Impacts of faster growing forests on wood properties with consideration of the potential effects of a changing climate on species choice (FASTFORESTS)

FINAL REPORT

Title of the research project	**Impacts of faster growing forests on wood properties with consideration of the potential effects of a changing climate on species choice]**
Coordinator of the project	Conor O'Reilly

BASIC PROJECT DATA

Project period	01.06.2014-31.05.2017
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URL of the project	http://www.fastforests.eu/

FUNDING

Total budget in EUR	797087
Public funding from Wood Wisdom-Net Research Programme:	Total funding granted in EUR by source:
France Ministry of Agriculture, Fisheries and Forestry Resources (MAAF)	157516
French Environment and Energy Management Agency (ADEME)	113586

Germany
Agency for Renewable Resources (FNR)   175543

Ireland
Department of Agriculture, Food and the Marine   350442
(DAFM - Cosford Programme)

Other public funding:

[Name of the funding organization, Country]   [amount in EUR]

Other funding:

EU, Sweden   17000 scientific services + 650 travel = 17650

ECC Teo Sawmills   5000 services (drying and x-ray scanning of boards)

[Name of the funding organization, Country]   [amount in EUR]

PROJECT TEAM (main participants)

Name	Degree	Job title	Sex (M/F)	Organization	Country
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Vilius Gendvilas	BSc	Researcher	M	UCD	Ireland
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Maarten Nieuwenhuis	PhD	Researcher	M	UCD	Ireland
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DEGREES

Year	Degree	Name	University	Supervisor of thesis	Supervisor's organization
2017	MSc	Alba Cabrera Berned	UCD	Maarten Nieuwenhuis	UCD
2017	MSc	Vilius Gendvilas	UCD	Conor O'Reilly	UCD
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PROJECT SUMMARY REPORT

The intensification of forest management offers a potential solution to the foreseen increase in demand for timber. But this intensification is not without its problems: these include a perceived decline in timber quality and negative perceptions among the public. This project focused two forest tree species: Sitka spruce (*Picea sitchensis* (Bong.) Carr.), the mainstay of Irish forestry and Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco.) which is a potential alternative candidate species for Norway spruce in the context of climate change in the three partner-countries.

The future climatic conditions in Ireland are likely to impact negatively on Sitka spruce growth rates so applying more intense management may not lead to increased production. It also appears that current management is close to optimal, so further gains through intensification may be modest, while at same time a reduction in timber output is expected because of climate change. Sitka spruce will be the wood processing industry's species of choice because it is forecasted to continue to be suitable in most of the country and because of silvicultural inexperience with and lack of markets for many of the alternative tree species. Unlike the other partner countries who may plant more Douglas fir instead of Norway spruce, an alternative candidate species for Sitka spruce has not been identified for Ireland. Nevertheless, current management practices need to be modified if Ireland is to sustainably increase the domestic timber supply and avoid or minimize any risks associated with climate change.

The results of this study suggested that current practice in Ireland of planting Sitka spruce at 2 x 2 m is close to optimal in relation to timber properties. However, dominant trees had the lowest quality timber, which suggested that management practices (e.g. thinning) could be changed to optimise wood quality. Visual assessment provides an indication of board MOE for Douglas fir in Germany. Log stiffness, based on measurements from acoustic tools, could be used to help segregate timber in the forest in both Sitka spruce and Douglas. With the same measurement technology is it possible to identify how forest management effects timber quality in the early stages of forest development.

Intensifying forest management practices can be socially acceptable if more timber is to be produced from existing forests. Other means of producing more wood from existing forests need to be identified. Improved communication among all stakeholder groups is needed so that, amongst other things, so that the reasons for applying certain practices are understood.

1.1 Introduction

1.1.1 Background

The intensification of forest management offers a potential solution to the foreseen increase in demand for timber. But this intensification is not without its problems: these include a perceived decline in timber quality and negative perceptions among the public. This project focused two forest tree species: Sitka spruce (*Picea sitchensis* (Bong.) Carr.), the mainstay of Irish forestry and Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco.), which in the context of climate change, may be a viable alternative species to Norway spruce in the three partner-countries. The project set out to test some of these assumptions and to recommend changes in practices that might help address some of these concerns.

1.1.2 Objectives

The main aim of the study was to determine if certain fast-growing species could be more intensively sustainably managed to maximise wood production in the context of a changing climate, while at same time meeting requirements for timber quality and the public's reassurance for an environmentally friendly forest industry.

Three specific objectives:
  i) To use modelling approaches to assess sustainable management options for optimising the quantity of future wood supply from forests using fast-growing species/ provenances.
  ii) To develop new approaches for the allocation of raw material to end products, increasing efficiency in production and reducing waste.
  iii) To identify means of improving the social acceptability of intensively managed forests.

1.2 Results and discussion

The impact of climate change and silvicultural practices on Sitka spruce stands in Ireland were assessed using Irish dynamic yield models (Growfor) and the Climadapt software, the Irish Ecological Site Classification System. Growfor models were used to forecast the impact of different thinning intensities and initial planting spacings, on the potential production of timber and the associated revenue, in Sitka spruce stands from YC10 to YC24. In general, stands planted at close spacings (1.7 m square) and thinned at light intensities (60-80% of Marginal Thinning Intensity (MTI)) using a 5-year thinning cycle, would produce the greatest volume.
Overall productivity was lower in widely spaced stands than in closer spaced ones, except for the unthinned stands. The financial analysis, which results in shorter rotations, indicated higher profit when wider spacings where considered, even when including harvest residues as an assortment in the analysis. The reasons for this are the higher establishment costs at high stocking densities and the low value of the harvest residue assortment. However, these management practices will have to be adapted to the new climate and soil conditions predicted for the coming decades, paying special attention to increasing risks, such as waterlogging, windthrow and drought.

Timber properties of standing Stika spruce trees in Ireland were measured indirectly using non-destructive methods based on acoustic velocity and Pilodyn penetration to estimate density. These measurements were compared with measurements made after processing. Dominant trees had a lower quality of timber compared to co-dominant and sub-dominant trees, with the best timber quality being produced by sub-dominant trees.

In Germany, national inventory data were used to forecast Douglas fir volume differentiated by age and diameter classes using the WeHAM model. The predictions were based on growth models using established silvicultural management systems. The results showed a clear differentiation of potential sawable roundwood volume, depending on the age structure of the stands.

In Germany, Douglas fir trees of different age (32, 42 and 78 years) were selected to form a matrix of artificial time-series analyses. All logs were scanned with an x-ray based CT scanner and boards sawn from selected logs were subjected to visual quality assessment and grading, and non-destructive testing for mechanical characteristics (MOEdyn) using resonance measurements. The age classes varied strongly from each other with relation to diameter increment, crown development, and internal stem structure.

Douglas fir is considered a fast-growing species in France with good mechanical properties. The species requires heavy and early thinning, with the exact prescription being primarily dictated by the initial planting density and the target final density. Several silvicultural practices are followed in France to encourage rapid over a 40-year rotation, delivering a high proportion of trees with a diameter >50 cm. Simulation of available volume performed in 2004 for 2012 suggested that current models fit the data very well. An estimation of available volume for 2020 to 2040 indicated a shortage of wood in France by 2040.

Timber demands for housing in France could be partially met by the expansion of Douglas fir forests, coupled with silviculture schemes to promote faster growth. There are some concerns in the industry over the impact of faster growth on timber quality. To investigate this, model chains for predicting wood quality were employed. The results showed that face a potential 20% decrease of the mechanical performance of Douglas fir in wood coming from intensively managed stands compared to control stands.

Higher planting densities increased timber quality in Sitka spruce in Ireland. However, stem twist reduced the yield of structural timber by 37%. The high proportion of juvenile wood affects timber stability and causes distortion, which may reduce the yield of structural timber.

Table 1. Impact of planting densities on subsequent strength class		
Planting density, trees ha-1		Strength class
1550 to 1850	Low	C14
2350 to 2550	Medium	C16
3100 to 3700	High	C18

Dynamic MOE of butt logs accounted for 71% of the variation in mean MOE, 48% of the variation in mean bending strength and 37% of the variation in clear wood density of timber boards in Sitka spruce. Acoustic tools proved to be useful in prediction of timber grade determining properties before processing. The timber quality prediction model developed for Douglas fir roundwood grade from tree parameters (quality classes A, B, C, D according to RVR 2015) reached an accuracy of 50% correct classification.

The classification for board visual strength (based on information on position within the tree and the log (heartwood/sapwood, tree height and log position) reached 45% correct for cants, and 63% for boards in Douglas fir.

The planting of more southerly provenances of a forest species may be one option to help mitigate the potential adverse effects of climate change on timber output. The efect of provenance choice on timber quility is not fully understood. Wood MOE of nine provenances of Sitka spruce in Ireland was assessed using acoustic velocity. Windthrow of an existing field trial reduced sample size considerably, so provenance effects were not significant. Further investigation is needed to determine if provenances differences in timber properties can be detected.

Social acceptance and stakeholder expectations of intensively cultivated forests
The social acceptability of intensified forest management practices and stakeholders' perceptions of the role of wood in construction in Ireland and France were investigated. Most stakeholder groups surveyed in Ireland and France believe that the current intensity of many forest management practices are unacceptable and showed a clear preference for a less intensive forest management approach. Generally, harvesting of large areas, having conifer-dominated stands and the use of chemicals in forests were not considered acceptable. At the same time, the need to intensify forest management and increase timber production is accepted by most respondents in both countries. Thus, some compromise needs to be reached. The study identified those practices which many respondents (i.e. >50%) found acceptable. Harvesting of areas < 4 ha and regular thinning is acceptable in both countries. Over 50% of stakeholders in both countries would accept stands with up to 50% conifers. In Ireland, the main quality factors that timber stakeholders along the supply- and demand-chain sought were good structural strength and a consistent high

quality in terms of moisture content, knots, and twist of boards. In France, the industry believes that wood still has a great potential for development, especially in construction. They are aware that silviculture impacts the quality of their products but their views on how intensification will potentially influence quality vary, with some expecting it to have negative consequence and others seeing it as an opportunity to improve quality.

1.3 Conclusions

The future climatic conditions predicted for Ireland are likely to negatively affect Sitka spruce growth rates. Sitka spruce is likely to remain the wood processing industry's species of choice and it is forecasted to continue to be suitable in most of the country. In addition, there is insufficient silvicultural experience with other fast-growing species and a lack of markets for many of the alternative tree species. Although the species is expected to continue to be suitable in most of the country (66%), climate change is expected to reduce its productivity levels by up to five yield classes at a national level during this century. The application of more intensive management practices may not lead to increased production. The current practice in Ireland of planting Sitka spruce at 2 x 2 m is close to optimal in relation to timber properties, but dominant trees had the lowest quality timber. Management (e.g. thinning) and other measures (breeding) should be directed towards reducing the number of dominant trees in a stand, thus resulting in more uniform stands. Foresters and sawmills might be interested having less variability in timber properties within the stand.

Against this forecasted reduction in potential growth and the high demand for forest fibre, the need arises to develop innovative management practices to sustainably increase the domestic timber supply and avoid or minimize any risks associated with climate change. If the clearfell system continues to be the main silvicultural system in Ireland, this research has demonstrated that to maximise both production and revenue from stable Sitka spruce stands, foresters should apply thinning to recommended levels presented in the study (60 to 80% of the MTI for most of the yield classes) on a 5-year cycle, rather than leaving the stands unthinned.

Silvicultural options, such as exploiting the possibility of using more productive alternative species and provenances on certain sites and changing forest practices to help alleviate the adverse effects of future climatic conditions on forest productivity, are required. Further research is needed to comprehensively tackle these issues over the longer term. For example, the accuracy of developed models is acceptable (66%) at this stage of the process, but future work could be devoted to increasing the accuracy of the models. Greater engagement with timber processors may help address some of their concerns in relation to timber quality.

Visual assessment provides an indication of board MOE for Douglas fir in Germany. Log stiffness based on measurements from acoustic tools could be used for segregating timber in the forest before the logs reach the sawmill. The approach may also be suitable for Sitka spruce. Acoustic velocity on standing trees provides a strong indication of log (i.e. measured soon after harvesting) dynamic MOE and undried board (measured soon after processing) dynamic MOE. This relationship becomes weaker with increasing tree and log height. With the same measurement technology is it possible to identify how forest management effects timber quality in the early stages of forest development.

Intensifying forest management practices has been a major cause of conflict in the past; any further intensification is likely to lead to further conflict. The study indicates practices that will be social acceptable if more timber is to be produced from existing forests. However, it has also shown that many of the practices being considered are not acceptable. Other means of producing more wood from existing forests need to be identified; e.g. the use of mixed species/age stands managed under alternatives to the clearfell system need to be investigated further. At the same time, there is a need for better communication among all stakeholder groups so that, amongst other things, a better understanding of why certain practices are being adopted can be obtained.

1.4a Capabilities generated by the project

The project has generated new knowledge about forest management intensification and how it impacts on timber quality. The effects of dominance class on timber quality had not been previously studied in Ireland and it also confirmed some existing knowledge. New data have been collated to complement existing databases and refine the understanding of silvicultural management, tree growth and wood quality for Sitka spruce in Ireland and Douglas fir in Germany and France. New models have been developed describing the relationship between silviculture based on input from standing and felled trees and timber quality.

Unpublished master's theses
Cabrera Berned, A. 2017. The potential impact of forest intensification on forest productivity and wood mobilisation under different climate change scenarios. Unpublished MScAgr thesis, University College Dublin.
Gendvilas, V. 2017. Effect of initial spacing and provenance on the quality of Sitka spruce timber. Unpublished MScAgr thesis, University College Dublin.

Unpublished doctoral theses
Simic K, Multi-scale evaluation of the influence of planting density on the properties of Sitka spruce, late 2017, unpublished

1.4b Utilisation of results

A national one-day seminar held on 25 May 2017 in Ireland promoted the findings of the research and their potential use by the forest industry. This event was attended by 50 individuals from the forest industry, research and forestry businesses. In a post-event evaluation report, many participants commented on the value of material presented and the panel discussions held during the day. A similar event was held in France, 30 May 2017. A new model describing the growth of Douglas fir was developed in France. This will be further developed. New knowledge generated in Ireland and Germany will be explored further before being transferring the results into practice. Interim results are transferred to the industry via seminars and local workshops. Recommendations for changes in practices are also via seminars directed towards the industry and research updates and information notes distributed through professional associations.

This project has fostered the development of research links among the partners that did not exist before the project started. These links are likely to continue as the partners share common research aims in their research goals and interests. Some of the research results of the project are being used in the preparation of new proposals. One MSc student has commenced his PhD in the University of Tasmania. He will study spacing and thinning effects on eucalypt wood properties as well as product quantity and quality.

1.5 Publications and communication

a) Scientific publications

1. Articles in international scientific journals with peer review

Articles in preparation
*Simic, K., Gendvilas, V., O'Reilly, C., Nieuwenhuis, M., and Harte, A.M. (2017) The Influence of Planting Density on Modulus of Elasticity of Structural Timber from Irish-grown Sitka spruce. International Journal of Design & Nature and Ecodynamics Vol. 0, No. 0. Accepted for publication.
*Cabrera Berned, A. and Nieuwenhuis, M. The potential impact of forest intensification on forest productivity under different climate change scenarios. Submitted to Irish Forestry, expected to be published in November 2017.
*Lanvin, J-D. et al. Modelling mechanical wood properties of fast growing French Douglas fir Expected 2018 in Annals of Forest science
*Gendvilas, V. and O'Reilly, C. Effect of initial spacing and dominance class on the quality of Sitka spruce timber, paper in preparation.

2. Articles in international scientific compilation works and international scientific conference proceedings with peer review

Simic, K., Gendvilas, V., O'Reilly, C., Nieuwenhuis, M., and Harte, A. The Influence of Planting Density on Modulus of Elasticity of Structural Timber from Irish-grown Sitka spruce. Published in Proceedings of Timber Structures 2017, 1st International Conference on Timber Structures and Engineering, 13-15 June 2017, New Forest, UK, pp 105-114; Presented on 15/06/2017

3. Articles in national scientific journals with peer review
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4. Articles in national scientific compilation works and national scientific conference proceedings with peer review

Simic, K., Gendvilas, V., O'Reilly C., Nieuwenhuis, M., Harte, A: "The effects of planting density on the structural properties of 23-year-old Irish grown Sitka spruce", In Proceedings of Civil Engineering Research in Ireland Conference, August 29-30, 2016, Galway, Ireland, pp 551-555.

5. Scientific monographs
[-]

6. Other scientific publications, such as articles in scientific non-refereed journals and publications in university and institute series

Cabrera Berned, A. (2017) The analysis of the impact of climate change on forest productivity in Forestry and Energy Review (Ireland)

a) Other dissemination
Posters at conferences
Simic, K., Harte, AM., (2017) Effects of forest intensification on the properties of sawn timber, Poster presentation, 2017 National Forestry Conference, Enfield, 31/05/17
National seminar in Ireland and project website http://www.fastforests.eu/seminar-24-may-2017-ucd-ireland/

1.6 National and international cooperation

The project participants held annual face- to- face meetings. In between these meetings were virtual meeting using Skype or similar. In Ireland industry supported the project by assisting researchers in locating suitable field sites, providing access to staff, existing field trials, inventory data, drying of boards and the x-ray scanning of boards. Each partner brought to the project a skill set and/ equipment and experience that was of benefit to the other partners: experimental approach, access to technology, modelling and datasets. Items of equipment was provided on loan among the consortium.