Project FCP-263: BIOFORCE (BIOmass FORestry CrEation): Creating geospatial data systems to upscale national forestry-based biomass production

Biomass Feedstocks Innovation Programme

Final Report

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Author: Verna Earth Solutions Ltd

Contents

Introduction

This is the final report for Project BIOFORCE (BIOmass FORestry CrEation): Creating geospatial data systems to upscale national forestry-based biomass production, funded by the Department for Energy Security and Net Zero under the Net Zero Innovation Portfolio, Biomass Feedstocks Innovation Programme.

This report summarises the aims, outputs, and outcomes of the project, delivered through work carried out between May 2022 and April 2024 by Verna, Forest Research, Cranfield University, and a range of expert partners and contributors.

This report was prepared in April 2024, when the project's involvement in the Biomass Feedstocks Innovation Programme was discontinued because of capacity constraints at Verna. Work on the outputs and outcomes of this project continues at all of the organisations involved, including to ensure that the sector-wide benefits of the outputs produced by the project are realised.

The entire project team are extremely grateful to the Department for its support for this project over the past two years, and in its prior phase, without which these sector-wide benefits would not have been possible.

Project aims

This project aimed to create and demonstrate new, upgraded versions of:

- **Verna's ForestFounder geospatial data system**.[i] ForestFounder assesses land areas for overall forestry potential at large scale and speed, taking into account factors related to: biophysical suitability/potential of different species; local impacts of tree-planting (e.g. environmental, socio-economic, cultural/historical), which also affect chances of regulatory approval; and forestry economics. It has been used widely to support landowners, investors, and stakeholders.

- **Forest Research's Ecological Site Classification system (ESC)**[ii], a decision support system which provides site-level data on climatic and edaphic suitability across many tree species. ESC is the industry-standard tool for site-level analysis, used hundreds of times per day across the sector. For most biophysical factors, ForestFounder uses datasets imported from ESC.

- **Cranfield University's Yield-SAFE**[iii] **and Farm-SAFE**[iv] **models**, which provide modelling of yield and economic returns from agroforestry relative to tree-only and agricultural systems.

The upgrades would result in new versions of ForestFounder and ESC, with significant new capabilities in a number of areas including:

- **Widening the range of species and forestry types** covered beyond Long Rotation Forestry, to include Short Rotation Forestry (SRF), Short Rotation Coppice (SRC), and agroforestry.

- **Improving how the impacts of climate change on forestry potential are accounted for**, including by moving ESC to using a probabilistic model accounting for changing likelihoods of climatic extremes, based on the latest UK Climate Projections 2018[v] data.

- **Upgrading ESC's yield-modelling engine** to effectively capture underlying tree and soil physiological processes to constrain the current knowledge base, improving representation of tree growth under changing climates.

- **Expanding ForestFounder's geographical coverage** beyond England, to include Scotland and Wales.

- Providing a self-service interface for ForestFounder.

The project would also produce new, publicly available versions of Yield-SAFE and Farm-SAFE, updated with the latest available data, to feed into ForestFounder and ESC and be available as a standalone resource.

The overall aim of these innovations is to support increases in sustainable biomass production[1] within the UK, by providing tools which enable landowners, investors, and stakeholders to better identify suitable sites for forestry-based production and use higher-yielding, more climate-change-resilient approaches.

Work delivered

Primary activities

Across the two years of this project, a substantial amount of novel and innovative work has been carried out, which has led to the project achieving the majority of its key aims. This section summarises the work delivered; sections 4 and 5 summarise the resulting outputs and outcomes.

The key workstreams have included:

- Data gathering for SRF (a range of species), SRC (willow and poplar), and agroforestry management systems (focused on poplar and sycamore): This has included:

  - A wide range of new data gathered from sites across Great Britain, including for example over 16,500 individual tree measurements from 11 SRF sites, 975

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[1] In line with the approach of the Biomass Feedstocks Innovation Programme, "biomass production" is used here in its widest sense. For example, this includes biomass production for chemical feedstocks, timber, and carbon sequestration, in addition to biomass for energy.

individual assessments from 3 SRC sites, and 510 individual tree measurements from 3 agroforestry sites.

- o Dendrochronology (tree core sampling) assessments across 3 of the sites, yielding circa 12,500 individual growth year data points for agroforestry and circa 4,600 individual growth year data points for SRF.

- o Researching and processing data from historical trials, that had not previously been collated and analysed. For SRF, this covered 14 replicated trials across the UK, representing 37 site assessments over 14 years post-establishment and circa 400,000 individual tree assessments. For SRC, it covered 54 sites and a total data warehouse of 1.6 million individual stem assessments.

- **Economic data gathering and analysis for agroforestry**: Forest Research and Cranfield collaborated to widely survey the literature and produce a comprehensive Excel data repository on woodland-related costings for agroforestry, including operational costings, grant aid, and woodfuel prices.

- Wide-ranging upgrades to ESC: This has included:

  - o Inclusion of new species based on analysis of new data (e.g. hybrid aspen, eucalyptus).

  - o Inclusion of new climate datasets, including based on UK Climate Projections 2018 data. This includes data allowing modelling risks of extreme conditions e.g. extreme drought, extreme cold.

  - o New growth/yield modelling approaches based on modelling underpinning physiological processes.

  - o Consequent revisions to models and results for a range of species e.g. including Sitka spruce, Scots pine, beech, including changes to yield estimates and a new drought risk indicator to help account for the risk of extreme drought events.

- **Upgrading, and providing documented, publicly available versions of the Yield-SAFE and Farm-SAFE models**: Yield-SAFE is a biophysical model that predicts the growth of trees and crops in agroforestry, tree-only, and crop-only systems. Farm-SAFE compares the financial benefits and costs of crop-only, tree-only, and agroforestry systems in rotations of up to 60 years.

- **Extending ForestFounder to cover Scotland and Wales**: Prior to this project, ForestFounder was only applicable to land within England. This workstream involved researching the different conditions, regulatory environments, and datasets in Scotland and Wales, creating a version of ForestFounder which is applicable to Scotland and Wales, and carrying out test runs of the model in Scotland and Wales.

- **Demonstrating ForestFounder through landowner partnerships in Scotland and Wales**: Prior to this project, ForestFounder had been applied extensively to many land areas in England as part of commercial projects. This workstream demonstrated ForestFounder's new capabilities in partnership with two landowners in each of Wales (Ministry of Justice, National Trust) and Scotland (Farr Estate, anonymous by choice). As part of these partnerships, the landowners also received surveys of their land from

professional foresters, supporting them to make better-informed tree-planting plans. This workstream also involved assessing some land in England surrounding the former route of HS2 Phase 2b.

- **Creating a self-service web-based version of ForestFounder:** Prior to this project, ForestFounder analyses were only delivered via tailored engagements agreed with clients, with outputs provided as geospatial data files for viewing in GIS software. In this workstream, an entirely new webapp was developed, allowing users to specify any land parcel via a point-and-click interface and receive an immediate breakdown across the parcel of its potential areas of suitability for different forestry types. Software development included creating a bespoke codebase for processing the enormous number of geospatial operations involved (e.g. many millions of polygon intersections) within a tractable timescale, plus a tailored front-end user interface for this set of use cases. This workstream also included testing the app, both internally and with a range of external test users.

In addition to all of the above work on the project's core innovations, work was carried out to generate a range of wider benefits. This included extensive work to disseminate the project's learnings (e.g. through stakeholder presentations, workshops, and training sessions), and the creation of opportunities for skills development (e.g. a successful student placement within the project team).

Project Management

The project was formally divided into 15 work packages, the spend incurred and progress against the project ambitions, is summarised in Table 1 below.

Table 1 - Progress against contracted work packages

ID	Workpackage Name	Project Partner Lead	Description (inc. Key tasks)	Actual Spend
1	Extend LRF ForestFounder to Scotland and Wales	Verna	Code extension of current (LRF-only) version of ForestFounder to all of GB, following plan developed in Phase 1.	£5,972
2	Test partnerships	Verna	Apply ForestFounder to real challenges in partnership with landowning organisations, check results (inc. on-the-ground), implement learnings/improvements in product.	£65,453

ID	Workpackage Name	Project Partner Lead	Description (inc. Key tasks)	Actual Spend
3	Continuously improve impact and commercial modelling	Verna	Update commercial, biomass supply impact, and environmental impact modelling, including based on data collected from test partnerships.	
4	Create ESC data for future climate change	Forest Research	Gather and analyse underlying UKCP18 climatic data to enable ESC to better adjust for climate change (across all species).	£114,905
5	Social / market research on agroforestry options	Verna	Establish typology of options, carry out research with agricultural sector on cultural and economic drivers, and determine agroforestry modes likely to be viable and acceptable for widespread deployment.	£11,302
6	Gather data for SRF, SRC, and agroforestry species	Forest Research	Data mining and field work to generate input data for ESC5 on new tree species required to model SRF, SRC, and agroforestry.	£208,640
7	Agroforestry yield and economic modelling	Cranfield University	Quantitative modelling of agroforestry growth rates and economics, by extending Cranfield models and using input data from FR fieldwork.	£110,484
8	Build and test ESC5	Forest Research	Code, test, and finalise new version of ESC covering SRF, SRC, and agroforestry, and better accounting for future climate change.	£158,905
9	Extend ForestFounder to cover SRF, SRC, agroforestry, and better account for climate change	Verna	Integrate ESC5 data, to expand ForestFounder to cover these species / forestry types, across GB, and using new, improved ESC5 future climate modelling.	£0

ID	Workpackage Name	Project Partner Lead	Description (inc. Key tasks)	Actual Spend
10	Build and test self-service ForestFounder	Verna	Code engine and interface for web version, and test/iterate to completion with real users.	£52,362
11	Build ForestFounder2	Verna	Integrate elements to create final ForestFounder2: operating GB-wide, based on ESC5 (inc. SRF, SRC, agroforestry, and better climate projections), and with self-service version.	£0
12	Final testing and demonstration	Verna	Final testing of full version, working with stakeholders to check full range of species/forestry types, check results, implement learnings/improvements and finalise.	£0
13	Continuously update / improve Commercialisation Plan	Verna	Ongoing improvements to Commercialisation Plan, including based on updated modelling, with updates at least quarterly and formal review by governance at least annually.	£0
14	Social value activities	Verna	Unified work package covering student placements, webinars for land managers, awareness-raising, and additional dissemination activities.	£23,520
15	Project management	Verna	Unified work package covering all project management, governance, and reporting - including mandatory BEIS requirements.	£46,670

Project outputs

The work described in the previous section resulted in the creation of a range of valuable outputs, in line with the original project plan. This section summarises these outputs.

Some of these outputs are already publicly available, and where this is the case links are provided.

Some of the project's key outputs include:

- **A new, upgraded version of ESC**: The new version of ESC, incorporating the advancements described above, has also been rebuilt with a new front-end user interface (using RShiny), and a new set of documented webservice endpoints for the ESC models and underpinning UK Climate Projections 2018 data across all four Representative Concentration Pathways (RCPs 2.6, 4.5, 6.0, and 8.5). The webservice endpoints enable third parties to integrate ESC within their own systems, facilitating the use of ESC within the research community and enterprises involved in developing afforestation schemes and/or forest management. At the time of writing, the ESC application programming interface (API) developed in this project is in use directly by six private companies and is central to their business activity. The new versions of ESC can be accessed at the live and test environments hosted at https://escapp.frdss.org.uk/[vi] and escapp.forestdsstest.org.uk[vii] respectively. The documentation for the ESC API can be found at ESCAPIs - Swagger UI (frdss.org.uk)[viii].

- **New versions of Yield-SAFE and Farm-SAFE**: This includes Yield-SAFE v2[iii], and associated detailed documentation on its calibration and use[ix],[x], and Farm-SAFE v3[iv] and its documentation[xi].

- **ForestFounder for Scotland and Wales**: ForestFounder's capabilities for use in Scotland and Wales are complete and demonstrated. It is now applicable in these nations to the same level of functionality as within England, extending its capability to the whole of Great Britain. (Potential to extend to Northern Ireland is currently limited by the availability of datasets across the island of Ireland, however work is underway under separate projects to progress this.)

- **Self-service ForestFounder webapp**: There is now a fully working and tested webapp in place. It is currently in a private, further testing stage, prior to commercialisation.

Challenges and Barriers

- **Agroforestry partnership on social research** fell through requiring a replacement solution whereby Verna Earth engaged a commercial research organisation to generate data sought.

- **HS2 Fieldwork did not progress** – partly due to the scale of desk preparation required, and partly due to the uncertainties surrounding HS2.

- **Internal capacity constraints** – resulted in the project being discontinued a year early.

Project outcomes

As a result of this project, substantial contributions have been made to the overall objective of the Biomass Feedstocks Innovation Programme (increasing sustainable biomass production) and to the forestry sector as a whole.

The core innovation outcomes include:

- **ForestFounder is now available in Scotland and Wales**, providing a new option for landowners and stakeholders in these nations to better identify, plan, and manage sites for forestry-based biomass production.

- **Self-service ForestFounder is ready for final testing and rollout**, so in the future can provide a new option for GB landowners at any scale to better identify, plan and manage sites for forestry-based biomass production.

- **The new Yield-SAFE and Farm-SAFE models are publicly available**, enabling land managers everywhere to better assess their potential yields and economic returns from a range of agroforestry options (relative to tree-only and crop-only systems).

- ESC is now available with UK Climate Projections 2018 data, a new user interface, revised/extended species models, and a documented API. This provides a significantly advanced ESC service to the entire sector, allowing landowners / forest management organisations to better model their options and build climate resilience into their plans. The API provides a consistent, scalable, and robust way to access ESC models and data, and this has also stimulated the development of additional services incorporating elements of the Woodland Carbon Code (streamlining the use of ESC and carbon lookup tables into a single web-based request).

In addition to these direct innovation outcomes, further benefits of the project include:

- **Significant advances in the underpinning evidence base** for forestry-based biomass production and geospatial tools in this domain. The bulk of this work will be openly available, including through scientific journal papers which are in preparation, and open datasets which will become available including in subsequent versions of ESC.

- **Raised awareness across the sector** (for example through multiple workshops and training sessions) of the potential of forestry for faster / more resilient biomass production, and the potential of geospatial systems to enable this.

- **Contributions to skills development within the sector**, upskilling people on forestry, biomass production, and geospatial functionality – for example through training sessions and providing a student placement.

As part of the project, modelling has been carried out to estimate the potential impact on national biomass supplies of the upgraded versions of ForestFounder and ESC produced by this project. Under conservative assumptions on market uptake and consequent impact on land-management decisions, the headline estimates include:

- An increase in annual UK sustainable biomass growth in 2050 of ~984,000 oven-dry tonnes/year.

- An increase in annual UK biomass harvest in 2050 of ~716,000 oven-dry tonnes/year (~15-20% of current national production).

- A permanent increase in UK natural carbon stocks (related to land-use change towards forestry) of ~4.4m-26.5m tonnes CO_2e.

As described in the following section, at completion of its involvement in the Biomass Feedstocks Innovation Programme the project is on-track to achieve all of its intended outputs, and therefore to enable the outcomes on which this impact modelling is based.

Social Value and Dissemination

Events

Presentation and workshop sessions conducted at:

- Conference of the Chartered Institute of Ecologists and Environmental Managers, 2022

- Climate tech dinner discussion, 2022

- The Agroforestry Show, 2023

- the Chartered Institute of Ecology and Environmental Management tree-planting conference, 2023

Both events received excellent engagement and follow-up from attendees.

Student Placement

Student placement completed, producing valuable contributions from the student and great feedback from her on the experience of working on the project.

Next steps

This project has achieved its aims to a substantial extent, and its involvement in the Biomass Feedstocks Innovation Programme has only come to an end because of temporary capacity constraints at Verna.

The work will therefore continue, and the key next steps are to deliver the final elements of the planned innovations. This will include:

- Further extensions and improvements to ESC: All the ESC outputs to date are available publicly. ESC is now moving to an iterative, open access development model working collaboratively with community user groups. Further developments planned include:

- Extending the new climatic modelling (e.g. including drought risk) to a greater range of species.

- Extending coverage to include Northern Ireland i.e. full UK coverage.

- Providing an interface for bulk data download (datasets are currently provided on request).

- Updated and wider training resources e.g. videos.

- Integrating the new ESC and Yield-SAFE/Farm-SAFE capabilities into ForestFounder: Enabling ForestFounder to cover the new species and forestry types now supported, underpinned by updated climate and yield modelling.

- Commercialising the new versions of ForestFounder: This will include making ForestFounder available in Scotland and Wales via the client-engagement route to market, and finalising and launching the self-service version.

- Completing dissemination of the project's research outputs: This will include scientific journal papers, trade shows, and presentations to stakeholders (stakeholders and practitioners), covering several aspects of the work, including the new field data, economic research, and new ESC capabilities.

Contacts

The core project team consists of:

[Verna](#), where the best contact is Dr Matthew Brown (matthew.brown@verna.earth).

[Forest Research](#), where the best contact is Dr Mike Perks (mike.perks@forestresearch.gov.uk).

[Cranfield University](#), where the best contact is Prof Paul Burgess (p.burgess@cranfield.ac.uk).

Acknowledgements

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[v] Met Office Hadley Centre (2018) UKCP18 Probabilistic Climate Projections Centre for Environmental Data Analysis (viewed on 14 April 2024).

[vi] Forest Research, Ecological Site Classification live version (viewed on 14 April 2024).

[vii] Forest Research, Ecological Site Classification user evaluation version (viewed on 14 April 2024).

[viii] Forest Research, Ecological Site Classification API documentation (viewed on 14 April 2024).

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