Environment and Rural Affairs Monitoring & Modelling Programme

ERAMMP Year 1 Report 13:
Integrated Modelling Platform (IMP) Progress

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Version History

Version	Updated By	Date	Changes
0.1	PMO	30/4/19	Initial draft.
"1.0"	PMO	30/4/19	Draft with incorrect ver. number – limited WG circulation
0.11	PMO	8/5/19	Mainly formatting edits – draft for SG
0.12-0.13	PMO	17/9/19	Formatting edits. Removed past tense.
0.14	PMO	27/9/19	Approved for publication
1.0	PMO	30/9/2019	As published

Contents

Abbreviations and some of the technical terms used in this report are expanded in the project glossary:
https://erammp.wales/en/glossary (English) and https://erammp.cymru/geirfa (Welsh)

1 What is the IMP?

The Integrated Modelling Platform (IMP) is a tool designed to explore and stress-test policy and management interventions for the land use and environment of Wales under a range of future Welsh economic and climatic futures. It comprises a chain of specialised, state-of-the-art models covering agriculture, forestry, land use allocation decisions, water, air, soils, biodiversity, ecosystem services and valuation. The platform takes an integrated approach, recognising that policy effects in one sector have indirect effects in other sectors. Thus, the platform explicitly accounts for biophysical and socio-economic interactions and feedbacks between sectors. Importantly, the platform has a modular structure such that individual models can be updated, changed and replaced if needed while maintaining overall function.

The primary aim of the IMP is to enable rapid assessment of natural resource policy options. User specified interventions (such as changes in agricultural subsidies) serve as inputs for the IMP, alongside various other environmental and socio-economic variables. Outputs from the platform can be used to assess environmental, agricultural and socio-economic impacts of policy options. The output variables selected will be aligned where possible to the WG public goods and sustainable land management outcomes of interest to the Welsh Government including:

- Air quality
- Public health
- Greenhouse gas balance
- Biodiversity
- High water quality
- Productivity
- Conservation of heritage
- Improvement of the natural landscape
- Social outcomes (e.g. public access, outdoor recreation).

1 What is the IMP?

2 Platform Development

Eight compatible, well-tested and policy-relevant models have been selected for inclusion in the IMP. Furthermore, the linkages between these models have been established (Figure 1).

Decisions have been reached about relevant spatial and temporal scales at which the IMP will provide outputs. Progress has also been made with regard to the user interface, which will allow the user to manipulate inputs and visualise outputs to prioritise and spatially target policy interventions. Initial "baseline" runs for current conditions have been completed by the core models and "data cubes" have been created from these outputs. The models are in the process of running economic and climate change scenarios, and these outputs will be added to the data cubes. Work is underway to automate data passes between these data cubes to develop a prototype for internal testing by the modelling team. The prototype will contain a limited set of economic and climate scenarios and policy interventions, which demonstrate the functionality of the platform.

Following this testing phase the prototype of the linked system were demonstrated to the Welsh Government Strategic Evidence Group (SEG) on 17th July 2019.

Options for further elaboration of the model runs contained within the platform (i.e. the number of economic and climate scenarios and policy interventions represented) and functionality of platform were presented at the SEG meeting to inform further development from the prototype to the full working version of the IMP.
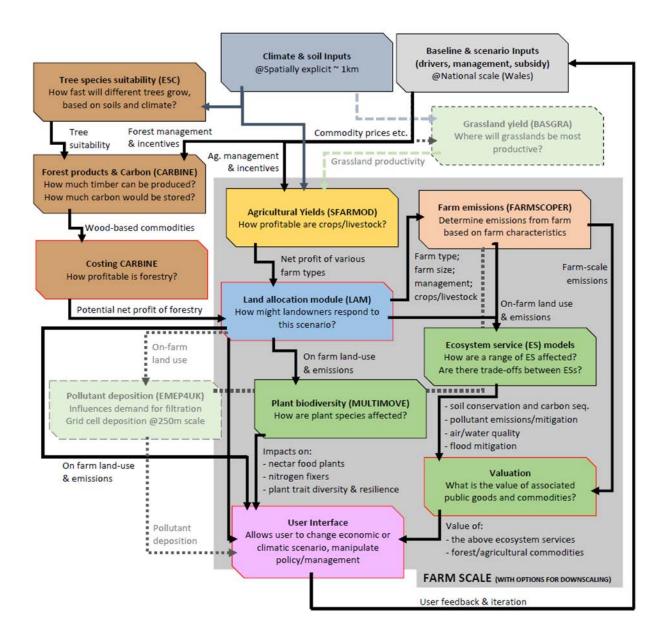
Figure 1. Simplified schematic displaying the component models of the Integrated Modelling Platform (IMP) and the links between them. Black-bordered boxes represent either inputs or component models (name shown in brackets where applicable). Red-bordered boxes represent intermediate stages in the IMP chain. Black arrows represent the flow of data, with floating text representing the types of data being passed between models. Faded boxes may not be included in the IMP's first year.

2.1 Inputs

Inputs to the IMP not only provide user flexibility, but also socio-economic and environmental realism. For example, national-scale datasets on soils, elevation and farm practices (e.g. fertiliser use, livestock management) are used to decide where land use transitions are feasible or profitable. Furthermore, each iteration of the IMP is underpinned by a "scenario". Each available scenario captures a combination of (1) current or projected future climate data (based on UKCP18 scenarios when they

are available at the resolution required by the IMP); and (2) current or projected future economic data, such as prices of wheat and milk (reflecting different Brexit trade scenarios). The user will be able to change the scenario through the interface, allowing comparison with baseline data. However, each scenario will primarily serve as a backdrop for the assessment of different management or policy interventions.

The IMP prototype will focus on comparisons with baseline for one extreme climate future (4°C increase in temperature) and one economic scenario (removing direct farm payments), but other scenarios will be explored in the full model.

2.2 Models and data flows

To anticipate effects of policy interventions on land use and the supply of public goods, it is vital to consider the profitability of farming and forestry practices. In the IMP, SFARMOD (yellow box, Figure 1) estimates the profitability of various agricultural activities within each farm holding in Wales. To do so, SFARMOD uses scenario information as well as user-specified management and policy options. These options include agricultural subsidies and rules relating to the area of land under different productive or unproductive management types (e.g. sheep, wheat, fallow). ESC and CARBINE (brown boxes, Figure 1) collectively estimate the productivity and carbon storage potential of forestry, based on scenario information and management options. Information on the price of timber as well as the costs of establishing and managing forestry is then used to estimate the profitability of five different forest management options at the scale of a farm holding. SFARMOD takes this as an input to allow on-farm woodland to be considered as a potential alternative land use within a farm. In year 2, the BASGRA grassland model (grey-green box, Figure 1) will be implemented to improve estimates of grassland yield within each farm under different scenarios and management parameters.

Given a particular scenario and set of management and policy options, SFARMOD estimates the profitability of both the current farm type and all potential alternative farm types for each farm holding. Profitability of different farm types is compared within the Land Allocation Module (the "LAM", blue box, Figure 1). Transitions from current land uses are determined through a set of rules and thresholds comparing the current farm type with the most profitable alternative farm type. If the current farm type is viable, the LAM considers whether there is a more profitable alternative farm type. If there is, and the increase in profitability from the new farm type is sufficient to make transition worthwhile (given the capital investment needed to transition) the farm will change land use to the more profitable farm type; if not, farm land use will not change. If, however, the current farm type is *not* viable, the farm will change to the most profitable viable farm type. If no viable farm type is available the farm will be sold and the LAM will consider if forestry is a profitable alternative instead. If so, forestry will be established, and if not, the land will be left to re-wilding. Once the land allocation is established for each farm, FARMSCOPER (salmon box, Figure 1) determines the emissions from farms based on their size and typology. Emissions include nutrients (e.g. P), greenhouse gasses (e.g. CO_2) and pollutants (e.g. NH_3-N), and may be affected by user specified mitigation measures.

While farm-scale land use is adequate to determine effects on emissions, sub-farm land use is required to understand effects on ecosystem services and biodiversity.

Models related to these components will work using the underlying Decision-Making Units (DMUs) used by SFARMOD when calculating profitability of all potential land uses. DMUs are sub-farm clusters of fields sharing similar climate, soil, current land cover and elevation.

DMU-scale land use and scenario information is then used by the ecosystem service (ES) model and the MULTIMOVE model (top two green boxes, Figure 1) to determine effects of management and policy options on ES and biodiversity. The ES model estimates peatland GHG emissions, habitat connectivity, pollutant emissions effects on water quality, soil conservation and carbon sequestration. In addition, the biodiversity model MULTIMOVE estimates habitat suitability for a wide variety of plant species, including some that are endangered or important for pollinators. For year 2, options are being explored to also include the British Trust for Ornithology's (BTO) bird models, which would fit in a similar place to MULTIMOVE in the model chain and highlight the impacts of scenarios and interventions on an additional taxa. Year 2, will also add the EMEP4UK model to provide estimates of PM2.5 deposition. A small number of indicative runs of EMEP4UK will be included in the IMP prototype to illustrate how its projections of changes in $PM_{2.5}$ can result in implications for human health.

In the final stage of the IMP, the ES and public goods are valued (using monetary or non-monetary values as appropriate). ES valuation follows a hierarchy of valuation methods (market prices, avoided costs, revealed preference and stated preference) using value transfer approaches and following best-practice guidelines. ES values are presented with (1) clear statements about what values are (and are not) captured for which beneficiaries, and (2) levels of uncertainty. ES values are also placed in the context of better known values of commodities such as crops, livestock and timber.

2.3 Spatial scales

The spatial scale at which the IMP operates varies from start to finish. This is partly because different input data are available at distinct scales or resolutions; digital elevation data are gridded at very high resolutions (~5m) while agricultural census data are only available at the scale of the farm holding. Furthermore, different component models in the IMP chain demand input data at distinct scales in order to run effectively.

However, decisions are being reached about spatial scales within the user interface, which is not subject to the same limitations as the IMP. Effects of scenarios and management/policy interventions on land use, public goods and commodities could be presented at three different spatial scales, relevant to different users:

1. **For Welsh Government** outputs are presented firstly at the farm-scale, representing the scale at which land use is allocated in the IMP. There are around 60,000 farms in Wales.
2. **For Welsh Government** outputs can be presented at the DMU-scale if more detail is required.
3. **For the general public** to avoid data protection issues, outputs can be aggregated to a grid with a resolution between 200 and 1000m (likely

250m).Data can also be aggregated for display within the user interface to administrative boundaries or Wales (or other spatial units if desired).

The prototype of the IMP will show outputs at the farm-scale and DMU-scale.

2.4 Temporal scales

The IMP runs for static time slices that reflect the near-term focus of supporting post EU exit natural resource policy planning, and longer-term scenario testing of the resilience of policy interventions under climatic and socio-economic change. The IMP is run firstly using input data relevant to the present day. However, it is also run using input data from three future time slices, relevant to distinct policy commitments:

1. **2025:** This time slice is most useful in consideration of current agreements with land managers, immediate outcomes of Brexit and short-term prospects for Natural Resources Policy goals.
2. **2050**: This time slice is appropriate for considering interactions between policy and long-term climatic and socio-economic change.
3. **2100**: This time slice is most relevant for adherence to the Well-being of Future Generations Act, and is critical to understand long-term forestry-related impacts.

2.5 Outputs

Each iteration of the IMP will produce many output variables, mostly relevant to one or more public goods identified by Welsh Government (Table 1). Outputs for a single set of inputs are likely to be of interest to researchers, Welsh Government and the general public (Figure 2, screen a). However, the most useful property of the IMP is that two runs can be visualised in parallel, allowing direct comparison of outputs resulting from changes in parameters. For example, outputs for a given climatic or socio-economic scenario can be directly compared with outputs based on current, baseline inputs (Figure 2, screen b). Furthermore, a comparison can be made between outputs with and without policy or management interventions; this is the appropriate way to investigate the *difference* that an intervention might produce (Figure 2, screen c).

Comparing two IMP outputs based on different inputs is not only critical to assess the impacts of individual scenarios or policy changes (Figure 2); such comparison can also be used to highlight where in the Welsh landscape an intervention could be targeted to maximise benefits (or minimise damage) to public goods. For example, a subsidy for mixed deciduous woodland might improve air quality and health in some areas more than others (e.g. depending on population density). Such priority areas for interventions would be clearly highlighted in the user interface, and would depend on the public goods that the user considers to be most important.

Table 1. Categories of public goods/ sustainable land management outcomes identified by Welsh Government and examples of potential corresponding outputs from the IMP. See Figure 1 for the names and positions of component models within the IMP.

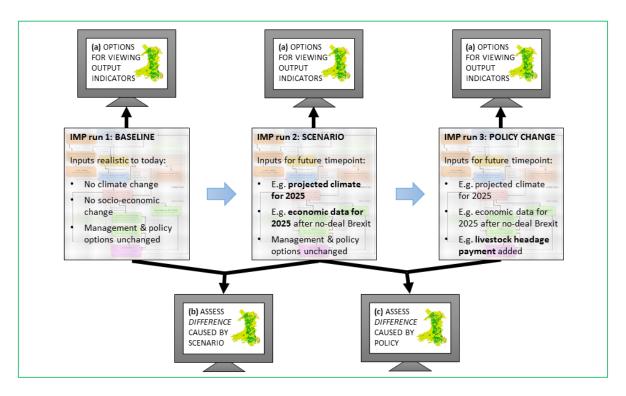| Public goods/ SLM outcomes	Relevant IMP outputs	Relevant models
Greenhouse gas balance	Tree carbon stocks; soil carbon stocks; GHG emissions (e.g. from agriculture/ forestry management).	CARBINE, FARMSCOPER, ES
Biodiversity	Habitat extent, quality and connectivity; resilience of biodiversity; plant species richness; nectar yield; woodland biodiversity metrics.	MULTIMOVE, ESC
Water quality	Nitrate and phosphorus concentrations; WFD exceedance.	FARMSCOPER, ES
Air quality	Farm emissions (e.g. NH_3); Deposition of pollutants (e.g. $PM_{2.5}$, PM_{10}, Nitrogen and Sulphur compounds).	FARMSCOPER, EMEP4UK
Public health	Areas affected by poor air quality (based on (e.g.) $PM_{2.5}$ deposition); avoided health damages.	EMEP4UK, ESC, ES
Productivity	Farm livelihoods (profits, costs etc.); Food security (crop yields, livestock numbers).	SFARMOD
Improvement of the natural landscape / Conservation of heritage	Spatial distribution of land uses; Land use impacts on historic features via land use change; Changes in species with negative conservation impacts (e.g. weeds).	ES; MULTIMOVE
Social outcomes (e.g. public access, outdoor recreation).	Recreational woodland indicator; access to natural areas.	ESC, ES, Valuation

Figure 2. Simplified schematic demonstrating how the IMP can be implemented and iterated in practice. Outputs of a single IMP run can be usefully interpreted through a user interface (screen a). However, by comparing outputs from two different iterations of the IMP, it is also possible to assess the effects of specific scenarios (screen b) and management options (screen c).

2.6 User interface

The user interface for the IMP aims to provide clarity, ease of use, explicit recognition of uncertainty, and transparency in model assumptions, limitations and operation. The structure of the prototype interface is currently being drafted to iterate with Welsh Government. It will allow the user to interact with the IMP in three key stages (Figure 2):

1. First, the user may view **baseline** outputs, which arise when the IMP is run using a set of default input parameters that are realistic to present day (Figure 2, IMP run 1, screen a).

2. Second, the user chooses a **scenario**. The scenario represents a run of the IMP under a combination of projected future climate and socio-economic conditions. Outputs of this run of the IMP can be viewed in isolation, for example to consider the state of public goods following 25 years of climate change (Figure 2, IMP run 2, screen a). Alternatively, the interface will display the difference between outputs from the scenario and outputs from the baseline (Figure 2, IMP run 2, screen b). This will allow meaningful consideration of the predicted direction of change under a given scenario.

3. Finally, the user selects one or more **management and policy options**, for example subsidies and land management practices. Again, IMP outputs can

be viewed in isolation (Figure 2, IMP run 3, screen a). However, the change in outputs that result from including the management and policy options might be more useful (Figure 2, IMP run 2, screen c).

Although the development of the prototype interface is at an early stage, the mock-up screen shots shown in Figures 3 and 4 illustrate the concept of a single page application providing a highly interactive and visually rich scenario and policy exploration tool.
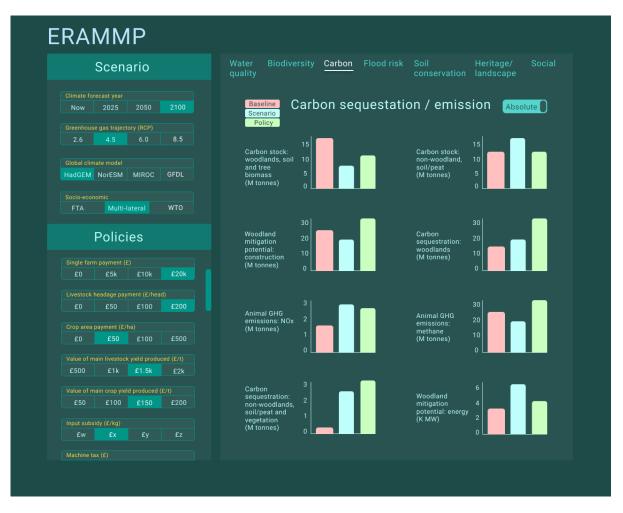

Figure 3. Mock-up of interface illustrating a side-menu for setting a scenario and then applying policies. The output panel on the right displays appropriate graphics (in this case charts) capable of displaying absolute values of and relative changes between baseline, scenario and application of policies for chosen goods and services.
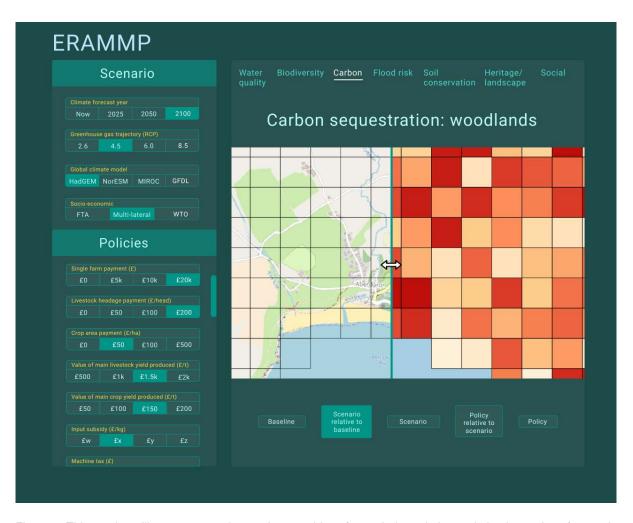
Figure 4. This mock-up illustrates some interactive map ideas for exploring relative and absolute values for goods and services against scenario changes and policy interventions. There will be gridded and polygon map options depending what local, regional and national views are needed.

3 Next steps

The structure of the IMP for the first year is almost final [at the time of writing; May 2019], following several IMP modeller workshops. The next steps for the IMP are:

- **Collating the data cubes from the component models for baseline, climate and economic scenarios** (Figure 2, IMP run 1). These data cubes include data for the baseline run, an economic scenario where CAP subsidies are removed and a climatic scenario with +4°C change.

- **Implementing the LAM.** The rules and thresholds within the Land Allocation Module will be finalised, converted into computer code and implemented within the modelling chain.

- **Adding policy interventions.** A number of potential demonstrator policy/management interventions are being identified and input parameters matching these interventions will be applied to the linked IMP chain and outputs added to the data cubes.

- **Continuing to draft the interface and seek feedback from end users.** An interface for the IMP prototype is being iterated with WG to identify the desired functionality, as well as key outputs and scales for display.

- **Demonstration of the prototype of the IMP to the WG Strategic Evidence Group (SEG).** An initial working prototype of the IMP focussed on the IMP's ability to explore interventions was demonstrated to the WG SEG on 17th July 2019.

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