Ecosystem Services and Climate Change Adaptation: Towards an Integrated Model of Optimal Rotation Length

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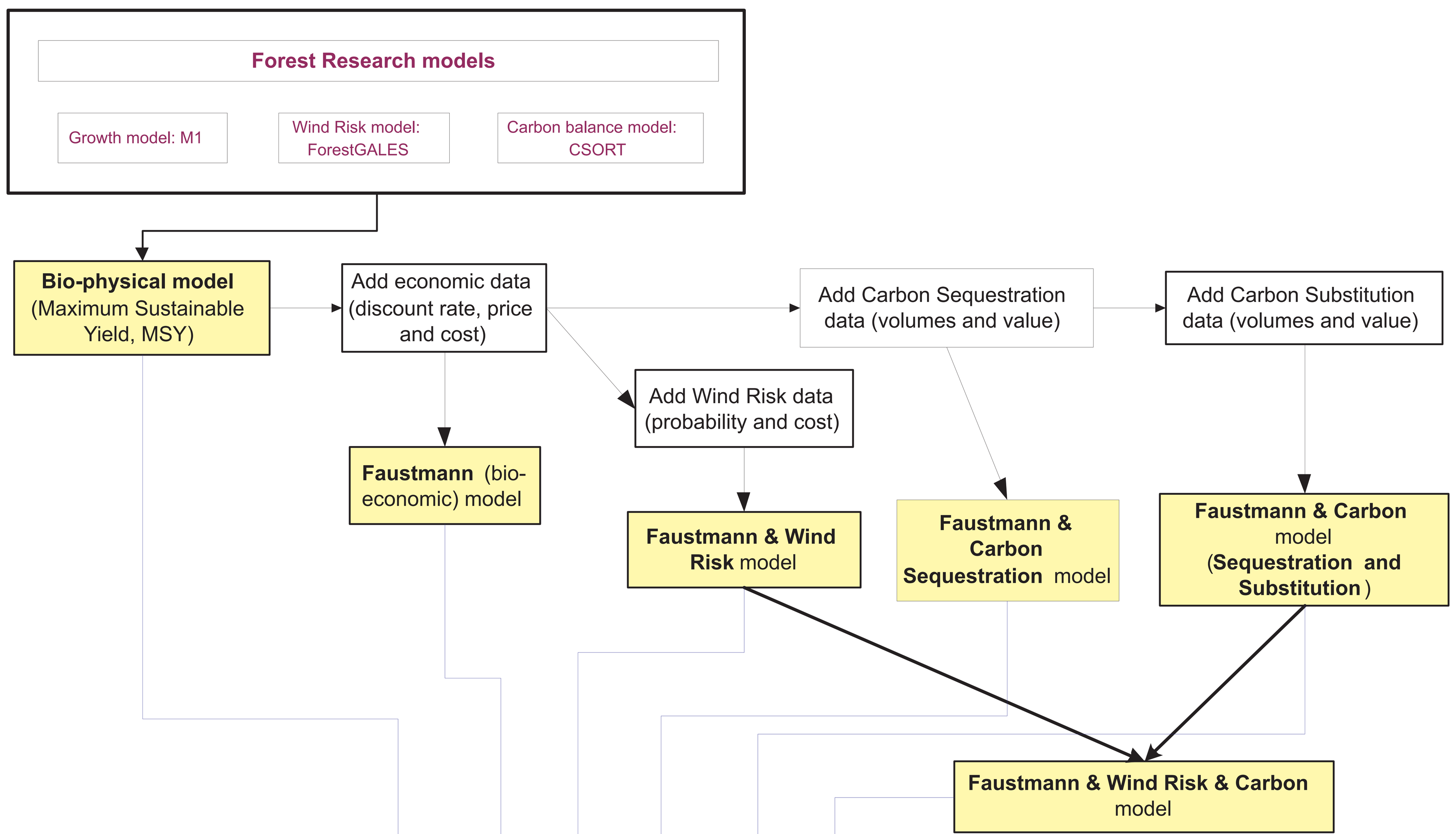
Forests can be managed to provide a range of ecosystem services. In theory efficient allocation and/or use of resources are determined by applying an optimisation procedure of some kind. This underpins the development of optimal rotation length models starting with Faustmann's landmark work on forestry in 1849.

Wind risk is one of the most significant threats to Europe's forests, with storms currently responsible for over 50% of all primary damage by volume from catastrophic events. Climate change is expected to increase the frequency of storms. This highlights the importance of accounting for wind risk in adapting forest management to climate change.

A stand level model of optimal rotation length is being developed in part to assist with deciding how best to adapt forest management in the UK to climate change. The model currently accounts for timber and carbon benefits in the presence of windthrow risk, with potential extensions to other ecosystem services, as well as wider climate change related risks (e.g. drought, pests and diseases) under consideration. The approach combines estimates from Forest Research's timber yield, carbon accounting, and wind-risk models with information on prices, costs and discount rates, estimating the rotation length that maximises economic returns. Preliminary results for an illustrative example (Sitka spruce Yield Class 14 at a moderately exposed site) are presented below.



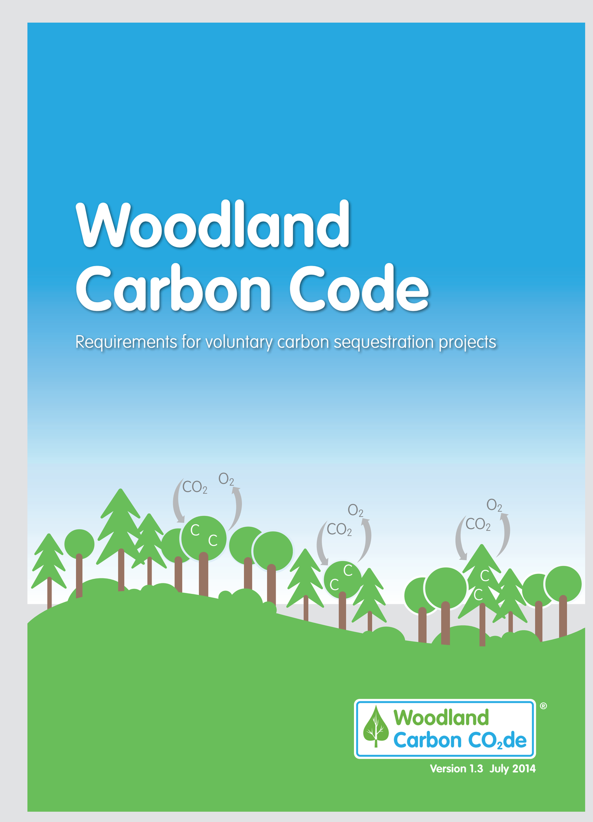
RESULTS	MSY	F	FW	Fseq	FC	FWC
Optimal rotation length (years)	52.9	42.7	39.2	50.5	48.3	40.8
Wood harvest (m3/ha)	686	528	463	653	621	495
Land Expectation Value (£/ha)	-456	-283	-369	420	667	455

The model maximises the Land Expectation Value (LEV), which is equal to the Net Present Value (NPV) over an infinite series of rotations.

Notes: the 'maximum sustainable yield' (MSY) model is based on ecological principles and is aimed at maximising timber volume produced per unit of land over time. This corresponds to the point of maximum mean annual increment (MMAI). This model does not depend on economic information, including discount rates.

Currently there is no salvage value assumed in cases of windthrow and an extra cost of site clearance after windthrow is a fifth of standard planting costs. Other input parameters are discount rate: 3.5%, timber (standing sales) price: £15/m^3 over bark, (re-)planting costs: £2,000/ha, carbon price: £3/tCO_2e.

Preliminary sensitivity analysis indicates that at sites with relatively low windthrow risk, optimum rotation length is very sensitive to the assumed price of the carbon sequestered. Initial results suggest that the optimal harvesting decision is not to harvest at all at such sites if carbon prices are towards the middle or higher end of the range for market prices of £3/tCO_2e to £10/ tCO_2e thought to apply currently to carbon sequestration projects certified under the UK Woodland Carbon Code.



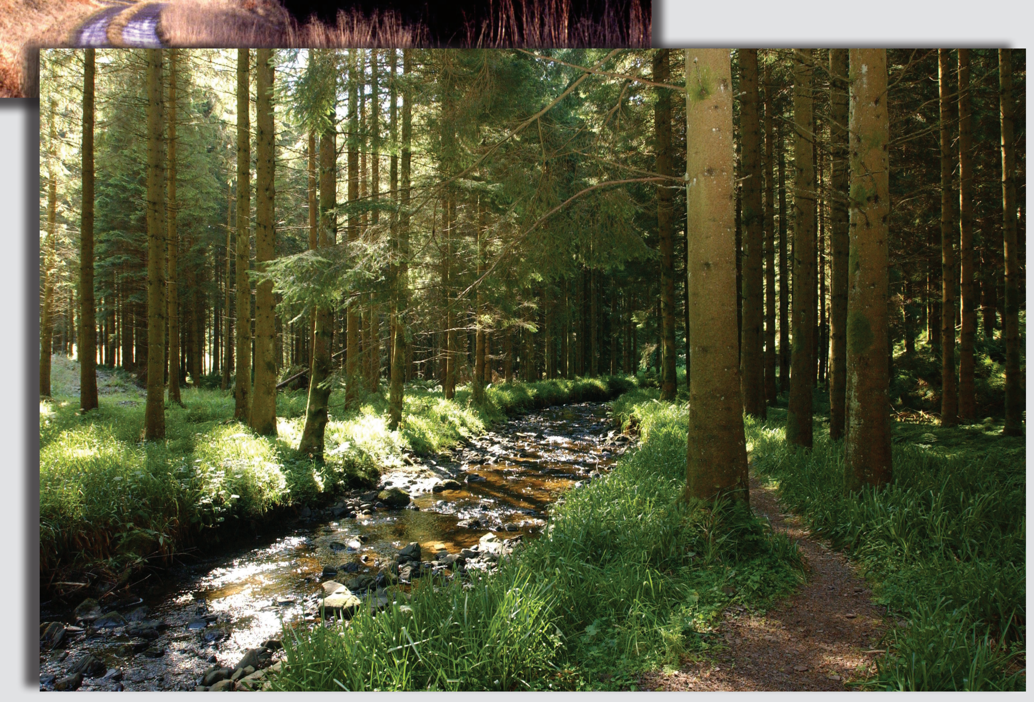
The Code currently covers carbon sequestration from UK woodland creation projects. 201 projects covering an area of 15,400 hectares of woodland and projected to sequester a total of 5.7 million tonnes of CO_2 have been certified to date (as at 30th September 2014 - see: http://www.forestry.gov.uk/pdf/wccoct2014.pdf/$FILE/wccoct2014.pdf)

For models including economic factors, the results show (as expected) that the longest rotation length is associated with models with carbon sequestration benefits included. The shortest is for the models with wind risk included. Others – including the full model, are intermediate. Optimal rotation length rises as the discount rate falls, with higher timber volumes and values of the LEV (i.e. forestry becomes more profitable). Optimal rotation length increases most for the Faustmann model (increasing by about 7 years in the example when the discount rate falls from 3.5% to 1.5%). It increases least for the models with wind risk at relatively windy sites, because wind risk is the main determining factor. (In the example it increases by half a year). Models with carbon benefits are intermediate.

The model currently focuses on single species and single age stands. If the model is to be extended to cover mixed species stands, further experimental research on yields, carbon benefits and windthrow risks associated with mixed species stands would be needed.

Potential practical applications of the model as a tool to aide decisions are being explored through in-depth interviews with public and private sector forest planners, and by trialling the model in a case study in southern Scotland.

Model calibration is using data from Craik Forest in southern Scotland. This covers an area of 4,729 ha across an altitudinal range of 175-425 m. The main forest species is Sitka spruce (*Picea sitchensis*) comprising 58% of the forest. Other conifers represent 8%, broadleaves 10%, and the remainder (24%) comprising felled areas, permanent open space and other ground. At present over 85 per cent of the forest is managed on a patch clear-felling system, and can be classed as 'Intensive even-aged forestry'.



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