SUOMEN
ILMASTOPANEELI
The Finnish Climate
Change Panel

MAIN MESSAGES FROM RESEARCHERS CONCERNING THE CLIMATE IMPACTS OF FOREST UTILIZATION

Jyri Seppälä, Antti Asikainen, Tuomo Kalliokoski, Markku Kanninen, Sirkka Koskela, Ilkka Ratinen, Johanna Routa

The Finnish Climate Change Panel

Report 1/2017

JYRI SEPPÄLÄ[1], ANTTI ASIKAINEN[2], TUOMO KALLIOKOSKI[3], MARKKU KANNINEN[3], SIRKKA KOSKELA[1], ILKKA RATINEN[4], JOHANNA ROUTA[2]

[1]Finnish Environment Institute SYKE
[2]Natural Resources Institute Finland, Luke
[3]University of Helsinki, HU
[4]University of Jyväskylä, JU

1. INTRODUCTION

Discussion on the climate impacts of forest utilization has intensified in the scientific community during the 2010s. The Finnish Climate Change Panel conducted the first review on scientific messages concerning the climate impacts of forest utilization in 2013 (Ilmastopaneeli 2013). A revised review was made in 2015 (The Finnish climate change panel 2015). In 2016, the climate panel decided on a follow-up review concerning forest utilization, due to the increasing amount of interest in and need for additional knowledge on forest usage created by the ambitious climate goals set by the Paris Agreement.

The climate impacts of forest utilization continue to be the primary focus of this follow-up assessment, as decision-makers feel the messages given by research concerning this topic to be conflicting. The goal of the assessment is to clarify the conclusions that the Finnish scientific community agrees upon, and to bring this knowledge to the awareness of decision-makers in a more concrete manner than previous assessments. Rather than offering lengthy explanations, the aim has been to formulate short and concise main messages (claims), based on which it will be easier to plan climate-sustainable forestry in Finland, while following the emissions reduction pathway of the EU.

Forest utilization is important for Finland because of its effects on the employment and export revenues. New expectations are placed on our forest industry growth due to the goals for bioeconomy growth set by the government. Finland expects growth particularly from softwood pulp because of its positive global market outlook. The concurrent aim is to increase wood construction and respond to the climate goals set for Finland by the EU by increasing the utilization of wood-based raw materials in energy production and traffic fuel consumption. The government's policy is to increase the annual harvesting of domestic wood from the current ca. 66 million m^3 to approximately 80 million m^3 by 2025 (Valtioneuvosto 2015).

Increasing wood utilization in Finland is justified by the country's yearly net annual increment currently being over 100 million m^3. This gives Finland the chance to significantly improve employment and export revenues by increasing forest utilization. Finnish forest utilization is concurrently perceived as sustainable, and cost-effective responding to the EU's climate goals is possible through it (Koljonen et al. 2017). On the other hand, claims contradicting these views and the effects of the planned policies on the sustainability of forestry have been made by the scientific community (BIOS 2017).

Environmental impacts fundamentally relate to the sustainability of the forest utilization. These impacts also strongly relate to forest carbon balance, biodiversity, and environmental water loading, but also to socially important utilization forms such as forest recreation. Of all the usage forms, the environmental impacts caused by increasing forest utilization, i.e. changes in carbon balance and biodiversity have caused the most discussion, as forests play an integral part in these questions and concurrently their maintenance involves international obligations to Finland. Finland is bound by a wide range of international agreements that obligate the protection of biodiversity (the CBD agreement in particular). The decision of the 2nd Kyoto protocol has regulated the carbon balance of wood utilization, and will continue regulating this until 2020. According to this decision, Finnish carbon sinks must remain at approximately 19.3 million t CO_2 on a yearly basis (-20.5 million t CO_2-eq with wood products).

EU's LULUCF (Land Use, Land Use Change and Forestry) regulations obligate the conservation of carbon sinks from the land-use sector and forests during 2020–2030. The climate targets agreed upon during the Paris climate negotiations are working in the background of the LULUCF regulations. According to a draft published during the summer of 2016, forestland managed in the EU must have accountancy regulations and reference levels after 2020. For forest utilization and EU regulations to support the mitigation of climate change, we need impartial research knowledge for backing up decision-making. However, combining the

results from various studies conducted with different assumptions into a more decipherable form for decision-makers is a separate job, one which this report by the climate panel is aiming to accomplish.

2. EVALUATION PROCESS OF THE CLAIMS AND RESEARCHERS INVOLVED IN THE PROCESS

During the autumn of 2016, a preparatory committee of the climate panel identified various fields related to the climate impacts of forest utilization that needed clarification in society. Pre-prepared materials were sent to ten specifically chosen researchers in this field. Eight of these researchers participated in an expert meeting organized at the beginning of November. Based on the provided feedback, the preparatory committee of the climate panel prepared materials that were presented at a seminar on December 8th, 2016. Approximately 30 forest researchers, The Bioenergy Association of Finland, the Finnish Forest Industries, and ca. ten civil servants from ministries handling forest-related issues were invited to attend the seminar.

Eight claims were presented during the seminar. After each presentation the claim was discussed and each claim was voted. Only the researchers were allowed to vote. Approximately 20 researchers in addition to seven researchers that were members of the preparatory committee were present. Voting was conducted by showing colored cards representing the following statements:

Green: Approves the claim as such
Yellow: Approves the claim with rephrasing
Red: Does not approve claim's basic idea
White: Not enough expertise to evaluate the claim

The discussions for each claim were written down. Central research needs were also identified during the seminar, and seminar participants were asked to prioritize the three most important ones.

After the seminar, the preparatory committee rephrased the claims based on feedback received during the seminar. The claims were resent via email to the seminar participants and to three researchers that had been unable to attend the seminar. These rephrased claims were used for a second round of voting. Two researchers refused to vote due to their busy schedules. Each researcher voted on their own. The researchers had the possibility of seeing the voting results from the seminar, of comparing the rephrased claims with the original wordings presented at the seminar, and of providing written comments to the claims. Voting was carried out using the same color card method as during the seminar.

The preparatory committee sifted through the feedback, and made some minor wording modifications to certain claims. The premise was only to increase the understandability of the claims, so no further re-voting took place. The only exception to this was claim 2, which was rephrased and the new wording was sent to the researchers via email, along with the change of re-voting ("yes"/"no").

Results for the work were presented March 13, 2017 to civil servants working with forest-related issues at the Ministry of the Environment, Ministry of Agriculture and Forestry, and Ministry of Economic Affairs and Employment. Descriptive texts of the claims were improved upon based on discussions with the civil servants. Rephrasing of the claims was not conducted.

Researchers that voted (21 participants):

Ekholm, Tommi (VTT[1])	Leskinen, Pekka (SYKE[2])	Repo, Anna (SYKE/JY[7])
Hynynen Jari (Luke[3])	Lindroos, Tomi (VTT)	Salminen, Olli (Luke)
Ilvesniemi, Hannu (Luke)	Lintunen, Jussi (Luke)	Sievänen, Risto (Luke)
Kallio, Maarit (Luke)	Liski, Jari (IL[4])	Soimakallio, Sampo (SYKE)
Kilpeläinen, Antti (UEF[5])	Mäkelä, Annikki (HY[6])	Sokka, Laura (VTT)
Koponen, Kati (VTT)	Peltola, Heli (UEF)	Venäläinen, Ari (IL)
Lehtonen, Aleksi (Luke)	Pukkala, Timo (UEF)	Vesala, Timo (HY)

The preparatory committee behind the claims:

Asikainen, Antti (Luke)	Kanninen, Markku (HY)	Kalliokoski, Tuomo (HY)
Koskela, Sirkka (SYKE)	Routa, Johanna (Luke)	Ratinen, Ilkka (JY)
Seppälä, Jyri (SYKE)		

of which Antti Asikainen, Markku Kanninen, Ilkka Ratinen, and Jyri Seppälä are members of the Finnish Climate Change Panel.

[1]VTT Technical Research Centre of Finland Ltd
[2]Finnish Environment Institute SYKE
[3]Natural Resources Institute Finland Luke
[4]Finnish Meteorological Institute
[5]University of Eastern Finland
[6]University of Helsinki
[7]University of Jyväskylä

The preparatory committee was in charge of forming descriptive texts for the claims phrasing by considering the written comments made by the participant researchers. The voting results for each claim do not include the votes of individuals on the preparatory committee. Only results for the 21 researchers are visible. The preparatory committee stands behind the claims, which is why in practice seven green responses can be added to each claim.

3. CLAIMS

Claim 1

Silvicultural methods can be used to increase wood production in commercial forests. However, it is not possible to significantly increase the net growth of stemwood over upcoming decades. A substantial increase can only be expected during the 2050s or afterwards.

- **Silviculture has increased stemwood growth on mineral soils, and the total area of commercial forests has increased with the inclusion of peatlands into forestry utilization.**
- **Forest fertilization is the most rapid way of increasing forest growth in the near future, but the effects of fertilization on wood raw material quality must be considered.**

Researchers approved the claim in the following way (number of votes):

green	yellow	red	white
13	7		1

Color legend: green= approved as such; yellow = approved with rephrasing; red = basic idea of claim not approved; white = not enough expertise to evaluate the claim.

Viewpoints related to phrasing of claim

The wood production potential of Finnish forests has increased substantially over the last century. Part of this increase has been reached by incorporating new areas into wood production through peatland ditching, while part of the increase has been reached through other silvicultural methods. However, it is important to note that these increases have been attained over a fairly long time span.

The claim is mainly based on the estimate of the combined effects of various silvicultural procedures and Finnish forest age structure, and the temporal responses of these procedures (Hynynen et al. 2015, Henttonen et al. 2017). Fertilization can significantly increase the growth of the current standing stock, but its wide-scale utilization to achieve the additional growth of millions of cubic meters in the short-term is not realistic. It is additionally important to note that although peatland draining has created substantial standing stock growth post-war, this method will not be available in the future.

The term “significantly increase” used in the claim means additional growth of over 10 million cubic meters. Standing stock age class distribution strongly affects the fact that increased growth through silvicultural measures are attainable only after 2050.

Claim 2

Increasing loggings and wood harvesting will decrease the carbon sink and carbon stock of Finnish forests for at least forthcoming decades compared to a situation where they are not increased.

Researchers approved the claim in the following way (number of votes):

green	yellow	red	white
17	4		

Color legend: green= approved as such; yellow = approved with rephrasing; red = basic idea of claim not approved; white = not enough expertise to evaluate the claim.

Viewpoints related to phrasing of claim

The claim does not suggest that the carbon stock of Finnish forests will decrease due to increased harvesting. After increased harvests planned in governmental policies, Finnish forests will remain carbon sinks, i.e. carbon storage of the forests will increase. Growth of carbon storage, however, will be slower than without increased harvests.

Both long-term experiments and modeling studies show that individual forest stand carbon storage will be maximized without harvests. The wood volume of a thinned stand cannot reach that of an unthinned stand during the rotation period, despite the increased growth of the remaining trees. The carbon storage of a thinned stand therefore remains lower than that of an unthinned stand. After regeneration of an old stand, it will take decades until the growth in the new stand equals that of the old stand. Additionally, decomposition of the logging residues from final felling causes carbon emissions for several decades. Soil scarification can also accelerate soil carbon release, but definitive results on this question are still lacking. The strongest explanatory factor behind this claim at the country level is the current age class distribution. The forest carbon sink will not decrease over the upcoming decades when ca. 50% of Finnish forests growing on forestry land are less than 50 years of age, and the share of over 100-year-old forests is less than 5%. An increase in harvesting cannot increase the carbon sink of Finnish forests over the next decades, even if carbon sequestration would be at a lower rate in old forests than the yearly maximum carbon sequestration of forests. The claim also emphasizes the issue that forests are important as carbon storage, not just as carbon sinks. The average life cycle of wood-based products should be increased from the current few years, and the emissions reductions from replacing unrenewable material and energy usage should be increased, so that from the atmospheric viewpoint, regenerating an old forest would not equate to a large carbon storage discharge into the atmosphere.

During the discussions the researchers raised the issue of how impacts of harvesting depend on their allocation and execution. Increasing the intensity and amount of thinnings has a smaller effect than increasing final fellings. Country-level results are also affected by where the increase in harvesting occurs. Special emphasis was given to the situation where growth is larger than removal, in which case forests are aging, natural mortality increases, and the risk or various damages increases. From this it is possible to conclude that the growth of Finnish forests cannot continue indefinitely at the current level, even if harvests are not increased. However, within the timespan defined in the claim, forest growth during is more likely accelerating due to higher atmospheric carbon dioxide concentration, raised temperatures, and forest ditching that has been conducted on peatlands some decades ago.

Claim 3

In the long term, replacing fossil fuels with forest bioenergy produces climate benefits if this replacement is permanent, if forestland remains forest, and if forest growth remains unchanged or increases in the future.

The phrasing of this claim was modified from the original after voting took place. The original phrasing was:

In the long term, replacing fossil fuels with forest energy produces climate benefits if this replacement is permanent, if forestland remains forest, and if forest growth is not endangered in the future.

Researchers approved the claim in the following way (number of votes):

green	yellow	Red	white
20	1		

Color legend: green= approved as such; yellow = approved with rephrasing; red = basic idea of claim not approved; white = not enough expertise to evaluate the claim.

Viewpoints related to phrasing of claim

Accepting this claim without modifications was easy from the start for nearly all the researchers. Discussion was mainly formed on the terms ‘climate benefit’ and ‘long term’. In this context ‘long term’ implies a timespan of more than 100 years. The realization of bioenergy climate benefits only in the long term relates to the fairly slow growth rate of trees in Finland, and the fact that wood-based energy releases more carbon dioxide per produced energy than what is released from fossil fuels. Wood harvesting additionally decreases forest carbon sinks more than the amount of carbon contained in utilizable wood.

Increasing wood energy utilization also produces short-term climate benefits if rapidly decomposing logging residues and thinning material smaller than industrial wood are directed to energy usage instead of stemwood. However, their utilization rates remain fairly small. The basis of this claim is the average forest energy raw material base in Finland, which also includes the forest energy used and produced by industry.

The discussion in the expert seminar noted that forest biomass has an advantage as a replacement for fossil fuels, despite that climate-positive emissions effects are currently not visible even in the mid length – term. Terminating fossil fuel utilization is essential.

Claim 4

The greatest wood utilization climate benefits are gained through wood-based long-lasting products, whose carbon content can be kept in use for extended periods, and which replace products with large-emissions during their life cycles.

> **- Increasing harvesting and directing wood into the current forms of use will not produce climate benefits for decades at the least. Here, the current forms of use are defined as products and bioenergy with life cycles similar to current products and energies, and upholding of their current shares.**

Researchers approved the claim in the following way (number of votes):

green	yellow	red	white
13	8		

Color legend: green= approved as such; yellow = approved with rephrasing; red = basic idea of claim not approved; white = not enough expertise to evaluate the claim.

Viewpoints related to phrasing of claim

Currently approximately half the raw wood carbon content is directed to energy utilization in the manufacturing processes of both chemical and mechanical forest industry products, and is immediately released into the atmosphere similarly as during wood energy utilization. Wood energy increases atmospheric carbon dioxide content for the long time (compare with previous claim). Pulp is used to mainly produce cardboard and paper, whose carbon contents are also rapidly released into the atmosphere (less than ten years). Wood products manufactured into saw timber often store their carbon content for decades to come, which raises their status from the climate impacts viewpoint compared to current chemical forest industry products. Replacement benefits from wood construction are additionally better currently if they can be used to replace concrete and steel. However, of the total wood use, clearly less wood is directed into wood construction compared to pulp production. The climate impact of both chemical and mechanical forest industry products are negatively impacted by wood harvesting, decreasing forest carbon sinks more than what the utilizable wood contains carbon. Considering these viewpoints, increasing wood utilization with the portfolio of current wood products does not produce climate benefits for decades to come. According to certain studies this may even take centuries. This claim is supported e.g. by the studies of Pukkala (2016) and Soimakallio et al. (2016).

Several researchers that wished for rephrasing of the claim wanted clearer expression for what is meant by climate benefit. It means a situation, where forest utilization has released less greenhouse gases into the atmosphere compared to if wood had not been used. Certain researchers did not consider it self-evident that wood utilization will inevitably lead to climate benefits. According to them, wood utilization can also lead to climate drawbacks.

Certain researchers wished for extra mentioning in the sub-clause beneath the main claim that here only Finland is in the focus. Several researchers also wanted extra wording for how ‘use similar to current use’ is understood. The new phrasing suggestions concretely meant that the product distribution of wood-based products and the shares between their volumes are similar to the current situation.

Claim 5

Analyses should be used to complete the model calculations showcasing the future development of Finnish forests, which have been produced for political decision-making concerning forest utilization. These analyses should consider:

- **various climate change scenarios**
- **changes in nitrogen availability and in other factors that affect tree growth and soil emissions**
- **the risks involved in carbon storage persistence (e.g. the effects of pests and storms) and the magnitude of these effects**
- **other climate agents besides carbon effects (albedo, aerosols, black coal)**
- **the trends in the demand of wood-based products and the availability of imported wood affecting the volume of domestic harvests.**

The phrasing of this claim was modified from the original after voting took place. The original phrasing was:

The model calculations used to describe the future development of Finnish forests for political decision-making concerning forest utilization are laid on too narrow a foundation. Model examinations and supplementary analyses are needed that concurrently consider:

- various climate change scenarios, changes in nitrogen availability, and the risk assessments of increasing disturbances (pests, storms)
- the risks involved in the stability of forest carbon storage caused by changing conditions, and the magnitude of these effects
- other climate-affecting factors besides carbon effects (albedo, aerosols, black coal)
- the potential changes in the availability of imported wood
- the demand changes of future wood products

Researchers approved the claim in the following way (number of votes):

green	yellow	red	white
13	7		1

Color legend: green= approved as such; yellow = approved with rephrasing; red = basic idea of claim not approved; white = not enough expertise to evaluate the claim.

Viewpoints related to phrasing of claim

In connection with this claim, some of the researchers particularly emphasized the narrowness of the knowledge base used in decision-making compared to existing research knowledge. The effect of future Finnish forest development and the various wood use scenarios on forest carbon balance have been modeled using several different models. Results gained by various models predicting the future development of forest carbon sinks differ clearly from each other. However, calculations guiding decision-making have mainly focused on the quantitative and qualitative development of (wood production) forest resources, while climate change, and the growth change and risk assessments connected to it, have scarcely been considered. Additionally, the scenarios depicting forest effects have nearly solely been made using the forestry analysis and planning software MELA. With increasing future uncertainty, it is important for decision-makers to understand the narrowness of these scenario models. This means the recognition and quantification of the uncertainty created by the background assumptions made by the various modeling studies and the uncertainty caused by the differing structures of the various models. The need for increasing understanding of these uncertainties caused by long-term forest growth was particularly emphasized. On the other hand, the discussions noted that decisions are always made with imperfect knowledge, and the timescale of political actions, e.g. when looking at the reference levels of forest carbon sinks, is considerably short from the research viewpoint.

Claim 6

The goals set for various forest utilization methods, such as for wood production, carbon sequestration, conservation, and recreation, compete with each other, and most probably cannot be achieved concurrently.

- **Assessment methods for measuring the development of climatic, economic, biodiversity, ecosystem, and recreational impacts due to forest utilization must be developed, and their use in decision-making should be increased from current levels.**

The phrasing of this claim was modified from the original after voting took place. The original phrasing was:

The goals set for various forest utilization methods, such as for wood production and recreation, compete with each other, and most probably cannot be achieved concurrently.

- Assessment methods for measuring the climatic, economic, ecosystem, and recreational effects development of forest utilization must be developed, and their use in decision-making should be increased from current levels.

Researchers approved the claim in the following way (number of votes):

green	yellow	red	white
11	10		

Color legend: green= approved as such; yellow = approved with rephrasing; red = basic idea of claim not approved; white = not enough expertise to evaluate the claim.

Viewpoints related to phrasing of claim

Various utilization methods were generally not considered exclusive of each other, and the competitive situation between the utilization methods is seen as very versatile. Despite this, it is nearly impossible to concurrently accomplish individual methods in full. Combining wood production and recreational use was considered easy. Goals for biodiversity and carbon sequestration were considered more contradicting with wood production and/or harvesting goals. Researchers also questioned whether goals have actually even been set for the various utilization methods. Certain researchers also stated that there is inconclusive information on how the various utilization methods compete with each other, i.e. how strongly various ecosystem services compete against each other. Alternative phrasing suggested for the claim included: “Various forest utilization forms, such as wood production and recreation, can have partially contradicting goals, in which case all goals cannot be realized concurrently” and “The goals set for various forest utilization forms, such as wood production and recreation, compete against each other”.

Including carbon sequestration in the claim was considered important, and ‘utilization method’ was suggested to be replaced by ‘ecosystem services’. Certain utilization methods/ecosystem services were generally viewed as easy to combine, while others may compete strongly against each other. In any case, researchers believed that compromises will have to be made between the various utilization methods. Time perspective was also considered to influence the actualization of the claim. Discussion was also held over how much of each utilization method should be used from the viewpoint of land use.

Claim 7

A significant increase in forest harvests may lead to clear weakening of forest biodiversity, unless the matter is adequately considered when implementing silvicultural practices and conservation networks.

The phrasing of this claim was modified from the original after voting took place. The original phrasing was:

A significant increase in forest utilization may lead to clear weakening of forest biodiversity, unless the matter is adequately considered when implementing silvicultural practices and conservation networks.

Researchers approved the claim in the following way (number of votes):

green	Yellow	red	white
15	4		2

Color legend: green= approved as such; yellow = approved with rephrasing; red = basic idea of claim not approved; white = not enough expertise to evaluate the claim.

Viewpoints related to phrasing of claim

Forest are the single most important habitat for endangered species in Finland. Thirty six percent of all endangered species live primarily in forests. As a whole, changes in forest habitats are the primary cause of endangerment for nearly 700 species (Rassi et al. 2010). Forest regeneration and management actions are additionally the most significant reason for endangerment and threat to Finnish nature types (Raunio et al. 2008). Various actions have been used to slow down the development of endangerment, but current measures are not sufficient in stopping it (Juslén et al. 2016). Researchers from the Natural Resources Institute Finland (Luke) and Finnish Environment Institute (Syke) have investigated how harvesting carried out according to various bioeconomy scenarios affect forest biodiversity (Korhonen et al. 2016). The report clearly notes the need to increase protection and enhance conservation measures in commercial forests, if forest biodiversity does not want to be weakened through increased harvesting.

Researchers involved in the voting suggested rephrasing the term ‘significant’, so as to narrow down its interpretation. In this context significant means the approximately 15 million m^3 increase in logging outlined by the government.

4. PRIORITIZED RESEARCH THEMES

The three near-future research themes prioritized in the expert seminar (8.12.2016):

1. The effects of silviculture on forest growth and development
2. Substitution benefits of wood products
3. The importance of time span on assessing the climate effects of forests

The research topics have not been arranged in order of importance.

GLOSSARY

Carbon sink = forest carbon storage growth; a positive change in forest carbon balance.

Carbon source = a decrease in forest carbon storage; a negative change in forest carbon balance.

Carbon storage = the carbon in living and dead organic matter in and on top of the soil.

Change in carbon balance = standing stock growth + soil-bound carbon – trees removed in harvest – carbon released from soil – carbon released from decomposition of litter on top of soil. All these changes are calculated during a specific time frame (e.g. per year).

Carbon sequestration = the uptake of a carbon-containing substance, particularly carbon dioxide (CO2) from the atmosphere in a land or sea environment.

Climate benefit = a condition, where forest utilization has caused less greenhouse gas emissions to the atmosphere than if wood would not have been used.

Climate drawbacks = a condition, where forest utilization has caused more greenhouse gas emissions to the atmosphere than if wood would not have been used.

LITERATURE

BIOS 2017. Tutkijoiden julkilausuma: Suomen metsänkäyttösuunnitelmat kiihdyttäisivät ilmastonmuutosta ja heikentäisivät luonnon monimuotoisuutta. 24.3.2017.

Hynynen, J., Salminen, H., Ahtikoski, A., Huuskonen, S., Ojansuu, R., Siipilehto, J., Lehtonen, M., Eerikänen, K. 2015. Long-term impacts of forest management on biomass supply and forest resource development: a scenario analysis for Finland. European Journal of Forest Research 134: 415-431. DOI 10.1007/s10342-014-0860-0

Ilmastopaneeli 2013: Pingoud, K., Savolainen, I., Seppälä, J., Kanninen, M., Kilpeläinen, A. Metsien käytön ja metsäbioenergian ilmastovaikutukset. Suomen ilmastopaneeli. Raportti 2/2013.

The Finnish climate change panel 2015: Seppälä, J., Kanninen, M., Vesala, T., Uusivuori, J., Kalliokoski, T., Lintunen, J., Saikku, L., Korhonen, R., Repo, A. 2015. Climate impacts of forest use and carbon sink development . Report 3/2015.

Juslén, A., Pykälä, J., Kuusela, S., Kaila, L., Kullberg, J., Mattila, J., Muona, J., Saari, S. & Cardoso, P. (2016). Application of the Red List Index as an indicator of habitat change. Biodiversity and Conservation 25: 569–585.

Koljonen, T., Soimakallio, S., Asikainen, A., Lanki, T., Anttila, P., Hildén, M., Honka-tukia, J., Karvosenoja, N., Lehtilä, A., Lehtonen, H., Lindroos, T.J., Regina, K., Salminen, O., Savolahti, M. & Siljander, R. 2017. Energia ja ilmastostrategian vaikutusarviot: Yhteenvetoraportti. Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja 21/2017. 106 p.

Korhonen, K.T., Auvinen, A-P., Kuusela, S., Punttila, P,, Salminen, O., Siitonen, J., Ahlroth, P., Jäppinen, J-P., Kolström, T. 2016. Biotalousskenaarioiden mukaisten hakkuiden vaikutukset metsien monimuotoisuudelle tärkeisiin rakennepiirteisiin. Luonnonvara- ja biotalouden tutkimus 51/2016.

Henttonen, H.M., Nöjd, P., Mäkinen, H. 2017. Environment-induced growth changes in the Finnish forests during 1971–2010 – An analysis based on National Forest Inventory. Forest Ecology and Management 386, 22-36.

Pukkala, T. 2016. Does management improve the carbon balance of forestry? Forestry 2016; 1–11, doi:10.1093/forestry/cpw043.

Soimakallio, S., Saikku, L., Valsta, L., Pingoud, K. 2016. Climate change mitigation challenge for wood utilization – the case of Finland. Environmental Science and Technology 50(10), 5127–5134.

Raunio A., Schulman A., Kontula T. (2008). Suomen luontotyyppien uhanalaisuus – Osa 1. Tulokset ja arvioinnin perusteet. Suomen ympäristö 8:1–264.

Rassi, P., Hyvärinen, E., Juslén, A., Mannerkoski, I. (toim.) (2010). Suomen lajien uhanalaisuus – Punainen kirja 2010. Ympäristöministeriö & Suomen ympäristökeskus, Helsinki. 685 s.

Valtioneuvosto 2015. Kansallinen metsästrategia 2025. Valtioneuvoston periaatepäätös 12.2.2015. Maa- ja metsätalousministeriö 6/2015.