Those studies that have examined the effectiveness of policies are usually focused on agriculture and/or forestry in developing countries (for example, Mertz *et al.*, 2009; Ibarra and Hirakuri, 2007).

However since the situation and main issues (within forestry it is mostly deforestation) in these countries are very different from these in Europe, these findings are not applicable to most of Europe. As mentioned by Mertz *et al.* (2009), who focused on situation of agriculture in rural Sahel, the main drivers for shaping strategies in agriculture in such countries are economic, political and social factors. Although some links or measures to climate change might occur, they are usually very minor. The author also pointed out that there is a lack of knowledge of regional climate change scenarios and the need for better understanding of the whole problem as well as possible adaptive strategies. Ibarra and Hirakuri (2007), who examined effectiveness of forest policy in Costa Rica, found out that the greatest problem was to develop consistent policies with rigorous control in practice. According to this study, the main issue in Costa Rica was to introduce logging with lower impacts on the environment and sustainable forestry in general; the so called Costa Rican forest sector reform. The authors discovered that the reform was not effective at all, mainly due to high costs of measures required by the law and lack of sanctions and control at the same time. It simply led to illegal activity and unsustainable forest management (the less expensive option).

As described above, issues in developing countries are completely different from those in the European Union (EU) and so there is a need to understand the impact of policy on forest adaptation in Europe.

1.1 Aims and objectives

Policies for adapting to climate change have only been analysed for developing countries. This research aims to analyse the effectiveness of current forestry policies in terms of supporting climate change adaptation in forests in three countries: England, Czech Republic and Sweden. The choice of these countries was based on the fact that they are all members of the European Union and so their policies and regulations must comply with the European legal framework. At the same time, these countries have very different forestry characteristics: England is the second least forested country in the EU (although within the UK the average is increased by Scotland and Wales), the Czech Republic is close to the European average for forest cover, and Sweden is the second most forested country in the EU. In addition, each country has its own forestry problems and issues that should be covered by their policies and regulations.

The main objectives of this study are to:

- determine the main impacts of climate change on forests in England, Sweden and Czech Republic by examining how forests will be impacted by new weather conditions and how their structure and biodiversity has changed in recent decades;

- analyse current forestry policies involved (at both international and national level) in terms of their effectiveness for climate change adaptation and mitigation of its impacts on forests; and

- propose future options for policies to assist with forests adaptation to climate change, including potential changes in structure of new forests (e.g. new, more suitable and resistant species).

2 LITERATURE REVIEW

2.1 European forest

In the European Union (EU), more than 40% of surface area is covered with forests and other wooded land. The most forested countries are Finland (77%), Sweden (75%) and Slovenia (65%) and on the opposites are Malta (1%), Ireland (10%) and Netherlands (11%) followed by the United Kingdom (12%). The Czech Republic and its forest cover is somewhere in the middle with 34% of the total land of the country (European Commission, 2006b). According to FAO (2010), the composition of European forests (excluding Russian Federation) is 59% of conifers and 41% of broadleaved trees. The proportion of conifers has been declining in favour of broadleaves (in the last 20 years, the representation of broadleaves increased by 2 per cent). Furthermore 12.3% of European forests are in protected areas while 99.3% of species are commercial (FAO, 2010).

2.2 Climate Change

Since the 1990's, the climate change has become an increasingly important topic globally. In 1997 the Kyoto protocol was signed and the countries which ratified the document agreed on greenhouse gas emissions reduction by 80% below 1990 rates by 2050 (Committee on Climate Change, 2009). One of the tools that can be very useful in tackling climate change is planting trees and forests creation in general because they convert carbon dioxide (CO_2) from the atmosphere into organic compounds during photosynthesis. According to Read *et al.* (2009a), by 2030 the world forests could help to cut the current concentration of CO_2 in the atmosphere by 25%.

Climate change brings higher temperatures and also different weather conditions. Generally, in Europe the main implications are hotter summers with reduced rainfalls and warmer and wetter winters. There are also enhanced probabilities of storms and similar phenomena (IPCC, 2007).

2.2.1 Impacts of climate change on forests

There is a mutual relationship between climate change and forests in general. Trees can help tackle global warming by decreasing atmospheric concentrations of CO_2 emissions, but at the same time, climate change affects trees by more extreme weather conditions and higher concentrations of CO_2 in the atmosphere (Ray *et al.*, 2010). The main and most important impacts are described in table 2-1:

Table 2-1 Main impacts of climate change on trees

Change expected	Beneficial effects	Negative effects
Increased CO_2	- Higher growth rates. - Water loss reduced by closure of leaf pores.	- Lower timber quality (unless different species are used). - Risk of nutrient imbalances.
Reduced summer rainfall		- More frequent droughts can be crucial for some species and it will affect forest industry. - Timber quality reduced. - Trees less resistant to pests and diseases. - Higher tree mortality (especially street trees). - Increased risk of fire.
Increased winter rainfall		- Reduced stability, waterlogging, more wind throws. - Higher mortality of fine roots, especially after drier summers. - Risk of soil-borne diseases and infections. - Limited root depth that can lead to decreased tree stability and lower resistance to summer droughts.
Increased storm frequency		- Greater storm damage.

Source: Forestry Commission, 2010; Ray et al., 2010; Broadmeadow, 2002

Higher concentration of CO_2 and higher temperatures will enhance tree growth but the timber quality will be significantly lower. Due to more extreme fluctuations of weather and water supply in Europe, some species will no longer be suitable for the climate conditions. Furthermore, there is a greater risk of infections, diseases and pests invasions affecting trees (Forestry Commission, 2010; Ray *et al.*, 2010).

Climate change will have also impacts on forest soil. Soil serves as storage of carbon and nitrogen, bounded in its organic matter (Broadmeadow *et al.*, 2002). Both of these are sensitive to temperature changes; with increasing temperature their concentration in soil starts decreasing owing to higher rate of release (Kirschbaum, 1995). As a result, the concentration of CO_2 in the atmosphere will increase even more. The most critical situation may occur in the case of peats that can change from the largest carbon sinks into the largest carbon dischargers (Broadmeadow *et al.*, 2002). As shown in a recent study by Mellilo *et al.* (2011), higher temperatures can also have a positive effect on the ability of trees to absorb CO_2 from the atmosphere. Due to the greater release of nitrogen (N) from soil there is a higher concentration of N in the air and it stimulates vegetation to absorb more CO_2. Nevertheless according to Mellilo *et al.* (2011), the amount of carbon released from soil is still significantly higher than the volume absorbed by trees.

Forest ecosystems consist not only from trees but other fauna and flora as well and all the organisms will be affected by climate change. Changes in biorhythms can occur which may lead to disruption of synchronisation of particular organisms (Broadmeadow *et al.*, 2002).

2.2.2 Climate projections and scenarios

It takes many years or decades for a planted tree to mature so the planning horizons in forestry are between 50 to 100 years. In order to develop policies most suitable for changing climate conditions, it is necessary to take the possible changes into account (Read *et al.*, 2009a). As the main sources for this purpose, the Intergovernmental Panel for Climate Change (IPCC) Assessment Reports are used. The most recent one was launched in 2007 and at the moment, the fifth report is being developed with a launching date at the end of 2014 (IPCC, 2011). The Assessment Reports deliver new findings and information about progress of climate change, climate projections for the future within various scenarios and connected impacts to decision makers who can adjust policies on basis of the predictions.

2.3 Regulatory framework

2.3.1 International regulations

The United Nations Conference on Environment and Development (UNCED), also known as the “Earth Summit” in Rio de Janeiro in 1992 was the first important international milestone in environmental protection. At this summit, the Rio forest principles and Chapter 11 of Agenda 21 were ratified and officially became the first international consensus on forests (United Nations, 1992).

One year later at the Ministerial Conference in Helsinki, three documents on forestry were accepted: General Guidelines for the Sustainable Management of Forests in Europe (Second Ministerial Conference on the Protection of Forests in Europe, 1993a); General Guidelines for the Conservation of the Biodiversity of European Forests (Second Ministerial Conference on the Protection of Forests in Europe, 1993b) and Strategies for a Process of Long-term Adaptation of Forests in Europe to Climate Change (Second Ministerial Conference on the Protection of Forests in Europe, 1993c). Essentially, this conference was dedicated to the realisation of UNCED principles at national and local level (Second Ministerial Conference on the Protection of Forests in Europe, 1993d). In 1998, another Ministerial Conference took place in Lisbon. Unlike the previous one it was focused more on socio-economic aspects of forests and six Pan-European Criteria (PEC) for sustainable forest management were accepted (Third Ministerial Conference on the Protection of Forests in Europe, 1998).

In 2000, the United Nations Forum on Forests was established on the basis of all the important international agreements and documents and in 2006, four shared Global Objectives on Forests were agreed (United Nations Forum on Forests, 2011).

2.3.2 European Union regulations

In general, there are three main documents by the European Union: The Forestry Standard (COM(2005) 84), The Forest Action Plan (COM(2006) 302) and the Communication on Innovative and Sustainable Forest-based Industries (COM(2008) 113) (European Commission, 2010). They are mainly focused on sustainable forest management (SFM) and development of European forests in the context of socio-economic and environmental issues. Emphasis is also placed on forest products as an important source of renewable energy (European Commission, 2005, 2006a, 2008a). The EU Forest Action Plan sets up the main objectives of the EU forestry policies for years 2007-2011 and these are: improving long-term competitiveness, improving and protecting the environment, contributing to the quality of life and fostering coordination and communication (European Commission, 2006b).

Besides the policies and legislation focused on forests, there are various regulations that mention forests marginally, for example forests in the EU countries can be subject to the Single Payment Scheme (SPS). These are usually new forests created since 2009 that comply with particular requirements and regulations (Forestry Commission England, 2011). The EU not only produces guidance on forest management and grant schemes, but also regulates the marketing of forest reproductive material (European Council, 1999). In addition, European forestry policy must meet and be linked to other EU regulations and strategies, mainly the Rural development, Environment, Energy and Industrial policies (European Commission, 2006b).

1.3.3. European Union Grants for forestry

The main European source of subsidies for forestry is the European Agricultural Fund for Rural Development (EAFRD), which serves as a financial instrument of Common Agricultural Policy (CAP) focused on rural development (European Council, 2005). In general, the fund should support the competitiveness of agriculture and forestry, the environment and the countryside and the quality of life and the management of economic activities in rural areas. The umbrella

strategy for all Member states is the Rural Development policy for years 2007-2013 and based on it, every country developed their own National Plan which must be in accordance with EU strategic guidelines. Every National Plan should identify particular areas where the financial support from the EU is mostly desirable and these must comply with the main EU priorities and be consistent with other EU policies (European Commission, 2008b).

Basically, there are four main axes of the subsidies from the EAFRD currently. These are following (Europa: Summaries of EU legislation, 2011):

- Axis 1 - Improving the competitiveness of the agricultural and forestry sector (promoting knowledge and improving human potential; restructuring and developing physical potential; improving the quality of production and products; provisional measures)

- Axis 2 – Improving the environment and the countryside (support for sustainable land use methods regarding preservation of the environment and natural resources; biodiversity; NATURA 2000 sites; water and soil protection; climate change mitigation; handicapped regions; forest-environmental payments)

- Axis 3 – Quality of life in rural areas and diversification of the rural economy

- Axis 4 – LEADER (implementation of local development strategies through public-private partnerships, so called “local action groups”)

2.4 Conclusion

Climate change is a burning topic that will in the future affect most of aspects of human life. Trees are considered to be a cost-effective tool to decrease concentrations of carbon from the atmosphere but at the same time they are affected by climate change as well, mostly in a negative way. Since planning in forestry is a long-term activity, it is necessary to take all the possible impacts into account and to evaluate viability and suitability of particular species for the site. It is important to consider the fact that trees and forests have various

functions and climate change can affect all of them. The impacts can be not only ecological but also social, cultural and economic. In general, governments should keep in mind all the aspects and possible effects and try to develop such policies that would help forest managers to be as effective as possible in terms of climate change and to manage forests in the most efficient way, including forests adaptation to the future weather conditions.

3 METHODOLOGY

3.1 Data collection

Data for this study was collected for three countries, always with an attempt to obtain information that would be comparable to each other. First of all, general data was necessary for the basic background, including information about forests in the European Union/Europe and international legislation (including EU policies and grant system). The main sources used were institution of the EU and international organisations such as the FAO. Afterwards, data for England, Czech Republic and Sweden was collected from various sources, mainly regarding forestry, climate change and legislation, as described in table 3-1 and figure 3-1. Data collection involved analysis of relevant policies, institutional websites and through contacting institutions listed in table 3-1.

Table 3-1 Summary of data sources

Data	**Countries - sources**		
	Czech Republic	**England**	**Sweden**
Forest cover	Ministry of Agriculture of the Czech Republic, Czech Forest Management Institute	Forestry Commission	Royal Swedish Academy of Agriculture and Forestry
Forest categorisation	Ministry of Agriculture of the Czech Republic, Czech Statistical Office, Czech Forest Management Institute	NA	Royal Swedish Academy of Agriculture and Forestry, Swedish University of Agricultural Sciences
Forest ownership	Ministry of Agriculture of the Czech Republic	Forestry Commission	Swedish University of Agricultural Sciences
Species structure	Ministry of Agriculture of the Czech Republic, Government of the Czech Republic, Czech	Forestry Commission, White (1995)	Royal Swedish Academy of Agriculture and Forestry, Swedish

	Forest Management Institute		Society for Nature Conservation, Swedish University of Agricultural Sciences
Climate change	Ministry of Environment of the Czech Republic, European Forest Institute, Czech Hydrometeorological Institute, European Commission	DEFRA, Forestry Commission, Hadley Centre, European Commission	Swedish Meteorological and Hydrological Institute, Rossby Centre, European Commission
Legislation	Ministry of Agriculture of the Czech Republic, Ministry of Environment of the Czech Republic, Czech Forest Management Institute	DEFRA, Forestry Commission, Forestry Commission England, Natural England	Swedish Forest Agency, Ministry of Environment of Sweden

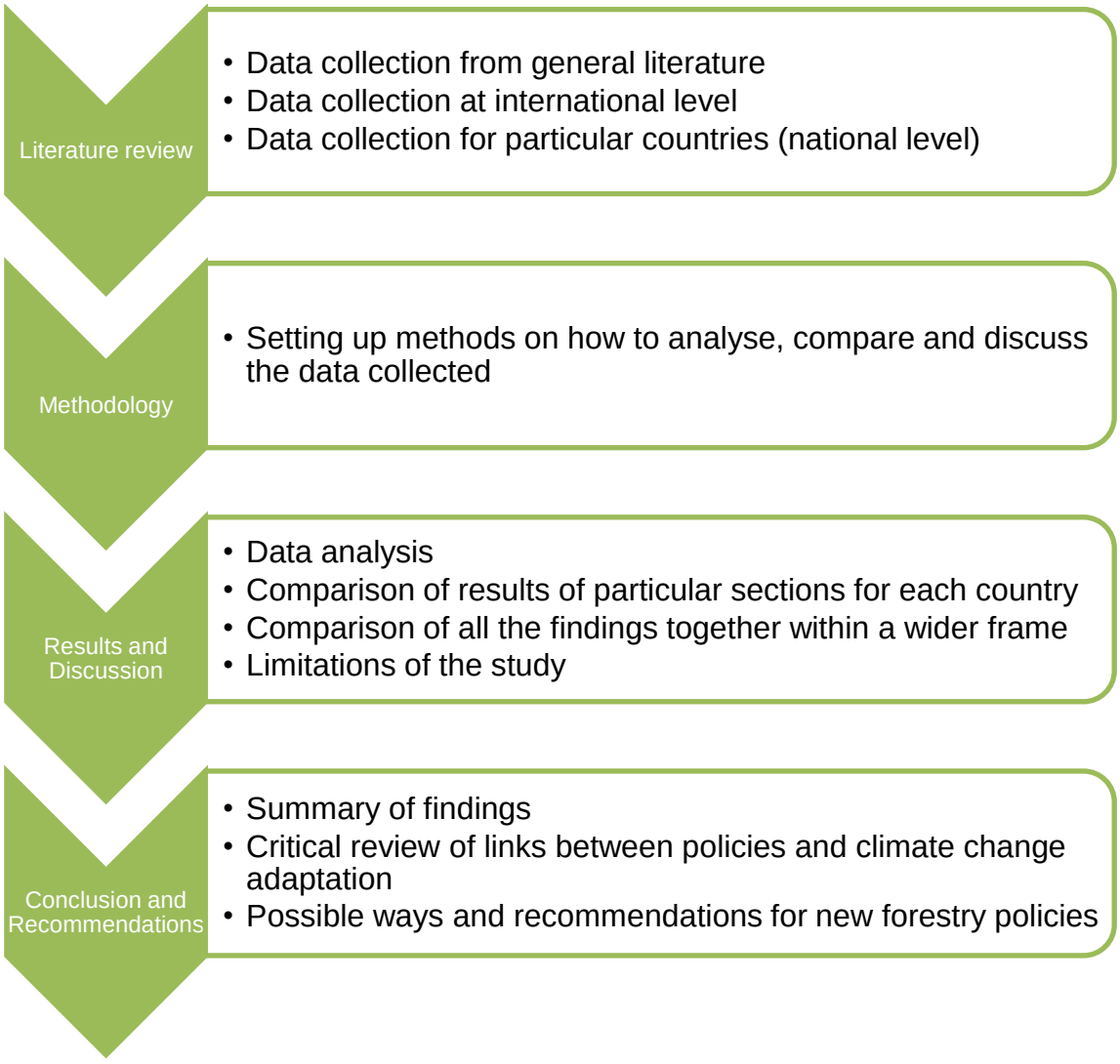

Figure 3-1 Methodology flow chart

3.2 Discussion and analysis methods

All the data collected were put into figures and compared for all the countries. Considering the fact that not all the information was available for each country or the outputs were not exactly in the same form, there was an attempt to obtain information that would be as similar as possible, in order to prevent bias. However, it was not always possible.

The data were divided into categories in order to enable clearer analysis of each indicator within all three countries. Since the categories are strongly

interlinked and interdependent, the final stage provides a combined analysis of all the results to provide the complex picture of the forestry situation, forestry policies and how these are influenced by climate change.

4 RESULTS AND DISCUSSION

This section describes the key policies, grants and legislation within each of the case study countries. This is followed by a comparison of the key forestry characteristics in each country, within the context of the legislation.

4.1 Legislation

4.1.1 Forestry regulations

All the legislation at national level must be in compliance with particular regulations of the European Union (EU) or other international documents where applicable.

In general, the legislation is very similar for all the three countries (see table 4-1 and Appendix A for more details). However, both Swedish and Czech regulations are more detailed in terms of forest production. These are focused more on forestry planning, felling, forest restoration and reforestation. There is also an emphasis on origin of seedlings and suitable tree species structure. In the case of England, an environmental impact assessment (EIA) is needed for most actions within forests. Biodiversity protection is a common point for all the countries. Nevertheless, English legislation appears slightly more bureaucratic, as it prescribes what licences and permissions are needed for each activity but does not actually provide any closer details connected with these activities. On the other hand, England appears to be more concerned about biodiversity and site protection. These divergences most likely result from different forest structure, ownership and use of forests in the three countries.

Table 4-1 Summary of main forestry legislation in Sweden, England and the Czech Republic

	Sweden	**England**	**Czech Republic**
Reforestation	Plantation/natural regeneration by the end of the third year after felling		Suitable species should be used within good timing; if suitable, natural restoration is recommended; after cleaning, reforestation required within 2 years and stands must be assured in 7 years
Forest creation		Environmental Impact Assessment required	Approval required; seeding materials must originate from the same/similar location and altitude; certificated seeding material required for some species
Forest felling	Thinning must encourage forest development and timber stock must stay large enough	Felling licence required	Thinning restrictions (percentage of forest area)
Regeneration felling	Restricted by age and size of a stand; felling notification 6 weeks in advance; permit required in case of mountain areas and vulnerable hardwood species		
Logging			Not permitted in stands younger than 80 years; should be done in the most sensitive way to prevent any disturbances to an ecosystem
External stress	Measures to prevent insect damage		Preventive measures necessary to

			protect forests from harmful factors
Forest maintenance			Improvement of stability and resistance of a forest by suitable tree structure and layout
Forestry planning			Main tool of national forestry policies; developed for ten-year-long terms
Sustainable forest management		Soil, water, air condition; forestry workers; biodiversity and heritage protection	
Biodiversity protection	Biodiversity protection and habitat regulations in protected areas	Conservation and improvement of biodiversity, habitat regulations linked to European Protected Species	Habitat regulations in protected areas

Source: Ministry of Rural Affairs of Sweden (1979), Swedish Forest Agency (2011a), Forestry Commission (2004, 2011b), Parliament of the Czech Republic (1995)

4.1.2 Forestry grants

Besides legislation and regulations, forestry is also affected by system of grants and subsidies that should encourage to better maintenance of stands and good practice in general. Grant schemes operating in each country are described in table 4-2.

Table 4-2 Summary of grants in forestry in Sweden, England and the Czech Republic

	Sweden	England	Czech Republic
More suitable/valuable species	X		X
Skills development and increased competitiveness	X		
Biodiversity protection, cultural heritage	X	X	
Forestry planning		X	X
Research		X	
Forest regeneration/ restoration		X	X
Maintenance		X	X
Forest creation		X	
Small owners support			X

Source: Swedish Forest Agency, 2011b; Forestry Commission England, 2010; Parliament of the Czech Republic, 2010

As shown in table 4-5 and Appendix B, grants and subsidies within England, Sweden and the Czech Republic vary significantly. In general, Sweden does not need to support new planting at the expense of agricultural land because their forest cover is sufficient and it is not necessary to increase it even further. So the Swedish subsidies are focused mainly on biodiversity and cultural heritage and competitiveness of the forestry sector. The only exception is support for regeneration of deciduous tree species in southern Sweden (nemoral zone), where these species are basically native. The financial help in this case is necessary because such forests are more demanding and so their maintenance is also more expensive and at the same moment, the profit is lower than in case of Norway spruce.

In England, there are grants available for almost all activities connected to forests or forestry. Generally, the whole process of woodland creation from very beginning (planning) through to creation itself and maintenance up to restoration or regeneration is included in the grant schemes. Since forest cover of the country is very low and insufficient, the Government is trying to encourage people to convert agricultural land into forests and preserve of woodland.

The Czech Republic is again somewhere in the middle of the other two countries. Since there is less pressure on agricultural land afforestation, the grants are available more for improvements in technologies as well as in forests as such. Due to the recent issues regarding Norway spruce (that will be exacerbated by future climate changes), the Government is trying to change the structure of forests through their grant schemes on forest restoration and regeneration.

4.2 Forested land

In terms of total forested area, the Czech Republic, England and Sweden differ significantly, as shown in figure 4-1.

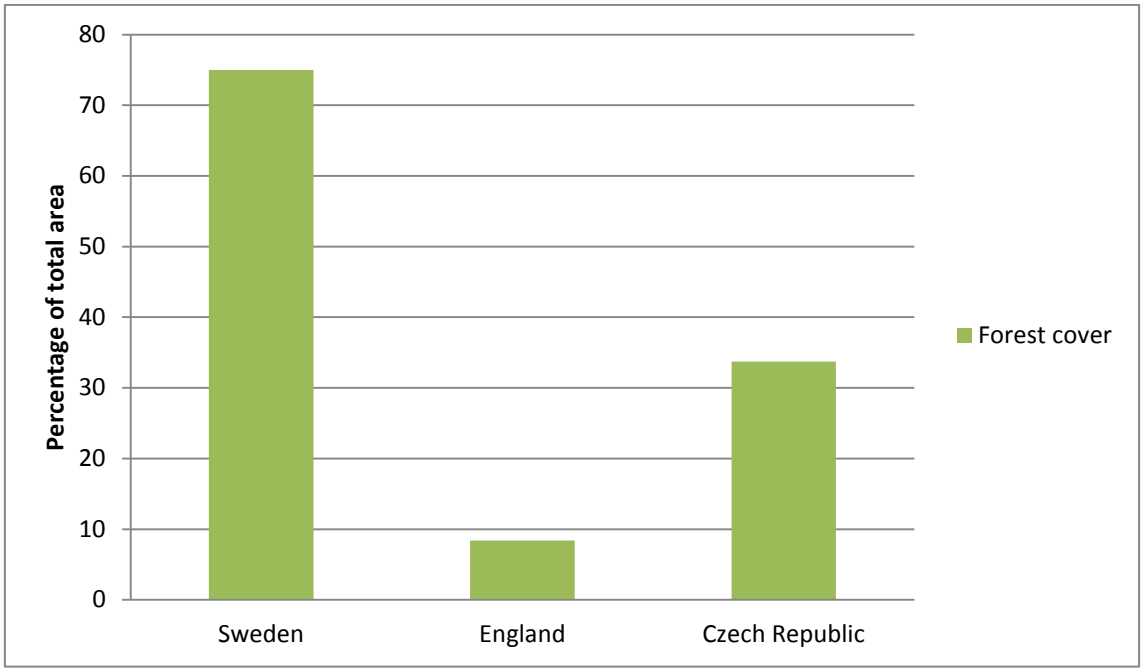

Figure 4-1 Forest cover in Sweden, England and the Czech Republic in per cent of total area

Source: Royal Swedish Academy of Agriculture and Forestry, 2009; Forestry Commission, 2003; Ministry of Agriculture of the Czech Republic, 2011

In Sweden, total land area counts for 40.8 million hectares of which 75% is covered by forest, which means 30.6 million hectares of forests (Royal Swedish Academy of Agriculture and Forestry, 2009). This makes Sweden one of the most forested countries in the EU, second only to Finland (European Commission, 2006b). The Czech Republic is somewhere in the middle and its forest cover is close to the EU average (European Commission, 2006b). The forested land takes up 2 657 400 ha, comprising 33.7% of the total area of the country (Ministry of Agriculture of the Czech Republic, 2011). In contrast with these countries, woodland in England comprises around 1.1 million hectares which is 8.4% of the whole area of the country (Forestry Commission, 2003) and it would theoretically rank the country as the second least forested country in the EU. Within the UK, the average is increased by Scotland and Wales to 12% and so Great Britain as whole holds the position of the fourth least forested country in the EU (European Commission, 2006b).

4.3 Forest categorisation

In Sweden, 75% of forests are productive forest land, 19% non-productive forest land and 6% other wooded land (Royal Swedish Academy of Agriculture and Forestry, 2009). This structure is described in figure 4-2. According to the Swedish Society for Nature Conservation (2010), the Swedish forestry model is particularly focused on productive function and other functions, especially biodiversity protection, are undervalued. In order to increase profitable forest production, there are tendencies for coniferous monocultures. There is insufficient protection of forests above the montane level, old-growth or virgin-like forests and so these are being logged as well and in total about 25% of the logged forests do not fulfil requirements stated by the Swedish Forestry Act (Swedish Society for Nature Conservation, 2010). These requirements are described in section 4.6. According to the Swedish Forest Agency (2009) in total, almost 20% of forests are protected in Sweden (15.7% protected by the law and 3.6% protected voluntarily). As mentioned by the Swedish Society for Nature Conservation (2010), in these numbers, such kind of forests that are not actually considered as forests according to the Swedish Forestry Act (non-productive forests and unstocked forest land) are included and in fact only 3.3% of productive forests are formally protected.

For England, data on categorisation of forests in terms of their use were not available. However, the proportion of productive forests is most likely lower than in the two other countries, considering their species structure. Nevertheless, there are numbers on protected forested land. According to the Forestry Commission (2008b), there are 113 000ha (10.3% of the total forested land) of protected forest in England, spread into Special Areas of Conservation (24 000ha), National Natural Reserves (9 000ha) and Sites of Specific Scientific Interest (80 000ha).

According to the Czech Forestry Act (Parliament of the Czech Republic, 1995), forests in the Czech Republic can be divided into three groups, namely protective forests (stands in mountains or other unfavourable places protecting

vulnerable land from soil erosion and other adverse effects), forests of special function (stands in hygienic protection areas or in national parks and other protected areas) and economic forests (all other forests). The proportion is described in figure 4-3. There is also a high number of forests protected by the law that can usually be found in national parks or other protected areas. In 2007, such protected forests counted for 750 000 ha in total, representing 28.2% of forested area at that time (Government of the Czech Republic, 2008).

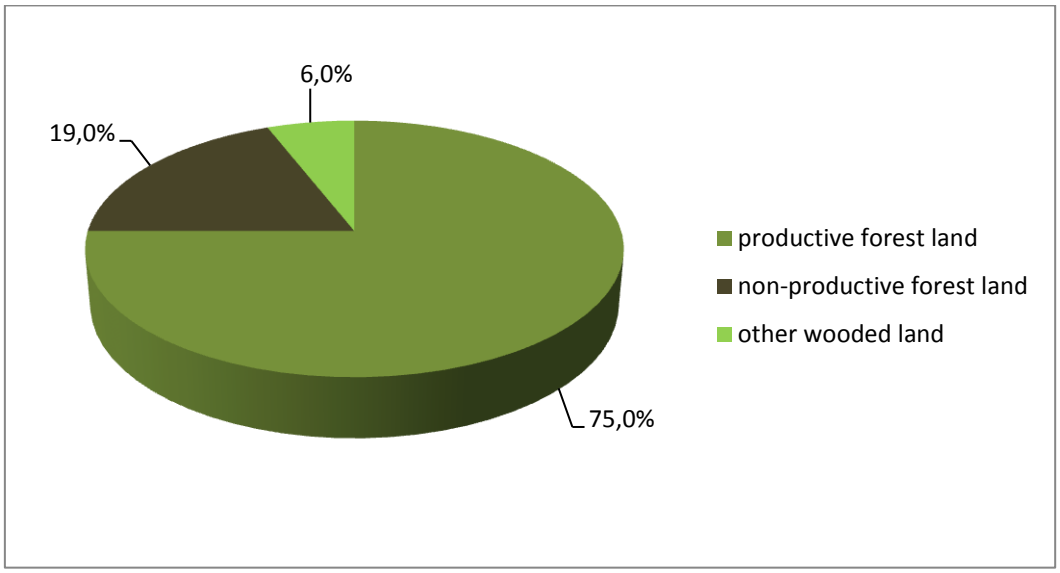

Figure 4-2 Categorisation of Swedish forests according to their use in per cent

Source: Swedish University of Agricultural Sciences, 2010

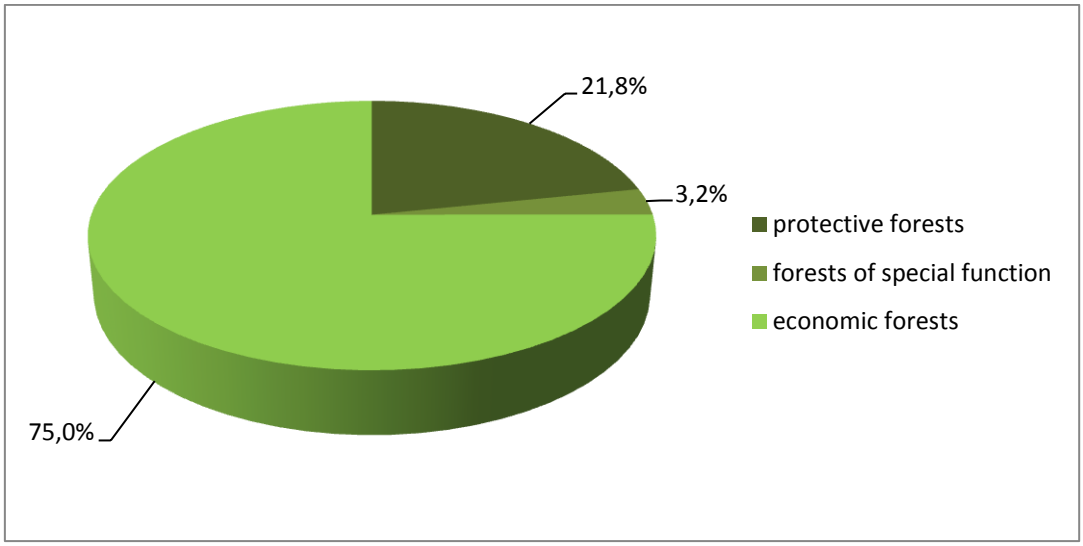

Figure 4-3 Categorisation of Czech forests according to their use in per cent

Source: Czech Statistical Office (2008)

Although the categorisation used in the Czech Republic and Sweden is slightly different, both countries have similar proportion of productive forests, management of which is driven by economic factors. In order for biodiversity protection as well as conservation of social and cultural functions, it is necessary to establish policies and regulations so that even productive forests were managed in a sustainable way, particularly when they comprise three quarters of all forest cover in both countries.

Regarding protected forests, the Czech Republic has the largest proportion of these from all the three countries. Protected forests are not only those of special function or protective ones but also a small percentage of forests considered as productive. In Sweden, the representation of protected forests is slightly lower, also mostly covering non-productive forests. In England, the proportion of protected forest land is significantly lower. Considering the fact that forest cover in England is deeply below the European average, it is a bit surprising that the protected area is not larger in order for forest and biodiversity conservation.

4.4 Ownership

The structure of forest ownership is similar in England and Sweden, and corresponds to the European average as well. In both countries, around 50% of forested land is owned by individuals (Swedish University of Agricultural Sciences, 2010; Forestry Commission, 2008b) and the average in the EU is 60% (European Commission, 2006b). However, the situation in the Czech Republic is the complete opposite. The majority of forests (over 60%) are owned by the state and the proportion of privately-owned forests is half that of the other two countries (Ministry of Agriculture of the Czech Republic, 2011).

One of the main specifics of the Swedish forestry model is a big proportion of so called “family forestry”. Over 50% of forest land in the country is owned and managed by family businesses (Swedish University of Agricultural Sciences, 2010). Logically, it is necessary to differentiate between forests owned by small entrepreneurs and by big enterprises and in order to do so, two different groups of forest management plans were developed: Landscape ecology plans for enterprises and Green forest management plans for family businesses. Furthermore, the accent is put on voluntary management planning (Royal Swedish Academy of Agriculture and Forestry, 2009). The proportion of forest owners is shown in figure 4-4.

In England, almost half of the forests (47%) are owned by individuals, the second biggest group of owners are public bodies that possess 24.4% of forested land in the country and the third one are private businesses who hold 15.1% of forests (Forestry Commission, 2008b). The structure of forest ownership in England is described in the figure 4-5.

As shown in figure 4-6, around two thirds of the forest in the Czech Republic (60.2%) are state-owned, 24% are in private ownership and the remaining 15.8% are owned by municipalities (Ministry of Agriculture of the Czech Republic, 2011).

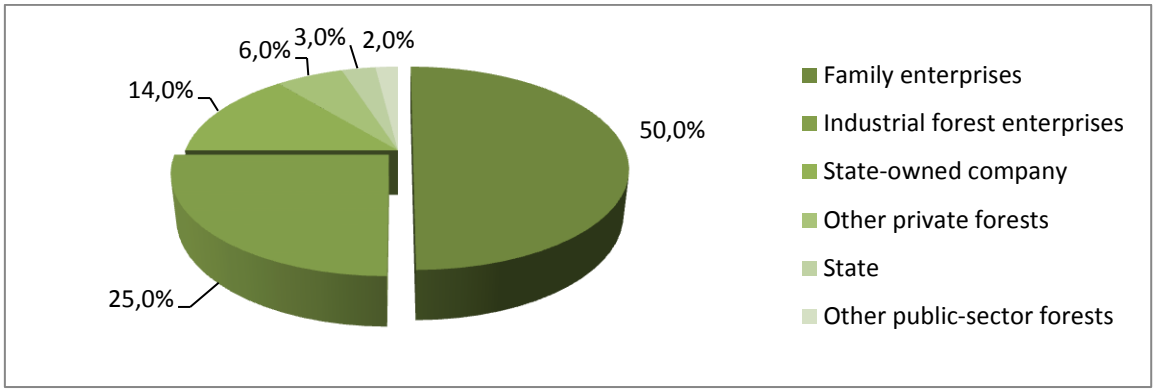

Figure 4-4 Structure of forest ownership in Sweden in per cent of forested land

Source: Swedish University of Agricultural Sciences, 2010

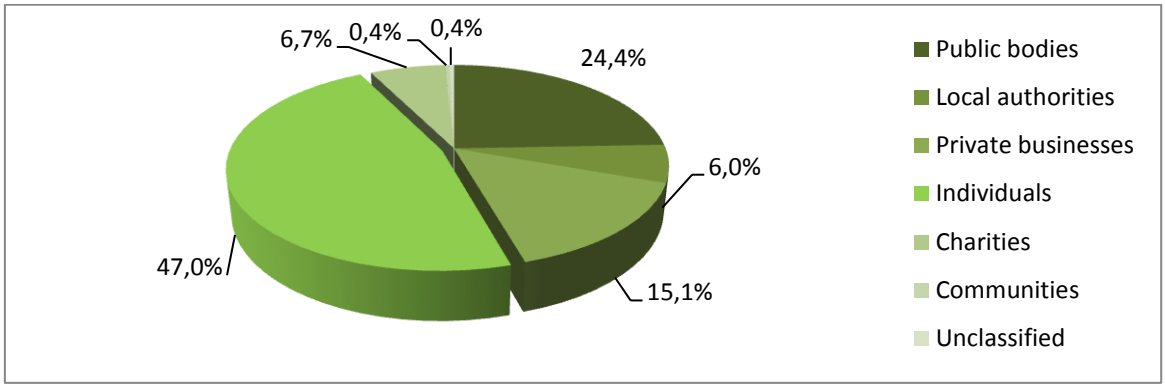

Figure 4-5 Structure of forest ownership in England in per cent of forested land

Source: Forestry Commission 2008b

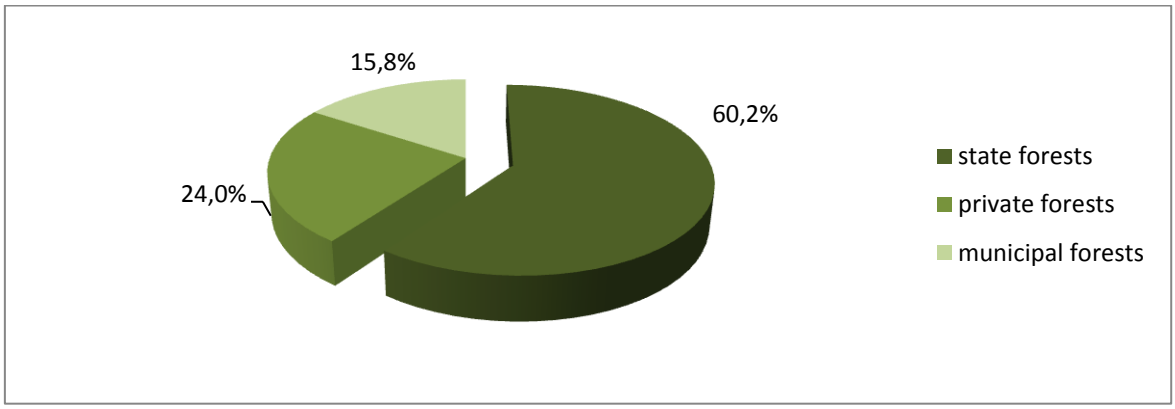

Figure 4-6 Structure of forest ownership in the Czech Republic in per cent of forested land

Source: Ministry of Agriculture of the Czech Republic, 2011

Specific aspects of the particular forestry ownerships are described in table 4-3.

Table 4-3 Specific aspects of forestry ownerships

	Further differentiation of owner in terms of legislation	**Control system and forest management**	**Forest use**
State and public bodies	Might be necessary, especially in case of forests used for special purposes, for example by Ministry of Defence.	Managed and controlled by special governmental bodies, in some cases can be less transparent. In case of renting, forests might be managed by tenants.	Productive forests, forests of any other special function.
Municipalities and local authorities		Controlled and managed by municipalities who may have their own regulations.	Productive forests, forests of any other special function.
Businesses	It is necessary to differentiate between big businesses and small family enterprises because both groups are very specific.	Managed by owners and controlled by the state. Definitely must comply with all legislation and regulations.	Productive forests
Individuals		Managed by owners and controlled by the state. Definitely must comply with all legislation and regulations.	Productive forests, forests of any other special function.

4.5 Species structure

In Sweden, there are eight vegetation zones within the country but these can be divided into two main groups: the boreal zone covering most of the country with its typical coniferous and dominated forests; and the nemoral zone containing mainly deciduous forests in the southern part of the country (Royal Swedish Academy of Agriculture and Forestry, 2009).

Conifers count for over 80% of all trees in Sweden (Swedish Society for Nature Conservation, 2010). According to Koca *et al.* (2006), these are seven most important native species in Sweden: Norway spruce, Scots pine, Silver birch, Mountain birch, Beech, Oak and Lime. In general, Norway spruce and Scots pine comprise the vast majority of the boreal and boreo-nemoral forests. The most important deciduous species is Mountain birch, which forms the treeline in Scandinavia and grows in mountain areas in the northwest. Usually, other broadleaf trees can be found in boreal zone as well but they are a minor component. On the other hand they are dominant in nemoral forests in the southern part of Sweden. Broadleaf trees can in most cases be found as far north as 62°N which is the northern boundary for most deciduous European species is (Limes Norrlandicus). In recent decades, lime has been spreading as a minor species in areas north of Limes Norrlandicus (Koca *et al.* 2006). The proportion of particular species is shown in figure 4-7.

Unlike the rest of the United Kingdom, where conifer trees dominate (for example in Scotland they account for 90% of all forests), England is dominated by broadleaf trees. In total, there are about 1.3 billion trees in England from which 523 million are conifers, 577 million are broadleaves and the remaining 179 million are small woods of area from 0.1 ha to 2 ha (Smith *et al.*, 2010). The most common species in England are Scots pine and Sitka spruce from the conifers family and the main broadleaves trees are oak and ash (Forestry Commision, 2008a; White, 1995). The proportion of all the most important species represented in England is described in figure 4-8.

The current species structure of Czech forests is very different from the natural structure. According to the Czech Ministry of Agriculture (2010), originally, the majority of trees were broadleaves (65.3% of forested land) and conifers counted for 34.7% only. Nowadays, the proportion is completely opposite with 74.12% of conifers and 24.83% of broadleaved trees. The most widespread species is Norway spruce, followed by Pine and Beech. The complete species structure of Czech forest is shown in figure 4-9. In the last couple of years there has been an emphasis on re-establishing the natural composition of forests and so the percentage of conifers has been declining while the proportion of broadleaved trees increasing (especially Oak, Beech, Maple, Lime and Ash) as well as the representation of mixed forests (Ministry of Agriculture of the Czech Republic, 2010). Even though the proportion of broadleaved trees has almost doubled since the 1950s, the representation of broadleaved trees and Douglas fir is still not sufficient (Government of the Czech Republic, 2008).

The species structure the Czech Republic can be considered as similar to Sweden. There is a vast majority of coniferous trees, mostly pine and spruce, and these are used largely for production purposes. The situation in England is the complete opposite with higher species diversity. Except for oak and ash, no other species covers over 10% of forested land. For Sweden, it is to be expected that the representation of conifers will be quite strong, mostly because of climate of the country. On the other hand, the composition of forests in the Czech Republic is not natural at all. The original structure was similar to that of the current English, with mostly broadleaved forests and pines (Government of the Czech Republic, 2008). Norway spruce, originally growing in the boreal zone only, was introduced in Central Europe in the middle of the 19th century and in most countries replaced the original species, mostly for economic reasons (Klimo *et al.* 2000). However, the financial lucrativeness of Norway spruce in countries such as the Czech Republic is not as large as it used to be, mainly because of low stability of the stands (Souček and Tesař, 2008). At the moment, a huge number of spruce forests are already in stress in the Czech Republic. As mentioned by the Czech Ministry of Environment (2004), 29% of spruce stands are seriously threatened by climate change and another 53% are

high-risk, which means that in total 45% of all Czech forests might be seriously affected by the changing climate.

However, in Sweden not all the forests are natural. In boreo-nemoral and nemoral zone, many broadleaved forests were turned into spruce monocultures in the 1990s (Holgén and Bostedt, 2004). Although the viability of spruce in southern locations has been decreasing due to changing climate (Koca *et al.*, 2006), in some areas, the vast majority (70%) of forest cover comprises from Norway spruce and Scots pine (Holgén and Bostedt, 2004).

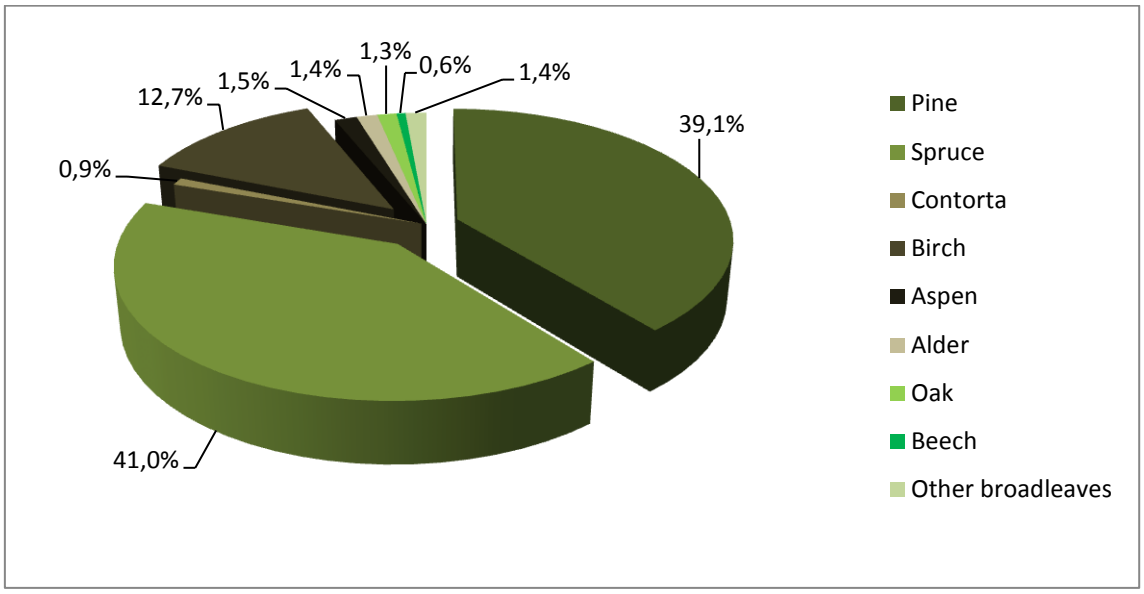

Figure 4-7 Structure of species in Swedish forests in per cent

(Source: Swedish University of Agricultural Sciences, 2010)

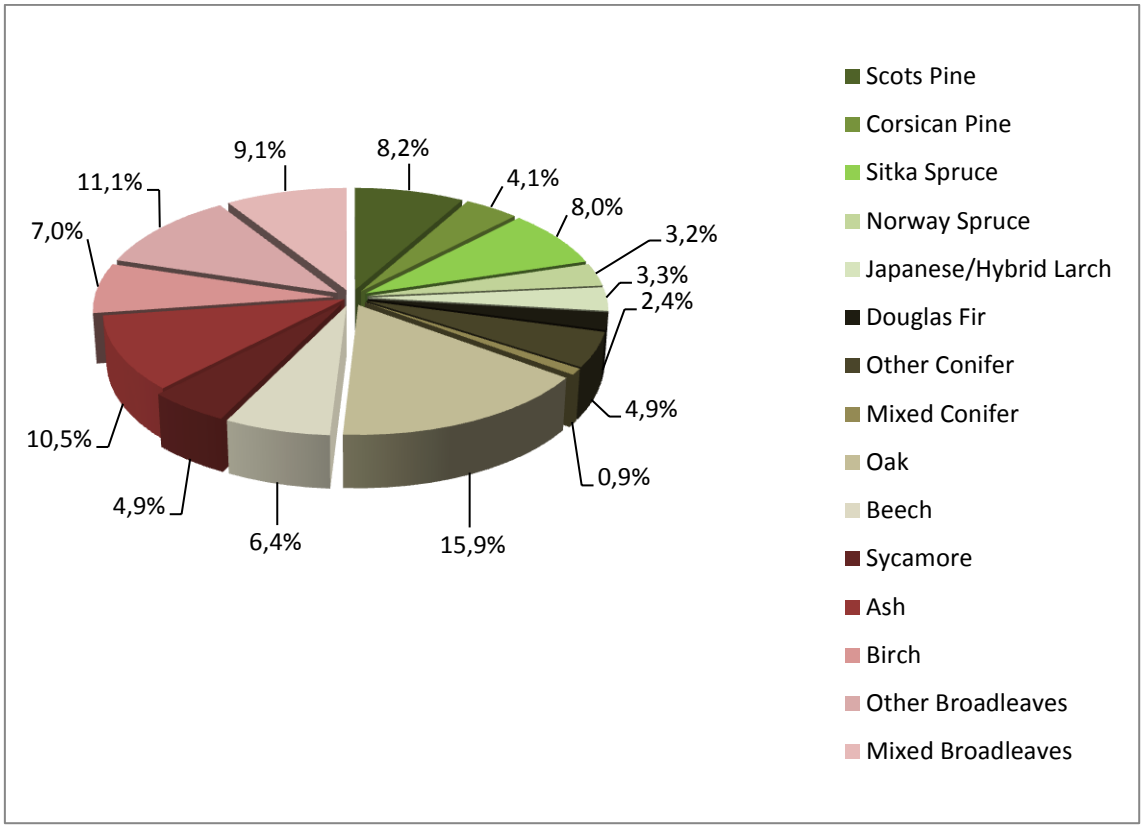

Figure 4-8 Structure of species in English forests in per cent

Source: Forestry Commission 2008; White 1995

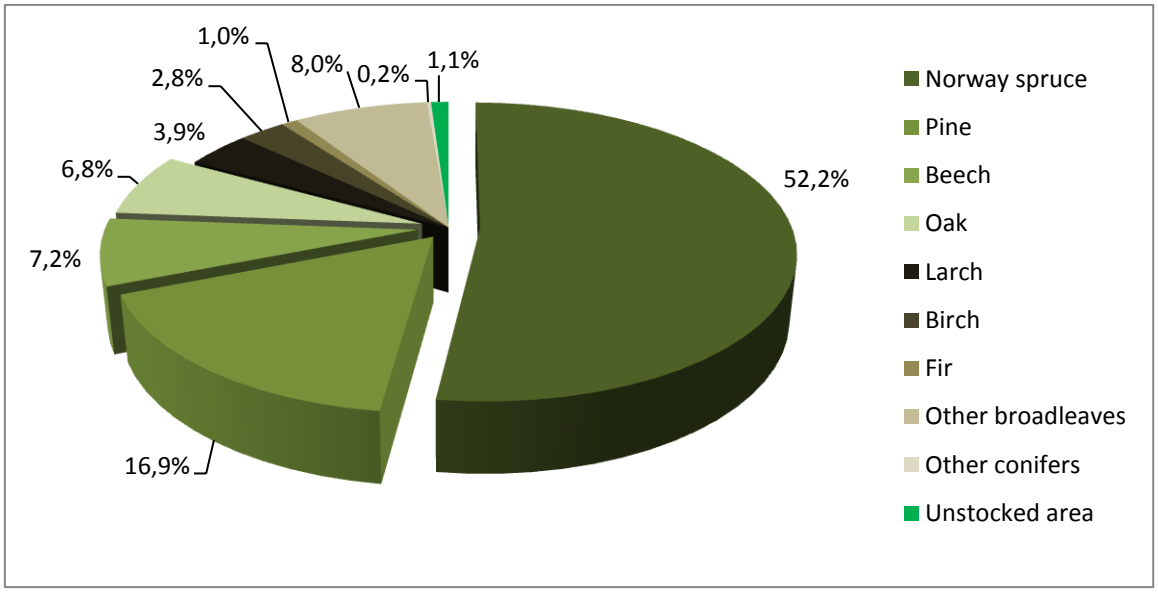

Figure 4-9 Structure of species in Czech forests in per cent

Source: Ministry of Agriculture of the Czech Republic, 2010

Comparison of the forest structure in all the three countries is described in table 4-4 where all trees in each country are divided in two groups: conifers and broadleaved trees; with list of particular species and total area occupied.

Table 4-4 Comparison of forest structures

	Total forested area in mil. ha	**Coniferous trees**		**Broadleaved trees**	
		Per cent of total forested area	**Species (according to their representation)**	**Per cent of total forested area**	**Species (according to their representation)**
Czech Republic	2.6	74.2	Spruce Pine Larch Fir	24.7	Beech Oak Birch
England	1.1	35	Pine Spruce Larch Fir	65	Oak Ash Birch Beech Sycamore
Sweden	40.8	81.5	Spruce Pine Contorta	18.5	Birch Aspen Alder Oak Beech

Source: Royal Swedish Academy of Agriculture and Forestry, 2009; Swedish University of Agricultural Sciences, 2010; Forestry Commission, 2003, 2008; Ministry of Agriculture of the Czech Republic, 2010, 2011; White 1995

4.6 Climate Change

According to Murphy *et al.* (2009), the Central England Temperature (CET) has risen by 1°C since the 1970s. In general, the impacts of climate change are

supposed to be greatest in the region of South West England and smallest in northern England. As mentioned in the latest climate projections by UKCIP (Murphy *et al.* 2009), under the medium emission scenario, the central estimates for South West England in 2050s show increases in both winter and summer mean temperature, as well as in mean daily maximum and minimum temperature. Precipitation in winter is also expected to rise by 17%. On the contrary, the amount of summer rainfall will decrease by 19%. All the values are relative to the period of 1961-1990. As each region in England is very specific, the impacts of climate change will vary significantly and therefore it is not possible to summarise the data for the whole country into one specific number but the values are given in a range of minimums and maximums (lowest and highest change). Changes relative to 1961-1990 for 2080s for all three emission scenarios (high, medium and low) at the central estimate level for the UK are shown in table 4-5.

Table 4-5 Changes in mean temperature and mean precipitation in the UK in 2080s relative to 1961-1990 levels, based on the HadCM3 model

		Mean temperature, winter [°C]	**Mean temperature, summer [°C]**	**Mean precipitation, annual [%]**	**Mean precipitation, winter [%]**	**Mean precipitation, summer [%]**
High emissions (A1F1)	Highest change, UK	3.8	5.3	+3	+47	0
	Lowest change, UK	2.1	3.1	+6	-3	-49
Medium emissions (A1B)	Highest change, UK	3.1	4.2	+2	+33	+1
	Lowest change, UK	1.8	2.5	-3	-2	-40
Low emissions (B1)	Highest change, UK	2.7	3.1	+3	+30	+1
	Lowest change, UK	1.7	1.9	-1	-2	-30

Source: Murphy *et al.* (2009)

As a tool to predict suitability of particular tree species to a site, the Forestry Commission developed the Ecological Site Classification (ESC). As a basic criterion of the model, there are six factors describing particular locations. These are: soil fertility, soil moisture availability, accumulated temperature (warmth index), wind exposure, moisture deficit (droughtiness index) and continentality (Pyatt *et al.* 2001).

As shown in National Vegetation Classification, the majority of forests types in England are located in areas where the soil is moist or wet owing to either surface or ground water (Hall *et al.*, 2004). If summers become warmer and dryer, these may be the most problematic areas and species such as willows or

alders may no longer be suitable for the new weather conditions. On the other hand, the species that prefer dry soil may struggle during wetter winters (White, 1995).

According to Read *et al.* (2009b), the most problematic location of the whole country will probably be southern England and the oak forests. In addition, other species that have better predispositions to succeed in the competition, for example Sitka spruce may also struggle (Read *et al.*, 2009a). Due to the warmer and milder climate, there may be tendencies for exotic species to grow that might be more vulnerable to weather fluctuations, especially spring or autumn frosts or winter colds. Another problem is windy weather that can be crucial primarily for conifers with more shallow roots (Broadmeadow *et al*., 2002).

Based on the UKCP09 predictions and the ESC modelling, suitability of five major tree species in the UK (beech, Douglas fir, pedunculate oak, Sitka spruce and Scots pine) was calculated by Read *et al.* (2009b). In general, the main broadleaf species as beech or pedunculate oak will be on the decline because the climate in southern England will not be as suitable. Conditions in northern England are ideal for Sitka spruce and its concentration in western England will most likely decrease. This declining trend can be expected in the case of Douglas fir as well. The only conifer species very suitable for England will be Scots pine (Read *et al.* 2009b).

According to Read *et al.* (2009b), there will be opportunities for some trees not commonly planted or “minor” species to cope with the consequences of climate change more successfully. In the case of southern England within the high emission scenario, the most suitable species in 2080s will be Norway maple, Sweet chestnut and Corsican pine.

Another useful tool for forestry management is Spatial Estimator of the Climate Impacts on the Envelope of Species (SPECIES), which models the availability of species distribution and climate space for particular species. The estimations are based on soil water availability, growing degree-day and temperature and

use statistical comparison with distribution data to enable data assessment (Pearson *et al.* 2002). As mentioned by Berry *et al.* (2007), each species will have a different response to changing climate; some of them may be on the decline and the more competitive ones will move in order to follow favourable climate conditions. Nevertheless even such species may not necessarily have to find a suitable habitat and may decline as well.

Generally, a trend of changing structure of forests can be expected across England. Summer droughts will be the greatest risk to broadleaved mixed stands and yew forests. In the case of conifers, the impacts of climate change will most likely not be that crucial but the persistence of stands will depend more on management decisions (Mitchell *et al.* 2007).

According to Kullman and Öberg (2009), the temperature in Sweden has been increasing and forests and their species structure is a very good indicator of these changes. The authors undertook a study in southern Scandes and showed that tree lines of all species there have risen by 300m in elevation along a 250km north-south gradient and at the same time, average annual temperature has increased by more than 1°C. Considering climate projections for Sweden, described in table 4-6, it is very likely that this trend will continue and Swedish climate will become more continental. The projections for Sweden are based on the ECHAM5 model and show modelling of change in temperature (in degrees Celsius) and in precipitation (in per cent) compare to 1961-1990 within A1B SRES scenario (Swedish Meteorological and Hydrological Institute, 2010).

Table 4-6 Climate projections for Sweden for years 2069 and 2100 compare to 1961-1990 levels using ECHAM5 model, describing change in mean temperature (T) in degrees Celsius and mean change in precipitation (P) in per cents

2069								
	SPRING		SUMMER		AUTUMN		WINTER	
	T [°C]	P [%]	T [°C]	P [%]	T [°C]	P [%]	T [°C]	P [%]
ECHAM5	3.9	+37	2.3	-14	3.8	+15	4.5	+71
2100								
	SPRING		SUMMER		AUTUMN		WINTER	
	T [°C]	P [%]	T [°C]	P [%]	T [°C]	P [%]	T [°C]	P [%]
ECHAM5	3.4	+21	3.6	-10	3.6	+8	6.1	+43

Source: Swedish Meteorological and Hydrological Institute (2010)

As shown in the projections for Sweden, the most extreme change is expected during winter months for both precipitation and temperature. In general, the boreal forest is supposed to move northward and to higher altitudes and the structure will consist of Scots pine, Norway spruce and mountain birch (Koca *et al.*, 2006). According to the same authors, there will be a shift of the Limes Norrlandicus up to north and so broadleaved trees will spread in the central boreal region and by Baltic coast (lime, silver birch and oak). In the boreo-nemoral zone, proportion of deciduous trees, especially beech and lime, will increase on expenses of spruce and pine (Koca *et al.*, 2006).

In the Czech Republic, the main tool for climate change projections and modelling is called ALADIN-CLIMATE/CZ. The most recent predictions are based on the SRES scenario A1B and are available for the periods 2010-2039 and 2040-2069 (Pretel *et al.*, 2010). The values are given for a grid of 25km in two forms, namely the simple version (ALADIN 25S) and the corrected version (ALADIN 25C) amended by quantile method, and separately for spring, summer, autumn and winter. After correction by quantile method, the ALADIN values are very close to the real, observed values (Pretel *et al.*, 2010). In table

4-7, predictions for the Czech Republic by both the ALADIN models as well as the HadCM3 (Hadley Centre's climate model) model are shown.

Table 4-7 Climate change projections for the Czech Republic for periods of 2010-2039 and 2040-2069 using ALADIN25C, ALADIN25S and HadCM3 models, compare to 1961-90 values, describing change in mean temperature (T) in degrees Celsius and mean change in precipitation (P) in per cents

2010 - 2039								
	SPRING		**SUMMER**		**AUTUMN**		**WINTER**	
	T [°C]	**P [%]**	**T [°C]**	**P [%]**	**T [°C]**	**P [%]**	**T [°C]**	**P [%]**
ALADIN25C	1.16	+12	1.09	+3	1.16	+8	1.14	-10
ALADIN25S	0.98	+10	0.90	+1	1.23	+6	0.90	-9
HadCM3	0.90	+10	1.23	+3	1.63	-7	1.43	+8
2040 - 2069								
	SPRING		**SUMMER**		**AUTUMN**		**WINTER**	
	T [°C]	**P [%]**	**T [°C]**	**P [%]**	**T [°C]**	**P [%]**	**T [°C]**	**P [%]**
ALADIN25C	2.6	0	2.7	0	1.9	+17	1.75	-10
ALADIN25S	2.2	-2	2.4	-2	2.0	+15	1.4	-10
HadCM3	2.2	+23	3.4	-8	3.4	-7	3.0	+26

Source: Pretel et al. 2010

As shown in the table 4-7, the HadCM3 model seems to be more extreme in its predictions than both the ALADIN models. For comparison with England, it is better to use HadCM3 global model since it is the same one as used in the UK and compare it to the medium emissions scenario (A1B). However it is necessary to keep in mind that the English predictions are for 2080s, which is 20 years further time horizon and so are slightly higher than these for the Czech Republic that are up to the 2060s only.

Regarding forestry strategies in terms of adaptation, according to Pretel *et al.* (2010) there is a big debate between changes in structure and composition of forests in order to assist adaptation to climate change and natural and historical protection of sites. However, it is important to note that the current structure of

most Czech stands is not natural. The biggest issue within the Czech forests and climate change is unsuitability of Norway spruce, that has already been in stress in many places in the country and even a small fluctuation in weather conditions can be crucial (Souček and Tesař, 2008; Pretel *et al.*, 2010; Ministry of Environment of the Czech Republic, 2004). Generally, spruce forests are most threatened by frequent rotation of hot and cold weather as well as droughts and wet periods. In addition, pests and invasive species have become a serious problem in the recent decades (Klimo *et al.*, 2000). The largest disturbances to Czech spruce forests at the moment are caused by an outbreak of bark beetle. In the last 30 years, conditions have been very favourable for its reproduction, mostly because of increasing temperatures and improved weather, but also because trees are weakened by air pollution and so they tend to be affected more easily (Zemek *et al.*, 2010). Finally, changes in water distribution are expected in Central Europe and will most likely result in droughts and water stress resulting in an increased risk of fires (Lindner *et al.*, 2008).

In general, the development for the UK and the Czech Republic is very similar but there are some greater changes in precipitation expected in the UK, especially summer droughts will be larger and more serious in the UK than in the Czech Republic. In comparison, projections for Sweden seem to be the most extreme in terms of both temperature and precipitation change.

All the data and projections used had been developed within the ENSEMBLES project by the European Union. However, there was a different global climate model used for Sweden (ECHAM5) than for the other two countries (HadCM3) and so the numbers are not fully comparable (different limitations of each model).

4.7 Assessment of effectiveness of policies in connection with climate change

In Sweden, the policy makers care especially about the southern part of the country, where the boreo-nemoral zone is. The current species structure of these forests is very different from the natural one and the trees growing there at the moment will not be suitable with increasing temperatures and changes in precipitation (Koca *et al.*, 2006). In order to return to a more natural structure, the Swedish Government introduced a grant supporting planting native broadleaved species in the boreo-nemoral zone. However, this grant is focused on transformation and restoration of existing forests only and not on increasing forested area. Swedish legislation also emphasises production functions of forests and guides forest owners on how to fell trees or undertake the process of reforestation. The whole forestry legislation appears to be quite liberal with no further considerations of climate change and its possible impacts on forests. As mentioned by Kullman and Öberg (2009), the structure of forests has been changing in reaction to increasing temperature and changes in precipitation. The species are moving northwards where the conditions are more suitable and there are new species coming from southern locations. This means that the structure not only of boreo-nemoral forest, but the whole Swedish forest is going to change (Koca *et al.*, 2006). Nevertheless, the Swedish legislation does not take into account any of these facts and is essentially not linked to climate change, even when there will most likely be a need to guide forest owners towards forest adaptation.

In the Czech Republic, the greatest issue is artificial Norway spruce monocultures. In total, 82% of spruce stands are threatened by changing weather, most of them already at stress level (Ministry of Environment of the Czech Republic, 2004). At the moment, the greatest problem is outbreak of bark beetle that invades spruce, and due to lack of other species or mixed forests, there is essentially nothing to control its further spread (Zemek *et al.*, 2010). Although the Czech Forestry Act (1995) states that suitable species only must be planted in Czech forests, there is no further specification or guidance on how

this should be done or what species to plant. As mentioned in the Act, in the case of afforestation, the planting material must originate from the same or similar location. Taken word for word, if establishing a new forest in area where only spruce monocultures are grown, the new forest should comprise of spruce as well. There are grant schemes that should encourage changing structure of forests where is not optimal. However, there is not enough guidance or forestry legislation that would help forest adaptation to climate change.

In England, the changing climate will most likely cause the most harm to oak forests in the southern part of the country (Read *et al.*, 2009b). Due to small forest cover, English grant schemes are quite extensive and try to encourage new forest development, which is in this case very important. Nevertheless, it is vital that the newly planted forests are suitable for future weather conditions. As mentioned by Read *et al.* (2009a), planning horizons in forestry are between 50 and 100 years and so the possible climate changes should be taken into account. According to Read *et al.* (2009b), due to climate change, a decline of beech and oak can be expected there, but at the same time, these trees are still being planted within the grant schemes (Forestry Commission, 2011c). Apparently, any stronger link between the English policies and grants and climate change is missing. Although significant research has been done on suitability of tree species in the future (for example Mitchell *et al.*, 2007; Berry *et al.*, 2007; Read *et al.*, 2009a,b), in practice it does not seem that the species structure of newly planted forests would be regulated in order to aid English forests with climate change adaptation.

Nevertheless, adaptation to climate change does not necessarily have to be based on such radical measures as changes in species structure, at least in the short and medium term. As mentioned by Roberts (2008), it is very important to focus on reducing all stress factors that do not have their origin in climate change, because as a result, the forests will be more resilient to climate change if they do not have to handle other unfavourable issues. Furthermore, Roberts (2008) shows that in the short and medium term, the main steps for forest adaptation should be changes in forest management and reduction of external

stress. In the long term, changes in species structure and composition are the most suitable measure (Roberts, 2008). In table 4-8, the main adaptation measures proposed by the FAO (2011) and IPCC (2007) are described and linked to particular precautions included in the legislation of all the three countries.

Table 4-8 Overview of adaptation measures proposed by the FAO (FAO, 2011) and IPCC (Alcamo *et al.*, 2007; Fischlin *et al.*, 2007) and appearance of these in legislation of Sweden, England and Czech Republic

	Sweden	England	Czech Republic
Changes in species structure			
Adaptive forest management (to decrease impacts of extreme weather events)			
Multispecies planting, deciduous trees mixed with conifers	(In southern part of the country only) ✖		✖
Fire protection			✖
Forest Inventories, better monitoring	✖	✖	✖
Reduction of external stress (pollution, pests, …)	✖	✖	✖
Maintenance of forest health	✖	✖	✖

Source: FAO, 2011; Alcamo et al., 2007; Fischlin et al., 2007; Forestry Commission, 2004, 2011b; Swedish Forest Agency, 2011a; Parliament of the Czech Republic, 1995

Table 4-9 summarises the link between particular forest and forestry characteristics of each country and their legislation. It is clear from this analysis that there are no direct links to climate change either within regulations or the grant schemes.

Table 4-9 Summary of legislation and grants in each country covering main points of the discussion (green = fully covered, amber = partially covered, red = not covered)

	Regulations			Grants		
	Sweden	**England**	**Czech Rep.**	**Sweden**	**England**	**Czech Rep.**
Forested land	✔	✔	✔	✘	✔	✔
Forest categorisation	✔	✔	✔	✔	✔	✔
Ownership	✔	✔	✔	✔	✔	✔
Species structure	✔	✔	✔	✔	✘	✔
Climate change	✘	✘	✘	✘	✘	✘

Source: Ministry of Rural Affairs of Sweden, 1979; Swedish Forest Agency, 2011b; Forestry Commission England, 2010; Forestry Commission, 2004; Forestry Commission 2011b; Parliament of the Czech Republic, 1995, 2010

In summary, none of the three countries legislation or policies includes sufficient measures for climate change adaptation of forests, at least from a long term point of view. As mentioned by Roberts (2008), specific policies are usually very general and do not go into detail of specific vulnerabilities. In Sweden, the legislation is strongly focused on the productive function of forests and there is little guidance on what trees species are suitable (except from the boreo-

nemoral zone) or how to mitigate impacts of changing climate on forests. There are some regulations on coping with pest infection in the forest, which can reduce an external stress and how to maintain healthy forests. The situation in the Czech Republic is slightly better. Some effort is apparent to define rules on how to plant or restore forests and improve quality of stands (in favour of mixed forests) but anything more specific is missing in the legislation. There are also suggestions for faster rotation cycles in order to reduce possible impacts of negative weather conditions. In addition, some points of the Czech legislation are focused on reducing external stress to trees. From a long term point of view, England seems to be more concerned about quantity rather than quality of newly planted or restored forests, most likely because of lack of forests in the country in general. At the same time, the UK Forest Standard (Forestry Commission, 2004) fully describes the main points of sustainable forest management and places significant emphasis on mitigation of external stress factors.

In comparison, the situation in developing countries, where the effectiveness of policies has been studied (for example Mertz *et al.* 2009 or Ibarra and Hirakuri 2007) is completely different. In these cases, policy makers need to initially focus on getting the whole sector working, establish basic rules and regulations and ensure those are respected and followed. There is also a lack of public education and understanding of the main issues connected to the sector (Mertz *et al.* 2009). It is obvious that significant effort is required for such policies to work effectively. Clearly, only a functional system of legislation, control and monitoring can offer possibilities for further development in questions and issues that are not primarily necessary for basic forest management.

4.8 Limitations of the study and recommendations for future research

There are two main limitations of the study, the first connected to data and the second to time restrictions.

Since three different countries were compared in the study, it was not always possible to obtain all the data in exactly the same format and so they were not fully comparable. The biggest bias can be probably seen in the data for climate projections for each country. As shown in the data for the Czech Republic where two different models were compared, the differences were significant. Although the projections for the Czech Republic and England were based on the same model (HadCM3), Swedish data were not. It is because within the ENSEMBLES project, the participating countries were using different global models to develop their projections. Although the primary data from HadCM3 global model are most likely available for all the countries, in case of Sweden they were not in a format suitable for this study because officially, ECHAM5 global model is used by Swedish government to produce these projections. Besides that, climate change projections in general are based on significant assumption and cannot be taken as absolute predictions. Another data limitation is the fact that terminology within the three countries was not same in all categories. For example forest categorisation according to their use is different in the Czech Republic and Sweden, while the data for England was not available.

Due to time restrictions, it was not possible to go further in the research of legislation of particular countries and so mainly a review of policies and law on regional and local level is missing. Since forestry is a very specific sector, strongly dependent on local conditions, the national level of legislation is a general framework and is usually complemented by regulations on regional level. It was also not possible to examine the English grant scheme and obtain specific numbers on species structure of newly planted forests within English Woodland Grant Scheme (EWGS).

The suggestions and recommendations for future research are basically linked to the limitations of the study, which means:

- Obtain data that are fully comparable;

- Further examine the legislation at a regional and local level and examine the usefulness of EWGS in connection with climate change adaptation.

5 CONCLUSION AND RECOMMENDATIONS

Climate change is a pressing issue and its impacts are most likely to be even more serious in the future. As shown in tables 4-1, 4-2 and 4-3, all the countries included in this study are expected to be affected by new weather conditions. It is therefore important to develop forestry policies that would help forests to adapt to these changes in both the short and long term.

All the three countries are attempting to manage their main forestry issues. In the case of Sweden and the Czech Republic, forestry policies are more focused on productive function of their forests and include measures on mitigating external stress to forests as well. In England, the main focus is on afforestation and increasing the area of forest cover, although the system of subsidies does not take suitability of species for future climate into consideration. There is also guidance on improvement of external conditions and reduction of stress caused by non-climatic factors.

In future, it will be necessary to include not only short term measures but the long term ones as well, mostly to consider possible changes of species structure that would be more suitable for changing climate. Sustainable forest management will be vital for maintaining healthy and resilient stands. In Sweden, the southern border of boreal zone has moved northwards and this trend will most likely continue. As a part of this change, the species composition will also transform. New weather conditions may have a negative impact on forestry industry in the country and if so, some steps from the government will be needed. For the Czech Republic, the main issue will most likely be Norway spruce monocultures, which will become even more unsuitable and threatened by pest outbreaks. The government should support planting of mixed forests with at least some proportion of deciduous trees to create more resilient forests. In England, there will probably also be a need for a change of species composition, especially in the southern part of the country. Some species from continental Europe may be a good alternative but it will be necessary to

consider possible problems linked to such a decision (for example pests or fungal diseases).

European forests are valuable natural resource that can be used for many purposes and their magnitude will most likely increase even more in future, so it is very important to care of them and improve their conditions. Forestry planning is a long term process and so every step should be evaluated carefully and all the factors and consequences should be taken into account.

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LIST OF ABBREVIATIONS

ALADIN – Aire Limitée, Adaptation Dynamique, Development International

CAP – Common Agricultural Policy

CET – Central England Temperature

CO_2 – Carbon Dioxide

DEFRA – Department for Environment, Food and Rural Affairs

EAFRD – European Agricultural Fund for Rural Development

ECHAM – European Centre for Medium-Range Weather Forecasts climate model, Hamburg

EIA – Environmental Impact Assessment

ESC – Ecological Site Classification

EU – European Union

FAO – Food and Agriculture Organization of the United Nations

HadCM3 – Hadley Centre Coupled Model, version 3

IPCC – Intergovernmental Panel on Climate Change

SFM – Sustainable Forest Management

SPECIES – Spatial Estimator of the Climate Impacts on the Envelope of Species

SRES – Special Report on Emissions Scenarios

UK – United Kingdom

UNCED – United Nations Conference on Environment and Development

GLOSSARY

Afforestation: Establishment of a forest at a place where was no forest before.

Bark beetle: A small beetle of Scolytus genus infesting phloem, wood and fruit of plants that is considered to be a very dangerous pest to trees.

Biodiversity: The degree of species/life forms variation within an ecosystem.

Boreal forest: A largest terrestrial biome located in the northern part of the northern hemisphere (Alaska, Canada, Finland, Japan, Kazakhstan, Mongolia, Norway, Russia, Sweden) with its typical coniferous forests, also known as taiga.

Broadleaved forest: Woodland containing more than 80% by area of broadleaved species.

Conifer forest: Woodland containing more than 80% by area of coniferous species.

Deforestation: Removal of forest cover where the land is thereafter converted to a non-forest use.

ENSEMBLES: climate change research project involving 66 partners from across Europe

Forest: An area with a high density of trees. According to the forestry definition, forest must consist of trees 5 meters high at minimum and with canopy closure of at least 25 per cent.

Limes Norrlandicus: A biogeographical boundary in Sweden dividing the southern temperate zone and the northern boreal zone (taiga).

Monoculture: Cover of one tree species where other trees comprise for less than 10% of the stand.

Nemoral forest: A temperate, frost-resistant forests containing deciduous trees. In Europe is located in northern parts of western, central and eastern Europe as well as in southern parts of Scandinavia.

Photosynthesis: The process in green plants and certain other organisms by which carbohydrates are synthesized from carbon dioxide (CO_2) and water using light as an energy source. Most forms of photosynthesis release oxygen as a by-product.

Woodland: A low-density forest forming open habitats with lots of sunlight and limited shade. In British woodland management, woodland stands for any smaller area covered in trees, however dense.

APPENDICES

Appendix A Legislation summary

A.1 Swedish legislation

The main document for Swedish forestry is the Swedish Forestry Act (Ministry of Rural Affairs of Sweden 1979, Swedish Forest Agency 2011a). It sets up the main points for forest management:

- Reforestation: new forest must be planted or naturally generated after felling by the end of the third year after felling (in case the soil's capacity is not fully exploited)
- Forest felling: thinning must encourage forest development and the timber stocks must stay large enough.
- Regeneration felling: regeneration felling is prohibited before certain age of the forest and is restricted on forests above 50ha; notification is required at least 6 weeks in advance and in case of mountains woodland and vulnerable hardwood species a permit is required.
- Insect damage: in case when pests breed in the bark of newly felled conifers and the volume of affected trees exceeds 5m3/ha, such trees must be removed from the forest immediately.
- Nature consideration and cultural heritage: biodiversity must be protected and the cultural heritage and social aspects should be taken into consideration but the conservation requirements should not make ongoing forestry activities significantly harder.
- Reindeer husbandry.

Another document affecting forestry in Sweden is the Environmental Code (Ministry of Environment of Sweden, 2000). The Forestry Agency is empowered to enforce the Code in the forestry sector. In practice it means that consultations with the Agency are required in case of significant impacts of forestry processes on the natural environment. The Agency is also responsible for protection of small habitats containing fauna and flora species of special interest (Swedish

Forest Agency, 2011a). The Agency is is further responsible for supervising compliance with the Council Directive 1999/105/EC on marketing of forest reproductive material (Swedish Forest Agency, 2011a).

A.2 English legislation

The main bodies responsible for policies in forestry in England are the Department for Environment, Food and Rural Affairs (DEFRA) and the Forestry Commission (FC). Although the majority of forests in England are in private ownership, all of them are regulated by the Forestry Commission (FC). The FC is responsible for every single process linked to forests including (re)planting, felling licences, control of reproductive materials and so on (Forestry Commission, 2004). Besides these, the FC also tries to encourage new forest development through a system of grants (Forestry Commission, 2011a). With regards these, several rules need to be followed (Forestry Commission, 2011b):

- An Environmental Impact Assessment (EIA) is necessary for both woodland creation and deforestation, as well as for other actions that can significantly affect a forest and its environment
- A felling licence is needed for felling trees
- There are habitat regulations which mean that for such operations that could have an effect on European Protected Species a licence is required
- Under the Countryside & Rights of Way (CRoW), an approval is needed to prohibit public access to a forest
- The Forestry Commission controls all the seeding materials as well as international trade with forestry material

The main document at the UK level is The UK Forest Standard which sets out standards for the sustainable management of British forests and as such, the document served as a basis for the UK Woodland Assurance Standard (UKWAS). It establishes also the Woodland Plan, an essential management tool for British forestry (Forestry Commission, 2004). According to the UK Forest Standard (Forestry Commission, 2004), the main points and requirements for sustainable forest management are:

- Forest soil condition that should be stable or improved
- Water quality protection and improvement, water yield maintenance, water discharge patterns disturbance only if unavoidable
- Protection and practising of forest carbon sinks and stores, avoiding air pollution
- Production and supply of timber and other forest products should be considered from a long-term point of view as stable or increasing
- Conservation and improvement of biodiversity
- Competency, safety and efficient practices of forestry workers
- Protection and improvement of cultural and social aspects as rural development, recreational function, quality of life in surrounding areas, communities involvement, skills training and public education
- Protection of heritage features and enhancement of landscape quality

A.3 Czech legislation

The main legislation document of Czech forestry is the Czech Forestry Act (Parliament of the Czech Republic, 1995) which sets up basic principles and regulations on sustainable forest management as well as obligations and requirements for anyone who enters a forest. Support (both financial and consultancy) for foresters and forest managers is also established in the document. The main points linked to forest management are the following:

- Regional plans for forest development are the main tool of national forestry policies
- Forest management plans are usually developed for ten-year-long terms and include requirements for maximal amounts of felling, soil improvement and proportion of reinforcing woods
- In case of artificial reforestation or planting in new areas (previously approved), the seeds/seedlings/plants must originate from the same or similar location and altitude
- For Norway spruce, Scots pine and European larch, only seedlings from certified sources can be used

- Stands must be restored by suitable trees within good timing and continuously to improve their condition and, where suitable, it is recommended to use natural restoration
- Thinning cannot exceed three tenths of the stand (there can be an exception given in case of thinning in favour of future stands)
- After cleaning, the area must be reforested within two years and stands must be assured in seven years
- It is necessary to do such preventive measures to protect forests from harmful factors (their early detection and spreading prevention) and from fire
- It is required to improve stability and resistance of a forest by suitable tree species structure and layout
- It is prohibited to log in stands younger than 80 years
- Logging should be done in the most sensitive way to prevent any disturbances to an ecosystem

Appendix B Grant schemes summary

B.1 Swedish grants

The Swedish Forest Agency is not only responsible for forest policies and connected legislation but it is also empowered to redistribute grants and subsidies in forestry. According to the Swedish Forest Agency (2011b), there are five grants available for forest owners in Sweden:

- Financial support to increase the area of woodland with hardwood species in southern Sweden: a scheme by the EU, applicable on forests bigger than 0.5ha which are created at least from 70% by deciduous trees with a minimum of 50% content of one or more native species (these are ash, beech, elm, hornbeam, lime, maple, oak and wild cherry). However, these subsidies do not increase the forested area, just support planting of

deciduous species instead of Norway spruce, which would normally be the main alternative in this area.

- Skills development for competitive and sustainable forestry: a scheme by the EU that should strengthen competitiveness in rural areas and conduce to sustainable forestry, available for both those who wish to educate others ("project support") and those who want to educate themselves or their colleagues ("enterprise support").
- Financial support to preserve and develop the biodiversity of forests and their cultural heritage assets: a scheme by the EU which serves as a compensation to forest owners who have to adjust their management in order to protect biodiversity or cultural heritage.
- Nokås, a grant to promote nature conservation and cultural heritage: a scheme that encourages forest owners to conservation of nature, biodiversity and cultural heritage.
- Financial support for forestry operations in hardwood woodland: this scheme covers partially costs of regeneration and tending of woodland with hardwood species (woodland over 0.5ha size with at least 70% of deciduous species from which a minimum of 50% consists of one or more indigenous species such as ash, beech, elm, hornbeam, lime, maple, oak and wild cherry).

B.2 English grants

The principal source of financial support for creation of new forests and their sustainable management in England is the English Woodland Grant Scheme (EWGS). The scheme as such consists of various grants, each focused on particular action linked to forests. Generally, this system of grants tries to encourage owners to both plant new forests and re-establish old ones as well as to maintain existing forests.

The grants available are:

- Woodland Planning Grant (WPG) that helps to create sustainable management plans (such plans must comply with the UKWAS) that also

encourage forest owners to access another grants schemes and UKWAS as well;

- Woodland Assessment Grant (WAG) to gain more information about the sensitivity of the site and associated research that could help to develop and improve sustainable management;
- Woodland Regeneration Grant (WRG) for re-establishment of forests after felling and woodland regeneration and for reaching desirable change in the woodland and better suitability for sustainable management;
- Woodland Management Grant (WMG) that support maintenance or improvement of forests and sustainable woodland practice;
- Woodland Creation Grant (WCG) which is a system of single farm payments per ha that supports national and regional priorities such as biodiversity, public access or industrial land restoration
- Woodland Improvement Grant (WIG) supporting such improvements and interventions that do not have economic value but can be beneficial for the habitat or have social value.

Other grants can be locally available (Forestry Commission England, 2010). In addition a new grant focused on woodfuel and timber production is supposed to be launched in 2011 (Forestry Commission England, 2011). Besides the EWGS, the Environmental Stewardship (ES) scheme is also applicable for forests in England. The ES consists of four particular schemes: Entry Level Stewardship (ELS); Organic Entry Level Stewardship (OELS); Uplands Entry Level Stewardship (Uplands ELS) and Higher Level Stewardship (HLS) (Natural England, 2011).

B.3 Czech grants

According to the Czech Forestry Act (1995), the subsidies in forestry are granted by the Ministry of Environment (forests within national parks and other protected areas), defence (forests that are the property of the Ministry) or agriculture (all other forests) as well as particular county councils. The main priorities that can be subject to forestry subsidies in 2011 are the following (Parliament of the Czech Republic, 2010):

- Restoration of stands damaged by pollution or anthropogenic factors: both natural and artificial restoration; protection of immature stands; soil improvement
- Restoration and growing of forest cover: natural as well as artificial restoration; transformation of stands with unsuitable species structure; growing of forests up to the age of 40 years
- Support of small owners' associations: compensation of costs on administration of united forestry holdings
- Ecological and environment-friendly technologies: careful removing or moving of felled wood (using horse, ropeway or machine not heavier than 10 tonnes without drawing on the ground); brushwood crushing prior to forest restoration and spreading of the material across the forest
- Specific gamekeepers' activities
- Digital forestry planning that can be used for purposes of public administration of forests
- Breeding and training of national breeds of hunting dogs and raptors
- Other economic forestry activities: hardwood genetic reproduction and preservation; seed orchard operation

Appendix C Guidance for authors - Environmental Science & Policy (Elsevier, 2011)

Article structure

Authors should be as concise as possible. The maximum length of manuscripts, inclusive of title, author affiliations, abstract, acknowledgements, references and figure captions is 7000 words. If the total number of figures and tables together exceeds 6, the word limit must be reduced at the rate of 200 words per item over 6. Authors are encouraged to maximise use of the "Supplementary Material" facility to supply information which will only be available online.

Subdivision - numbered sections: Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...),

1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line.

Appendices: If there is more than one appendix, they should be identified as A, B, etc. Formulae and equations in appendices should be given separate numbering: Eq. (A.1), Eq. (A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly for tables and figures: Table A.1; Fig. A.1, etc.

Vitae: Include in the manuscript a short (maximum 100 words) biography of each author.

Abstract

A concise and factual abstract is required. The abstract should state briefly the purpose of the research, the principal results and major conclusions. An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.

Highlights

Highlights are mandatory for this journal. They consist of a short collection of bullet points that convey the core findings of the article and should be submitted in a separate file in the online submission system. Please use 'Highlights' in the file name and include 3 to 5 bullet points (maximum 85 characters, including spaces, per bullet point).

Keywords

Immediately after the abstract, provide a maximum of 6 keywords, using British spelling and avoiding general and plural terms and multiple concepts (avoid, for example, 'and', 'of'). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

Units
The SI system should be used for all scientific and laboratory data. If it is necessary to use other units they should be added in parentheses. Temperatures should be given in degrees Celsius. Where units or abbreviations may cause ambiguity or be misunderstood by an international readership, units should be explained and abbreviations spelled out in full. For example, the unit 'billion' should be qualified when used.

Tables
Number tables consecutively in accordance with their appearance in the text. Place footnotes to tables below the table body and indicate them with superscript lowercase letters. Avoid vertical rules. Be sparing in the use of tables and ensure that the data presented in tables do not duplicate results described elsewhere in the article.

References
Citation in text:

Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Any references cited in the abstract must be given in full. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either 'Unpublished results' or 'Personal communication' Citation of a reference as 'in press' implies that the item has been accepted for publication.

Web references:

As a minimum, the full URL should be given and the date when the reference was last accessed. Any further information, if known (DOI, author names, dates, reference to a source publication, etc.), should also be given. Web references can be listed separately (e.g., after the reference list) under a different heading if desired, or can be included in the reference list.

Reference style:

Text: All citations in the text should refer to:

1. Single author: the author's name (without initials, unless there is ambiguity) and the year of publication;

2. Two authors: both authors' names and the year of publication;

3. Three or more authors: first author's name followed by 'et al.' and the year of publication.

Citations may be made directly (or parenthetically). Groups of references should be listed first alphabetically, then chronologically.

List: References should be arranged first alphabetically and then further sorted chronologically if necessary. More than one reference from the same author(s) in the same year must be identified by the letters 'a', 'b', 'c', etc., placed after the year of publication.