Biomass Feedstocks Innovation Programme: FCP-263

Phase 1 report

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Contents

1. Assessment of proposed innovation

1.1. Technical description

This joint project between Forest Research (FR) and Forest Creation Partners (FCP) will upgrade FR's Ecological Site Classification tool (ESC) and FCP's ForestFounder system, greatly increasing their impact on UK biomass supply.*

Current status of ESC and ForestFounder

The current ESC (ESC4) provides site-level data on the climatic and edaphic suitability of 60+ Long Rotation Forestry (LRF) tree species at any location within GB. Through a web interface (see **Figure 1**†), users can select a location and investigate data on which species are likely to be (un)suitable on that site under current and future conditions. Estimates of future conditions are currently based on the UK Climate Projections 2009 (UKCP09).

ESC increases biomass supply by enabling higher-yielding and/or more climate-change-resilient species choices during afforestation and/or restocking. ESC is well-known in the sector and used 300+ times/day.

ForestFounder currently assesses large land areas within England for LRF forestry potential, 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 takes a defined input land area (up to the whole of England) and uses a wide range of geospatial data to produce an output map identifying zones likely to be suitable for LRF afforestation, and which species and/or forestry types they are suitable for. For most biophysical factors, ForestFounder uses datasets imported from ESC.

ForestFounder increases biomass supply by enabling afforestation, and facilitating the choice of higher-yielding and/or more climate-change-resilient species and/or forestry types. Its algorithmic approach uses computational power to make assessments possible which would be prohibitively expensive and/or time-consuming using traditional, human-powered approaches. (ForestFounder does not entirely remove human expertise, as some factors must be assessed on-the-ground. But its algorithmic assessments identify undiscovered high-potential land at a speed and scale impossible for humans, allowing human efforts to focus where they add value.)

ForestFounder has been used to support large landowners, investors, and policymakers. **Figures 2 and 3** show examples of its impact.

Proposed innovation

This project's innovation is to create new versions, ESC5 and ForestFounder2, improved in four key ways:

i. **Widening the range of species and forestry types, to cover Short Rotation Forestry (SRF), Short Rotation Coppice (SRC), and agroforestry.** This will add species including Willows, Poplars, Alders, Eucalypts, Paulownia, and classic orchard species (for agroforestry)‡, and assessment of all key LRF+SRF species

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* Note that in this report, "biomass" is interpreted in its widest sense, irrespective of the end use. For example, this includes timber for use in construction.
† Figures are contained in Annex A.
‡ Rauli was investigated in Phase 1, but deprioritised because of vulnerability to Phytophthora.

under agroforestry approaches. It will use species-specific data gathered from new fieldwork (e.g. coring trees) and digitising published/archived data. This will enable coverage of higher-yielding forestry types (SRF and SRC), and integration of biomass production on land socio-economically appropriate for agriculture (via agroforestry).

ii. **Improving how climate change is accounted for, across all species.** ESC currently uses broad averages of projected climatic conditions, based on the UK Climate Projections 2009 (UKCP09)[1]. ESC5 will use UK Climate Projections 2018 (UKCP18)[2] data, processed to underpin species-specific climatic suitability modelling via the CEH CHESS-Scape datasets[3,4] and future climate scenarios, in a probabilistic model accounting for changing likelihoods of climatic extremes (hazard risk). This will enable choices of species and/or forestry types that will be higher-yielding and/or more resilient under future conditions.

iii. **Expanding geographical coverage of ForestFounder to include Scotland and Wales**, enabling identification of forestry biomass opportunities across GB.

iv. **Providing a self-service web interface for ForestFounder**, enabling cost-effective use by landowners/investors of any size (including all farmers). Phase 1 research showed that a self-service product would widen the addressable market to all landowners. This will greatly increase the area across which ForestFounder can cost-effectively find forestry biomass opportunities.

Elements (i) and (ii) will include fundamentally upgrading ESC's yield-modelling engine. ESC currently projects growth/yield based on matching foresters' field experience/measurements of growth rates to static average measures of climatic/edaphic conditions.[5,6,7] The new engine, "3PG-SoNWaL", will instead model underlying tree and soil physiological processes, under dynamic, probabilistic climatic/edaphic conditions. This will improve accuracy for all species (including under future climate change), and enable modelling of species' sensitivity to extreme conditions (e.g. cold-intolerant eucalypts, drought impacts on productivity). This work will be based on recent research by FR and the Centre for Ecology and Hydrology (NERC Landscape Decisions PRAFOR project[8]), providing the theoretical underpinnings to substantially upgrade the current FR Physiological Processes Predicting Growth ("3PG") model, which covers UK pine and spruce[9,10,11,12], to a drought-responsive 3PG-SoNWaL model underpinning full biomass species parameterisation for ESC5. The new model will further inform planting/management decisions by evaluating the probability of climatic hazards over the forest rotation, and integrating measures of exposure and vulnerability.

Figure 4 shows all planned ESC upgrades. **Figure 5** shows the new 3PG-based modelling engine.

Phase 1 research

In Phase 1, we researched and designed the innovation, produced exemplar outputs, and planned its creation and demonstration in Phase 2.

We assessed 100+ pieces of literature[§] and conducted 56 research interviews, spanning technical, market, and policy experts, and prospective users/customers.

Phase 1 outputs related to technical feasibility included:

[§] A list of key references identified is provided in Annex B.

- A detailed plan (10 pages plus full Gantt chart) for upgrading ESC, including gathering/analysing data for SRF, SRC, and agroforestry, integrating the 3PG-based engine, and moving to UKCP18-based climate modelling.
- Exemplar biophysical suitability datasets for Willow and Eucalyptus, using UKCP09 and initial data to demonstrate how the final datasets will be constructed using UKCP18, extensive field data, and the ESC5 engine. **Figure 6** shows examples.
- Exemplar biophysical suitability datasets for 60 LRF species, adjusted for drought-sensitivity using UKCP09, demonstrating how ESC5 will use UKCP18 data.
- A detailed plan (18 pages plus full Gantt chart) for upgrading ForestFounder to cover (i) Scotland and Wales, and (ii) the wider range of forestry types, including identifying data and algorithms to assess local-impact and economic factors (alongside ESC5 data for biophysical factors).
- Design work on a self-service interface for ForestFounder2.

Phase 1 research discovered opportunities, unforeseen at the outset, to further enhance impact on biomass supply. It became clear that covering agroforestry, and supporting the numerous smaller-scale agricultural landowners, both offered huge potential. This led to the inclusion of agroforestry and the self-service ForestFounder interface in the innovation design.

Technical feasibility and robustness

We have checked and evidenced that the innovation is technically sound and robust at three levels:

i. **Underlying science and economics:** The science/economics modelled is based on input from the leading experts and literature. ESC and ForestFounder follow procedures that have been industry-standard for many years, just done computationally rather than manually. Our Phase 1 research added to this knowledge base.

ii. **Computational approach:** ESC5/ForestFounder2 will be built using environments/platforms that are globally understood, used, and validated (e.g. PostgreSQL/PostGIS, R, RShiny, Amazon Web Services), and extensively checked and tested in Phase 2. The current versions of ESC and ForestFounder used this approach, and have been widely tested and used in real applications. In Phase 1 we produced detailed plans for extending this approach to the new applications.

iii. **Input data:** Third-party datasets will be from reliable, transparent sources (e.g. Ordnance Survey, Forestry Commission, Environment Agency, British Geological Survey). FR data will be produced following FR’s industry-leading processes (see section 2.5). In Phase 1 we identified all third-party datasets required, checking they met robustness standards, and produced exemplar FR datasets demonstrating quality.

Phase 1 discussions with experts in the field have also provided third-party assurance that the planned innovation is technically sound.

As a final level of assurance, we have surveyed the market for third-party products/services solving technically similar problems, demonstrating that they are technically tractable.

Technology development status

The innovation is currently at TRL6: Across each element of the innovation, the current versions of ESC/ForestFounder, together with the Phase 1 development work (see above), constitute at least a representative prototype or model of the planned ESC5/ForestFounder2 functionality. (Some elements could be rated at TRL7, e.g. for the extension to Scotland and Wales the current ForestFounder version is an actual system prototype. But the integrated innovation is TRL6.)

Our Phase 2 plan will take it to TRL9, as ESC5 and ForestFounder2 will be in their final forms, applied and tested through our demonstration partnerships.

Scalability

ESC5 and ForestFounder2 are designed from scratch as nationwide solutions, and there are no technical barriers to GB-wide scalability. The current version of ESC is already GB-wide. The current version of ForestFounder operates England-wide, and this project includes expanding it to GB-wide. (Northern Ireland is omitted from both ESC and ForestFounder2 because of data availability issues. FR and FCP plan to solve this outside of this project.)

The ForestFounder2 engine will in-principle be scalable internationally, and FCP plans to develop international versions.

1.2. Impact on sustainable biomass supply

How ESC5 and ForestFounder2 will increase national supply

ESC5 and ForestFounder2 will increase domestic biomass supply in three primary ways:

i. **Identifying land for afforestation, leading to land being planted that would not otherwise have been:**

   a. Identifying suitable sites for forestry is a complex problem, requiring assessment of many factors related to biophysical, economic, social, and regulatory processes.

   b. This is a key barrier to increasing afforestation rates. For example, our own research (over the past two years and during Phase 1) and third-party studies (e.g. references 13,14,15) have consistently highlighted both (i) navigating and predicting the regulatory approval process and (ii) forecasting economic returns from forestry as important barriers to planting.

   c. Compared to human-powered methods, ForestFounder carries out suitability assessments of any size more quickly and easily, and makes assessments possible on a scale that would otherwise be prohibitively expensive/time-consuming (e.g. recent projects have included assessing estates of over 30,000 hectares).

   d. This means that use of ForestFounder leads to (at minimum) suitable land being identified and planted more quickly than if ForestFounder were not available, and (often) land being planted that would not otherwise have been identified at all as an afforestation opportunity.

   e. ForestFounder2 will extend this capability to Wales and Scotland, and to land which would not be considered for LRF but would for other forestry types (e.g. agroforestry), greatly increasing its impact.

ii. **Enabling better choices of forestry type for (re)planting projects, leading to higher-yielding types being chosen:**

   a. Whereas current ESC and ForestFounder cover LRF only, ESC5 and ForestFounder2 will cover SRF and SRC. These forestry types produce biomass more quickly (see example photo at **Figure 7**).

   b. When land managers are planning to plant (for the first time, or following felling), an ESC5-powered assessment (whether directly or via inclusion in ForestFounder2) will flag up all suitable forestry types, allowing them to consider alternative types they may not have been aware of and their relative benefits for the project.

   c. In a significant number of cases, this is likely to lead to a higher-yielding forestry type than would otherwise have been chosen. E.g. in Phase 1 interviews, multiple landholders said they were keen to explore SRF, but did not have the knowledge or confidence as to whether/where it would be suitable within their estates.

iii. **Enabling better choices of individual tree species for planting/restocking projects, leading to higher-yielding and/or more climate-resilient production:**

   a. Within a forestry type, decisions are needed about the mix of tree species.

   b. ESC5-powered assessments will enable land managers to select those species best suited to the site from a wider range, and better taking into account the impact of climate change during the project's lifetime.

   c. These improved decisions will lead to faster growth initially, and continued/resilient growth in the future as the climate changes.

   d. ESC is already embedded as an industry-standard support tool for these decisions.

In addition to these three primary ways, ESC5/ForestFounder2 will also support increases in domestic biomass supply by informing national policymaking and market/investment assessments by large institutions. E.g. ForestFounder's ability to perform national-scale assessments was used under contract to Defra to inform the National Food Strategy (2021)[16]. ForestFounder2 will greatly enhance this capability.

In all of these areas, ESC5 and ForestFounder2 will have much greater potential impact than the current versions. Our quantitative modelling of impact (below) treats the current versions as a baseline, isolating the impact of the innovation to be created by this project.

In addition to evidence from quantitative modelling, our Phase 1 research has confirmed that expert stakeholders believe ESC5/ForestFounder2 have potential to achieve significant impact on national biomass supply.

The additional biomass produced as a result of ESC5/ForestFounder2 will be sustainable: see section 1.3.

Quantitative estimates of impact

During Phase 1, we developed a quantitative model which estimates the impact that creating and deploying ESC5 and ForestFounder2 will have on UK biomass production in 2050. The model is focused on the national biomass amounts grown and harvested in the year 2050, as the year of the UK's net-zero commitment, although there will obviously be positive impacts on biomass production in preceding and subsequent years.

It models the three primary ways in which ESC5 and ForestFounder2 will increase production, described above (the additional impact via informing national-scale policy/market assessments is impossible to model quantitatively).

The model was developed by FCP, with support and guidance from FR. All of the model's inputs are based on the best available data/information. In some cases third-party sources were used, e.g. estimates of total suitable land were informed by Committee on Climate Change modelling/recommendations. Wherever possible, estimates of the impact of ESC5/ForestFounder2 assessments were based on past experience e.g. average outcomes of projects undertaken using the current ForestFounder. For modelling the impact of new capabilities to be created during Phase 2, initial assumptions are based on the team's expert judgement (taking into account comparable past experience); these assumptions will be refined during Phase 2 using data collected from demonstration projects. In all cases, where there is significant uncertainty in parameters we have erred on the conservative side, so as to model the lower end of likely impact.

The model produces a range of estimates for the net impact of creating and deploying ESC5 and ForestFounder2 (against a baseline of the current versions of ESC and ForestFounder), depending on whether pessimistic, central, or optimistic assumptions are selected for a range of input parameters.

Across all scenarios, the modelling suggests that ESC5 and ForestFounder2 have the potential to create a significant impact on national biomass supply. Estimated UK biomass production in 2050 is increased by an appreciable percentage of current national production levels (today). These impacts amount to a large increase in the impact of ESC5/ForestFounder2 compared to the current versions – in some scenarios upwards of a tenfold increase.

The model is attempting to estimate impacts on a complex, national-scale picture, in some cases with relatively little empirical data on which to base input parameters. It makes a number of broad approximations. As such, we do not claim that these estimated impacts are definitive. However, they do provide an approximate estimate of the scale of the potential national impact of the innovation, which is significant.

We plan to continuously improve both the model's architecture and its underpinning data in Phase 2, including based on data collected from demonstration partnerships (spanning multiple metrics).

1.3. Wider environmental impacts

As a software-based innovation, the direct environmental impacts of its development and operation are negligible compared with the impacts of the tree-planting it facilitates. Phase 1 work has therefore focused on those impacts.

Tree-planting can have a wide range of positive and negative environmental impacts. There is a large body of research on this. Some of the key issues are summarised in the UK Forestry Standard (Chapter 6).[17] Examples include:

- **GHGs:** Afforestation can produce net GHG benefits through CO_2 sequestration, provided emissions from soil disturbance and establishment operations are outweighed by tree growth.
- **Air:** Trees can improve air quality by absorbing pollutants.

- **Water:** Trees often improve water quality, but can exacerbate acidification of watercourses. They can mitigate flood risks, but can place stress on groundwater in dry areas.
- **Soil:** Trees protect and enhance soils, but forestry operations can disturb/damage soils or affect nutrient/pH balances.
- **Biodiversity:** Trees provide valuable habitats and can enhance biodiversity, but inappropriate planting can damage rare/threatened habitats/species.

As confirmed by desk research and interviews in Phase 1, there is a strong regulatory regime across GB to minimise the risk of negative impacts and maximise positive outcomes. A rigorous approval process is required for all significant new planting, governed by the Environmental Impact Assessment (Forestry) (England and Wales) Regulations 1999 (amended 2017)[18] and the Forestry (Environmental Impact Assessment) (Scotland) Regulations 2017[19], in conjunction with the UK Forestry Standard[17]. Wider environmental regulation further reduces risks e.g. the Environment Act 2021[20] will require biodiversity net gain in many cases in England, preventing inappropriate conversions of habitat to woodland. Subsidy regimes encourage benefit maximisation e.g. England Woodland Creation Offer payments are higher for planting with environmental benefits[21], and Welsh Glastir subsidies are allocated competitively to the highest-benefit proposals.[22]

These strong safeguards will ensure that, as with all new GB planting, planting facilitated by ESC5/ForestFounder2 is very likely to have strong net-positive environmental impacts.

ForestFounder is also designed to promote practices going beyond regulatory minimums, further minimising risks.

Consequently, our assessment is that ESC5/ForestFounder2 will have significant, net-positive environmental impacts.

We have not been able to quantify most of these positive impacts during Phase 1. While our modelling of biomass supply impact (see section 1.2) estimates the planting area likely to be created by ESC5/ForestFounder2 nationally, environmental impacts are highly site-specific and estimation would require modelling encapsulating a huge body of research.

However, we have broadly estimated the additional GHG benefit (beyond increased biomass supplies). This occurs because afforesting suitable land increases the average carbon stock on it, across the plant-grow-harvest-replant cycle. We used the UK Woodland Carbon Code[23] (WCC) to conservatively model this increase across different forestry types, producing estimates spanning ~50-300 tonnes CO_2e/hectare (this excludes increases in carbon below ground, which can be substantial but are not modelled by the WCC). Scaled up over the planting estimated by our biomass supply impact modelling, with appropriate reductions for lower density where planting is agroforestry, this corresponds to ESC5/ForestFounder2 increasing above-ground UK carbon stocks by ~4.4m-26.5m tonnes CO_2e.

We will improve/refine our assessment of environmental benefits during Phase 2, including attempting quantification of non-GHG benefits (e.g. modelling biodiversity impacts using methods such as the Natural England Biodiversity Metric 3.0[24]). This will harness expertise across our partnerships, and any relevant support/expertise from the Lot-2 Demonstrator.

2. Phase 2 plan

2.1. Plan, deliverables, and milestones

We have developed a detailed Phase 2 plan, which includes 24 work packages (many of which are interdependent) and 25 key milestones.

The key stages in developing the innovation include:

- **Underpinning research,** including gathering data on SRF/SRC/agroforestry species and systems (through digitising existing data and collecting field data e.g. collecting dendrochronology tree cores, mensuration), analysing and processing UKCP18 climate data, and economic and social/market research e.g. into agroforestry modes.
- **Coding, debugging, and user-testing ESC5 and ForestFounder2.** This progresses in stages and, while the full versions are reliant on all the above research, key functionality can be built/tested in parallel with the research. E.g. the ESC5 climate model, the expansion of ForestFounder to Scotland and Wales, and the creation of ForestFounder2's self-service interface.
- **Testing and demonstration through partnerships** with a mix of private, public, and institutional landholders across England/Scotland/Wales. These will provide "real-world" tests of ESC5/ForestFounder2 in varied situations spanning 100k+ hectares, with results tested/validated including via on-the-ground checks.[**] These demonstration partnerships will begin as soon as new functionality is available to test (e.g. ForestFounder operating in Scotland and Wales), and proceed in parallel with the creation of ESC5/ForestFounder2, finally providing tests of the full versions once built.

In parallel with these strands are work packages on:

- **Continuously improving our biomass supply impact, environmental impacts, and commercialisation modelling,** including via data collected throughout demonstration partnerships.
- **Social value activities,** including student placements, landowner webinars, communications programme, and additional dissemination activities.

All project activities are supported through a fully resourced project management and governance/reporting work package, running throughout the project.

The plan culminates in completion of the project and all key deliverables (including final report to BEIS) by February 2025, with only final communications activities continuing into March 2025. The number and timing of milestones is based on completion of significant, objective, and measurable outputs/deliverables; where milestones fall close together we would group them into single invoices, respecting BEIS's preference for quarterly invoicing. We can adjust the milestone plan should BEIS desire more/fewer total milestones, or a regular periodicity.

The critical path was derived from the detailed Gantt chart using the standard Critical Path Method. It shows that creating the ESC5 engine, and the underpinning research, are the project's rate-limiting steps; this will be taken into account when

[**] These Phase 2 demonstration partnerships are likely to directly generate GHG/biomass benefits. While their purpose is to refine/prove the innovation, they will involve applying ESC5/ForestFounder2 to 100,000+ hectares. This is likely to result in new/optimised planting. Using the same methodologies and assumptions as in sections 1.2 and 1.3, this could increase national carbon stocks by ~170k-1.0m tonnes CO_2e, and annual biomass production (by 2050) by ~38,000 oven-dry tonnes/year.

focusing project/risk-management scrutiny. We have taken a conservative approach to resource planning and risk management (see below), and even within the critical path there is contingency time should tasks overrun or unforeseen challenges arise.

As instructed, our project plan is comprehensive and not reliant on the Lot-2 Demonstrator e.g. FR has identified 10+ sites where SRF/SRC/agroforestry data can be collected. However, if the Demonstrator provides useful opportunities (e.g. access to additional useful sites) we will incorporate them.

The Phase 2 plan was developed collaboratively by the project team, based on Phase 1 research and design work (see section 1.1). The process was led by the Project Lead.

Phase 2 deliverables, milestones, resourcing, and timescales were designed by the team member(s) with the most relevant skills/experience, drawing on outside expertise where necessary, and independently reviewed by colleagues. Where relevant, delivery and/or resourcing requirements were modelled using methods such as three-point estimation, to ensure robustness. This included forecasting required person-days per task on a weekly basis, allocating these to individuals with the required skills, and adjusting timing of tasks (not on the critical path) where it was cost/time-efficient to re-profile individuals' utilisation. The entire plan was independently reviewed by the Project Lead and two other team members.

2.2. Project team

Continuing the core structure from Phase 1, this project is jointly planned and delivered by Forest Creation Partners (FCP) and Forest Research (FR), with a joint FCP/FR core team. FCP is Project Coordinator and single point-of-contact for BEIS; FR sub-contracts to FCP.

A number of other sub-contractors have agreed to join the team, providing expertise in particular areas important to the project's success.

(As discussed above, we have also secured non-commercial demonstration partnerships with a range of landholders.)

Our project team has been constructed to cover all the required technical, project management, and other skills, including:

- Project management.
- Team management.
- Logistics.
- Communications and engagement.
- Commercialisation planning.
- Forestry science across all required species/types, spanning Long Rotation Forestry, Short Rotation Forestry (SRF), Short Rotation Coppice (SRC), and agroforestry species (e.g. fruit/nut bearing species) and management.
- Climate and environmental science, including biodiversity/ecological assessment.
- Data research/processing.
- Economics research/modelling.
- Social/market research.
- Computational modelling/simulation.

- Software development.
- Financial modelling/forecasting.

Members of FR's Technical Support Unit will assist with field data collection and analysis.

2.3. Project management

Each work package, deliverable, and task has an assigned lead member of the project team.

The core FCP/FR team will meet fortnightly by video, and in-person at least six-monthly (Covid permitting). Standing agendas will include progress against plan; issues, risks, and mitigations; quality assurance; financial management; governance/reporting; and social value. Project documentation will be kept up-to-date and reviewed at each meeting, including Gantt chart, risk register, and budget. Updates and actions will be documented, including to feed into governance/reporting (see below). Incurred/forecast costs will be updated at least monthly and evidenced invoices submitted to BEIS no more frequently than quarterly in line with agreed milestones.

The team will use shared systems (via MS Teams) for secure, simultaneous communication and file access/editing/version control, with data regularly backed up to a separate secure location, plus Trello to maintain detailed shared action/issue lists.

Work by sub-contractors (beyond the core FCP/FR team) will proceed according to agreed, contractual scope-of-work and/or service-level agreements. A core team member will lead each sub-contractor relationship, meeting them at least monthly to discuss progress, issues/risks, quality assurance, financials, and reporting. Sub-contractors will attend project and/or governance meetings where relevant.

A similar approach will be taken to demonstration partners (including lead point-of-contact, written agreement on scope, regular meetings and involvement in project/governance meetings), but with documentation/processes adjusted to recognise the non-commercial nature of these relationships.

2.4. Risk management

We have created a comprehensive initial Risk Register for the Phase 2 project, showing our current assessment of key risks, mitigations, and contingencies, including factors beyond the project's control. It covers Covid risk.

Risk management will follow the PRINCE2 Risk Management Procedure i.e. the identify-assess-plan-implement-communicate cycle.

In line with this, the Risk Register will be a living document, reviewed/updated at all team meetings. It will also form part of submissions to governance/reporting (see below), with review/challenge sought from these groups.

2.5. Quality assurance

FCP and FR have established quality assurance (QA) methodologies, tested through successful delivery of projects for major clients, which will be applied to this project. FR's processes are accredited to ISO14001.

These include:

- **Project design incorporating explicit QA stages/activities:** Our plan includes many tasks/deliverables specifically focused on testing/validation.
- **Independent review of all plans and outputs by a team member not closely involved in their development:** Each task and deliverable has an identified QA Lead from within the project team.
- **Independent external review for key deliverables/milestones:** For this project, we will seek review as appropriate from expert sub-contractors/partners, third-party experts (e.g. academics), our BEIS Monitoring Officer, and relevant oversight/governance groups (see below).

In addition to these QA processes, there are additional checks for data outputs, including:

- **Manual inspection** for anomalies/artifacts.
- **Algorithmic inspection** e.g. checking geospatial geometries are valid.
- **Internal consistency** e.g. checking sub-sets combine to recreate parent data.
- **Consistency with similar data** e.g. running the same analysis via multiple routes, or comparing to physically similar systems.

Outputs passing QA are pooled into a shared filespace forming a ‘single source of truth’, with consistent formatting/conventions.

2.6. Governance

We have designed the project oversight and governance framework to:

- Provide robust accountability checks and constructive challenge.
- Harness the value of external expertise from partners and key stakeholders.
- Ensure ongoing alignment of project direction with goals/needs of both prospective users/customers and key stakeholders (e.g. policymakers).

The key mechanisms are:

i. **Internal FCP oversight:** The Project Lead is a company director. As a major project, it is reviewed at each quarterly FCP board meeting.

ii. **Internal FR oversight:** This project reports to the six-monthly Science and Innovation Group Programme Board, chaired by the FR Chief Scientist. This process is led by the FR project lead.

iii. **BEIS oversight:** The Project Lead will ensure that all BEIS monitoring and reporting requirements are met, including monthly Monitoring Officer meetings, quarterly reports, six-monthly stage gates, site visits, KPIs, and benefits management planning/reporting. Project team meetings will include preparing for these as a standing item. In Phase 1 we have found this architecture to provide useful accountability, feedback, and challenge, and have valued the productive relationship with our Monitoring Officer. We hope to develop a similar relationship in Phase 2, including informal interaction between meetings when issues arise or feedback is sought.

iv. **Practitioner Working Group:** Comprising representatives of end-users/customers for the innovation, this group will provide support and challenge to maintain focus on meeting user needs. It will meet at least six-monthly, with members engaged between meetings where relevant. It will be chaired an independent consultant, providing independent governance and 20+ years’ experience in the sector. Members include all demonstration partners plus representatives from the forestry investment community.

v. **Policy Advisory Group:** Comprising representatives of relevant policy/advisory bodies, this group will provide support and challenge to ensure project alignment with national policy objectives. It will meet at least six-monthly, chaired by the Project Lead, with members engaged between meetings where relevant. We would of course be delighted to have a BEIS representative join the group. The Chair of the Practitioner Working Group will attend this group to represent practitioner perspectives.

We will bring the Practitioner and Policy Groups together at least annually for a joint meeting, aiming to do this in-person (Covid permitting). As well as providing joined-up support/challenge for the project, this will enable networking and knowledge-sharing between the groups.

We also welcome support/challenge from the Lot-2 Demonstrator, and will invite them to join one/both of the Groups if they wish.

Delivering the project will involve many visits to investigate sites, in conjunction with sub-contractors and partners. In addition to satisfying BEIS requirements for annual site visits, we would be pleased to facilitate BEIS representatives joining any of these visits to further inform oversight/input. We will also offer this to Practitioner and Policy Group members where appropriate.

2.7. Reporting

Our reporting plans are aligned with the project management and oversight/governance arrangements outlined above.

The Project Lead will ensure we meet BEIS requirements for monthly Monitoring Officer meetings, quarterly reports, six-monthly stage gates, site visits, KPIs, and benefits management planning/reporting. Project team meetings will include preparing for these as a standing item, using up-to-date project documentation (e.g. Gantt Chart, Risk Register, budget) as an input.

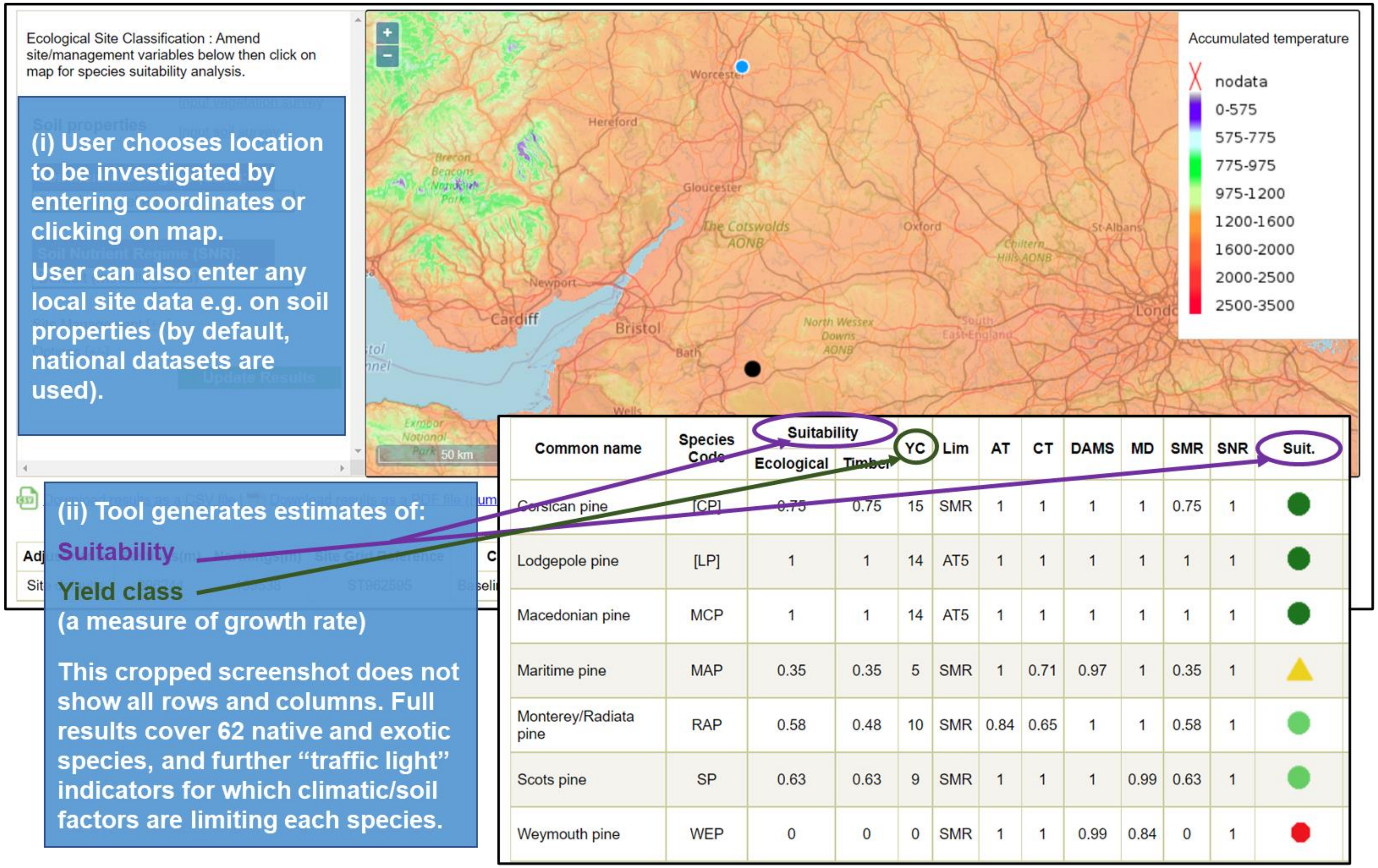
All reports/documentation will be submitted by BEIS deadlines, or at least a week before the corresponding meeting, whichever is the earlier.

To achieve a streamlined approach, reporting to BEIS will also provide a basis for reports to the other governance mechanisms above, including internal FCP/FR oversight, and the Practitioner and Policy Groups. (Documentation may be adapted for non-BEIS external audiences, e.g. to remove confidential/sensitive information.)

The Project Lead will remain responsible for KPI reporting, and meeting any other BEIS information-sharing requirements, for at least three years after project closure.

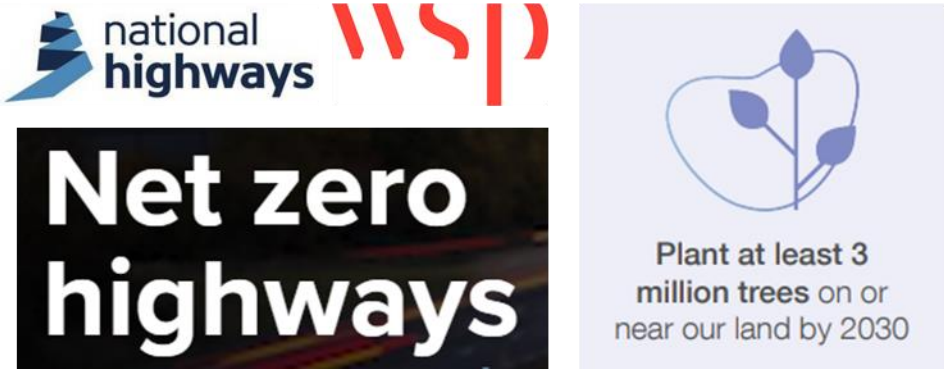
Annex A: Figures

Figure 1: Example of current Ecological Site Classification interface



Common name	Species Code	Suitability		YC	Lim	AT	CT	DAMS	MD	SMR	SNR	Suit.
		Ecological	Timber									
Corsican pine	[CP]	0.75	0.75	15	SMR	1	1	1	1	0.75	1	●
Lodgepole pine	[LP]	1	1	14	AT5	1	1	1	1	1	1	●
Macedonian pine	MCP	1	1	14	AT5	1	1	1	1	1	1	●
Maritime pine	MAP	0.35	0.35	5	SMR	1	0.71	0.97	1	0.35	1	▲
Monterey/Radiata pine	RAP	0.58	0.48	10	SMR	0.84	0.65	1	1	0.58	1	●
Scots pine	SP	0.63	0.63	9	SMR	1	1	1	0.99	0.63	1	●
Weymouth pine	WEP	0	0	0	SMR	1	1	0.99	0.84	0	1	●

Figure 2: Example of ForestFounder's impact – enabling tree-planting by National Highways



"Forest Creation Partners were able to very quickly identify potential new tree-planting areas across our client's substantial, England-wide land holdings - allowing us to provide a better view on options for their journey to net zero carbon and biodiversity net gain."

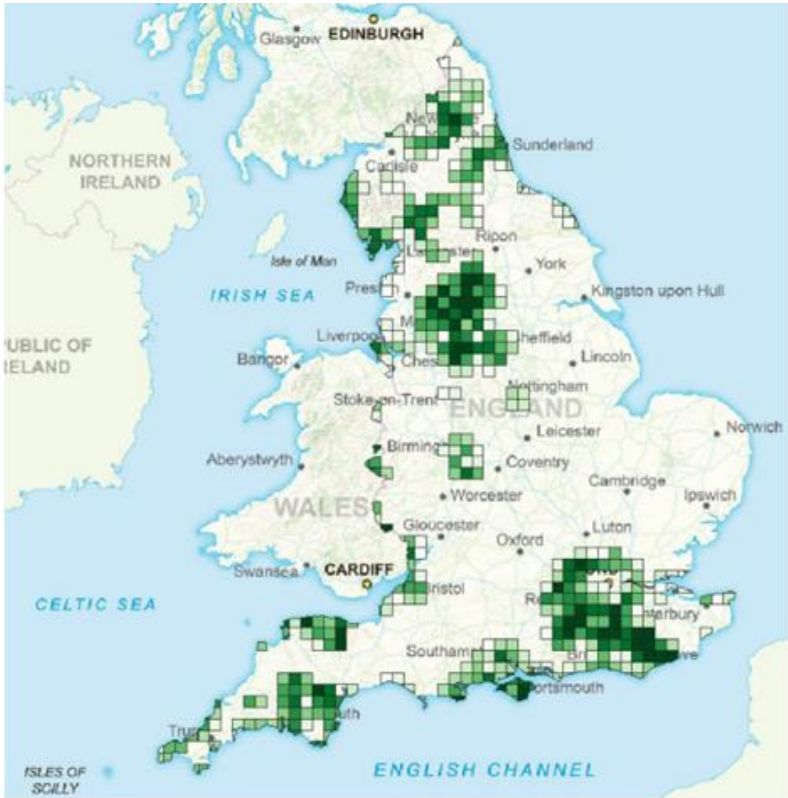
– James Peet, Principal Consultant, WSP

Figure 3: Example of ForestFounder’s impact – underpinning tree-planting recommendations in the National Food Strategy

National Food Strategy

“This map takes the least productive 14% of farmland in England (providing less than 3% of calories produced in England) and shows – within this area – the suitability for forest planting. Darker = greater proportion of land suitable. SOURCE: Forest Creation Partners.”

– National Food Strategy



“Forest Creation Partners' unique data and mapping capability gave us invaluable input in helping to understand how to achieve the UK’s climate and food goals”

– Dustin Benton, Chief Analytical Adviser, National Food Strategy

Figure 4: How ESC5 will be upgraded from ESC4. Depicts ESC4 structure, with ESC5 upgrades in call-out boxes.

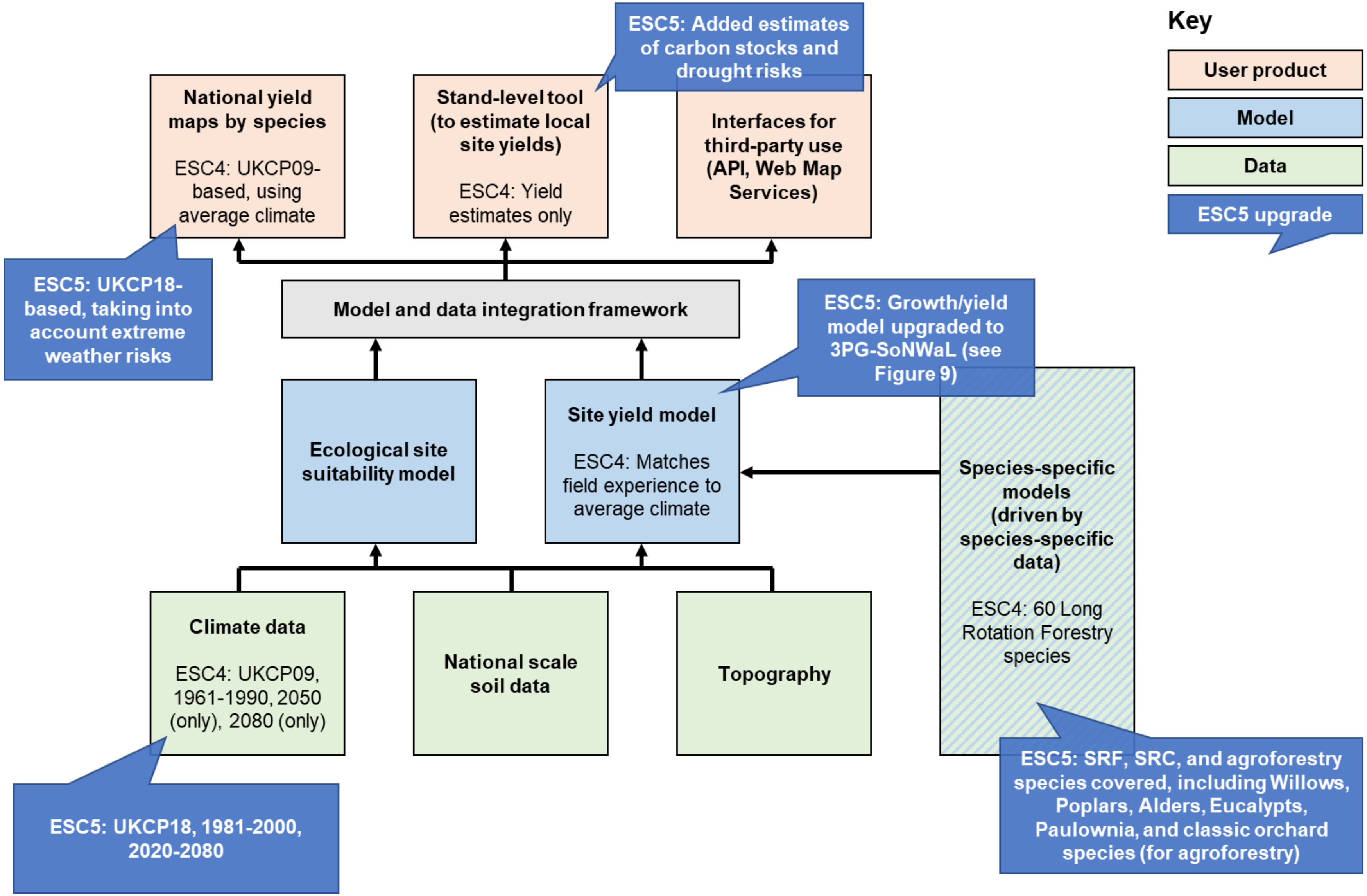


Figure 5: New growth/yield modelling engine for ESC5, based on physiological processes.

This is a schematic of the 3PG-SoNWaL model (Physiological Processes Predicting Growth – Soil Nitrogen under Water Limitation). It is explained more fully in the detailed ESC upgrade plan developed in Phase 1.

This will be integrated into ESC5, based on prior research by Forest Research and the Centre for Ecology and Hydrology (NERC Landscape Decisions PRAFOR project).

It will replace the current ESC growth/yield engine, which is based on matching foresters' field experience to climatic/edaphic conditions, with direct modelling of tree and soil physiological processes under probabilistic climatic forecasts.

This will improve accuracy for all species, and allow modelling of species that are sensitive to extreme conditions (e.g. cold-intolerant eucalypts).

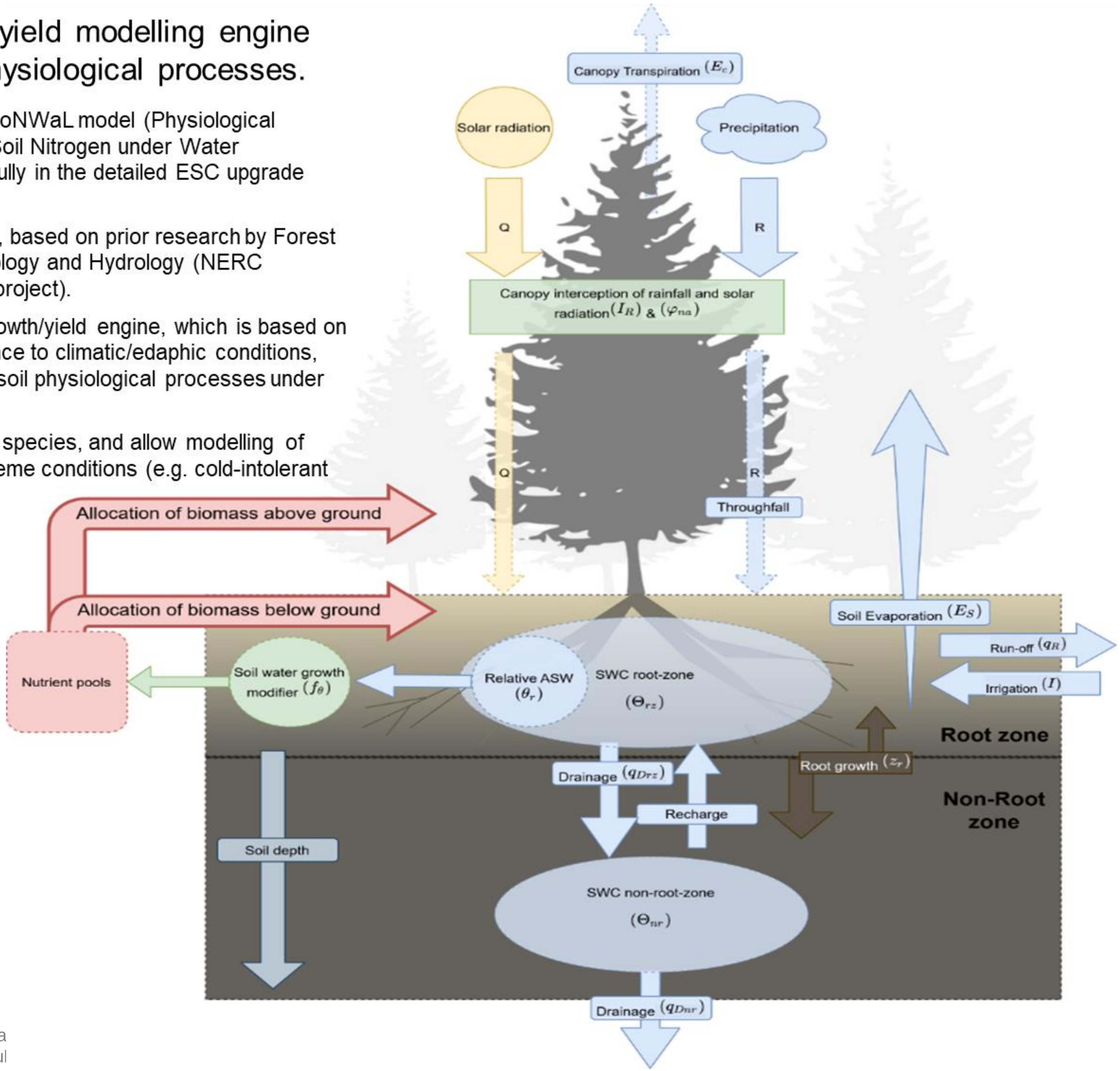


Figure 6: Exemplar datasets produced during Phase 1, for eucalypts.

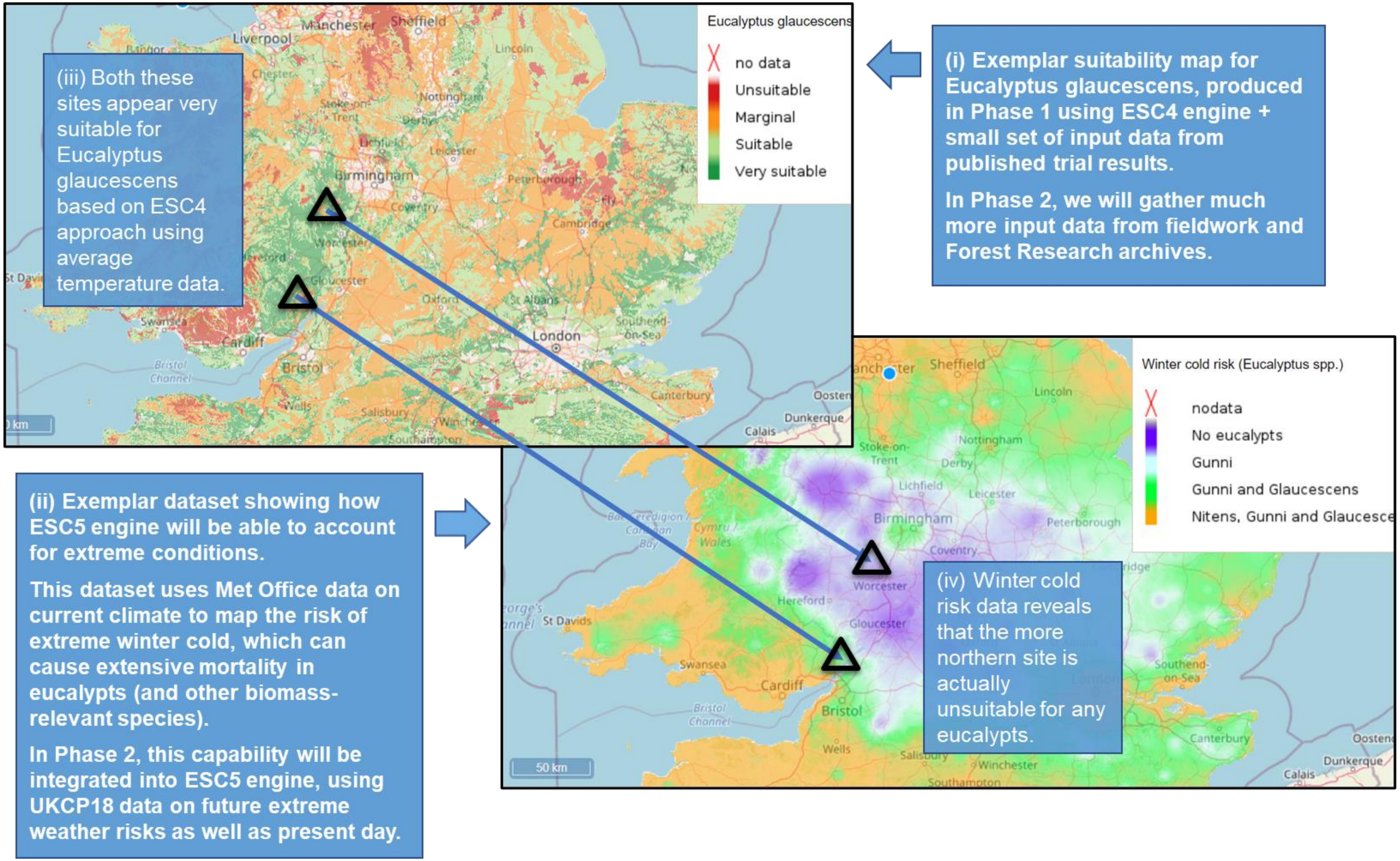


Figure 7: Example of growth speed of Short Rotation Forestry.

Photograph from Phase 1 visit to Forest Research experimental site: This trial stand of Eucalyptus is only approximately 12 years old, illustrating its rapid growth. High-performing SRF Eucalyptus can produce an average of over 20 oven-dry tonnes per hectare per year, over ~20-year rotations

Annex B: Key references

This list is divided into those sources which are directly referenced in this document, and those which are not referenced in this document but were particularly helpful in our underlying research. These lists do not include every piece of literature assessed in our research, only those which proved to be of significant use.

Not directly referenced in this document:

- England Trees Action Plan, Department for Environment, Food, and Rural Affairs 2021 (viewed on 14 February 2022).
- Woodlands for Wales, Welsh Government, last updated 30 April 2021 (viewed on 14 February 2021).
- Scotland's Forestry Strategy 2019-29, Scottish Government 2019 (viewed on 14 February 2022).
- English woodland creation hub, Forestry Commission England, last updated 10 February 2022 (viewed on 14 February 2022).
- Welsh woodland creation hub, Natural Resources Wales (viewed on 14 February 2022).
- Scottish woodland creation hub, Scottish Forestry (viewed on 14 February 2022).
- Undertaking an Environment Impact Assessment in Forestry, Forest Research 2009 (viewed on 14 February 2022).
- English EIA screening form and guidance, Forestry Commission England 2021 (viewed on 14 February 2022).
- Welsh EIA screening form, Natural Resources Wales (viewed on 14 February 2022).
- Scottish EIA screening form, Scottish Forestry (viewed on 14 February 2022).
- Forest Research Biomass Energy Resources, Forest Research (viewed on 14 February 2022).
- Land Use: Policies for a Net Zero UK, Committee on Climate Change 2020 (viewed on 14 February 2022).
- Copernicus Global Land Cover (viewed on 14 February 2022).
- Who Owns England?, Shrubsole G and Powell-Smith A (viewed on 14 February 2022).
- Who Owns Scotland?, Wightman A (viewed on 14 February 2022).

Directly referenced in this document:

[1] The UK Climate Projections 2009, National Archives record of Met Office 2009 (viewed on 14 February 2022).

[2] The UK Climate Projections 2018, Met Office 2018 (viewed on 14 February 2022).

[3] Robinson, E.L.; Blyth, E.M.; Clark, D.B.; Comyn-Platt, E.; Rudd, A.C., Climate Hydrology and Ecology Research Support System Potential Evapotranspiration

Dataset for Great Britain (1961-2017) [CHESS-PE]. NERC Environmental Information Data Centre 2020 (viewed on 14 February 2022).

[4] Robinson, E.L.; Blyth, E.M.; Clark, D.B.; Comyn-Platt, E.; Rudd, A.C., Climate Hydrology and Ecology Research Support System Meteorology Dataset for Great Britain (1961-2017) [CHESS-met]. NERC Environmental Information Data Centre 2020 (viewed on 14 February 2022).

[5] Beauchamp, K., Bathgate, S., Ray, D. and Nicoll, B. (2016). Forest ecosystem service delivery under future climate scenarios and adaptation management options: a case study in central Scotland. Scottish Forestry, 70. 30-41.

[6] Ray, D., Petr, M., Mullett, M., Bathgate, S., Marchi, M. and Beauchamp, K. (2019). A simulation-based approach to assess forest policy options under biotic and abiotic climate change impacts: A case study on Scotland's National Forest Estate. Forest Policy Economics, 103. 17-27.

[7] Davies, S., Bathgate, S., Petr, M., Gale, A., Patenaude, G., Perks. M.P., (2020). Drought risk to timber production - does the return cover the risk? - a comparison of commercial conifer species in Scotland. Forest Policy & Economics, 117:102189.

[8] PRAFOR: Probabilistic drought Risk Analysis for FORested landscapes – Landscape Decisions (viewed on 14 February 2022).

[9] Van Oijen, M., Zavala, M.A., 2019. Probabilistic drought risk analysis for even-aged forests. In: Sillmann, J., Sippel, S. and Russo, S. eds. Climate extremes and their implications for impact and risk assessment. Elsevier.

[10] Almeida, Auro C, and Peter J Sands. 2016. Improving the Ability of 3-Pg to Model the Water Balance of Forest Plantations in Contrasting Environments. Ecohydrology, 9: 610–30.

[11] Xenakis, G., Duncan R., and Mencuccini, M. 2008. Sensitivity and Uncertainty Analysis from a Coupled 3-Pg and Soil Organic Matter Decomposition Model. Ecological Modelling, 219: 1-16.

[12] Minunno, F., Xenakis, G., Perks, M.P. & Mencuccini, M. (2010). Calibration and validation of a simplified process-based model for the prediction of the carbon balance of Scottish Sitka spruce (Picea sitchensis) plantations. Canadian Journal Forest Research 40: 2411-2426.

[13] Woodland Creation: Opportunities and Barriers, Royal Forestry Society 2020 (viewed on 14 February 2022).

[14] Agriculture (Wales) White Paper – Consultation Document, Welsh Government 2020 (viewed on 14 February 2022).

[15] Accelerating Woodland Creation – Conference Report, Institute of Chartered Foresters 2020 (viewed on 14 February 2022).

[16] The National Food Strategy, Independent Review led by Henry Dimbleby 2021 (viewed on 14 February 2022).

[17] The UK Forestry Standard, Forestry Commission England, Forestry Commission Scotland, Natural Resources Wales, and Forest Service Northern Ireland, last updated 23 June 2021 (viewed on 14 February 2022).

[18] The Environmental Impact Assessment (Forestry) (England and Wales) Regulations 1999 and its 2017 amendments, legislation.gov.uk (viewed on 14 February 2022).

[19] The Forestry (Environmental Impact Assessment) (Scotland) Regulations 2017, legislation.gov.uk (viewed on 14 February 2022).

[20] The Environment Act 2021, legislation.gov.uk (viewed on 14 February 2022).

[21] England Woodland Creation Offer Grant Manual 2021, Forestry Commission England, last updated 12 January 2022 (viewed on 14 February 2022).

[22] Glastir Woodland Creation Scoring and Selection Process, Welsh Government (viewed on 14 February 2022).

[23] UK Woodland Carbon Code, managed by Scottish Forestry on behalf of Scottish Forestry, Forestry Commission England, Welsh Government, and Northern Ireland Forest Service (viewed on 14 February 2022).

[24] The Biodiversity Metric 3.0, Natural England 2021 (viewed on 14 February 2022).