Vulnerability assessment of ecosystem services for climate change impacts and adaptation (Vaccia)

ACTION 9: Assessment of impacts and adaptation measures for forest production; Case study at Northern Häme and Lapland *(Short name: Forest Production)*

Main results

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Main Results

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Contents

Main Results 2
1. The objectives of the action. 3
2. Methods employed 3
3. The main results 4
   3.1 Occured and expected changes in forestry 5
   3.2 Tree growth accelerates 5
   3.3 Occurence of extreme events and competition will downscale tree growth enhancement 7
   3.4 Climate change will increase profitability but also risks in forestry 8
   3.5 Challenges for silviculture 9
   3.6 Scheduling of new modifications in silviculture is the key for succesful adaptation. 10
4. Needs for further studies 11

1. The objectives of the action.

The aim of the action was to clarify how climate change will influence the forest production and production conditions and how that will influence the productivity of alternative silvicultural schemes.

The other aims was to communicate the results in common seminars with practical forestry organisations and NGO´s both at local community levels where the action case studies were made and at national level and to get feedback on adopting different adaptive measures under uncertain future and discuss estimations how the change is likely to influence the income of the forest owners.

The scientific aim of the action was to design a tool to analyse the transient change that climate change is implying on forest growth and development by combining intensive continuous measurements of climate and the response of forest to that with a forest growth model based on biological growth processes. The aim was to combine biologically based models with economical optimisation to study the best silvicultural practises under changing climate. Established interactions were further simplified into management level models.

2. Methods employed

The study combined long term measurements of climate and forest ecosystem processes, process based models of tree and stand growth, optimization models of forest productivity and forest management models with climate change scenarios. The communication of the results and feedback from the forestry actors was asked in three seminars organised at different phases of the study.

The atmospheric and forest ecosystem measurements were done at the SMEAR II and SMEAR I stations situated at the University of Helsinki forestry field station in Juupajoki and at University of Helsinki research station in Salla (both part of Finnish LTSER network). Both stations measured continuously meteorological variables and atmospheric properties, tree carbon uptake and transpiration and processes and ecosystem conditions along with the vegetation structure that influence these fluxes. Tree growth was measured continuously and also periodic forest inventory has been done to clarify the distribution of biomass into different fractions.

The study used existing and reported process based models to predict tree growth changes. Production changes are calculated with canopy models SPP that was able to consider the impacts of growing season length, seasonal temperature and water and CO_2 availability. During the project the connection with SPP and process based model MicroForest were improved to consider also the influence of nitrogen availability. The above models were linked with a process-based tree growth model

PipeQual to study the impact of changes in productivity of growth. The modified tree growth models and variable projectories of forest owner decision making were further analysed with the forest management tool SIMO to study how the local forest structure is likely to change. Figure 1 summarises the used method

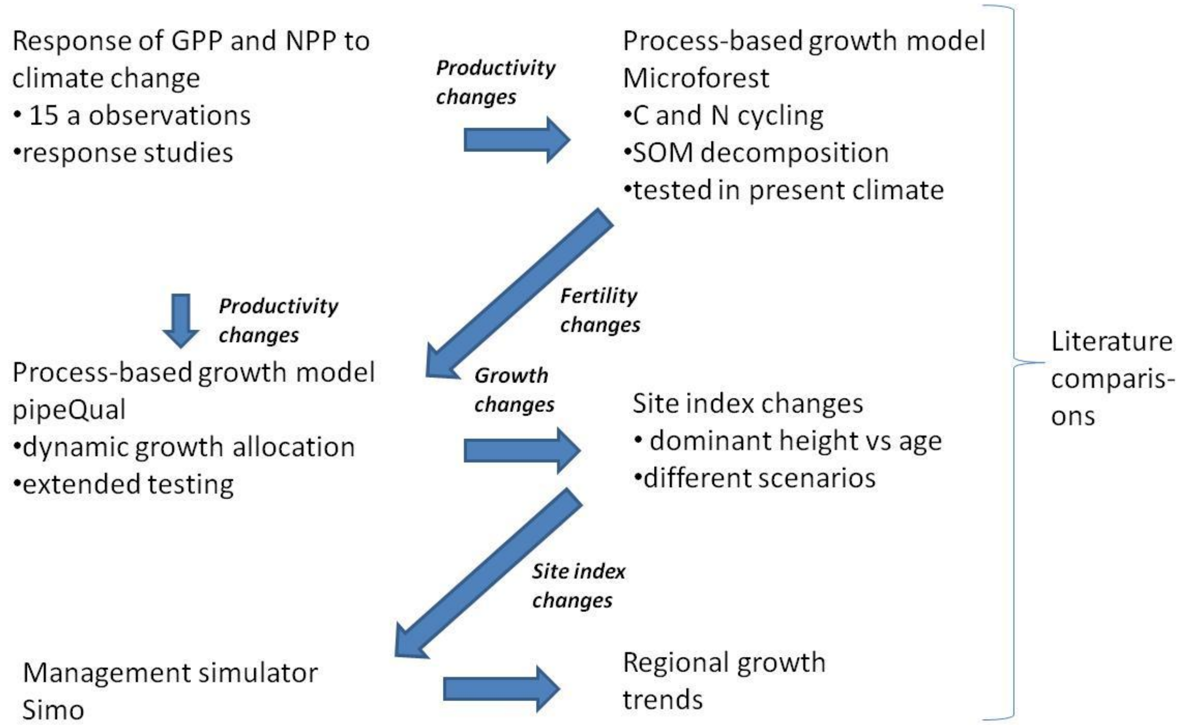

Figure 1. Schematic presentation of the used approach to analyze climate change impacts on forest productivity

During the project three seminars were held with the practical forestry organisations and representatives of the local communities and national level NGO´s. In the first seminar the action was introduced and comments and feedback on the aspects that are felt as strongest concerns were collected. In the second seminar, the results from the analysis of expected changes in profitable silviculture were introduced, and in discussion the likely behaviour of forest owners in changing conditions was predicted and its impact on the local communities was treated. In the third seminar, the overall development of the forests at national level were discussed.

3. The main results

The technical reports and the reports of the stakeholder meetings present the detailed results of the action. In the following we summarize the main outcome of the climate change studies and the various discussions at the stakeholder meetings.

3.1 Occured and expected changes in forestry

Occurred CO2 increase of about one third from the preindustrial era and simultaneous slight temperature increase have not yet produced clearly distinguishable growth response in Finnish forests according to tree ring time series. Parallel to climate change there has been increase in nitrogen deposition and a drastic change in the forest structure due to sift in silvicultural practices since 1950's that both drive forest productivity to the same direction as climate change. Overall the stem wood growth of Finnish forests has almost doubled over the last 50 years.

The predicted CO_2 increase and the climatic feedback mechanisms lead to temperature rise of about 2–5°C by the end of 21st century. We estimated that by 2100, CO_2 and temperature-induced increase in leaf specific Gross Primary Production (GPP) in pine will be 16%, 31% and 41% depending on the used scenario (B1, A1B and A2, respectively). Significant part of the increase can be attributed to longer growing season, as in the midsummer the maximum increase in instantaneous photosynthetic rates in 2085 caused by elevated CO_2 are only 10–15% higher than in the present. The production increase will be higher in birch due to steeper instantaneous temperature response and higher temperature optimum of photosynthesis than in pine. Our analysis predicts a that elevated CO_2 decreases instantaneous transpiration rates in both pine and birch. Due to the longer growing season in the future, however, the annual cumulative leaf specific transpiration will remain approximately at the present level while at forest level, the leaf area increase may elevate the annual transpiration.

3.2 Tree growth accelerates

Increased GPP alone results in smaller growth enhancement than that of GPP because soil nutrients are simultaneously depleted as has been observed in FACE studies. However, temperature driven acceleration in N cycling and change in within-tree biomass allocation along with productivity changes caused approximately 8% rise in pine stemwood production in mature stand per °C temperature. This largely resulted from lower allocation below ground. The observed temperature response of soil CO_2 efflux and increase in active growth and decomposition period (temperature >5°C) length predict 6% increase in the rate of decomposition per °C rise in temperature. Average growth increment in closed-canopy stands with CO_2 scenario B1 and mean annual temperature rise of 2°C was 16% and 31% in southern Finland and in Lapland, respectively (see Figure 2). The extreme CO_2 scenario A2 and temperature rise of 5°C resulted in growth enhancement of 40% in southern Finland and 80% in the north. In this scenario climate in Lapland eventually becomes warmer than the present climate in southern Finland but wood production will remain at a slightly lower level as the initial pools of soil organic matter and correspondingly organic nitrogen are smaller in the north. The experimental results from the large scale CO2 enhancement experiments have produced similar results in terms of elevated CO2 while soil warming experiments produced similar outcome in terms of enhanced nitrogen availability.

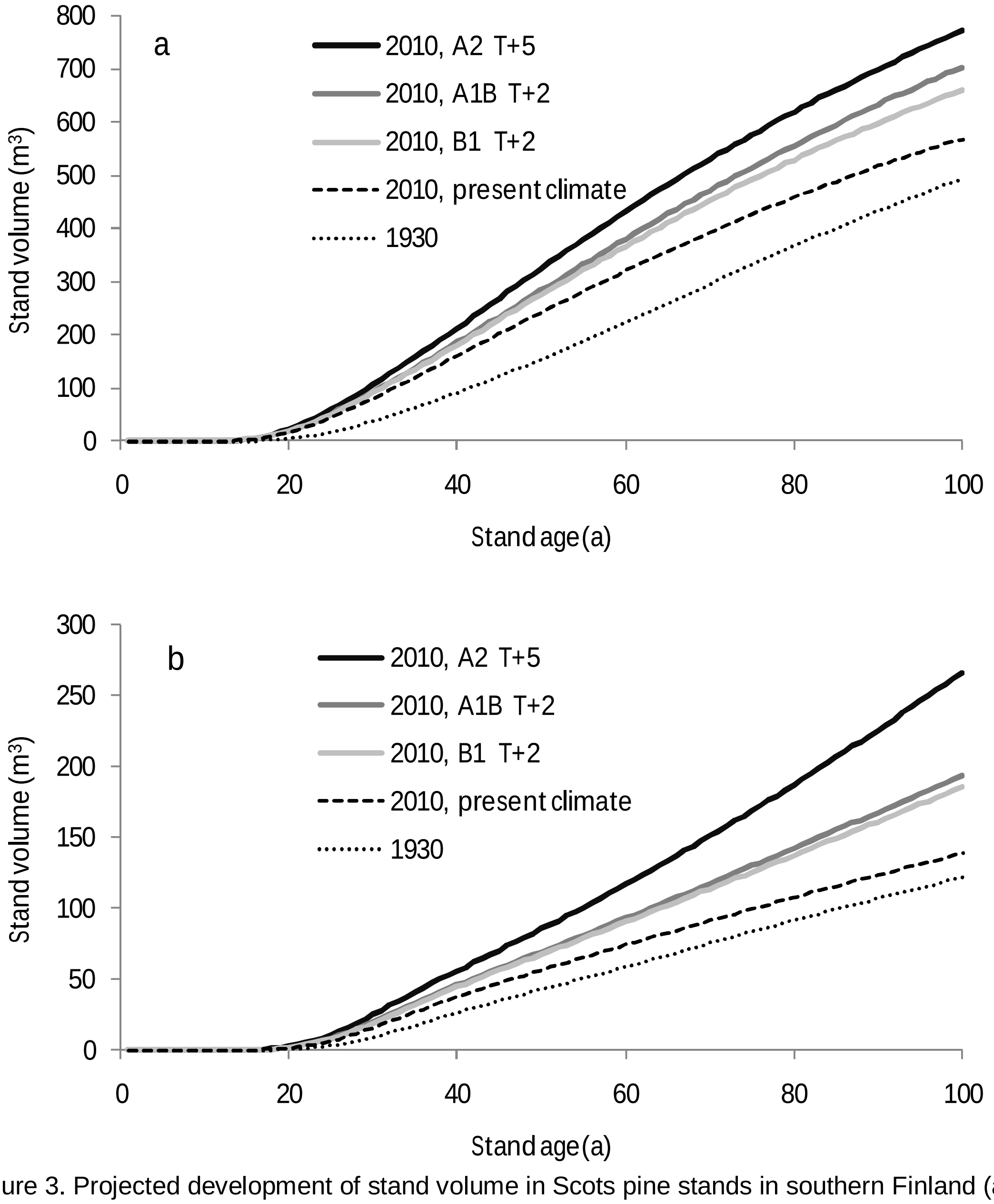

Figure 3. Projected development of stand volume in Scots pine stands in southern Finland (a) and in eastern Lapland (b). The simulated stands were established in 1930 (actual climate and nitrogen deposition history) and in 2010 with different CO_2 and temperature rise scenarios and assumption of nitrogen deposition remaining at present level of 0.5 g N m^{-2} a^{-1} in southern Finland and 0.2 g N m^{-2} a^{-1} in the north.

3.3 Occurence of extreme events and competition will downscale tree growth enhancement

The average number of drought day does not increase considerably with the climate change but it may imply occasional more severe drought periods that may severely influence growth and enhance leaf turnover and increased mortality. The number of drought days would be about double to that of 2006 with similar rainfall pattern in the new climate with elevated temperature. Overall, increase of drought days was not predicted to cause any significant reduction in the plant productivity but it may have direct influence to growth which is more sensitive to drought than GPP. In the long term historical growth data there was a slight decrease in both pine and spruce growth during dry years while the impact lasted longer in the latter.

Elevated temperature, CO_2 concentration and more rapid turnover rate of soil organic matter that releases more nitrogen to plant use will lead to eutrofication of the sites. This will favor more rapid post disturbance development of grasses and herbs. Also comparable size seedlings of broadleaved species such as birches are better competitors for resource capture in high resource availability during early development in comparison to conifers. For Southern Finland we may assume that in 2100 the peak biomass of herbs and grasses on the fertile MT site will double that of rich OMT site currently and it will be about the level in current rich OMT site on poor CT site. Although the growth is enhanced at single stand level, at the regional level, the forest structure is still very much influenced by the current forest structure and the bigger differences are starting to show at the later half of this century (see Figure 3)

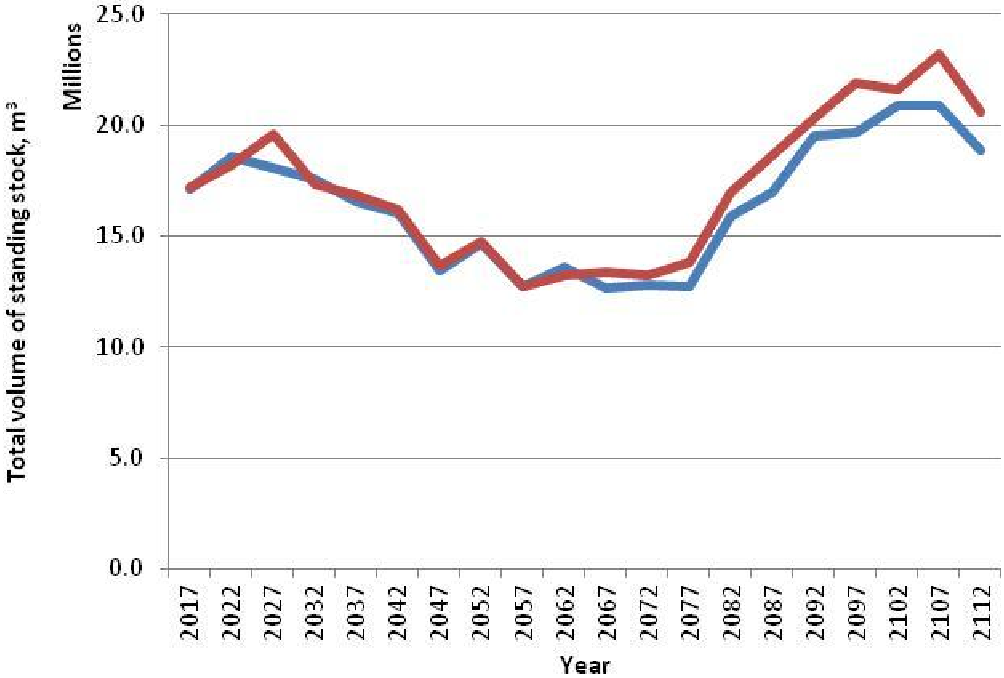

Figure 12. The simulated development of total standing stock (m3) at the case study region of Häme for current climate (blue line) and assuming a climate change scenario B1 (red line).

3.4 Climate change will increase profitability but also risks in forestry

Overall, the silviculture will become more profitable with changing climate as the forest productivity increases. The net present value of the final harvest can more than double in South Finland and triple in the north. The more vigorous ground vegetation growth makes forest regeneration more difficult and costly. In the present transient phase, the increased growth is partially decoupled from the need for increased effort in stand establishment as the forests have been regenerated in the current climate but the growth benefits from the improving growth conditions.

Warmer climate will expose forests to new, harmful insects and pathogens and even some of the currently harmless ones may become problematic. Although, on average, drought will not be a major factor decreasing growth, it may have an important role in triggering mortality in combination to different biotic vectors. Also climatic change will expose the forests more to the storms as the soil is gradually less frozen during the high wind periods of the autumn and winter. Non-frozen soils will also make the harvesting operations more difficult, particularly on wet areas.

The need for considering the requirements of other ecosystem services such as carbon sequestration, water production and biodiversity will increase with changing climate along with the trend of increasing use of forests for recreation. Their impact on forest management can be considerable depending if they can be assigned a clear economic value or if they are included in the norms guiding forestry. The demand for renewable fuels is already starting to influence silviculture. If wood harvesting for bio-fuel is badly organized, it may have significant long term impact on forest fertility but, on the other hand, it provides in changing climate new possibilities on alternative silvicultural practices that are based on coppicing. The situation in Lapland is particularly interesting as the role of silviculture is smaller than other land uses in those northern Forests. With changing climate, silviculture will become more profitable and conflicts between land uses will increase, particularly as the share of protected areas of the total land area is high.

3.5 Challenges for silviculture

The biggest challenges silviculture is facing in the changing climate are linked to tree species and provenance selection, regeneration methods, stocking densities and timing of harvesting operations and to disturbances caused by drought, storms and fungal and insect attacks. The non-frozen soil will impose large practical challenges on harvest operations, particularly on wet soils. These will influence both management of single stands and planning of regional forest management and even the selection of applied silvicultural chain.

Higher site fertility and more frequent disturbances improve the profitability of broadleaved tree management relative to that of conifers. Also species with currently only marginal economic value such as oak, elm and ash become wider available with climate change. However, the risk involved in the large inter-annual variation in weather limit the usability of more southern species/ provenances still many years to come.

More intense competition by ground vegetation and competing tree species imply that the opportunity window for stand regeneration becomes much shorter than currently and increases both scarification and herb-layer treatment needs and makes their correct timing more acute. Avoidance of large scale natural disturbances due to drought or wind-throws need to be considered when stocking densities and timing of harvesting is planned. Out of the current species spruce is the most vulnerable to both of these disturbances. These factors influence the relative advantages of different silvicultural chains and need to be considered when planning between currently dominant clear-cutting based silviculture, continuous cover silviculture or fast rotations silviculture is done.

Increased precipitation outside growing season and more intensive rainfall periods and more rapid decomposition of organic matter may increase run-off from forested areas and increase erosion and nutrient leaching immediately after clear-cutting. On the other hand, the more rapid development of ground vegetation and higher overall biomass in forests will have an opposite effect. On average the run-off during growing season will not change much but increasing precipitation outside growing season may increase nutrient leaching if no methods are adapted to prevent it. This additional load may have a harmful influence on small scale head water bodies whose water quality is weakened by the warming climate.

Utilization of forest bioenergy, carbon sequestration and other climate influences and securing the other ecosystem services that forests provide may imply new conflicting requirements on the use of forests. The positive climate impacts of forest based bioenergy need to be compared against the influences it has on the carbon store in the forests. Very intensive bioenergy use may not be compatible with the maintenance of biodiversity as already the present practices have lead to large scale decrease in dead wood material in the forest and consequent decline on species diversity. Climate change imposes also a challenge on regional planning of forest mosaic as it should support the opportunity of species migration in south- north direction.

3.6 Scheduling of new modifications in silviculture is the key for succesful adaptation

Adaptation of silviculture is problematic as there is still considerable uncertainty of the expected climate by 2100 yet the currently established forests reach their maturity then. In practice this means that optimal tree species composition could then be very different from the present. Use of pine on present dry growing sites is well justified as regeneration is easy in the current climate and the future growth will accelerate in the future. Also, there is currently no good alternative but the further in the future we go, also alternative tree species become viable on these sites. On fertile site it is rational to establish mixed spruce- hardwood stands. Spruce-birch mixture is already at present competitive combination to pure spruce stands. If climatic changes impose problems for spruce, the hardwoods can be grown and harvested as planned. In southern Finland one could try more valuable hardwoods such as oak in the mixture that are currently only marginally used due to temperature limitations.

Climate change facilitates the use of more varied silvicultural chains. These should be considered already when making present species selections. For example one could anticipate the future regeneration problems by selecting species that can be regenerated through coppicing on fertile sites. Hybrid aspen is a viable option already currently and possibility for regeneration through coppicing makes it an interesting alternative if ground vegetation competition increases. Increasing fertility favor continuous cover forestry and higher temperatures allow usage of other shade tolerant species such as beech in the future. Increasing probability of wind-throws need to be considered in such alternatives.

In clear-cut regeneration scheme correct timing of sapling stand tending and thinnings become more critical. More rapid tree development increases competition and causes risks for trees that are targeted in silviculture. Increasing fertility requires denser stands for wood quality control, in particular for pine. Also possible windthrows need to be considered when optimal stand densities after thinning are designed. In forest based bioenergy production the depletion of soil based nutrients become more critical as the growth is increasingly nutrient limited.

Safe-guarding forest biodiversity requires more attention to maintenance of different type forest environments and their south- north continuum. Forestry operations need to consider watershed level entities in the protection of water courses and bodies that are also threathened by eutrophication. These requirements impose new demands on the regional level planning of forest management. The new situation also adds new demands on the training and education of forest owners and practisioners.

4. Needs for further studies

Although much is know, appropriate adaptation to climate change still requires better understanding of expected changes. Future research needs concentrate around following questions:

- How interannual variation of forest growth is controlled by weather patterns and how extreme events influence development directly and with delay.

- Surprisingly little is known how ecophysiological and reproductive properties of different tree species vary. Compared to trees, the properties of ground vegetation are even worse known.

- Soil organic matter and nitrogen turnover is critical factor in the growth response of trees in changing climate. The nitrogen dynamics and its linkages to tree life cycles is a central research question.

- The development of disturbances, and their severity and frequency will be a central issue in the forest response to climate change. Particularly development of biotic disturbances is very weakly known and requires more research.

- Maintenace of biodiversity requires better understanding of the properties of forests that are crucial for species success, so that their spatial and temporal continuum could be guaranteed.

- As the silviculture remains as the main factor influencing forest landscape, more effort should be paid to socio-economic studies on forest owners behavior under uncertain future and also more direct communication channels need to be established between climate change research and various stakeholder groups