

CoFoRD

Final Report

“Improving Timber Forecasts - ForecastModel”

DAFM Project Reference No: 14/C/824

Start date: 01/06/2015

End Date: 30/06/2018

Principal Coordinator and Institution: Dr Niall Farrelly, Teagasc

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Collaborating Research Institutions and Researchers: Prof Maarten Niewenhuis, UCD

Please place one “x” below in the appropriate area on the research continuum where you feel this project fits

Basic/Fundamental	—————→	Applied/Pre Commercial				
				X		

Please specify priority area(s) of research this project relates to from the National Prioritisation Research Exercise* (NRPE) report;

Priority Area (s)	L, B and Research for Policy
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Key words: (max 4) *Growth, Yield, Forecasting, Forest Management*

1. Rationale for Undertaking the Research

This section should outline the rationale for carrying out the research and identify the need / problem to be addressed

Timber forecasts have increased in importance in Ireland in recent years and serve to guiding planning and investment decisions on the infrastructure required to mobilise the forest resource. It is estimated that significant increases in timber volume are forecast in the next two decades and that the annual Net Realisable Volume will increase from 3.95 million m³ in 2016 to 7.86 million m³ by 2035 (Phillips et al. 2016).

While information on timber supply and production forecasts for state-owned forests are available from Coillte's Inventory and planning system, information about the private sector is less reliable owing to limited Inventory data, which are used as an input into the production model, the lack of knowledge about the management intentions of private forest owners and lack of information on accessibility of private plantations for thinning. However, there have been a number of specific developments which have the potential to improve timber supply forecasting systems for the private sector. Included in these are the potential to incorporate Forest Management Plans (FMP) into future private sector forecasts, the development of improved productivity estimate for Sitka spruce, and revised Management assumptions for private forests.

The ForecastModel Project is aimed at improving the private sector timber production forecast by addressing key components of the production forecasting chain, notably:

1. Assess how forest management plan data could be incorporated into improved future forecasting;
2. Develop methods for predicting the productivity estimate of private forest stands.
3. Investigate the potential of further integration of the Irish dynamic yield models into the national roundwood forecast.

2. Research Approach

Specify the research methodologies employed, emphasising novel techniques and also outline any modifications from the original approved project proposal

The research objectives were addressed by employing a combination of expert reviews, empirical modeling and scenario analysis.

The first study focussed on the potential of using forest management plans (FMP) for forecasting, the assessment of the management intentions of private forest owners, and on assessing the accessibility of private plantations. The potential for using detailed information on species, age, thinning status, top height, DBH/BA that may be available in new FMP for private forests was examined. For other forests that have no FMP data, more limited inventory information on age, top height/yield class, thinning status and spacing is likely to be available from older management plans or planting records in the Forest Service, DAFM.

Where FMP data are available, the potential exists to use the Irish Dynamic yield models (IDYM-GROWFOR interface) to generate more reliable forecasts; where lower quality data are available the BFC yield tables/models can be utilised. To assess if differences exist in volume output estimates using the two methods (FMP data and IDYM versus lower-quality data and BFC models), we derived forecast volumes for 201 stands of Sitka spruce and compared the results.

The impact of utilising more detailed inventory data for national roundwood forecasts was examined using a test dataset of private plantations in Co. Roscommon covering 50 stands of Sitka spruce. The dataset contained detailed information on basal area, top height, mean diameter breast height, stems per hectare and thinning status, and stands were grown forward to a reference period with the IDYM. This was compared to other scenarios based on more limited data being available; measured yield class in the field (field YC), and predictions of yield class using site classification models (local YC and national YC). The method using national YC was based on the same procedure as in the current All-Ireland Forecast, which was used as the baseline for projected forecast volumes and the sensitivity analysis of crop parameters. Stands were treated as per the rules of the All-Ireland Forecast and outputs were compared to determine if differences were apparent in forecasted volume between the methods.

In order to understand private forest owners' management intentions, the knowledge of which would assist with determining the appropriateness of using FMP data for national forecasting, a survey of 85 representative forest owners was carried out. Other elements of forecasting examined included assessing the reliability of the thinning assumptions in the All-Ireland forecast project by examining the thinning status of a sub-sample of 50 private forests in the field. In addition a protocol for assessing the harvesting potential of forests, using information on species, site productivity, access, location relative to markets, and timber quality, all of which will influence how and when these stands will be harvested was developed.

A second study focussed on develop methods for predicting inventory parameters. A dataset of Sitka spruce (n=130) was used to generate a productivity estimate for Sitka spruce using the relationship between yield class and site factors. A national model was developed, as well as a local model that takes into account the local variability in soil quality. Models were validated using an independent dataset (n=63). Analysis to ascertain whether other inventory parameters (top height, dbh, stocking, basal area) can be modelled based on site factors for stands that lack management plans or complete inventory data was also carried out.

A third study to investigate the potential incorporating the IDYM into a national round wood supply forecasting system was conducted. A scenario analysis was developed to compare volume output for stands with varying levels of inventory detail for a test dataset of 67 stands of Sitka spruce. Where the full suite of inventory parameters was available, the Irish Dynamic Yield Models were used to generate stand volume (base line). For other scenarios, the deterioration in the level of available data was simulated and missing parameters (sph, dbh, basal area and top height) were generated using the British Forestry Commission yield models (Forest Yield; Mackey, 2015) based on a given age, yield class, planting spacing and thinning status, and these estimated parameters were used as surrogate data in the IDYM. Four scenarios were assessed as follows:

- S1: Base line - Full inventory information available for use in IDYM (e.g. age, sph, top height, dbh, basal area)
- S2a: Missing basal area data (age, sph, top height, are available)
- S2b: Missing dbh data (age, sph, top height, dbh are available)
- S3: Missing sph, dbh/basal area (age and top height are available)
- S4: Only age and predicted yield class are available

In scenario 4, the local yield class model was used to assign an estimation of yield class to a stand based on easily obtainable site characteristics. The outputs of the scenario analysis were investigated to determine the impact of missing parameters on the accuracy of outputs.

Finally a time study was conducted based on the collection of data for the various parameters required as input values into the four scenarios. Relevant data on the additional time required for collecting

detailed inventory information versus more limited information were assessed. The time required to collect data were then scaled up to stand level.

3. Research Achievements/Results

Outline main results achieved

A comparison of volume output from 201 stands modelled using the IDYM data (top height, basal area, stocking, age) and the BFC yield models (measured yield class, species, spacing) is presented in Figure 1. For the BFC yield tables, two models are presented - the “forest yield” model (in green) was used to cover a wider range of stands with spacings not present in the original Edwards and Christie (1981) models. At an overall level, results indicate that volume output using the “forest yield” is not significantly different ($P < 0.41$) from that using the IDYM. Differences in volume output using the Edwards and Christie (1981) yield tables were apparent ($P < 0.05$) owing to a more limited number of models available and differences in stocking and basal area for stands.

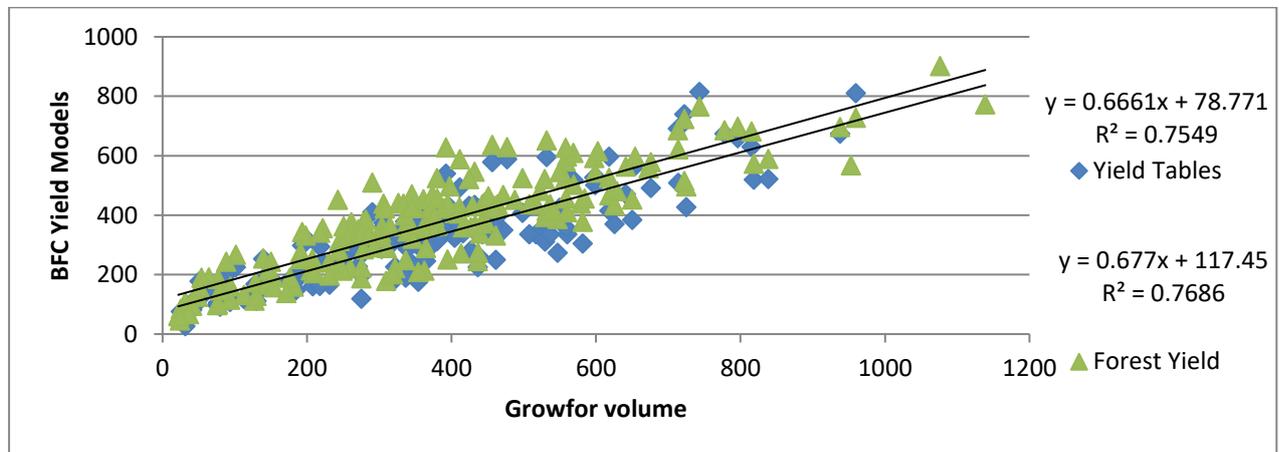


Figure 1: Relationship between total standing volume from IDYM and from BFC yield models for a range of Sitka spruce stands in Ireland.

A comparison of forecasted output from 2016 to 2035 for 50 private stands of Sitka spruce in Co. Roscommon indicated that where detailed FMP stand data were available a 35% increase in forecasted volume was apparent compared to the current methodology used in the All-Ireland forecast (Figure 2). The use of measured yield class and local yield class also resulted in a considerable increase in forecast volume, somewhere in the order of 25% over the current All-Ireland Forecast. The local yield class prediction model was more strongly correlated with measured field yield class than the national yield class estimate used in the All-Ireland forecast. The local yield class includes an estimate of local fertility, resulting in more precise local level estimates. Currently, these data have not been digitised for the whole country, but this could be completed in a relatively short time period. Other findings indicated that the number of stands in receipt of a thinning was in excess of those in the All-Ireland forecast.

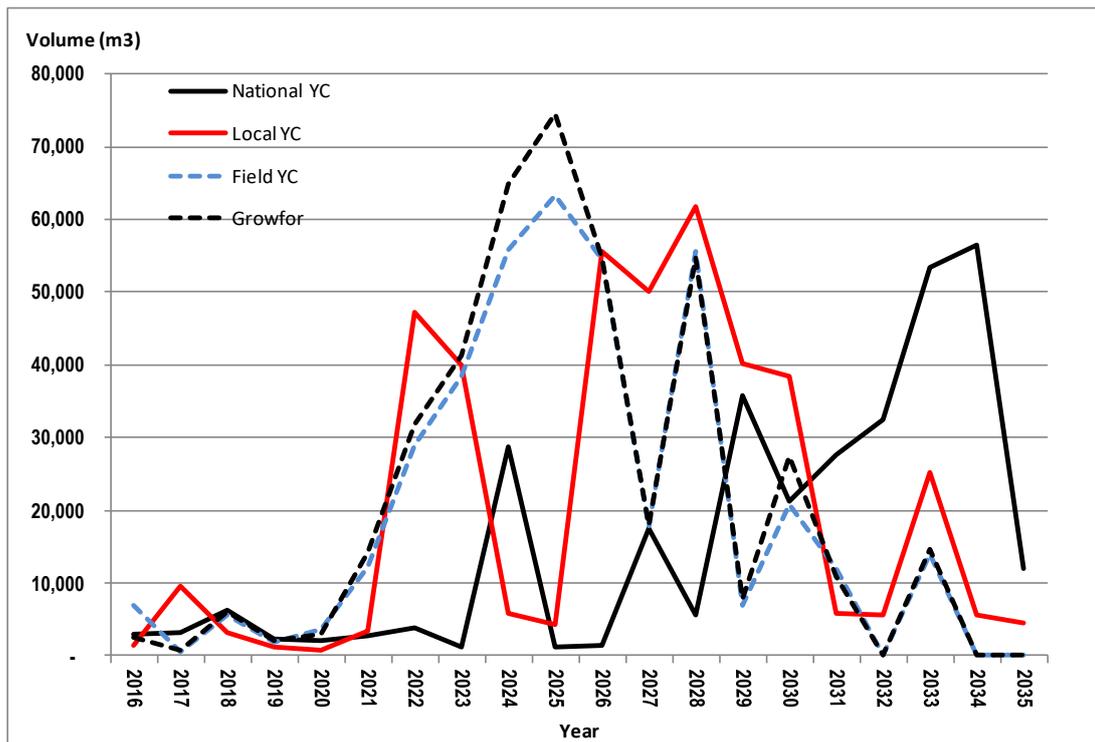


Figure 1: Sensitivity analysis of annual forecast volume for 50 private stands of Sitka spruce in Co. Roscommon

While the use of FMP data show increased output and may be the preferred basis for forecasting, only 55,000 hectares of private forest may be currently subject to the proposed new FMP, with 6% of the private estate potentially available for the next private sector forecast in 2021-2040.

The reliability of FMP data as a basis for forecasting may be subject to owners' intentions. A survey of 85 forest owners indicated that 66% of owners were aware of the existence of a FMP, while 44% were aware of the details of the plan. A total of 32% of owners indicated that they would adhere to every aspect of the FMP. One of the main reasons for deviation from the FMP was that owners required flexibility in management to harvest. All forest owners selected to participate in the survey had forests >10 hectares, which ensured that they had forest management plans. Considering the results of the survey and the area available for the FMP, this may indicate a quite limited potential to utilise FMP data in the next All National Forecast.

Results from the access survey indicated that 64% of stands were thinned, a considerably lower amount than the 84% of stands deemed to be suitable for thinning based on the All-Ireland forecasting thinning assumptions. A total of 54% of stands were in agreement. Of the 34% of stands that remained unthinned, the survey concluded that these were highly suitable for thinning, indicating that the owner had not pursued active management of the forest. It was also noted that a number of stands were harvested prematurely. With regard to rotation length, 4 out of the 50 stands had being felled significantly earlier than the assumptions about rotation length in the All-Ireland Forecast rules.

A study to assess the harvesting potential of forests stands concluded that most conifer crops that could produce commercial logs are considered harvestable. However, when the end product is lodgepole pine suitable for firewood or biomass, the harvestability is dependent on mean tree size, reforestation and haulage costs. Broadleaved crops capable of producing commercial sawlog are harvestable provided they are yield class 8 or higher. Based on the assumptions, these rules could be extremely beneficial to assist national forecasting efforts and may indicate revised rotations for biomass or firewood crops.

Two models were developed to provide an improved productivity estimate for Sitka spruce - a national model and a local model, the latter takes into account of local variability in soil quality. The local model includes windspeed, parent material fertility class and whether the crop is first rotation or second rotation. The national model uses windspeed, parent material and crop rotation. Both models were validated on an independent dataset (n=67) with the local model (Figure 3) showing improved performance over the national model (local: $R^2 = 0.45$; average error is $0.39 \text{ m}^3 \text{ ha}^{-1} \text{ an}^{-1}$ compared to national: $R^2 = 0.43$, error of 0.95). In 66% of cases the local model predicts the yield class within $\pm 4 \text{ m}^3 \text{ ha}^{-1} \text{ an}^{-1}$.

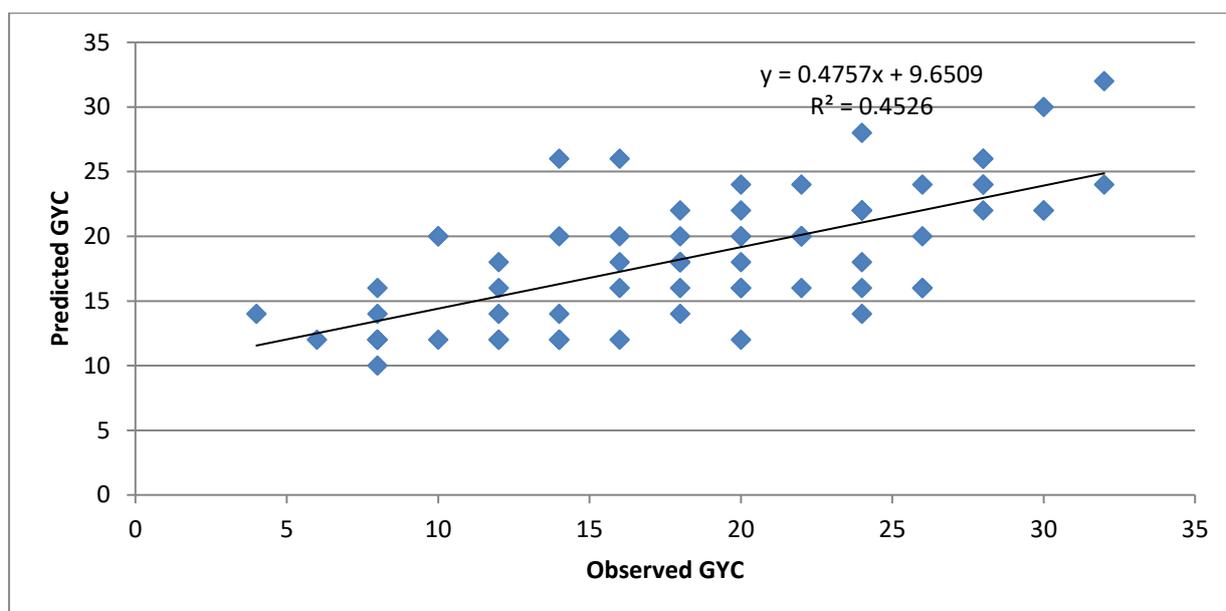


Figure 3: Observed versus predicted yield class for the local yield model on an independent dataset of 67 stands.

The results of the scenario analysis to compare volume output for stands with varying levels of inventory detail is presented in Table 1. For all stands combined (n=67) differences in mean total volume range from -6 to +11% for scenarios 2 to 4 compared to the baseline. On an individual stand level errors are larger, with average percentage volume errors in the scenario 2a and 2b at -13%. Of the two scenarios presented in scenario 2, scenario 2a where basal area is estimated from the Forest Yield tables shows a better fit than scenario 2b which is significantly different from the baseline ($P < 0.05$). Scenario 3 which uses top height and age to calculate yield class and where basal area and stocking is derived from "forest yield" shows an average volume error of 18% with 50% of stands within volume with 20% of the baseline. As expected in scenario 4, where yield class is estimated and all other attributed are derived from "Forest Yield", on average a larger mean error of 35% in volume prediction was observed. Considerable improvements for scenarios 2a, 3 and 4 are apparent when under stocked stands are removed from the analysis with all showing lower percentage errors for volume calculation.

Table 1: Volume output from four different scenarios of data quality using the IDYM.

Scenario	Description	Vol. m ³ ha ⁻¹	% Vol. error All stands	% Vol. error Full stocked	Diff (P<0.05)
1	Baseline	372			
2a	Missing Basal Area	341	-13.0	-8.0	0.71
2b	Missing Dbh	494	-13.0	-14	0.01
3	Measured Yield Class	343	19.0	15	0.81
4	Predicted Yield Class	338	37.0	10	0.83

A preliminary assessment of the time required to collect crop attributes was contrasted against changes in the precision of volume forecasts through the various scenarios. Scenario 1 which represents the preferred basis for forecasting took on average 75 mins per stand, including journey getting there. Scenario 2 represented stands lacking DBH/BA data, this scenario resulted in a 33% increase in time savings and a decrease in accuracy of forecasted volume by 8% for fully stocked stands provided basal area was calculated. In Scenario 3, similar time overheads to scenario 2 were encountered to collect top height and resulted in an under prediction of forecasted volume by 15 percent for fully stocked stands when compared to scenario 1. Scenario 4 represents no overheads in terms of field data collection or travel to site, but required the use of a refined production model to generate an estimate of local yield class. This scenario resulted in a reduction in forecasting accuracy by 15% when compared to scenario 1.

Although Scenario 4 has good potential to generate accurate national forecasts, at a stand level there was significant variability in forecasted volume error. This makes it less useful for local level forecasting purposes. Scenario 1, 2a and 3 have greater potential to forecast at a local level with higher levels of accuracy.

4. Impact of the Research

A summary of the impact of the research should be provided through the project outputs and outcomes however please provide a synopsis of the benefits / improvements the research has made to the area under investigation. Outline the benefits of the research to end users, e.g. industry, consumers, regulatory authorities, and scientific community etc

The research was aimed at providing tools that may assist in producing better estimates of the roundwood volume available to end-users by taking into account recent advances in research, data availability and GIS technology. The research has indicated that more accurate forecasts from private forests can be driven from the use of the Irish Dynamic Yield Models (IDYM). Where FMP data are available this should represent the preferred basis for forecasting. The use of alternative methods to derive forecasts of production show much potential including the use of British Forestry Commission Yield Models to fill in missing data required to generate forecasts using the IDYM. Where data such top height and age and/or yield class are available for stands, results of this study indicate that forecasts can be improved considerably over current methods. These methods could be used to increase the reliability of future forecasts of production.

The on-going development of improved methods of forecasting future roundwood supply from our expanding forest resource is paramount to the development of a sustainable forest industry in Ireland, which has multiple end use objectives including the provision of raw material for industry, the creation of jobs in forest harvesting / transport and processing facilities and the substitution of fossil fuels to meet renewable energy targets. The All Ireland forecast estimates that by 2028 the production capacity of Ireland's forests will almost double to 7 million m³, from the current 3.79 million m³.

The outputs of this research will provide the tools to derive improved estimates of volume output from private sector forests in Ireland and it will allow for a continuous refinement in forest growth and yield modelling capability. The research has succeeded in evaluating methods for improving roundwood supply estimates.

The development of more robust forecasts will help to generate the confidence needed by industry and potential investors in allowing them to quantify with greater accuracy any risks around future raw material supply. This in turn will instill confidence to the growing sector and help attract new entrants as well as encourage existing owners to expand where possible. It is expected that many of the advancements of this research will be available for the next private sector forecast due in 2020.

The scientific community has benefited from the research carried out in expanding their knowledge of growth and yield modelling. Staff in both organisations working on this project, Tegas and UCD, have developed new expertise in the area of growth and yield forecasting, and the fact that the Masters student was taken on by Coillte was to a large extent based on the expertise he had developed during this project.

4(a) Summary of Research Outcomes

(i) Collaborative and Industry links developed during this research

Links with the Forest Service, DAFM, including the National Forest Inventory team were created.

(ii) Outcomes where new products, technologies and processes were developed and/or adopted

Not relevant.

(iii) Outcomes with economic potential

The results of this research should significant potential to increase the accuracy of national forecasts, therefore with potential to increase confidence in timber processing and assisting in industry investment decisions. It increases the reliability of decisions especially at a local level allowing more informed decision to be made to further increase timber mobilisation efforts.

(iv) Outcomes with national/ policy/social/environmental potential

The results of this research have immediate potential to assist national forecasting efforts which are coordinated by Forest Service, DAFM. It will allow for the development of a more refined forecast that will have improved accuracy and provide information on the accuracy of the results. The research may suggest that the use of the IDYM in a revised methodology for the National Roundwood Forecast would improve significantly the accuracy of the results. This research provides a template for this to be achieved.

In addition results presented here suggest that the forest owner management intentions are less rigid than previous assumptions of management intentions. Overall, these results in increased accuracy of forecasts at national and local level.

4 (b) Summary of Research Outputs

(i) Peer-reviewed publications, International Journal/Book chapters.

Acceptable Format: Walsh, D.R., Murphy, O., Cosgrave, J. (2008). Echinococcosis - an international public health issue. Research in Veterinary Science 774, 891-902.

None published to date but there are plans to publish at least one from the project.

(ii) Popular non-scientific publications and abstracts including those presented at conferences

A research note will be prepared and will be submitted to COFORD for consideration for publication as a COFORD connects.

(iii) National Report

None

(iv) Workshops/seminars at which results were presented

1. Forestry Walsh Fellow Day in Teagasc (Athenry) in May 2016 with Teagasc researchers and technicians. Presentations on their research were given by Cian O' Connor.
2. Teagasc Walsh Fellow day (Dublin) in October 2016 with Teagasc researchers and technicians. Presentations on their research were given by Cian O' Connor.
3. A one-day seminar on Forest Management, Forecasting and Timber quality on 24 May, 2017, at UCD. Presentation entitled "Factors influencing the occurrence of windthrow in forest stands during Storm Darwin" given by Cian Gallagher.
4. Growth and Yield Modelling workshop organised by COFORD/Forest Sector Development, July 2017. Attributing stand productivity for Forecasting purposes and related topics presented by Dr Niall Farrelly.
5. Presentation of the ForecastModel project at European Forestry Institute Summer School in Waterford, June 2017
6. Poster presentation at Forestry and Energy Show, Stradbally, Co. Laois, May 2017. ForecastModel Project Developing methods that can improve private sector roundwood forecasts
7. Poster presentation at Talking timber, Ballyhaise, Co. Cavan. Sept 2017. The ForecastModel Project

(v) Intellectual Property applications/licences/patents

None.

(vi) Other

None.

5. Scientists trained by Project

Total Number of PhD theses: _____

Please include authors, institutions and titles of theses and submission dates. If not submitted please give the anticipated submission date

Total Number of Masters theses: _____

Please include authors, institutions and titles of theses and submission dates. If not submitted please give the anticipated submission date

Cian O'Connor stated his Masters research in 2015, but before completing it took up a position with Coillte.

6. Permanent Researchers

Institution Name	Number of Permanent staff contributing to project	Total Time contribution (person years)
Teagasc	1	0.44
UCD	1	0.09
Total	2	0.53

7. Researchers Funded by DAFM

Type of Researcher	Number	Total Time contribution (person years)
Post Doctorates/Contract Researchers		
PhD students		
Masters students	1	1.0
Temporary researchers	1	1.5
Other		
Total		2.5

8. Involvement in Agri Food Graduate Development Programme

Name of Postgraduate / contract researcher	Names and Dates of modules attended
None	

9. Project Expenditure

Total expenditure of the project: €146,382.00

Total Award by DAFM: €197,138.35

Other sources of funding including benefit in kind and/or cash contribution(specify): €

Breakdown of Total Expenditure

Category	Teagasc	UCD	Name Institution 3	Name Institution 4	Total
Contract staff	69,178.77				69178.77
Temporary staff					
Post doctorates					
Post graduates		23,381.51			23,381.51
Consumables	143.88				143.88
Travel and subsistence	9,530.58	2,687.48			12,218.06
Sub total	78,853.23	26,068.99			104,922.22
Durable equipment		624.70			624.70
Other	9358.41				9,358.41
Overheads	23,655.97	7,820.70			31,476.67

Total	111,867.61	34,514.39	146,382.00
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10. Leveraging

Summarise any additional resources'/funding leveraged by this award from other sources i.e. Additional Staff, National/EU funding secured, EI Commercialisation Fund

We are grateful for the support of the Forest Service, DAFM in the preparation of the forest owner survey and in the feedback about the project through a number of project meetings. Feedback regarding the use of Forest Management plans and data within the Forest Service was extremely useful in guiding the direction of the project. Henry Phillips an independent consultant who was involved in the National Roundwood Forecasting project and who has a particular interest in timber forecasting was also involved in the project. His involvement allowed the potential of forest management plans and the quantitative work on assessing data quality on forecast output was invaluable and provided a better understanding of how to improve national timber forecast efforts.

11. Future Strategies

Outline development plans for the results of the research.

There is significant potential to capitalise on the results of the research in time for the next All-Ireland National Forecast of timber production. The potential of fully integrating the IDYM into future forecasts is now possible and will result in increased accuracy of forecasts. The advantages of ground sampling which can collect crop data and supplementary data on access, thinning and harvesting potential of stands and serve to derive improved management options should be considered. The trade-off between accuracy and cost may need to be considered. Further work on the refinement of productivity models is planned and the use of top height as an indicator of volume production which may further improve accuracy. Further research is necessary to validate the growth function and the thinning function of the IDYM, this can be achieved through future research. A greater effort will be necessary to understand the management intentions of private forest owners, who may opt for flexible management options which may need to be more fully represented in forecasting modelling efforts. In addition a greater understanding of the dynamics of broadleaved and diverse conifer crops would be advantageous.

12. Consent to Publish Final Report on the DAFM Website and/or Through Other Dissemination channels

I consent to this report being made available to the public, through the Department's website and other dissemination channels. *

Yes No

13. Declaration

I declare that the information contained in this final report is complete and true to the best of my knowledge and belief.

Signed: _____ *Niall Jamnelly* _____ Project Coordinator

Date: 20/07/2018

*IPR sensitive information that the coordinator does not wish to make public should be highlighted in red font. All text in red font in this report will not be made publicly available by DAFM.

Guidelines for the Completion of Final Report

The attached Final Report Template should be completed for DAFM projects funded under the **2006, 2007, 2008, 2010 and 2011** Calls.

The aim of the final report is to provide a summary of all aspects of the research project. A final report is required for all projects and a percentage of the grant award will be withheld until it is submitted and deemed satisfactory.

Please note that the Department of Agriculture, Fisheries and the Marine may publicise information included in the Final Report. **All sections of the report must be completed.** Incomplete reports will not be accepted by DAFM and will be returned to the project coordinator for completion.

Two copies of the final report are required, 1) a signed hard copy and 2) an electronic copy.

A guideline of up to 400 words per relevant section is recommended.

Project Details

The project title, project reference number and actual start and actual finish date should be noted. Indicate on the research continuum from basic/fundamental research to applied/pre-commercial research where you feel the research project fits by placing 'x' in the most appropriate box. Indicate in the section provided **the priority area of research**

this project relates to from the National Prioritisation Research Exercise* (NRPE) report, There are 14 priority areas of Research as follows;

A Future Networks & Communications	H Food for Health
B Data Analytics Management, Security & Privacy	I Sustainable Food Production and Processing
C Digital Platforms, Content & Applications	J Marine Renewable Energy
D Connected Health & Independent Living	K Smart Grids & Smart Cities
E Medical Devices	L Manufacturing Competitiveness
F Diagnostics	M Processing Technologies and Novel Materials

In addition, key words relating to the project should be included in this section.

*<http://www.agriculture.gov.ie/research/14researchprioritisationactionplans>

1. Rationale for Undertaking the Research

This section of the final report should provide background information on why the research was needed. It should clearly outline the reason for carrying out the research and identify the problem / knowledge gap that needed to be addressed. It should address the question 'why was this research needed?'

2. Research Approach

Information provided on research approach should address the questions 'how the research was carried out?' Details should include work carried out and research methodologies used to address the issues identified in the 'rationale for undertaking the research'. Emphasis should be placed on novel techniques, materials, technology and equipment used. Scientific or technical difficulties encountered in the research and any significant modifications from the original proposal must be noted. Please note that this section does not require fine scientific detail, but is designed to give the reader an overall view of the research methods employed.

3. Research Achievements/Results

This section is simply designed to address the question 'what are the results of the research'. Emphasis should be placed on novelty and innovation. Tabulated scientific results are not required but a succinct summary of results obtained from each task should be illustrated.

4. Impact of the Research

A summary of the impact of the research should be provided through the project outputs and outcomes. The benefits / improvements the research has made to the area under investigation should be elucidated. Specifically, describe how the outcomes of the research have benefited the end users such as industry, consumers, regulatory authorities, policy makers and the scientific community.

4(a). Summary of Research Outcomes

The outcomes reported must detail the wider effect of the project from a sectoral or national perspective; these may be in the medium or long term. The summary of research

outcomes is a critical component of the final report. It is imperative that this section is completed fully and precisely, as DAFM is required to report on the outcomes of all research projects. In addition, this data is essential to DAFM in justifying value for money of its research programmes and in securing future funding. Therefore, please ensure that information in this section is accurately reported.

4(b). Summary of Research Outputs

Research Outputs are what are produced by the project in terms of activities, events, services that reach people. The summary of research outputs is a critical component of the final report as it provides quantitative data on the research. It is imperative that this section is completed fully and precisely, as DAFM is required to report on the outputs of all research projects. In addition, this data is essential to DAFM in justifying value for money of its research programmes and in securing future funding. Therefore, please ensure that information in this section is accurately reported.

5. Scientists trained by the project

The total number of PhD and MSc theses produced as a direct result of work carried out on this DAFM project should be noted. In addition, the authors, institutions and titles of the theses and submission dates should be specified. If theses have not been submitted before completion of the final report, please give details including the anticipated submission date.

6. Permanent Researchers

The number of permanent research staff who contributed to the project (on a cost neutral basis) per institution and associated time contribution must be captured.

7. Researchers Funded by DAFM

Details of numbers, total time contribution (in months) and of all, post doctorates (PD) & contract researchers; PhD students; Masters students; temporary researchers and other staff funded by DAFM should be included.

8. Involvement in Agri Food Graduate Development Programme

The names of students / researchers that participated in the Agri Food Graduate Development Programme should be included in addition to the names and dates of modules undertaken.

9. Project Expenditure

The aim of this section is to provide a summary of expenditure during the lifetime of the project. Please note that it is imperative that all figures included in this section correspond to figures included in the last progress report submitted and evaluated by DAFM. The names of the institutions involved must be included in the tables provided.

10. Leveraging

The aim of this section is to summarise any additional resources'/funding leveraged from this award from other sources e.g. Additional Staff (type of staff, value of staff secured), National/EU funding secured, EI Commercialisation Fund

11. Future Strategies

Future strategies to further develop the outputs of the research should be indicated. If the outputs of the research have not been taken up by end users, explain why this is the case. What further advances / work is required in your area of research in order for the outputs to be taken up by industry / consumers / end users? What follow-on research is required in this area to realise an end product? If further funding is required for research in this area, where do you intend to apply for funding e.g. Enterprise Ireland?

12. Consent to Publish Final Report on DAFM Website

The coordinator should indicate whether or not they consent to the publication of this final report on the DAFM website and/or through other dissemination sources. IPR sensitive material will not be published. The coordinator must indicate sensitive material by highlighting the text in red font where appropriate in the final report.

13. Declaration

The project coordinator must sign and date the report. Unsigned reports will be deemed incomplete and will not be accepted. The coordinator must also indicate their consent to the publication of this final report.