ALTERFOR

Deliverable 3.2 – Synthesis report: discrepancies between ES needs and ES outputs under current FMMs

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ALTERFOR

Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

List of tables

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

ALTERFOR

List of figures

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Abbreviations used

CSA – Case Study Area
DSS – Decision Support System
ES – Ecosystem Service(s)
FMM – Forest Management Model (in ALTERFOR a silvicultural concept, not a simulation model)
HWP – Harvested Wood Products
LCC – Local Case Coordinator
MSG – Management Support Group
PA – Project Administrator
PC – Project Coordinator
SC – Scientific Coordinator
WP – Work Package
WPLs – Work Package Leader(s)

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1 Introduction

The work in ALTERFOR is based on case study areas (CSAs[1]) in eight[2] European countries (from North to South: Sweden, Lithuania, Ireland, Netherlands, Germany, Slovakia, Italy, Portugal). Except Germany, which hosts two case study areas, there is one case study per country, resulting in a total of nine CSAs (Figure 1 and Table 1). These CSAs are forest landscapes covering sizes between several thousands up to several hundred thousands of hectares. They were selected as being representative for important problems at the interface of forest management and forest policy. Usually, the case studies' significance is not restricted to the country they are located in but extends to comparable situations in their whole respective climate zone. E.g. the Irish case study can serve as an example for vast peatland areas throughout the Northern part of Europe.

In ALTERFOR each country used its own decision support system (DSS) /forest simulation model. On the one hand, this has the advantage that the projections were done with the best possible applicability for the specific case study conditions. On the other hand, this diversity in applied methods meant that the overarching global frame scenarios prepared by the International Institute for Applied Systems Analysis - IIASA (ALTERFOR WP2 Leaders, 2016) containing climate and timber demand scenarios could not be incorporated in the same way and to the same extent in all case studies (for details see ALTERFOR WP3 Leaders, 2018). In brief, the three global frame scenarios are:

- Reference scenario – the scenario for future patterns of activity which assumes that the future is based on historical development, an increase in timber demand, with medium level of residue extraction
- EU Bioenergy scenario – the scenario for future patterns of activity which assumes an increase in biomass demand over time, with a medium level of residue extraction
- Global Bioenergy scenario – the scenario for future patterns of activity which assumes stringent climate change policies worldwide, leading to an increase in biomass demand over time, with a high level of residue extraction.

The scenarios also present different climate change effects, which may impact on forest productivity, disturbances, timber production and utilisation.

In order to partly overcome methodological differences resulting from applying different projection tools and different ways of incorporating the global frame scenarios, ALTERFOR at an early stage defined a standard set of output variables as a common requirement to be provided by all case studies (Nordström et al., 2018, under revision).

The ALTERFOR Milestone 11, projections with current forest management models (FMM) per case study, was completed on March 1, 2018 (ALTERFOR WP3 Leaders, 2018). It consists of a compilation of DSS results for Current FMMs under the three global frame scenarios - Reference, EU Bioenergy and Global Bioenergy. The next stage consisted of the local case study coordinators (LCCs) producing assessments of the six ecosystem services (ESs) included in ALTERFOR (biodiversity conservation,

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[1] At the beginning of this document we provide a list of ALTERFOR related abbreviations.

[2] Since the inception of the ALTERFOR project, 9 countries have been working with CSAs, according to the ALTERFOR proposal. However, the input of Turkey to D3.2 has been withheld due to institutional issues and changes in personnel.

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timber production, carbon sequestration, regulatory services, cultural services and water-related services) and timber for their CSAs. The LCCs were facilitated in this by example ES assessments from the ALTERFOR Ecosystem Service Expert Group. The ES assessments produced by the LCCs were then sent to the ES Experts, who produced synthesis reports for all ESs, bringing together the most important results and trends from the CSA reports.

This document consists of three main parts. The first part provides a cross-country overview of selected important DSS output variables and their projected development under current FMMs over 100 years. This part is intended to allow readers to get familiar with the basic information which was used by the LCCs and ES experts for producing their assessments. These assessments are presented in the second part to the full extent. In the third part, we come to a synthesis taking on the title of this paper, asking for potential discrepancies between ES needs and ES outputs under current FMMs.

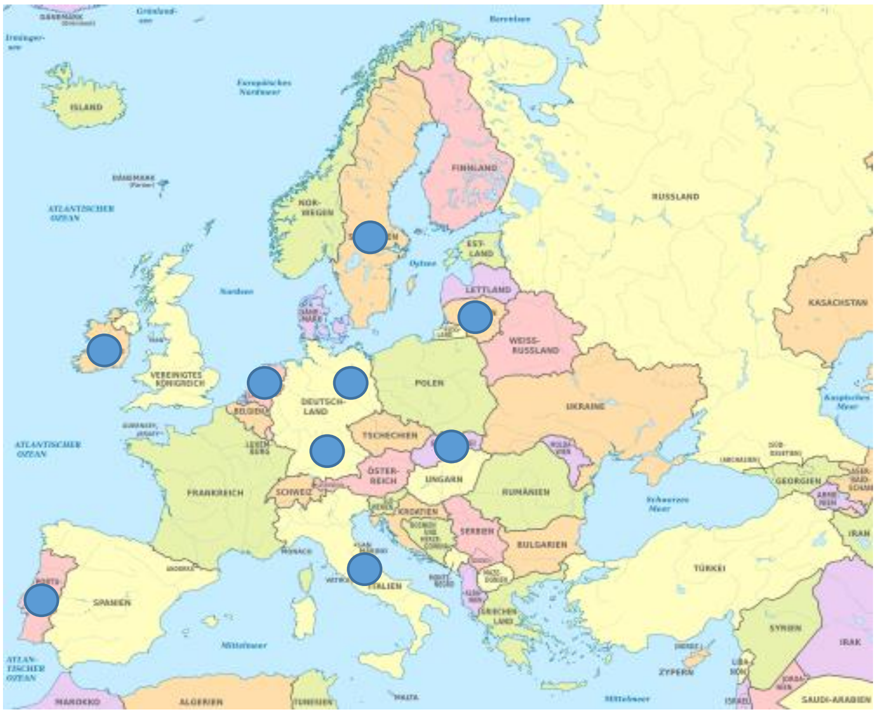

Figure 1. Map showing the countries where case studies are taking place.

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Table 1. Details of the case study areas used in ALTERFOR project.

(Country code) Name(s)	Area, 1000 ha (% forest)	Forest ownership (%)	Main stakeholders	Main ES	Available DSS(s)
(SWE) Kronoberg county	847 (77)	83 Private 17 Public	FOA[1], ENGO[2], forest industry, Swedish Forest Agency, public	Timber, Biodiversity, Water, Recreation	Heureka HoSim
(LTU) Telšiai	254 (34)	63 Private 37 Public	Institute of Forest Management Planning, state forest managers, PFO[3], ENGO, regional park	Timber, Biodiversity Water, Recreation	Kupolis
(SVK) Podpolanie	34 (57)	7 Private 93 Public	State forest managers, PFO, ENGO, general public	Timber, Biodiversity Water, Recreation	Sibyla
(IRL) Barony of Moycullen	81 (16)	22 Private 78 Public	Forest service, advisory services, PFO, ENGO, industries, public, fisheries, investment bodies	Timber, Biodiversity Water, Recreation	Growfor Remsoft
(ITA) Veneto	76 (100)	74 Private 26 Public	PFO, logging enterprises, municipalities, regional forest administration, ENGO	Timber, Biodiversity Water, Erosion control	InVEST RockyFO CO2Fix
(PRT) Sousa Valley	15 (10)	100 Private 0 Public	FOA, forest owner federation, forest industry, forest service, local municipality, other NGO	Timber, Recreation	StandSim SADfLOR
(DEU) Augsburg Western Forests (AWF)	150 (33)	50 Private 50 Public	PFO, ENGOs, forest service forest industry, general public (stable ownership structure for decades)	Timber, Biodiversity, Recreation, Water, Soil protection	SILVA
(DEU) Lieberose - Schlaubetal (LS)	90 (37)	44 Private 56 Public	PFO (their share steadily increasing), forest service ENGOs, forest industry, general public	Timber, Biodiversity, Recreation, Soil protection	SILVA
(NLD) Netherlands	3,734 (11)	52private 48 public	Government: National, Regional & Owners: Owner association, State forestry, National Trust, NIPF & General public	Timber, recreation, biodiversity	EFISCEN-space

[1] Forest owners' association; [2] Environmental non-governmental organisation; [3] private forest owners

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2 Cross Country DSS Result Comparison

The result presentation in the following text extensively uses so-called spider diagrams, all based the same layout (Figure 2). This diagram layout provides a separate axis for each case study along which the variable of interest is plotted. The axis directions roughly mirror the North-West/East-South order of the case studies.

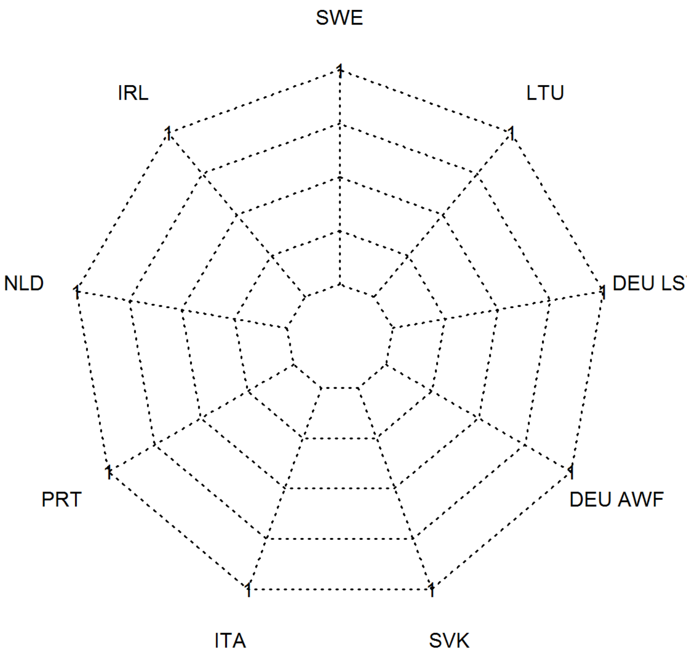

Figure 2. Generic spider diagram layout for the result presentation. Clockwise from the top: Sweden, Lithuania, Germany Lieberose-Schlaubetal, Germany Augsburg Western Forests, Slovakia, Italy, Portugal, the Netherlands and Ireland.

As the direct DSS output variables may relate to more than one ecosystem service each, we grouped their presentation into three sections: a) Classic Forestry Information, b) Structure and Diversity, and c) Carbon Sequestration related information. E.g. group 'a' does not only provide information about timber production, but also about regulatory services, and water protection. Similarly, group 'b' relates to biodiversity, but typically also to cultural services and water protection, etc. The information presented here is a condensed view on selected variables. The full detailed information this was drawn from and on which the ecosystem service experts based their assessments is available in the ALTERFOR MS 11 document (ALTERFOR WP3 Leaders, 2018).

2.1 Classic Forestry Information

As a general result for the projected standing wood volume, Figure 3 shows increasing values in almost each case study (exceptions are Portugal and Slovakia), most pronounced in the Netherlands, Sweden, and the Southern German case study Augsburg Western Forests (AWF). The effects of the global frame scenarios are only partly pronounced; where they are (Sweden, Ireland, Germany AWF), the Global Bioenergy Scenario, where climate change is assumed to be least severe, leads to the lowest volumes in the long run.

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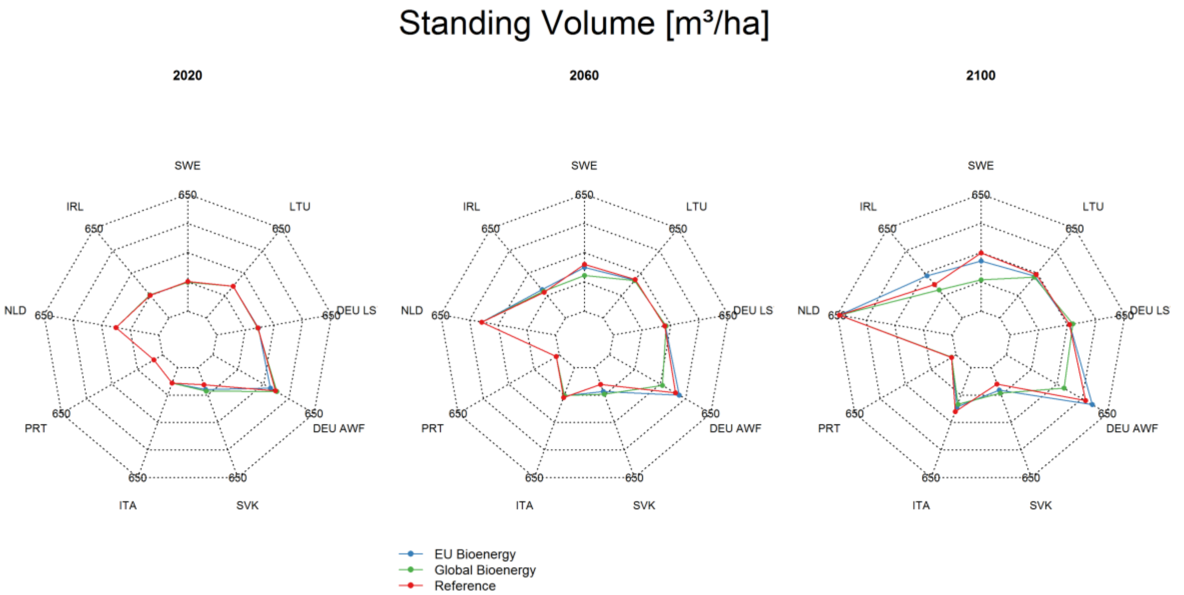

Figure 3. Standing Volume (m³/ha) projections in the single case studies for the three global frame scenarios (EU Bioenergy, Global Bioenergy, Reference), shown for the years 2020, 2060, and 2100.

The volume increments (Figure 4) generally show a slightly increasing trend for almost all case studies. Throughout the simulation time, the highest values were obtained for Sweden and the German AWF case study, lowest values for Italy and Portugal. In the beginning, there is almost no differentiation among the global frame scenarios; in later years, scenario differences emerge, whereby the Global Bioenergy scenario leads to the lowest increments in Sweden and Germany AWF, and the Reference scenario having lowest increments in Ireland and Slovakia. The harvest amounts are shown in Figure 5 on the same scale as the volume increments are in Figure 4 in order to facilitate comparison.

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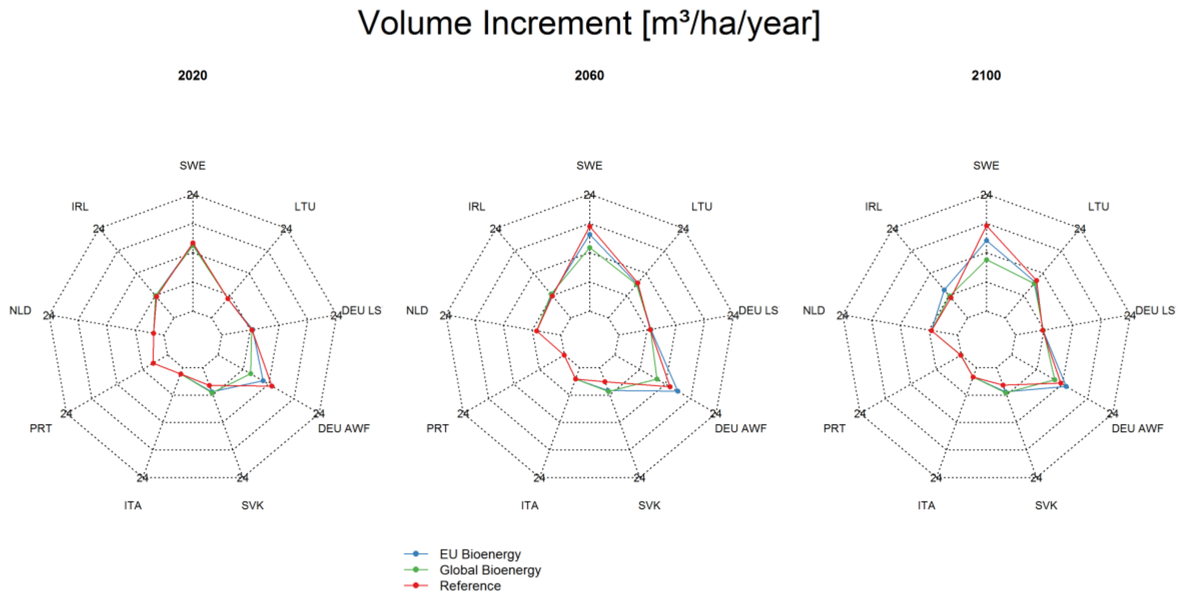

Figure 4. Volume increment (m³/ha/year) projections in the single case studies for the three global frame scenarios (EU Bioenergy, Global Bioenergy, Reference), shown for the years 2020, 2060, and 2100.

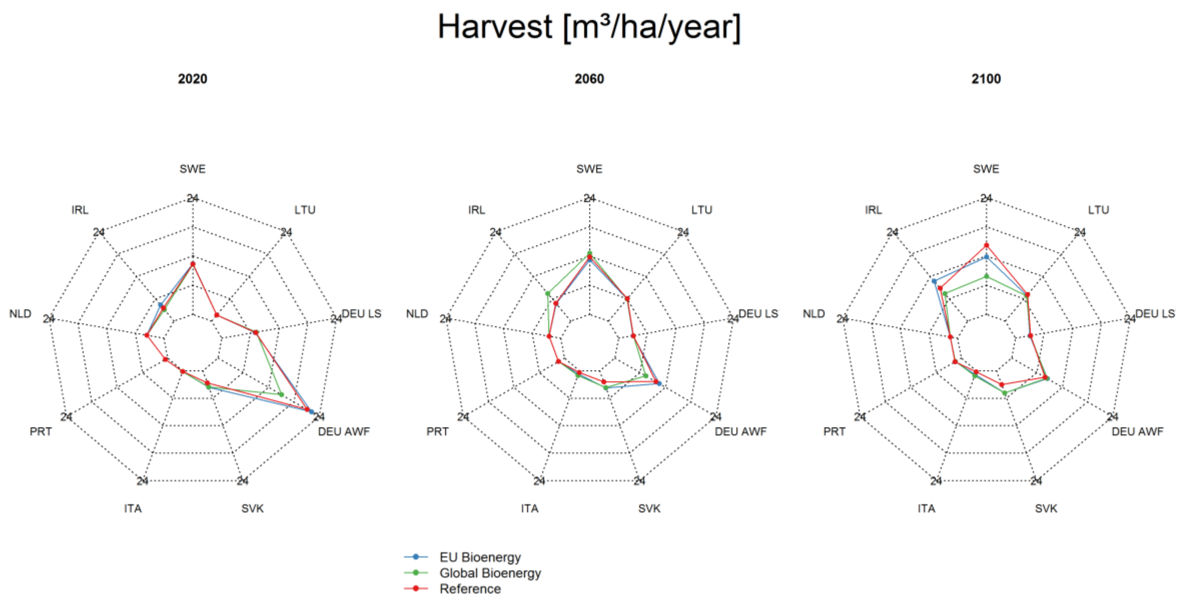

Figure 5. Harvest amount (m³/ha/year) projections in the single case studies for the three global frame scenarios (EU Bioenergy, Global Bioenergy, Reference), shown for the years 2020, 2060, and 2100.

As can be easily taken from Figure 5 (compared to Figure 4) the harvest amounts stay virtually always and everywhere below the increments, which explains the consistent increase of standing volumes shown above. The only obvious exception is the German AWF case study, where in the beginning many mature forest stands are harvested in a comparably short time. In Ireland, harvests slightly exceed the increment at the end of the simulation period, especially in the Reference and EU Bioenergy scenario. Scenario differentiation is almost not existing in the beginning but becomes

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somewhat more pronounced later in some countries (Sweden, Slovakia, Italy, partly Germany, and Ireland).

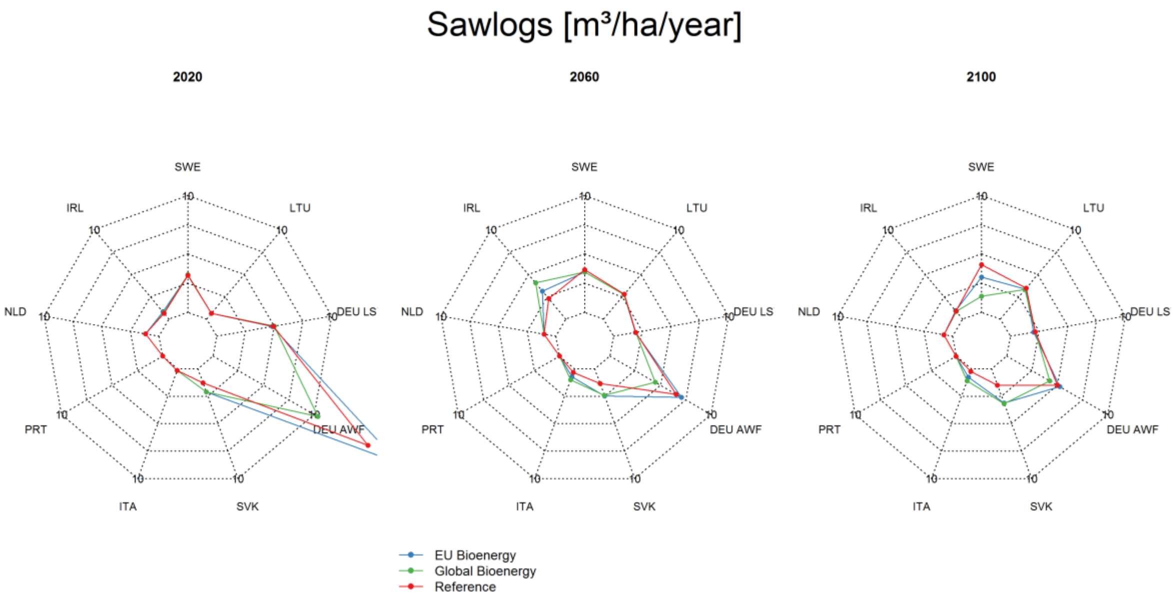

Figure 6. Harvested sawlog amount (m³/ha/year) projections in the single case studies for the three global frame scenarios (EU Bioenergy, Global Bioenergy, Reference), shown for the years 2020, 2060, and 2100.

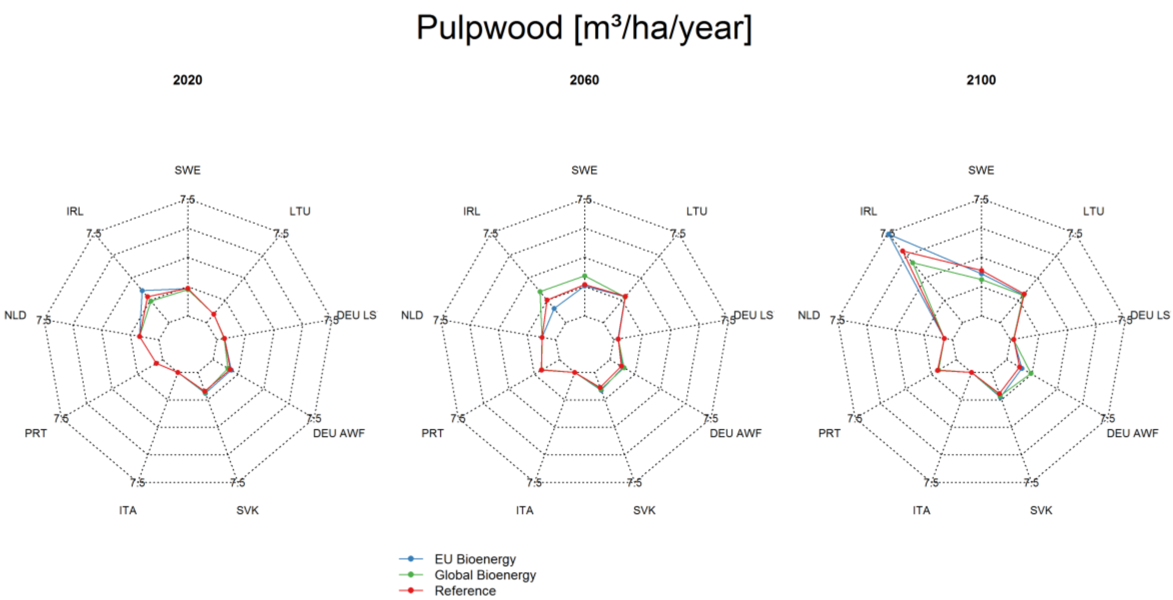

Figure 7. Harvested pulpwood amount (m³/ha/year) projections in the single case studies for the three global frame scenarios (EU Bioenergy, Global Bioenergy, Reference), shown for the years 2020, 2060, and 2100.

The differentiation of the harvested wood into sawlog (Figure 6) and pulpwood (Figure 7) shows that sawlog production is relevant in a part of the case studies only (Sweden, Lithuania, Germany, Slovakia, temporarily Ireland). The high initial harvest amounts in the German AWF case study as mentioned before are exclusively made up from sawlog which underlines these harvests taking place

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in mature stands. While sawlog production does not dramatically change its distribution across the case studies over time, there is more development in the harvested pulpwood amounts (Figure 7). We observe strong increases most prominently in Ireland, but also in Sweden, Lithuania and Portugal, in contrast to a reduction the Netherlands. For both sawlog and pulpwood there is almost no initial scenario differentiation, which however becomes evident towards the end of the simulation time span (i.e. eight decades later). This scenario differentiation is heterogeneous across countries; however in Germany AWF, Slovakia, and Ireland there is a common trend towards more pulpwood in the EU Bioenergy and partly the Global Bioenergy scenario compared to the reference scenario.

2.2 Structure and Diversity

The volume share of broadleaved species is in many countries, especially such with a long-term tradition of intensive forest management, taken as a measure for the success of forest transformation efforts from conifer plantations towards more site adapted forest conditions. When comparing this variable across the ALTERFOR case studies it has to be taken account, that – in such different countries – the share of broadleaves does not only mirror local forest history, but also site conditions.

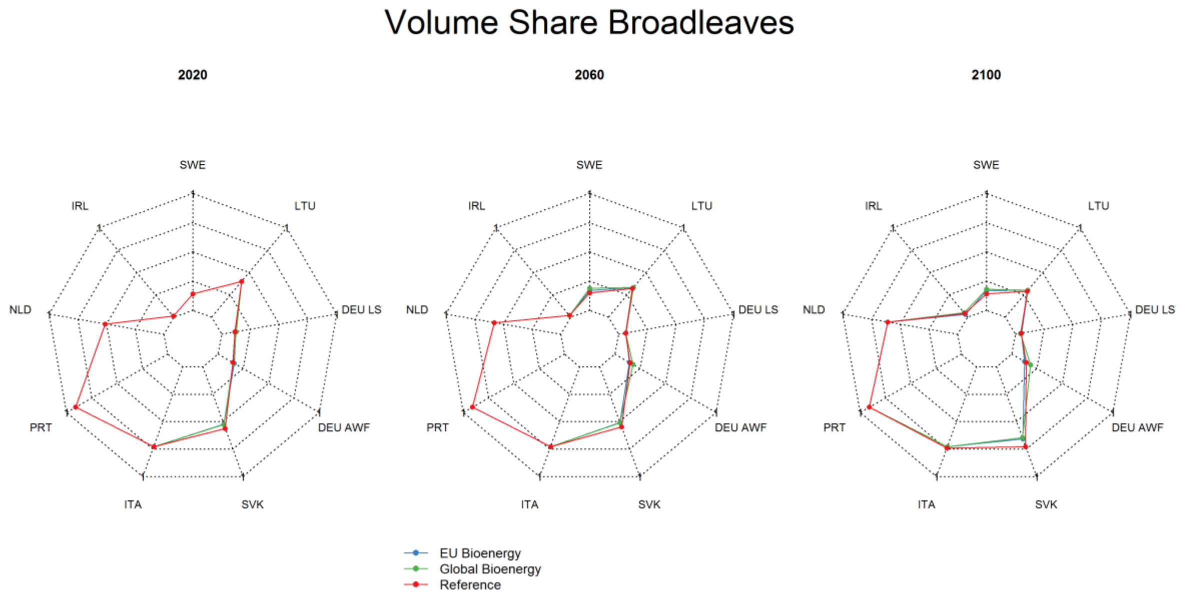

Figure 8. Standing Volume share of broadleaved tree species (0, …, 1) projections in the single case studies for the three global frame scenarios (EU Bioenergy, Global Bioenergy, Reference), shown for the years 2020, 2060, and 2100.

The latter is very evident in Figure 8 which shows intermediate to very high broadleaf shares in the Netherlands, Portugal, Italy, and Slovakia, and low ones in Sweden and Lithuania. Site suitability and forest management history are probably the most important reasons for the low shares in Ireland and Germany. Remarkably, there is virtually no scenario differentiation over time, and also almost no considerable change, except a slight decrease in Lithuania and an increase in Slovakia. For the German case studies, somewhat pessimistic assumptions were made about the forest transformation success, thus no evident increase was obtained in the simulation time span.

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Similar to the volume share of broadleaved species, the share of areas with understory does reflect management history as well as site conditions. This explains the initial distribution across countries (Figure 9) with very high values for the Netherlands, Portugal, and Italy in contrast to low values in Ireland, Lithuania, Germany, and Slovakia. During the simulation time there is almost no decrease, while significant increases are obtained for Slovakia and Germany. These increases result from ongoing forest transformation measures. In the German case studies this leads, due to pessimistic assumptions, to a considerable increase of stand structure, but not so much to a change of species shares in the standing volume (Figure 8). Scenario differentiation is negligible except for a slight trend in Italy towards lower values in the Global Bioenergy scenario.

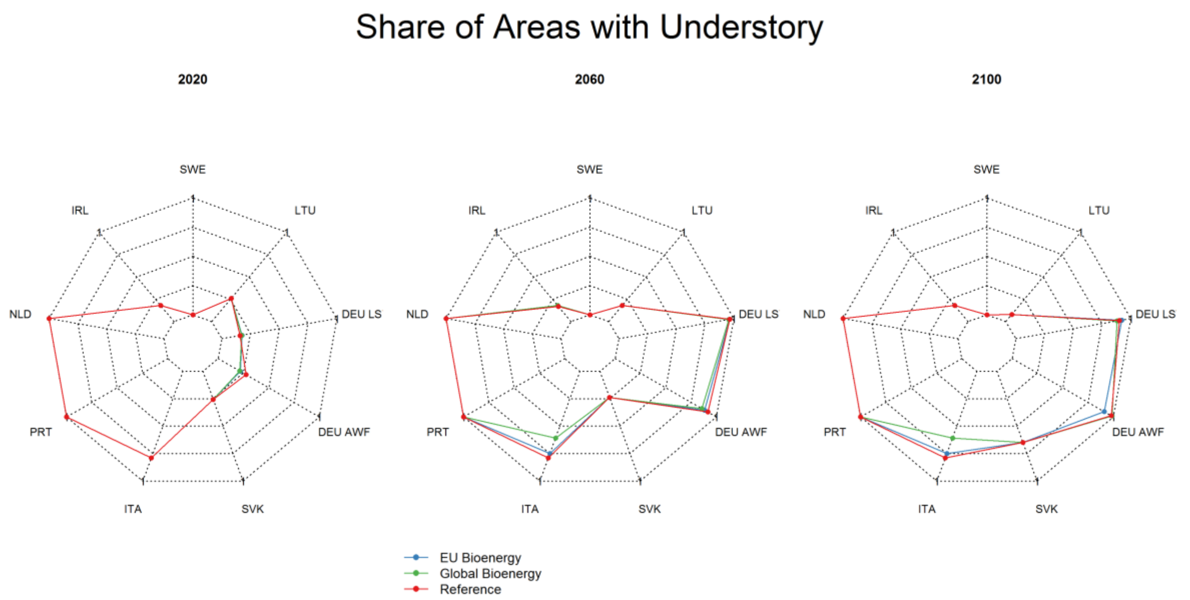

Figure 9. Share of forest areas with understory (0, …, 1) projections in the single case studies for the three global frame scenarios (EU Bioenergy, Global Bioenergy, Reference), shown for the years 2020, 2060, and 2100.

The volume per unit area made up by large trees is a standard indicator for forest diversity as such trees provide, due to their more complex structure and longer lifetime, more and more diverse niches for other plants and also animals. Figure 10, in this context, shows the volume of the trees with a diameter at breast height of more than 40 cm. In most countries, this volume is slightly increasing in the simulation time; a dramatic increase was obtained for the Netherlands where in 2100 the whole forest landscape is dominated by large trees. A scenario differentiation over time is observed for Sweden, Germany AWF, and Slovakia. In the former two cases the highest large tree volumes are obtained in the Reference scenario, while Reference has the lowest values in Slovakia.

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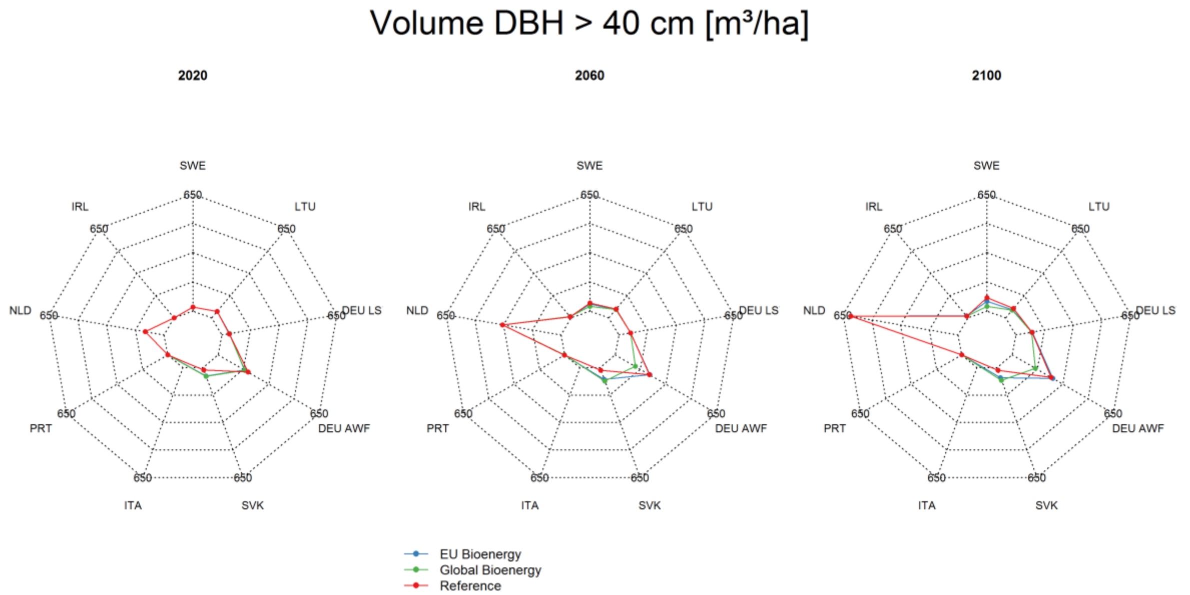

Figure 10. Volume made up from trees with a dbh of more than 40 cm (m³/ha) projections in the single case studies for the three global frame scenarios (EU Bioenergy, Global Bioenergy, Reference), shown for the years 2020, 2060, and 2100.

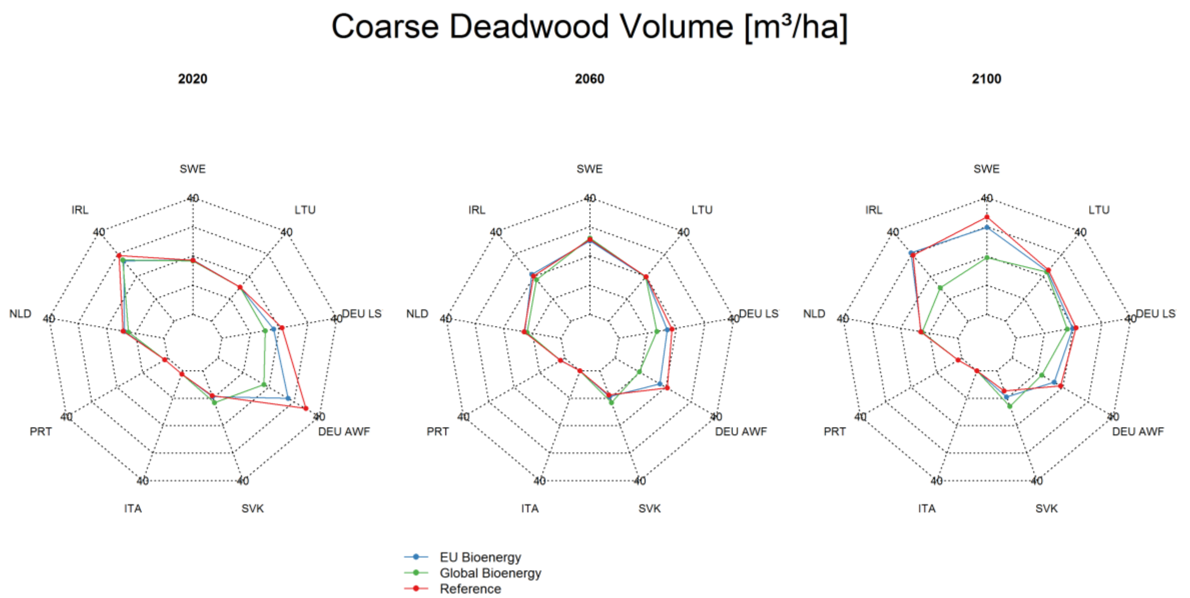

Figure 11. Coarse deadwood volume (m³/ha) projections in the single case studies for the three global frame scenarios (EU Bioenergy, Global Bioenergy, Reference), shown for the years 2020, 2060, and 2100.

Another prominent indicator for biodiversity which in addition plays an important role in the forest carbon cycle is the coarse deadwood volume per unit area. This variable is quite stable on a low to medium level in Italy, Portugal, the Netherlands, and Germany LST. In Ireland we obtained an interim minimum that increased to the comparably high initial values in the Reference and the EU Bioenergy scenario. A strong initial decrease was obtained for Germany AWF due to the decay of large amounts of harvest residues from the intensive harvesting in the beginning of the simulations. In Sweden and

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Lithuania deadwood volumes show a considerable increase. Most prominently in Ireland but also in Sweden and Germany AWF, there is a distinct scenario differentiation, where in the Global Bioenergy Scenario – due to a higher degree of energetic wood use – the least deadwood amounts accumulate. For Slovakia the opposite trend is evident.

2.3 Carbon Related Variables

The balances of carbon stored in the most important forest-bound stocks is presented in Figure 12. Initially, Lithuania, Slovakia, and Italy have a near zero balance, while it is negative for Germany AWF and considerable positive (i.e. net carbon uptake) in Portugal, the Netherlands, Ireland and Sweden. During the simulation time span the balances become more similar across the case studies. In the end, they are mostly positive between 0.2 and 2 tC/ha/year. Scenario differences are generally weak, except for Ireland, where the Reference scenario ends up with the only pronounced negative value (-1.5 tC/ha/year) while the balance in the other two scenarios is close to zero. Weaker, but still considerable scenario differentiations were obtained for Sweden and Germany AWF, but here they indicate highest values in the Reference scenario.

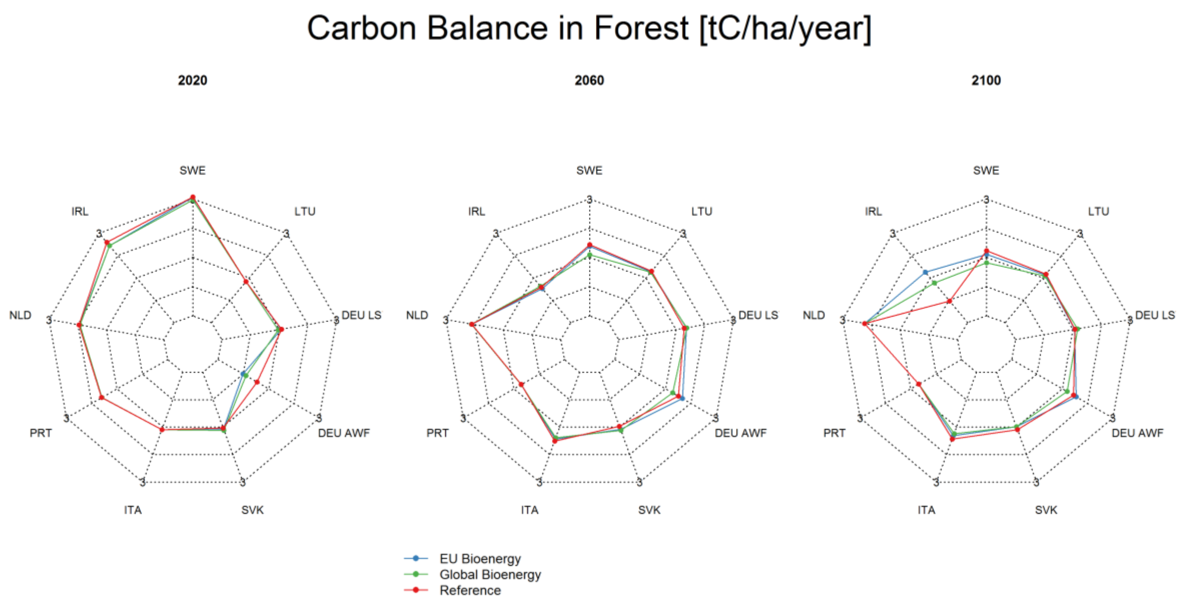

Figure 12. Forest carbon balance (tC/ha/year) projections in the single case studies for the three global frame scenarios (EU Bioenergy, Global Bioenergy, Reference), shown for the years 2020, 2060, and 2100.

The carbon balance in forest products relates to the forest product stocks corresponding to one hectare of forest area (Figure 13). Generally, the results do not show considerable scenario differentiation, except for Ireland with the lowest values for the Global Bioenergy scenario in the long run. While a few case studies (Sweden, Lithuania, Germany AWF, Ireland) have distinctly positive or negative balances in the beginning, consistent zero balances are obtained and kept only a few decades later; only Ireland comes back to a positive balance for the Reference and the EU Bioenergy scenario.

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An interesting contrast, however, is obtained for the carbon emission savings due to using wood (energetically and materially) instead of other materials (Figure 14). While we also observe a convergence of the different case studies, there are positive values (i.e. actual emission savings) prevailing still at the end of the simulation time for Sweden, Lithuania, Germany LST and AWF, Slovakia, and Ireland. In the other case studies the emission savings are virtually zero.

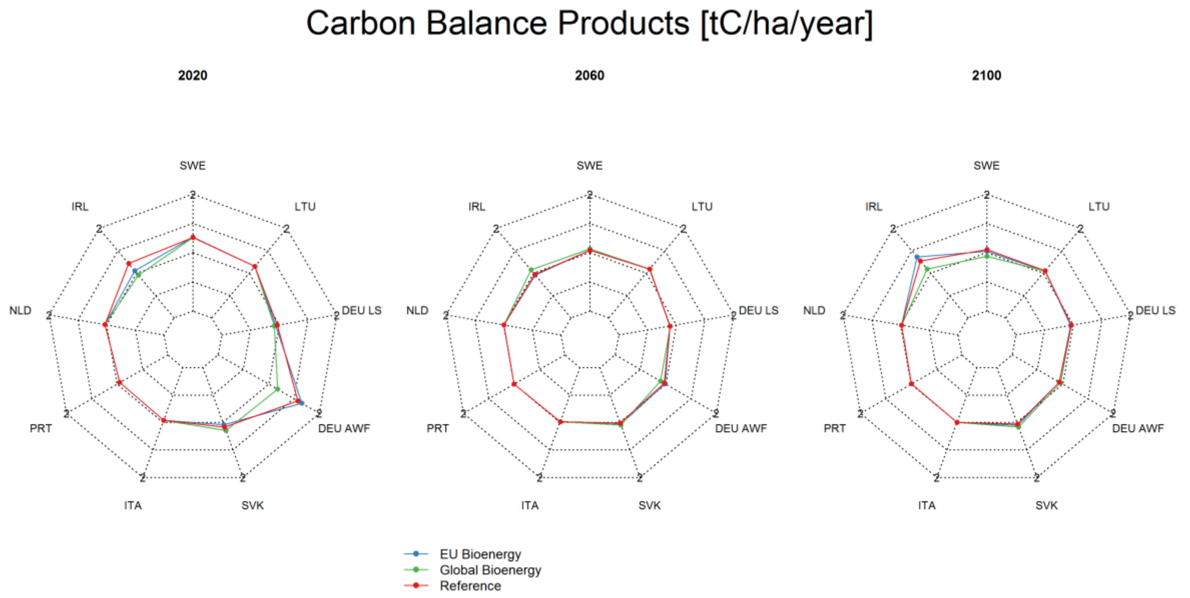

Figure 13. Wood product carbon balance (tC/ha/year) projections in the single case studies for the three global frame scenarios (EU Bioenergy, Global Bioenergy, Reference), shown for the years 2020, 2060, and 2100.

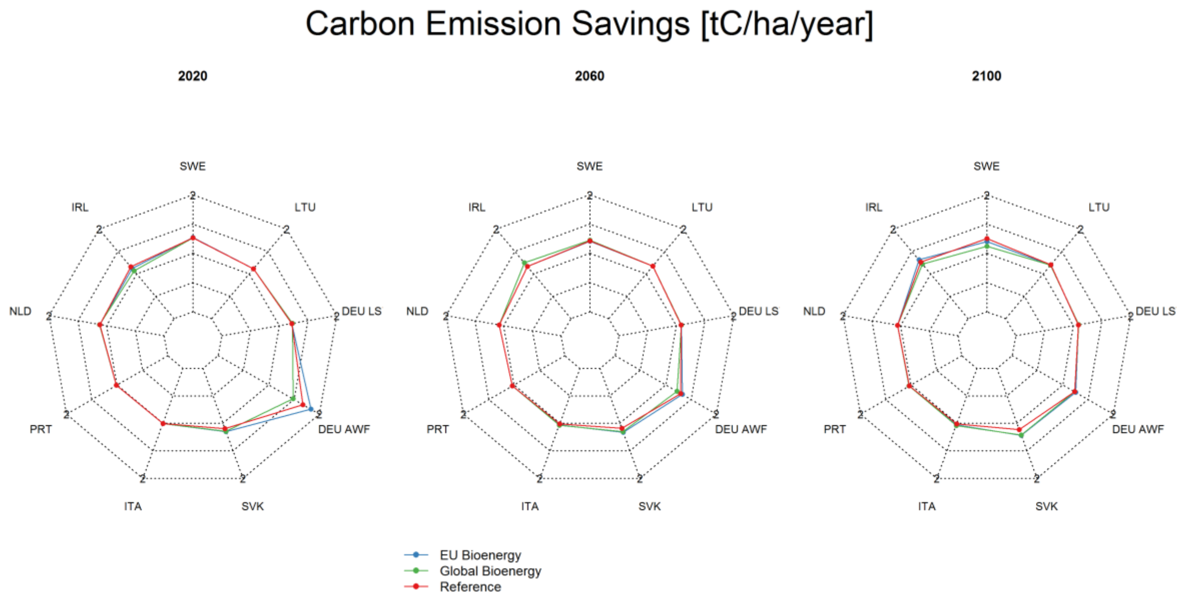

Figure 14. Carbon emission savings (tC/ha/year) projections in the single case studies for the three global frame scenarios (EU Bioenergy, Global Bioenergy, Reference), shown for the years 2020, 2060, and 2100.

The total carbon balances as presented in Figure 15 result from summing up the three sub balances (forest C-stocks, product C-stocks, and emission savings) mentioned before. Obviously, it also shows

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the general trend of convergence across the case studies during the simulation time to a total C balance between about 0 and 2 tC/ha/year. As a consequence of the sub-balances shown above, a pronounced scenario differentiation was observed only for Ireland, with near zero balances in the Reference and Global Bioenergy scenario and about 2 tC/ha/year in the EU Bioenergy scenarios.

The reasons for the long-term positive carbon balances are different. In Sweden and Germany AWF, it is a combination of increasing forest-bound C stocks and emission savings, while emission savings dominate in Germany LST, Slovakia, and Lithuania. In Ireland this is due to emission savings and product stocks, while in the Netherlands and Italy the positive balances come from forest carbon stock increases.

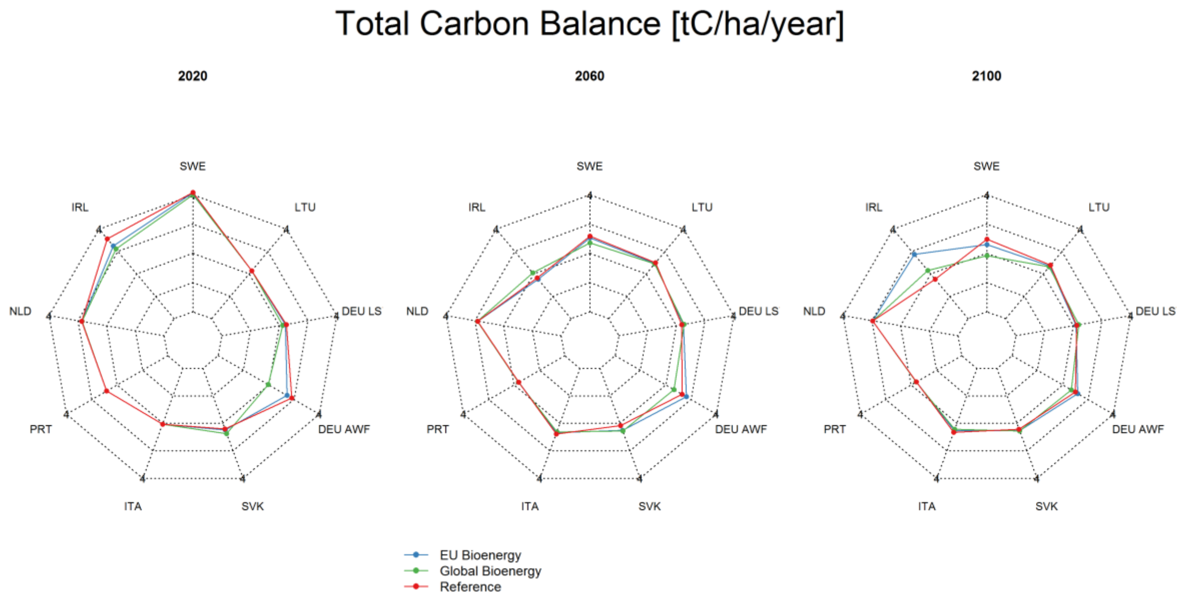

Figure 15. Total carbon balance (tC/ha/year) projections in the single case studies for the three global frame scenarios (EU Bioenergy, Global Bioenergy, Reference), shown for the years 2020, 2060, and 2100.

A general impression obtained based on all results presented above is that the differences obtained for the global frame scenarios are not very pronounced, while there are considerable differences across the case studies. Remarkably homogeneous trends among the case studies are consistent increases of standing volume, even or positive carbon balances, and structure and diversity related variables being mostly stable or even increasing.

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3 Ecosystem Service Reports by the Expert Group

In this section we provide the case study overarching ecosystem service assessments as provided by the ALTERFOR ecosystem service experts.

3.1 Biodiversity

Adam Felton and Matts Lindbladh

The LCCs provided output which varied both in the methods applied and the conclusions arrived at. The majority of LCCs focused their efforts on analysing changes to a number of individual metrics (e.g. % broadleaf, large trees, etc.) of regional relevance to biodiversity, whereas the other LCCs combined relevant metrics into single composite scores, which were then often disaggregated for interpretation. These measures were then contrasted over time for either all scenarios combined (Netherlands), the three global frame scenarios (Germany, Italy, Ireland, and Lithuania), or the three global frame scenarios plus a business as usual/current scenario that lacked the climate and market variability (Sweden, Portugal, Slovakia).

Whereas all countries worked on the basis that minimal changes to the FMMs would occur, this did not exclude the potential for additional external drivers affecting outputs to an extent that sometimes exceeded the impact of the scenarios assessed. There were four prominent examples of this. First, in Slovakia there has been a shift towards natural regeneration of structurally diverse broadleaf stands and the removal of Norway spruce. In Lithuania, the current trend is a shift towards Norway spruce. In the Netherlands, starting conditions were strongly influenced by shifts over the preceding decades towards mixed species stands, fewer introduced tree species, resulting in relatively young stands at the start of the simulations. Ireland's assessments were in-turn heavily influenced by active efforts to increase native woodlands, buffer zones, restrictions on harvesting and fertilizing in blanket bog catchment areas, a shift away from Sitka spruce mixtures, and requirements for uneven-aged management in broadleaf stands. In many of the CSAs these additional factors strongly contributed to the net outcomes of the scenarios assessed, and therefore need to be taken into consideration when looking for consistency in the implications of European or global level modeling scenarios across the case studies.

Overall the majority of the projections indicate some potential improvement in circumstances for forest biodiversity, but with distinctive drivers, or suites of drivers underlying these projected improvements. With the exception of Germany (Augsburg), for which the projected biodiversity improvements primarily stemmed from the increased presence of larger trees; the improvements seen for Slovakia, Netherlands, and Ireland were strongly influenced by drivers external to the scenarios considered (see above). Benefits for biodiversity accrued for both Slovakia and the Netherlands due to increasing older forests and broadleaves, with Ireland's benefits stemming from policy directives favouring broadleaf trees and natural forest conditions more generally. Slightly positive improvements in biodiversity over the time period assessed in Portugal were associated with an increased shrub understorey, with the small improvements projected for Italy, dependent on additional active conservation interventions that were likewise external to the scenarios. In contrast to projected improvements, Germany (Lieberose case study) reported a relatively low but stable outcome for biodiversity, whereas Lithuania and Sweden both reported general declines in the state

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of biodiversity. For Lithuania and Sweden these declines stemmed from a substantial increase in Norway spruce volume that was projected to be only partially compensated for by increases in broadleaves, deadwood, or tree size/age.

For some of the CSAs, the outcomes for biodiversity could not be readily distinguished among the different scenarios considered, as was the case for Germany (Lieberose), Portugal (other than for the Reference scenario), and Ireland. In the case of Sweden, for which projections generally resulted in a decrease in the suitability of forest habitat, the specifics of these projections did however differ depending on the scenario considered. For example, the Global Bioenergy scenario was best in terms of avoiding the dramatic increases in Norway spruce volume observed in other scenarios, but it also involved the lowest benefits in terms of increases to mean forest age, large tree abundance, dead wood volumes, while simultaneously increasing the rate of felling. In contrast, the Reference scenario provided the worst outcomes in terms of increasing forest density. A key point being that the component drivers of biodiversity (e.g. deadwood availability, tree species composition, etc.) are not perfectly correlated, and can often diverge even among scenarios which may otherwise be equated if their biodiversity implications are distilled into a single metric.

In those cases whereby the CSAs' biodiversity results could be readily distinguished among the scenarios considered, there is no clear pattern of one scenario consistently providing for the best biodiversity outcomes. Instead, the Reference and Global Bioenergy scenarios both stood out as often being associated with either the best or the worse outcomes depending on the CSA being assessed. In this regard, the Reference condition resulted in better outcomes for biodiversity in Germany (Augsburg), slightly better outcomes in Slovakia, and better outcomes for Italy (though in Italy's case, these benefits also relied upon additional biodiversity considerations taking place). In contrast, the Global Bioenergy scenario was associated with the most positive results in Lithuania and Sweden. These differences link directly to whether positive biodiversity outcomes were associated with high growth rates (which favoured the Reference scenario), or alternatively, if these high growth rates were instead associated with worsening forest circumstances (e.g. stemming from increased forest density).

Overall, these differences in outcome highlight the variety of determinants that are operating within these CSAs to dictate the future biodiversity of production forest lands. For many CSAs, policy decisions, initial stand contexts, and divergent goals all combined to dictate the highly varying outcomes of this assessment. Nevertheless, despite the variety in outcomes, at least there appeared to be general consistency among CSAs in terms of which forest characteristics overlapped more or less with forest biodiversity goals. For example, the LCCs appear to be in general agreement that increasing the availability of key forest structures (e.g. large trees, dead wood), raising the diversity of tree species composition, and minimizing the use of introduced tree species, would be consistent with achieving regional biodiversity goals.

3.2 Timber Provision

Maarten Nieuwenhuis and Peter Biber

No uniform trends were found in harvest volumes over time between CSAs or between scenarios (cf. Figure 5). The actual trends are the result of many factors interacting, such as the impacts of climate change on growth rates and increment, the different trends in timber prices and demands in the

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different CSAs and the response of forest owners to these trends, and a number of CSA-specific developments, such as the prohibition on fertilisation in the Irish CSA. In several CSs, the harvest volumes are increasing over time, such as in Italy, Lithuania and Portugal, while in other CSAs the volumes decrease over time, e.g. the two German case studies, the Netherlands, Portugal and in Sweden for the Global Bioenergy scenario. In the remaining CSAs, Ireland and Slovakia, the harvest volumes are constant over the planning period.

In most CSAs, there are no large difference between harvest volumes in the different scenarios, but increasing, decreasing or stabilising volume trends have different trajectories in some areas. For example, in the German Augsburg Western CSA, the stabilising volume trend to 8 m^3 ha^{-1} yr^{-1} takes longer in the Global Bioenergy scenario than in the other two scenarios. In Ireland, the stable harvest level depends on the presence or absence of a harvest moratorium in the Freshwater pearl mussel area and fluctuates widely over the planning period in all three scenarios, between values of 2 and 11 m^3 ha^{-1} yr^{-1}, reflecting the age class distribution of the forests over time. In Lithuania, potential harvest volumes increase on average from 4 to 7 m^3 ha^{-1} yr^{-1}, with the increase for the Ref scenario slightly higher to 7.5 m^3 ha^{-1} yr^{-1}. The Global Bioenergy harvest volume increase is the smallest because of less beneficial climate change effects. In Portugal, there are no significant differences in harvest volumes between the scenarios, with volumes high in the first two decades (1.5 m^3 ha^{-1} yr^{-1}) and then dropping below the increment until 2090.

In Italy there are large differences between the harvest levels between the scenarios at the end of the planning period. Volumes start low at 2 m^3 ha^{-1} yr^{-1} in all scenarios, and for the Ref scenario increase initially and then stay constant at 4 m^3 ha^{-1} yr^{-1}, while for the EU Bio scenario they increase to 8 m^3 ha^{-1} yr^{-1} and for the Global Bioenergy one to 12 m^3 ha^{-1} yr^{-1}. In Slovakia, harvest volumes for the EU Bioenergy and Global Bioenergy scenarios are equal (between 4 and 4.5 m^3 ha^{-1} yr^{-1}), but much higher than for the Reference scenario (3 m^3 ha^{-1} yr^{-1}). In Sweden, the harvest volumes are similar and relatively constant for the three scenarios, but the Global Bioenergy volume starts to drop in 2070, due to lower increment as a result of lower climate change effects on growth rates.

In terms of assortment volumes, again different trends are found between CSAs. For example, the proportion of sawlog decreasing in Ireland over time, while in Lithuania sawlog and residues volumes increase and pulpwood volume is constant. In the Swedish CSA, sawlog volume decreases dramatically after 2070 in the Global Bioenergy scenario as all older stands have been harvested. These trends are determined by a number of factors, such as the difference between increment and harvest volume, climate change effects, and local issues. For example, in the Irish CSA, Sitka spruce is replaced by lodgepole pine as a result of the ban on fertilisation, with Sitka producing a significant proportion of sawlog during the first part of the planning period, and then the volume of pulpwood increases as lodgepole largely ends up in that assortment.

With regard to volume increment, again no uniform trends were found between CSAs or between scenarios, as the impacts of climate change differ from area to area and between scenarios, with in some CSAs the reduced climate change effects in the Global Bioenergy scenario being beneficial for growth while in others the large effects in the Reference scenario leading to increased growth. In the Lithuanian CSA, increment is lowest in Global Bioenergy scenario due to lower climate change effects on yield. In the German Augsburg Western CSA, volume increment is highest in the EU Bioenergy scenario (with a peak value of 15 m^3 ha^{-1} yr^{-1} in 2060) and lowest in the Global Bioenergy scenario, while in the Lieberose Slaubetal CSA volume increment for all scenarios is between 7 and 8 m^3 ha^{-1}

yr^{-1} at the start and slowly drops to 6 m^3 ha^{-1} yr^{-1} at the end of the planning period. In the Irish CSA, volume increment drops over time for all scenarios, from 11 to 7 m^3 ha^{-1} yr^{-1} without the harvest moratorium, and from 10 to 6 m^3 ha^{-1} yr^{-1} with the moratorium in place, reflecting the replacement of the more productive Sitka spruce by lodgepole pine. Volume increment in the Portuguese CSA is quite irregular over time, with values ranging from 0 to 6 m^3 ha^{-1} yr^{-1}, and with the Ref increment values slightly higher than for the other two scenarios.

In almost all CSAs standing volumes increase over time, but there are distinct trends between scenarios in several of them. In Italy, standing volume increases from c. 70 m^3 ha^{-1} to 275 m^3 ha^{-1} in the Reference scenario, less so in the Global Bioenergy one (to 230 m^3 ha^{-1}), and in between these two for the EU Bioenergy scenario (to 250 m^3 ha^{-1}). In the Slovakian CSA, standing volume trends are similar for the EU Bioenergy and Global Bioenergy scenarios and lower for the Reference scenario. The standing volume share of broadleaves develops similarly for the three scenarios, with an initial slight drop and then a considerable increase, with the proportion in the Ref scenario slightly higher (80%) than in the other two scenarios (75%) at the end of the planning period.

In Sweden, the standing volume develops differently between the scenarios, with the Reference scenario volume ending at 330 m^3 ha^{-1}in 2110, while EU Bioenergy volume ends at 280 and Global Bioenergy volume at 180 m^3 ha^{-1}. In Ireland, standing volume is relatively constant in the Global Bioenergy scenario (at 200 m^3 ha^{-1}), while in the Reference and EU Bioenergy scenarios it increases to about 300 m^3 ha^{-1} by 2090 after which it decreases, especially in the Reference scenario. In the German Lieberose Schlaubetal CSA, harvest volume is below increment, resulting in standing volume increases for all scenarios from 250 m^3 ha^{-1} to 350 m^3 ha^{-1} over the simulation period. In Portugal, standing volumes for the three scenarios are very similar and fluctuate over the planning period, with values going down until 2070 to less than 20 m^3 ha^{-1}, then increasing rapidly by 2080 (to c. 65 m^3 ha^{-1} and decreasing again afterwards to 30 m^3 ha^{-1}.

Assessment Summary: Despite the heterogeneous trends presented above, no CSA in no scenario shows a critical development related to timber provision over the long run. Increasing standing volumes due to harvests being lower than the increments in many CSAs indicate a potential for increased sustainable harvest amounts with alternative forest management models if desired. In almost every CSA where there is an increased harvest potential and an evident scenario differentiation, this potential is lowest in the Global Bioenergy scenario.

3.3 Regulatory Services

José G. Borges

3.3.1 Regulatory services assessed

All nine LCCs reported the importance of regulatory services in their CSA. Eight LCCs listed wildfire protection while six LCCs listed wind/pest protection as important regulatory services in their CSA (Table 2).

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Table 2. Prominent catastrophic events in the CSAs

Country	Wind / Pest	Fire
Ireland	x	x
Sweden	x	
Italy		x
Germany (2 CSAs)	x (AWF)	x (LST)
Netherlands	x	x
Slovakia	x	x
Lithuania	x	x
Portugal		x

3.3.2 Methods applied

According to the regulatory services guidelines, LCCs might consider either stand (e.g., biometric) and landscape-level (e.g., spatial metrics) variables or other catastrophic event indicators to derive vulnerability classes and the corresponding provision of regulatory services over the planning horizon under each scenario. See Table 3 for on overview of what kinds of methods were used.

Table 3. Variables/indicators used to derive vulnerability classes and the provision of regulatory services in each CSA.

Country	Biometric variables	Spatial variables	Indicators
Ireland	x		x
Sweden	x		
Italy	x		
Germany	x		x
Netherlands	x		x
Slovakia	x		x
Lithuania	x		x
Portugal	x	x	x

All eight LCCs reported the use of biometric variables. Only one (Portugal) reported the use of spatial variables. Thus, in eight out of the nine CSAs, DSSs were not capable of assessing the vulnerability of the landscapes to either pest or wildfire spatial spread in any scenario. Six LCCs (i.e. seven CSAs) classified this vulnerability by way of an indicator variable and reported its change over the simulation time span in each scenario. The summary of results below focusses thus on these seven CSAs.

3.3.3 Results

In the case of Portugal, results suggest that the increase of temperature does not impact the overall vulnerability to wildfires. Nevertheless, climate change may impact vulnerability through precipitation, where, however, data were not available. The LCC reported that further analysis is needed to assess the impacts of landscape-level FMMs on landscape-level vulnerability over the simulation time span under each scenario. The current landscape-level FMM did not encompass fuel treatments. Moreover, the FMM was defined a priori according to the selection of an 'average' prescription for each stand. A management planning framework that enables the adjustment of

landscape-level FMM - e.g., by considering alternative spatial distributions of stand-level prescriptions and corresponding alternative shares of broadleaves - will most likely contrast impacts of scenarios on the provision potential of regulatory services.

In the case of the Netherlands, results suggest that the vulnerability to wildfires and to windstorms is not impacted by the climate scenario. The former may increase over the ALTERFOR temporal horizon while the latter may decrease. Nevertheless, the LCC reported that current modeling in EFISCEN-Space ignores ingrowth, and the mortality of larger trees seems to be underestimated. Therefore, all projections beyond the 40-year horizon should be regarded as highly uncertain, according to the LCC.

The LCC in Germany reported contrasting results for wind/pest (assessed for the AWF case study area) and wildfire risks (assessed for the LST case study area). In the case of the former, risk stays on a more or less constant level in the Reference and EU Bioenergy scenarios while it is substantially reduced to a low level on the long run in the Global Bioenergy scenario. In the case of wildfire, the LCC reports that after two decades the initial fire risk leaps from moderate to high levels and stays constantly high for the remaining simulation time. Nevertheless, the LCC points out that this may partly result from an overestimation of the shares of Scots pine over time. Another important reason is the increase of areas with understory (due to consequent natural regeneration).

The LCC in Ireland reported an increase of the average probability of windthrow risk in earlier periods of the ALTERFOR temporal horizon in all scenarios. Subsequent fluctuations derive from age distribution trends. The percentage of forest area with windthrow probability of 100% increases also in these same periods in all scenarios. The LCC reported further that the average fire risk in the CSA remained constant throughout all scenarios.

The LCC in Slovakia reported that in general, there was a rapid increase of the share of forest areas with the lowest risk of windstorm and bark beetle damage in the CSA. It was reported further that no substantial differences were found across scenarios.

The LCC in Lithuania reported an average lower vulnerability in the Reference scenario and average higher vulnerability in the Global Bioenergy scenario. The LCC reported further that vulnerability to wind tended to decrease over the ALTERFOR temporal horizon in all scenarios.

The LCC in Sweden reported that the absolute volumes lost in storm fellings can be expected to increase quite substantially in the Reference and EU Bioenergy scenarios. This is due to a big increase in the standing volume combined with an increasing mean height and the proportion of Norway spruce. Due to a substantially higher harvest level, the risk of storm felling will only increase moderately in the Global Bioenergy scenario.

In summary, in most CSAs the global frame scenarios did not have a substantial impact on the vulnerability of the landscapes. Results from Portugal show that the spatial distribution of stand-level FMMs over the landscape impacts the way the vulnerability evolves over time. However, results should be interpreted with caution considering the scenario development limitations as well as the modeling assumptions. They also suggest the potential of using landscape-level management scheduling approaches to address the provision of regulatory services and the protection against catastrophic events.

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3.4 Carbon Sequestration

Kevin Black

This document outlines some background information relating to GHG mitigation policies at the EU level, the generic methodology applied to provide estimates of carbon (C) sequestration and a summary of the results obtained at the landscape level for different case study areas (CSAs).

3.4.1 Introduction

The future ecosystem greenhouse gas (GHG) balance in temperate and boreal forests will be largely influenced by forest management activities (Magnani et al. 2007; Böttcher et al., 2008), future climate change (Hanewinkel et al., 2013) and natural disturbances, such as fires (Vilén and Fernandes, 2011). The influence of forest management in forest sinks has been exhaustively studied at the stand level, but these studies do not consider factors that influence forest C dynamics at the landscape level. Landscape factors such as atmospheric deposition and genetic gain have a small influence on forest productivity and C balance (Magnani et al., 2007), but management activities, such as harvest, clear fell, and new forest establishment, have been shown to have a significant effect on the landscape level forest carbon balance (C) due to a shift in age class structure (Böttcher et al., 2008, Black et al., 2012). The effect of natural disturbances on the forest C balance at the landscape level is difficult to determine due to the stochastic occurrence of fires in the landscape. Fire occurrences may be in turn influenced by management practices (e.g. prescribed burning, see Vilén and Fernandes, 2011) or reducing the fuel wood load by removal of harvest residues from the site (Sah et al., 2006).

In order to investigate the full forest climate change mitigation potential, analysis should be extended beyond the forest boundary to include wood product mitigation potential. Although the forest C stock increases when the rate of C uptake through growth exceeds the rate of C loss through decomposition and harvest, it is not possible to increase forest sinks indefinitely. This is because (a) the area of land available for afforestation, and thereby the creation of new C sinks is limited and (b) in the long term, the C stock of "sustainably managed" forests tends to reach an equilibrium (Broadmeadow and Matthews, 2003). In contrast, the use of harvested wood products (HWP) can continuously contribute to GHG emission reductions in the following ways: a) emissions can be reduced by using HWP to indirectly displace fossil fuels through product replacement of energy intensive materials such as plastic, steel and concrete which have higher levels of embodied energy than wood products (Stare and O Connor, 2010); and b) emissions can also be delayed for many years when HWP are used for long life products as in the building sector. However, over time the HWP system will also likely reach an equilibrium (Skog, 2008).

A positive climate change mitigation policy for managed forests can be described as the practice of sustainable forest management. If forest timber management is not sustainable, e.g., if wood is harvested without forest rejuvenation, or if the harvest volume in greater than timber increment, managed forests are more likely to revert to net emission (a C source). Hence, good sustainable forest management leads to carbon offset in the forests on the one hand and avoids GHG emissions by using wood products and fuel wood, on the other. The function of forests as C sinks at the stand, landscape and continental level is well documented (Desai et al., 2005, Magnani et al., 2007), so is the potential use of harvested wood as a C sink (Skog, 2008). However, very few landscape or regional

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level studies consider the whole life cycle from forest planting to HWP use, including product substitution effects (Rüter et al., 2016). This is because many timber utilisation options are controlled by economic and policy related drivers and these are difficult to link to specific forest management systems. In this report we consider the use of a simple C flow model, which includes all aspects of the C life cycle (excluding wood cascade effects), to assess potential C sequestration of various management systems at the landscape level under three difference EU policy scenarios.

3.4.2 Related EU policy

EU member states and other governments recognised the need to peruse efforts to limit increases in global average temperature to below 20 °C at the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015 (COP21). Prior to this agreement, the 2030 climate and energy framework agreement was adopted by EU member states in 2014. This agreement outlines 3 major commitments:

- 40% burden sharing reduction in GHG emission (1990 base year)
- a 27% share in renewable energy
- a 27% improvement in energy efficiency

In July 2016, the European Commission presented a legislative proposal to integrate greenhouse gas (GHG) emissions and removals from land use, land use-change and forestry (LULUCF) into the 2030 climate and energy framework (https://ec.europa.eu/clima/lulucf_en#tab-0-1), which led to a new LULUCF regulation adopted in May 2018. This new regulation identifies the role of forest sinks and HWP in achieving commitment targets across EU member states, and brings forth new obligations for the countries to account for the use of wood for energy and material, which may affect the use of product or energy substitution as a potential mitigation mechanism. There are also other policies, such as the EU forest strategy (2013), the energy efficiency directive (2012), that will influence the use of wood products for climate change mitigation, both directly or indirectly (see Rüter et al., 2016).

Global frame scenarios

In this study the implication of EU policies and measures on C sequestration at the landscape level and for HWP was tested using the global frame scenarios “Reference”, “EU Bioenergy”, and “Global Bioenergy” developed for the ALTERFOR project by the IIASA (for details see introduction section and ALTERFOR WP2 Leaders, 2016). For this analysis, we hypothesise that forest C sequestration at the landscape level and in HWP would vary under each scenario due to numerous factors such as:

- different climatic patterns, which may influence forest productivity and the forest sink,
- shifts in forest susceptibility to risks, such as pests, or large disturbances, such as forest fires,
- changes in rotation age, mean stand or age class distribution at the landscape level due to increase timber demand under the Reference, EU Bioenergy, or Global bioenergy frame scenarios,
- varying levels of harvest residue extraction leading to a change in the forest sink in the deadwood C pool and altered allocation of harvest residue for energy or product substitution,
- different levels of harvest leading to, for example, higher forest emissions which are partially offset by a higher diversion of timber to HWP and product substitution,

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- different allocation of sawlog or pulpwood to long term HWP stored products or higher allocations to energy or product substitution, depending on scenario and study region.

Although the above assumptions are reasonable at a regional level, each CSA adopted its own assumptions on how the three different scenarios may affect the forest, timber harvesting, HWP and product substitution. In some cases, the influence of different climate change patterns was included in the DSS modelling framework and hence captured the forest sink impact (e.g. Ireland, Germany, Sweden, Slovakia), but in other cases these was not included (e.g. Netherlands). Similarly, difference in the allocation of timber to HWP, energy or product substitution was defined in some study areas (e.g. Germany, Slovakia and Ireland), but not in other cases, such as Netherlands or Sweden where the behaviour of timber use under the three scenarios will not change (see relevant case study areas sections).

3.4.3 Methodology

The C balance model used for the estimation of C sequestration in this study includes most significant major forest C pools, C storage in HWP, CO2 emissions savings due to energy substitution and product substitution. A generic methodological framework was developed and implemented in R script to provide a harmonised approach to assessing C sequestration across the different country study areas (CSA). Full details on the methodology are outlined in the ALTERFOR guidelines by the author and the commented R script authored by P. Biber (available on request).

The forest C model does not consider emissions from fires, C stock changes in litter and non-CO2 emissions. Forest fires may be an important component of the forest C balance, particularly in Mediterranean countries (Vilén and Fernandes, 2011). Analysis of long term forest fire trends in the Mediterranean region suggest that the average C emission per ha of forest area burned varies from 2 to 13 tC/ha (Vilén and Fernandes, 2011). These authors suggest that average specific fire emission factors for Italy and Portugal over the period 1980-2008 were 8.9 and 11.6 tC/ha of forest area burned, respectively. Although the estimation of emissions from forest fires are relatively straightforward if the area or amount of biomass burned is known, simulation of GHG emission from fires required more complex modelling frameworks due to the random frequency of forest fires. Based on National submissions to the UNFCCC (UNFCCC, 2016), the proportion of total forest area subjected to wildfires for Italy and Portugal for the period 1990-2015 varies from 0.1 to 0.8% (mean=0.33%) for Italy and 0.1 to 5.6% (mean 1.23%) for Portugal. If the long-term trends outlined above are used, the average weighted C emissions from forest fires for CSAs in Italy and Portugal are estimated to be 0.02 and 0.16 tC/ha/yr, respectively. However, the UNFCCC data and emission factors published by Vilén and Fernandes (2011) suggests that the weighted emissions could range from <0.001 to 0.68 tC/ha/yr. Moreover, the impact of extreme fire events would have very large impacts on the forest C balance. For example, for the CSA in Portugal over 60% (8966 ha) of the total CSA area was burned in 2017. This would equate to annual C emission of 104,006 tC in 2017, equivalent to a weighted emission of 7.14 tC/ha. Therefore, the impact of forest fires on the forest C balance for these CSAs should be treated with caution.

Modelling of litter and soil C dynamics requires detailed inputs and calibration, so these have been excluded from the analysis. However, the IPCC default for C stock changes in mineral soils is considered to be zero for managed forests (IPCC, 2006), so this assumption is adopted where relevant. In cases where there are organic soils, such as study areas in Ireland and Lithuania, the

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default IPCC emission factors for drainage of organic soils (0.61 tC/ha/yr) and run off emission from DOC (0.31 tC/ha/yr) should be considered as part of the forest C balance (IPCC, 2006). Organic soil emissions have not been included in the generic modelling framework provided to all CSAs. Therefore, forest C balance outputs under all scenarios have been overestimated by ca. 1 tC/ha/yr for some CSAs. All other forest C pools are included in the analyses including above and below ground biomass and deadwood (harvest residue, stumps and dead roots). IPCC tier 1 methodologies are used to estimate C stock changes in biomass pools (IPCC, 2006).

Storage of C in HWP is based on the annual harvest output from each study area and global frame scenario. Harvest volume assortments are assigned to pulpwood, wood-based products and sawlog products and C stock changes are calculated using an exponential decay model and default half live values for HWP semi-finished products (IPCC, 2006). The historical HWP C stock was estimated based on national inventory submissions to the UNFCCC (UNFCCC, 2016). This was based on the initial HWP pools for forest management under article 3.4 of the Kyoto protocol.

The common approach to estimate energy or product substitution impacts is the use of displacement factors (DF) to estimate emissions saving due to product substitution. The DF is an index of the efficiency with which the use of biomass reduces net GHG emissions. The DFs are based on all manufacture, transport and processing emission and removal over an entire life cycle, but this is usually 100-300 years. The system boundary for most reported DFs include all processes from energy to produce materials, process emissions, biomass residues for energy, and end-of-life management, but exclude HWP stocks and C dynamics in forests (Stare and O Connor, 2010; Smyth et al., 2016, Oliver et al., 2016, Lundmark et al., 2014). For this study, conservative DFs of 0.47 and 0.54 tC/t wood were used for product substitution of wood-based panels and sawlog products, respectively (Smyth et al., 2016).

3.4.4 Scenario assumptions for each CSA

Detailed assumptions and potential climate change impacts under the different scenarios are discussed in detail under each CSA report. However, the following table summarises the assumptions and climate change impacts included in the FMM DSS under the three global frame scenarios for each country (Table 4)

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Table 4. A summary of imposed model effects/assumptions that may impact on the overall landscape C balance, including forest and HWP sinks and substitution effects.

Country	Climate change impact	Impact on harvest allocation to HWPs	Impact on allocation to energy substitution	Impact on allocation to product substitution	Impact on overall harvest
Germany	Yes, effect on productivity, species profile, disease and fire risk	Yes, increased allocation to HWP under Reference scenario	Yes, higher energy substitution under EU Bioenergy and Global Bioenergy scenarios	Yes, distinct scenario differences; among others energetic use Reference < EU Bioenergy < Global Bioenergy	Yes, depending on scenario. Also see change in sustainability index in CSA report
Ireland	Yes, effect on productivity and species profile	Yes, increased allocation to HWP under Reference scenario	Yes, higher energy substitution under EU Bioenergy and Global Bioenergy scenarios	No	Yes, depending on scenario.
Italy	Yes, less fire disturbance under EU Bioenergy and Global Bioenergy	No	Yes, higher energy substitution under EU Bioenergy and Global Bioenergy scenarios	No	Yes, increase in harvest under EU Bioenergy and Global Bioenergy
Lithuania	Yes, effect on productivity	No	No	No	Yes, decreased harvest under EU Bioenergy and Global Bioenergy
Netherlands	No	No	No	No	No
Portugal	Yes, higher yield increment in Reference and EU Bioenergy scenario	Yes, higher pulp or saw log to WBP under EU Bioenergy or Global Bioenergy scenarios	Yes, higher saw log to energy under EU Bioenergy scenario	Yes, higher saw log to products under Global Bioenergy scenario	No
Slovakia	Yes, effect of productivity and species profile	Yes, slightly higher pulpwood to WBP under Global Bioenergy scenario	Yes, increase of 95% pulpwood and 50% harvest residue to energy in EU Bioenergy scenario	Yes, slightly higher pulpwood to WBP under Global Bioenergy scenario	Yes, higher harvest for EU Bioenergy and Global Bioenergy scenarios
Sweden	Yes, effect on productivity,	No, but note high allocation	No	No	Yes, increase in harvest under

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	particularly in Reference and EU Bioenergy scenarios	of harvest to paper and pulp			EU Bioenergy and Global Bioenergy scenarios

3.4.5 Results

Detailed results for each CSA are presented in the Country reports as condensed in section 2. This section outlines general trends, drivers and conclusions. The analysis concentrated on a) description of C stock changes over the simulation period and identification of the major drivers influencing these temporal dynamics (2020-2100); b) general comparison of C stock changes across different global frame scenarios; and c) a comparison of C stock changes for different CSAs.

a) Temporal dynamics

The trend in forest C balance over the simulation period varies across CSAs (Table 5). However, there appear to be some consistent factors (drivers) contributing to the observed changes in forest C stock for the Reference scenario over the simulation period. General drivers include: a) the level of harvest relative to the volume increment; b) absolute levels of harvest; and c) changes in volume increment. The report for Germany provides a good indicator of sustainability, which appears to closely correspond to the forest C balance. This finding reiterates the concept that the principle of sustainable timber production ensures a positive forest C balance (see introduction). Drivers for changes in productivity, and hence forest C uptake, can be associated with numerous factors including (Table 5): a) climate change impact of growth or species index (e.g. Germany Augsburg, Ireland, Lithuania, Portugal); and b) shifts in age class distribution over time (e.g. Ireland, Italy). Shifts in age class structure can have both positive and negative effects on timber productivity (see Böttcher et al., 2008, Black et al., 2012). In Ireland, for example, C sequestration of managed forests is largely influenced by a ”shift in age class” structure towards younger stands (Black et al., 2012; Tolunay 2011). Age class shifts from maximum production age to older stands can also lead to a reduction in productivity (see CSA for Italy). In Sweden, the forest C sink trend is closely related to the level of harvest, which results in biomass C losses (Table 5), but it is also evident that productivity (hence C uptake) may be influenced by shifts in the age class structure over time (see final clearfell areas and mean age for the Reference with HL scenario).

Impacts of climate change on productivity and forest C stock changes under the different global frame scenarios appear to be positive or negative depending on the CSA (Table 5). Ireland reported a decline in productivity associated with a shift in species suitability from more productive Sitka spruce to lodgepole pine under the Reference scenario. This negative impact was partially offset by the positive effect of a warmer climate on productivity under the EU Bioenergy and Global Bioenergy scenarios. The results from the CSA in Lithuania indicate a positive climate change effect due to temperature increases. In the German CSAs, climate change interactions appeared to be more complex. In Slovakia, climate change impacts under the EU Bioenergy and Global Bioenergy scenarios resulted in a large increase in productivity, regeneration time after clear fell and harvest.

Changes in HWP and product substitution appear to be closely related to the level of harvest and the allocation of timber to different HWP categories. This is well demonstrated in the Polana CSA (Slovakia), where the increase in harvest resulted in an increase in inflow into HWP and product substitution. There also appears to be a trade-off between HWP storage and energy product

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substitution in some cases (see Lithuania and Slovakia). It is well established that a higher allocation of sawlog to HWP results in an increased removal of C for the forest sector (Skog., 2008, Lippke et al 2011), but displacement of sawlog for energy production appears to have lower climate change mitigation benefits, compared to long term wood products or product substitution options. These results are consistent with other studies (see Stare and O Connor, 2010; Smyth et al. 2016). Results from the Kronoberg CSA (with HL scenario, Sweden) shows a large initial harvest followed by a large drop off in harvest and HWP inflows. These harvest trends together with and a significant allocation of harvest to short term HWP (paper and pulp) leads to a reduction in the HWP sink.

Table 5. A summary of general temporal trends and identification of major drivers influencing C stock changes over time (for the Reference scenario only) for different CSAs.

Country	Forest sink trend	HWP and substitution trend	Description of drivers	Mean total C stock change over period	Rank *
Germany Augsburg forests	Transition from source of ca -1tC/ha to a stable sink of 0.5tC/ha over the period 2060-2100	Decline in sink up to 2040 followed by stabilisation after 2040	Higher initial harvest, partially offset by increased inflow of harvest into HWP	ca. 0.9 tC/ha/yr	3
Germany Lieberose area	Constant, close to neutral	Slight increase	No clear drivers	ca. 0.3 tC/ha/yr	6
Ireland	Decline from sink to source	Decline over period	a) Decline in volume increment due to younger age class transitions and negative climate change impact on species profile. b) Lower allocation of harvest to sawlog and long term HWP storage	-0.1 tC/ha/yr**	9
Italy	Initial increase from zero to ca. 1 tC/ha by 2040 followed by a slight decline up to 2100	No change	a) Initial lower harvest rates b) Slight decline in volume increments due to age class distribution transitions	ca. 0.6 t/ha/yr#	5
Lithuania	Initial increase from ca. 0.3 tC/ha to 1.2 tC/ha by 2040 followed by a slight decline up to 2100	Decline in HWP removals with a corresponding increase in product substitution emission reductions	a) Initial increase in volume increment, due to change in species profile and increase temperatures, which tapers off after 2050 b) A higher harvest form 2040 onwards c) Higher allocation of harvest to energy production	ca. 0.8 tC/ha/yr	4

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Netherlands	Slight increase over entire period	Slight decline over period 2020-2100	a) Decrease on harvest and allocation of wood to HWP and product substitution	ca. 1.6 tC/ha/yr	2
Portugal	Extremely variable 1 to -1 tC/ha/yr	Variable	Trends largely driven by differences in productivity	ca. 0.1 tC/ha/yr#	8
Slovakia	Decline up to 2040 followed by a steady increase to 2100	Slight decline in HWP products	a) Initial decline in volume increment followed by and increase, associated with age shifts class (prolonged rotations)	ca. 0.3 tC/ha/yr	6
Sweden (with HL scenario)	Large initial decline in the forest sink followed by a gradual decline over the time series	Slight increase in HWP, high allocation of harvest to paper (short term HWP storage)	High initial harvest followed by a drop in harvest (3fold) and a subsequent gradual increase in harvest up to 2100 b) age class shift (see felling area and mean age)	ca. 1.7 tC/ha/yr	1

Note negative values represent a net emission (i.e. a source) and positive values indicate a net removal of CO2 (i.e. a sink).
* 1= highest C sequestration, 9 = lowest
**including organic soil emissions.
excluding fire emissions for these CSAs (see methodology).

b) Comparison across CSAs

Comparison of Reference scenarios across the different CSAs is summarised in Table 5.

c) Comparisons across different global frame scenarios.

There were differences in the C sequestration for forest C sinks, HWP and substitution across the three different scenarios, but the magnitude and relative difference in the total C sequestration rate varies for different CSAs. Table 6 identifies the best C sequestration scenario within specific CSAs (highest ranking scenario) and summarizes potential reasons for the differences between scenarios within each CSA.

Table 6. A summary of comparison of global frame scenarios across CSAs.

Country	Description of differences between scenarios relative to Reference in specific CSA	Highest ranking scenario
Germany Augsberg forests	EU Bioenergy: a) Highest forest sink, consistent with higher sustainable wood production and higher volume increments relative to other scenarios b) More HWP storage and emission saving due to energy substitution associated with a higher sustained harvest and allocation to wood products Global Bioenergy:	EU Bioenergy

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	a) Lowest forest C sink due to lowest productivity associated with negative climate change impacts and change in species profile towards beech. Accumulation of C in DOM pool decreased due to high allocation of harvest residue to energy production b) Lowest sawlog harvest and hence lower HWP sink c) Lower energy substitution due to less harvest and despite higher allocation of harvest residue to energy production	
Germany Lieberose area	No clear differences	None
Ireland	EU Bioenergy and Global Bioenergy similar but both lower than Reference: a) Higher harvest compared to Reference but lower allocation of products into long term HWP storage and higher allocation into energy production. Net result was a lower overall HWP C removals b) Climate change scenarios under EU Bioenergy and Global Bioenergy have a larger impact on productivity and species profiles. Result was a lower forest C sink	Reference
Italy	EU Bioenergy and Global Bioenergy similar but both lower than Reference: a) Higher harvests and allocation of sawlog to energy production. Net slight higher overall HWP C removals but off-set by lower forest C sink compared to Reference scenario b) Larger harvest removal reduces occurrence of fires under Global Bioenergy and EU Bioenergy. The impact of fire risk on overall C balance needs consideration, so the Reference scenario may not reflect the best C sequestration option	Reference
Lithuania	EU Bioenergy and Global Bioenergy similar but both lower than Reference: a) Higher harvests to meet higher energy production amounts, but no change in the proportional allocation to energy production. Net slight lower overall HWP C removals but off-set by lower forest C sink compared to Reference scenario b) Larger harvest removals under EU Bioenergy and Global Bioenergy result in lower forest C sink, Net result is that the overall C sink is larger under Reference scenario. The results suggest that diversion of wood products into energy production may not be the best climate change mitigation strategy	Reference
Netherlands	No differences, assumed that harvest and HWP allocation patters do not change under difference scenarios. Also, no climate change impacts are included in the DSS	None
Portugal	No differences, trends largely driven by forest C balance	None
Slovakia	Global Bioenergy higher than EU Bioenergy, both higher than Reference: a) higher harvest volume and proportion of timber products to HWP and product substitution under Global Bioenergy. EU Bioenergy show a very high share of harvest to energy substitution b) Global Bioenergy and EIBIO show larger positive impacts of climate change on volume increment and higher demand for timber, compared to Reference scenario	Global Bioenergy

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Sweden (with HL scenario)	EU Bioenergy higher than Global Bioenergy, but both lower than Reference: a) higher harvest under EU Bioenergy and Global Bioenergy scenarios results in a larger decline in the forest sink, which is not offset by allocation of harvest to HWP because of high proportion of wood allocated to short term HWP products (paper)	Reference

3.4.6 Conclusions

In summary, temporal trends in the forest C sink for many CSAs appear to be closely related to variations in either the level of harvest, changes in productivity (or both). Forest C sink trends can be closely correlated with sustainable productivity indices. Changes in volume increment can also have a large impact of the forest sink and supply of timber for HWP at the landscape level and this appears to be driven by climate change impacts (Hanewinkel et al., 2013) or by shifts in the forest age class structure (Böttcher et al., 2008).

There is no clear indication of the most favourable C sequestration global frame scenario across all CSAs (Table 6). However, the Reference scenario appears to offer the most advantages for most CSAs, from a C sequestration perspective. Although this is associated with lower climate change impacts on forest productivity in some cases, it is evident the Reference scenario generally results in a lower allocation, or total supply, of wood product to wood energy. It is apparent that diversion of wood products, particularly sawlog, for energy production may not be the best forest climate change mitigation option. It is well established that a higher allocation of sawlog to HWP results in an increased removal of C for the forest sector (Skog., 2008, Lippke et al 2011), but displacement of sawlog for energy production appears to have lower climate change mitigation benefits compared to long term wood products or product substitution options. (see Stare and O Connor, 2010; Smyth et al., 2016). In cases where EU Bioenergy or Global Bioenergy scenarios produced the most advantageous C sequestration results (e.g. Augsburg, Germany), this was associated with higher sustainable production ratios rather than differences in the allocation of a higher harvest (Polana, Slovakia) to wood products. In these cases, even higher C sequestration potentials could be realised if harvest was allocated to long term HWP storage or product substitution.

This study highlights the importance of evaluating the complete C life cycle, and not just forest C stocks, under different scenarios. It is evident in some cases (e.g. EU Bioenergy and Global Bioenergy in the Slovakian CSA) that the forest sink can decrease over time due to higher timber demands, but a larger increase in emission savings in products resulted in a larger overall sink. This finding is consistent with other stand and regional level analysis (Lundmark et al., 2016; Oliver et al., 2014). However, in cases where there is a large demand for pulp (e.g. Kronoberg CSA in Sweden), the decline in the forest sink due to large increases in the level of harvest is not offset by HWP storage because of the small expected C half-life of pulp and paper products.

It is important to note that the occurrence of forest fires is high in CSAs within Italy and Portugal but the emissions from fires have not been included in the generic C sequestration DSS model used in this study. Future analyses should include GHG emissions from fires, particularly where the management under the different global frame scenario would lead to a reduction in fire risk (e.g. in Italy).

In conclusion, these results may have some relevance to mechanisms adopted for accounting for the forest management sink under the new EU LULUCF regulation

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(https://ec.europa.eu/clima/lulucf_en#tab-0-1). It is interesting to note that the method of construction of a forest reference level (FRL) used to formulate an accounting framework under the energy and climate change directive 2020-2030 compares the future use of biomass to energy production with the use in period 2000-2009. Depending on the country, this mechanism may bring new constraints to the profitability of the use of forest products for energy use in the future. This may also lead to adverse climate mitigation impacts in the case where forest fires may be prevalent or where the frequency of fires is expected to increase (see Italy CSA), since the risk of forest fire is suggested to decrease due to the removal of timber for bioenergy production (see Italy report). The interaction between large emissions associated with fires and a reduction in fire risk by increased bioenergy harvesting requires further investigation, since the GHG emission due to forest fires is not included in the current DSS. Another feature of the proposed FRL is the factoring out of the influences of past disturbances and management effects on the age class structure on the managed forest sink. This study provides some examples of the impact of age class effects on the managed forest sink at the landscape level.

3.5 Water Related Ecosystem Services

Davide Zoccatelli and Marco Borga

The importance of the five water-related ES among LCCs varies widely, resulting in local differences in the analysis. Some LCC selected the most important ESs (Italy, Sweden, Ireland, Lithuania and Germany), while others tried to analyse the general direction for all of them (Netherlands, Portugal and Slovakia). The most recurrent ES analysed are erosion control, chemical conditions, and water yield. Erosion control and chemical conditions are the main elements of water quality, while water yield is important mostly in water catchments or area with limited water availability.

Four LCCs analysed the variation of ESs in relation with the DSS outputs, as suggested in basic approach of the guidelines (Table 7). Some of these LCC applied the approach schematically with score for each factor, as suggested in the evaluation example, while others used a more discursive description. For three LCCs the ES indicators suggested in the guidelines are part of the DSS outputs and could be used for a direct quantitative analysis. In two cases an external model is used to evaluate ES indicators starting from DSS outputs.

Since this assessment was done starting from forest-related DSS, unspecific for water processes, uncertainties related with the outputs are expected to be high. However, it is difficult to assess the uncertainties relative to the single approaches. In general, a quantification of the ES indicators (Result type in Table 7) is more informative than a general indication on the direction of change, especially for comparison between alternative FMMs or for a landscape scale assessment.

For many LCCs climate change was not included in the analysis, because of the uncertainties on many environmental factors. When included, it was limited mostly to a general effect of temperature on tree growth or mortality, while water ES are strongly influenced by climatic regimes. At this stage of the analysis only current FMMs are analysed. The expected future management change is influenced mostly by the trends that are already in place, such as the young forests in Italy or Netherlands, the change in management for Ireland or the shift toward broadleaves in Slovakia. For these reasons, the effects on water related ES for many CSA are low, but with some exception. In Sweden the increase felling area, in conjunction with the effect of climate, is likely to increase wood production and

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negatively affect water quality. In Turkey future projections relate to an increase in forest stock and area, and this is expected to reduce erosion. In the Netherlands forests are expected to get older, and with less harvest ratio, improving most of the water related ES. The projected direction of change is driven mostly by local conditions, management objectives and wood prices, but it is not univocal across Europe. The main drivers for change identified by the LCCs are harvesting area and intensity (Sweden, Ireland, Netherlands and Slovakia), species composition (Slovakia, Netherlands and Germany) and forest age (Netherlands, Germany and Portugal).

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Table 7. Summary of the approaches and outputs for water related ES in each country.

COUNTRY	APPROACH	RESULT TYPE	ES ANALYZED AND TRENDS[1]	DRIVERS DESCRIPTION
SWEDEN	External model	Indicator quantification	Water quality (-)	Felling area, affecting MeHg concentration
IRELAND	DSS model	Indicator quantification	Erosion control (=)	Felling area, buffer zone creation
LITHUANIA	External model	Grade quantification	Erosion control (=)	Harvest volume
NETHERLANDS	DSS outputs	Direction of change	All ES (+)	Forest age, harvest volume
SLOVAKIA	DSS outputs	Direction of change	Water yield (+) Erosion control (-)	Species composition, harvest volume
GERMANY	DSS model	Indicator quantification	Water yield (=)	Stand density, species composition
PORTUGAL	DSS outputs	Direction of change	Water yield (+)	Harvest volume, age, fire risk
ITALY	DSS outputs	Direction of change	Erosion control (-)	Forest age, fire risk, touristic pressure

[1] trends can be positive (+), negative (-) or neutral (=)

The three scenarios analysed (Reference, EU bioenergy, global bioenergy) have been represented with some difference among LCCs. The effect of increased temperature on trees and on climate was not always included in the analysis, which in some case is limited to a variation in timber prices. As a result, in some case the distinction between scenarios does not affect the evaluation of water related ES (Lithuania and Netherlands). For other LCCs, the scenarios produced effects that can be considered negligible (Ireland, Italy, Germany and Portugal). The small impact relates to local management objectives that are unrelated with the changing parameters, or with the small variations of FMMs at this stage of the analysis. However, in few areas the difference between scenarios is relevant. In Slovakia the bioenergy scenarios are expected to increase significantly the harvest volume. Here, if the forest is managed correctly, the combined effect of more management and more favourable climatic conditions are expected to have positive effects on ES provision. Similarly, in Turkey the bioenergy scenarios are expected to largely increase the managed forest area size, with positive effects on erosion and maybe some negative impact on water yield. Instead, in Sweden the increase in final felling area, connected with the bioenergy scenarios, is expected to have a negative effect on the concentrations of methyl mercury and on soil erosion.

Overall the trends of water related ES across Europe seem to be complex. The final conclusions are influenced mainly by market prices and current trends already in place but differ between CSAs. The scenarios analysed describe an intensification of forest management that could result in an increase in the water related ES, a decrease, or in many cases may have no effect. Looking at the methodology applied, a large part of the differences seems to come from the consideration of different factors. Some LCCs included considerations on climatic factors (Slovakia and Italy) that were not included for other LCCs. Factors such as climate and land use changes have a major impact on water related ES, often shadowing the effect of the market, and could have a larger role in the evaluation.

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3.6 Cultural Services

Marjanke Hoogstra-Klein

For most of the CSAs, the RAFL index (RAFL: Recreational and Aesthetic Value of Forested Landscapes) as developed within the ALTERFOR project was used, with a case specific operationalization of the concepts. Germany designed their own fuzzy logic system tailored to some of the key variables available in their DSS. Lithuania decided to make use of different attributes provided in the RAFL index, but the translation to one single index was deemed to be unrealistic, among others by the stakeholders involved in the discussions on the quantification of the ES. Sweden also chose to focus on the development of different attributes of the RAFL index and not to calculate one overall score.

The first part of the analysis focused on comparing the developments of the overall RAFL score over time in the different CSAs for the three main scenarios. To do this, the relative change of the initial value and the final value was calculated. The changes were grouped according to the following classification:

- Stable: change in index between -5% and +5%
- Small increase (decrease): change in index between (-)5 and (-)10%
- Moderate increase (decrease): change in index between (-)10% and (-)25%
- Large increase (decrease): change in index >= 25%.

Table 8 provides an overview of the outcomes per CSA per scenario. It shows, first of all, that the relative developments vary between large decrease to large increase. In most of the CSAs, however, the initial value increases - or the decrease is so small that it is categorized as being stable. Only in the Portuguese CSA, a decrease in value is seen in all three scenarios. Based on this outcome, we can tentatively conclude that the majority of the projections indicate an improvement in the recreational and aesthetic beauty value of the CSAs. The relative development of the RAFL score is in some cases scenario dependent, as for example can be seen in the German cases, but in other CSAs it is independent from the future developments considered (e.g. Ireland, Italy, the Netherlands).

Table 8. Overview of the (relative) development of the RAFL index over time in all CSAs for the three scenarios, comparing initial value and final value.

Country	CSA	Reference	EU Bioenergy	Global Bioenergy
DE	Augsburg Western Forests	Small increase	Large increase	Moderate increase
	Lieberose Schlaubetal	Large increase	Moderate increase	Stable
IE	Barony of Moycullen	Stable	Stable	Stable
IT	Veneto	Moderate increase	Moderate increase	Moderate increase
LT	Telsiai	*No single index used*		
NL	Netherlands	Large increase	Large increase	Large increase
PT	Vale do Sousa	Large decrease	Large decrease	Large decrease
SE	Kronoberg	*No single index used*		
SK	Podpoľanie	Stable	Stable	Stable

Table 9 provides an overview of the final value (in 2100) of the RAFL index for all CSAs for all scenarios (in case available). The final values were categorized using the following classification: Very low: 0 – 0.2, low: 0.2 – 0.4, moderate: 0.4 – 0.6, high: 0.6 – 0.8, very high: 0.8 – 1.0. The table shows that the

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final scores vary between the CSAs in the different scenarios, from low up to high. This also implies that none of the CSAs achieve the lowest or the highest score. The best scores ("high") are achieved in Italy, the Netherlands, and Slovakia; the lowest scores ("low") are in the Portuguese CSA and in two scenarios in the Augsburg Western forests (Germany). All other scores are "moderate". The table also shows that, despite the fact that the value increases over time in most of the CSAs (see table 8), this not always results in a high value, even with a large decrease. This has in most cases to do with the relatively low value at the beginning. For example, despite the large increase in Augsburg Western forests (Germany) in the EU Bioenergy scenario, the final value is still low due to the low starting score. It is also interesting to note that in most of the CSAs the final value is independent of the scenarios analysed. Only in Augsburg Western forests (Germany) do differences exist in final value between the different scenarios.

Table 9. Final values of the RAFL in all CSAs.

Country	CSA	Reference scenario	EU Bioenergy	Global Bioenergy
DE	Augsburg Western forests	Low	Low	Moderate
	Lieberose Schlaubetal	Moderate	Moderate	Moderate
IE	Barony of Moycullen	Moderate	Moderate	Moderate
IT	Veneto	High	High	High
LT	Telsiai	*no single index used*		
NL	Netherlands	High	High	High
PT	Vale do Sousa	Low	Low	Low
SE	Kronoberg	*no single index used*		
SK	Podpoľanie	High	High	High

The development of the different concepts underlying the RAFL index shows much diversity among the CSAs, but is in most of the CSAs rather similar for the different scenarios - except in Sweden and Germany, where (some of) the scenarios affect the (relative) development of the different concepts. In Sweden, for example, the score for naturalness and historicity increase in all three scenarios, but much less in the Global Bioenergy scenario. The visual scale score developments are in Sweden even more complex. These scores increase strongly over time for both the Reference scenario and the EU Bioenergy scenario, whereas the increase in score for the Global Bioenergy is rather limited. However, at the end of the run, the score for the Reference scenario drops to such an extent that it ends at the same level of the score of the Global Bioenergy scenario. It is difficult to pinpoint the origins of the differences. The positive influence of climate change in the Reference and EU Bioenergy scenarios, and the decreased final felling and longer rotations in combination with increased volumes and mortality, are given as possible explanations. In Germany, different scenarios also lead to different outcomes, most notably in the scores related to the volume of (large) trees, which is much less increasing in the Global Bioenergy scenario than in the other scenarios.

As these two CSAs already show, a lot of variation exists between the (relative) developments of the concepts and attributes underlying the RAFL index. For example, in the Portuguese CSA - the only area with a (large) decrease in the RAFL index in all three scenarios -, the most striking change is the large decrease in stewardship (starting with the highest score and ending with the lowest score possible). This is due to large amounts of harvesting residues. In Slovakia, the largest change appears in the visual scale as the amount of understory increases in all three scenarios. This is the result of forests being regenerated with much vertical structure hindering visibility, leading to a decrease in

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the visual scale. This decrease is compensated by small increases in the other aspects. The Irish CSA shows a decrease in the naturalness score, which is mainly due to the wilderness aspect, which is determined by the amount of natural mortality volume. This decreases as forest types with lower mortality volumes replace the current forest types. This decrease is also made good by the small increases of the other concepts. In Italy, the largest increase is to be found in the historicity of the forests, as in all the scenarios forests will get older. The Lithuanian case study shows a large increase in naturalness and visual scale. In the Netherlands, three concepts (stewardship, visual scale, and historicity/imageability) are increasing, and are the reason for the increase of the Dutch RAFL index. This is caused by forests getting older, with less tree density and less harvesting, leading to less harvesting residues.

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4 Synthesis

As is self-evident, the results presented above reflect the heterogeneity of landscapes, forests, forestry and its goals across Europe. More interesting, the global frame frame scenarios with their climate and demand differentiation had in general no pronounced effects; this is partly due to methodological reasons (as mentioned in some of the ES expert reports), but also due to the fact that forests are slow-developing systems whose behaviour is dominated by lots of negative feedback loops creating a remarkable degree of idleness. Probably, the next step in ALTERFOR, the simulation of alternative forest management models under the same global frame scenarios will show stronger effects on ES provision levels than the current FMMs.

Based on the expert reports, none of the CSAs under the global frame scenario develops in a way that totally compromises the future provision of any desired ecosystem service using the current FMMs. However, there seems to be potential to increase the provision of several ESs in many case studies under alternative FMMs if desired. Especially for sustainable wood provision, the majority of CSAs allow for increased harvest amounts over the long run. Partly, this might be due to the current FMMs not yet fully covering the recently accelerated forest growth in Europe (Pretzsch et al. 2014).

However, it is not trivial to predict the consequences of such an increased sustainable timber provision on other services, e.g. carbon sequestration. The main potential carbon sinks taken into account in this study are forest bound carbon stocks, forest product stocks and product substitution effects, and their importance is different across the CSAs. Thus, if increased sustainable harvest in an alternative FMM stops the increase of forest bound C stocks, the overall carbon balance will not be reduced only if additional product stock accumulation and substitution compensate the reduced forest-bound accumulation. Interesting tradeoffs may also occur between harvest levels and regulatory services. If forest stands, due to under-harvesting, become too dense, they accumulate high risk especially for wind and consequential damages. Lower densities allow the single trees in a stand to develop more individual stability, and thus to form a more stable stand in the long run. However, there may be a transition time after the first density reductions (due to a harvest increase) during which wind risk is very high due to reduced collective stability and not yet sufficiently developed individual tree stability. Similarly, in fire risk regions uneven-aged mixed forests bear a by far lower risk than traditional even-aged plantation-like approaches, however, transition stages might be especially hazardous due to upcoming overstory that directs ground fires into the tree crowns. An increasing body of literature is investigating potential relationships between biodiversity and silvicultural measures with inhomogeneous outcomes (Dieler et al., 2017, Biber et al., 2015), whereby the treatment history seems to be decisive in the way biodiversity reacts to forest management. The existence of such possible tradeoffs or synergies including biodiversity is of considerable importance, as biodiversity is an important ecosystem service in all CSAs and its provision levels under current FMMs are among the most inhomogeneous ones obtained in this study. Cultural services' provision strongly depends on value judgements of the public, not so much on professional economic or scientific reasoning. Generally, most recreationalists throughout Europe seem to value most a managed forest which does not really look like being managed; this is nicely covered by the RAFL index applied in this study. While the projected provision of cultural services was stable or increasing in almost all CSAs under current FMMs, this happened on very different levels, showing an obvious potential for increases in many places. However, the current valuation by

the public may lead to interesting tradeoffs with biodiversity and timber provision with alternative FMMs, because too much of either can be expected to reduce the provision of cultural services.

A major lesson learned from the water related services results was that often the real drivers of these services are external factors (e.g., large area land use policies, climate change), whose accessibility is beyond the possibilities of ALTERFOR scenario definitions. So, the visible effects so far only represent the impacts of forest management (which is interesting per se), but it must not be forgotten that the possibly greater influence of other drivers is not contained in these results.

In general we can say that this report outlines a state-of-the-art European perspective on forest management and ecosystem service provision throughout Europe. The degree of detail in the silvicultural scenario and associated ecosystem service provision modelling, while embedded in large scale market and climate change scenarios and stakeholder preference research, is, to our knowledge, unprecedented for such a large collection of forest DSS/models and variety of forested landscapes. From this synthesis of results for current forest management models we can learn that: i) there is clearly potential to increase the provision of many ecosystem services with alternative forest management models; but ii) that the resulting (partly temporary) tradeoffs and synergies are too complex to simply be predicted based on the results reported here. Thus, from the authors' point of view there is no shortcut to exploring alternative forest management models other than the systematic scenario simulation and analysis which is the next step of analysis in ALTERFOR.

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