Guidance for Implementation

Strengths and weaknesses of three ecosystem services models applied in a diverse UK catchment

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Case study: Guidance for National Implementation

Welsh Government: Legislating sustainable development to secure long term well-being of Wales and its people

Glastir is the sustainable land management scheme, offering financial support to farmers and land managers.

Glastir: 6 Main Priorities → Ecosystem Services

Combating climate change → Regulating

Improving soil quality and management → Regulating, Provisioning, Supporting

Maintaining and enhancing biodiversity → Cultural, Supporting

Improving water quality and managing water resources → Regulating, Provisioning

Managing landscapes & historic environments and improving public access to the countryside → Cultural

Woodland creation and management → Provisioning, Cultural, Supporting

Glastir: 6 Main Priorities

Combating climate change

Improving soil quality and management

ca. £80M to Welsh farmers yearly
- **To benefit the environment**
- **To compensate for reduction in income**

Maintaining and enhancing biodiversity

The question is: Does it work?

Improving water quality and managing water resources

Managing landscapes & historic environments and improving public access to the countryside

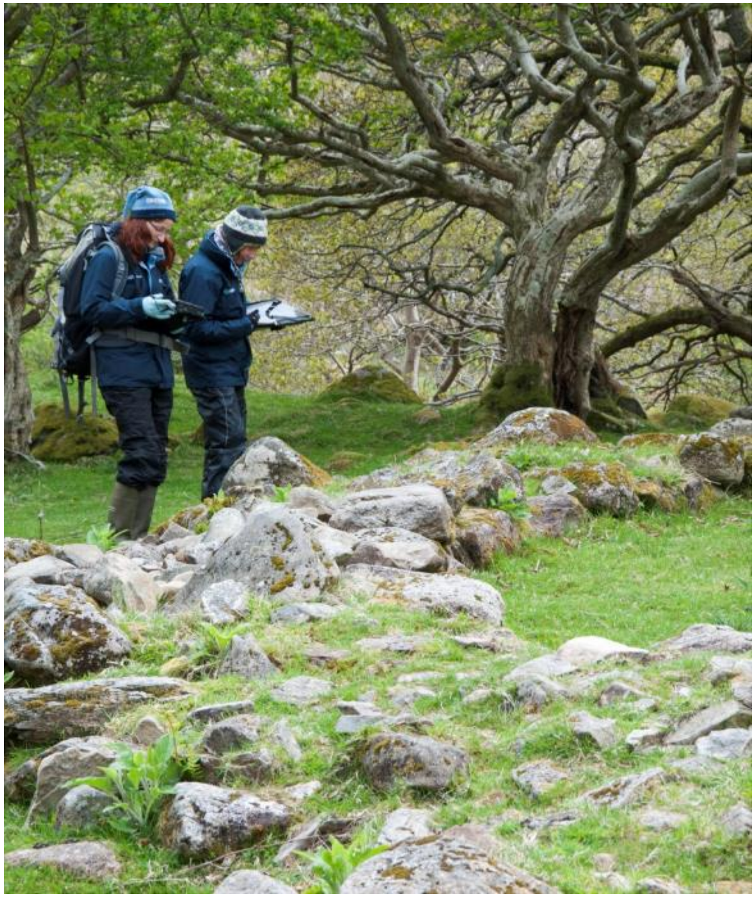
Woodland creation and management

Glastir Monitoring and Evaluation Programme (GMEP)

GMEP - A combined monitoring and modelling approach to maximize environmental, social and economic outcomes at the national scale

- Co-located collection of environmental data
- Modelling to target activities and predict impacts

Glastir Monitoring and Evaluation Programme

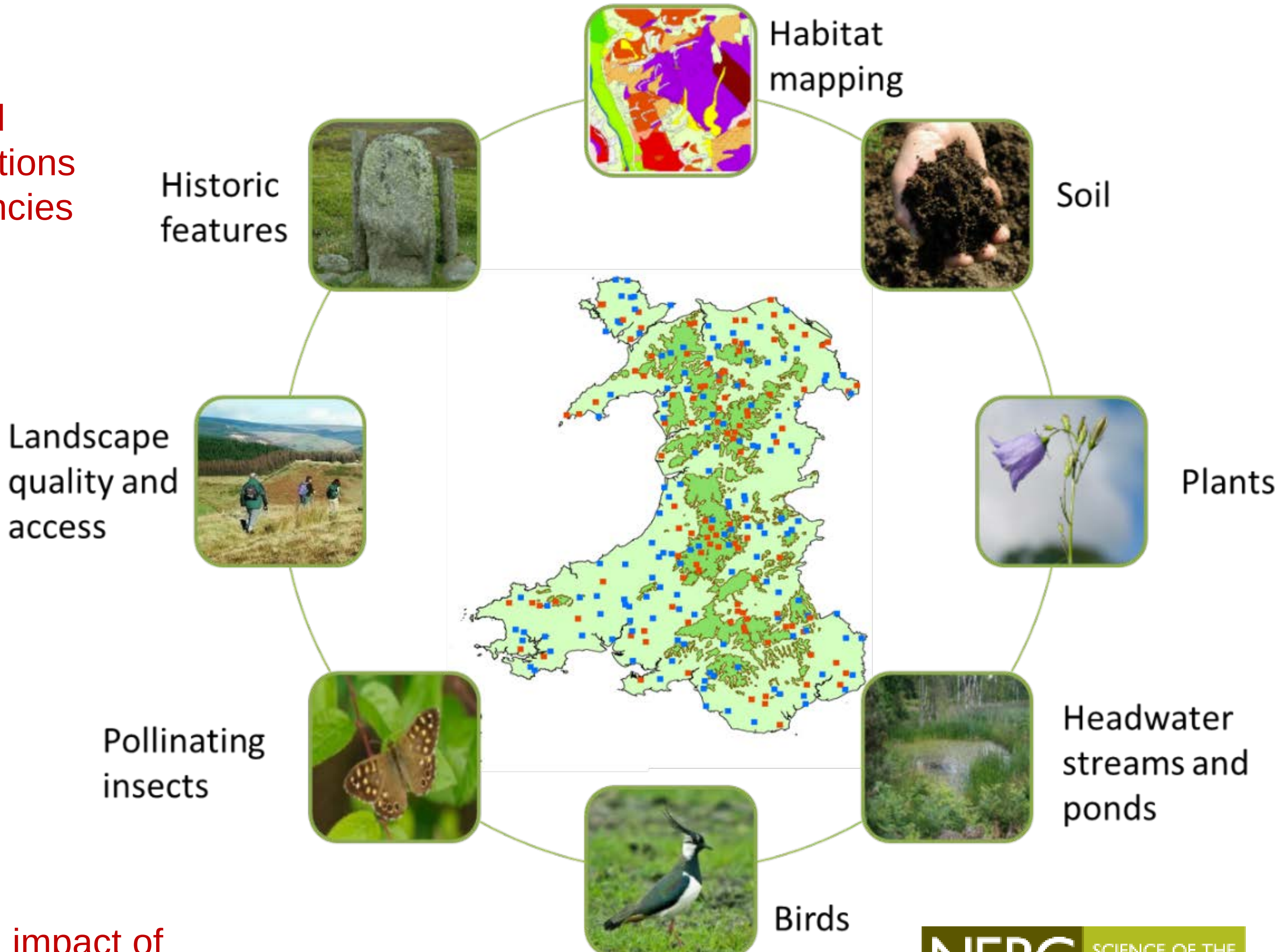


GMEP provides an objective, independent, scientific approach to:

- Identify ongoing national trends in the environment
- Quantify impacts of Glastir interventions against background trend
- Provide data for other national and international reporting requirements (e.g. Water Framework, Habitats and Bird Directives, Kyoto, etc)
- Attribute change and determine implications for ecosystem services
- **Provide Guidance for use and interpretation of Ecosystem Services Models and Outputs**

GMEP data collection: An ecosystem approach

Co-locating data collection enables understanding and analysis of correlations and interdependencies



Data will inform on impact of Glastir against background trends

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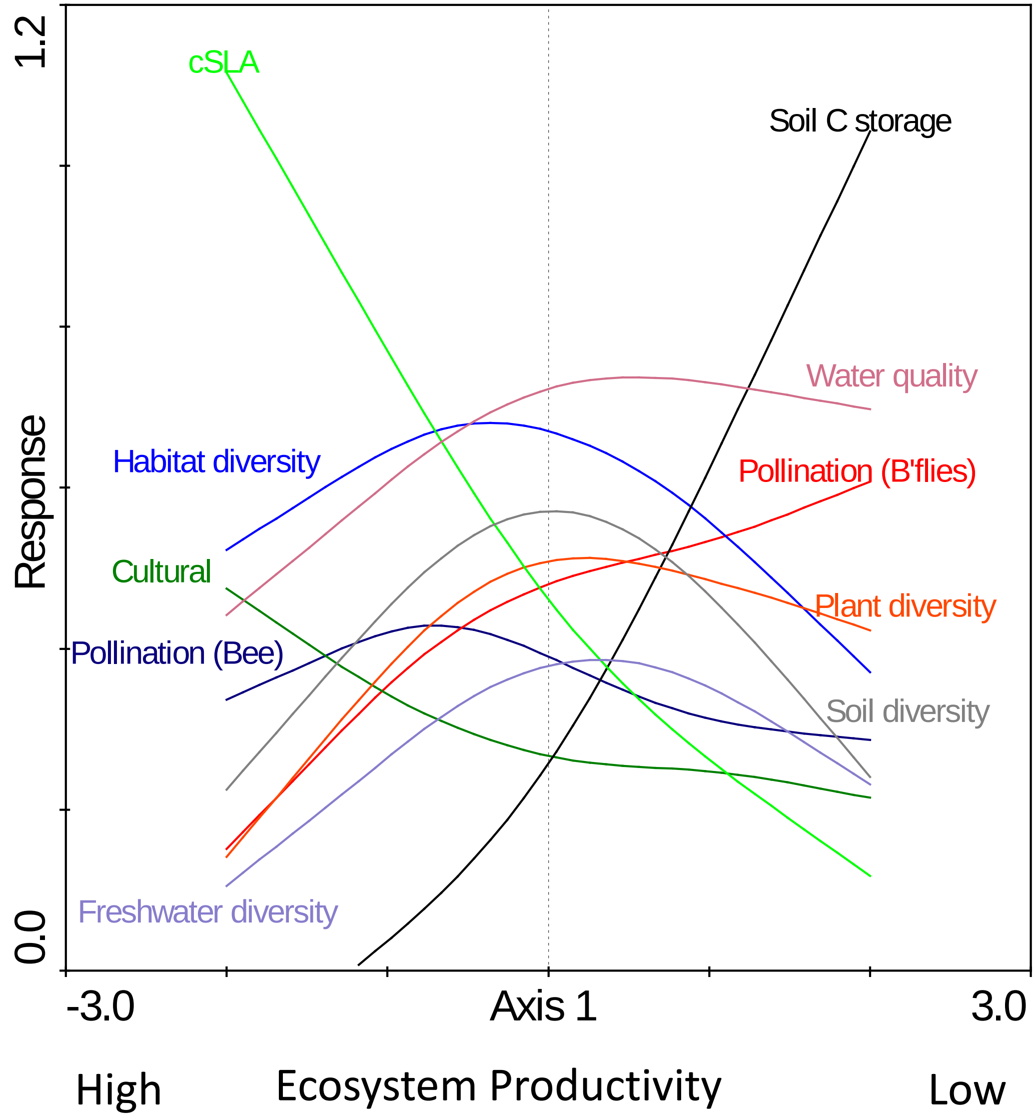
GMEP analyses: Identifying inter-dependencies

Response curves of ecosystem service indicators from analysis of 2007 Countryside Survey (GB scale)



Maskell et al 2013
J Appl. Ecol 50:561-571

GMEP modelling: Anticipating outcomes

ES models allow the evaluation of the impact of land-use change and/or alternative management options on ecosystem service delivery.

In GMEP, a suite of models are applied to forecast possible outcomes:

- Changes at national scale due to a wide number of drivers
  e.g. current land management, air pollution, climate change
- Changes due to legacy of past agri-environment schemes
- Glastir interventions, with upscaling for projected uptake

Many tools available, ranging in complexity and scale. Which to choose ?

We compare 3 spatially explicit ecosystem service tools to provide guidance for implementation:

ARIES ARtificial Intelligence for Ecosystem Services

InVEST integrated valuation of ecosystem services and tradeoffs

LUCI LAND UTILISATION & CAPABILITY INDICATOR

Ecosystem services model comparison

- The three models differ in approach and produce a wide range of different outputs for any given service.

InVEST — integrated valuation of ecosystem services and tradeoffs

Combines land use and land cover data with information on supply (biophysical processes) and demand to provide a service output (economic or biophysical). Freely available to download.

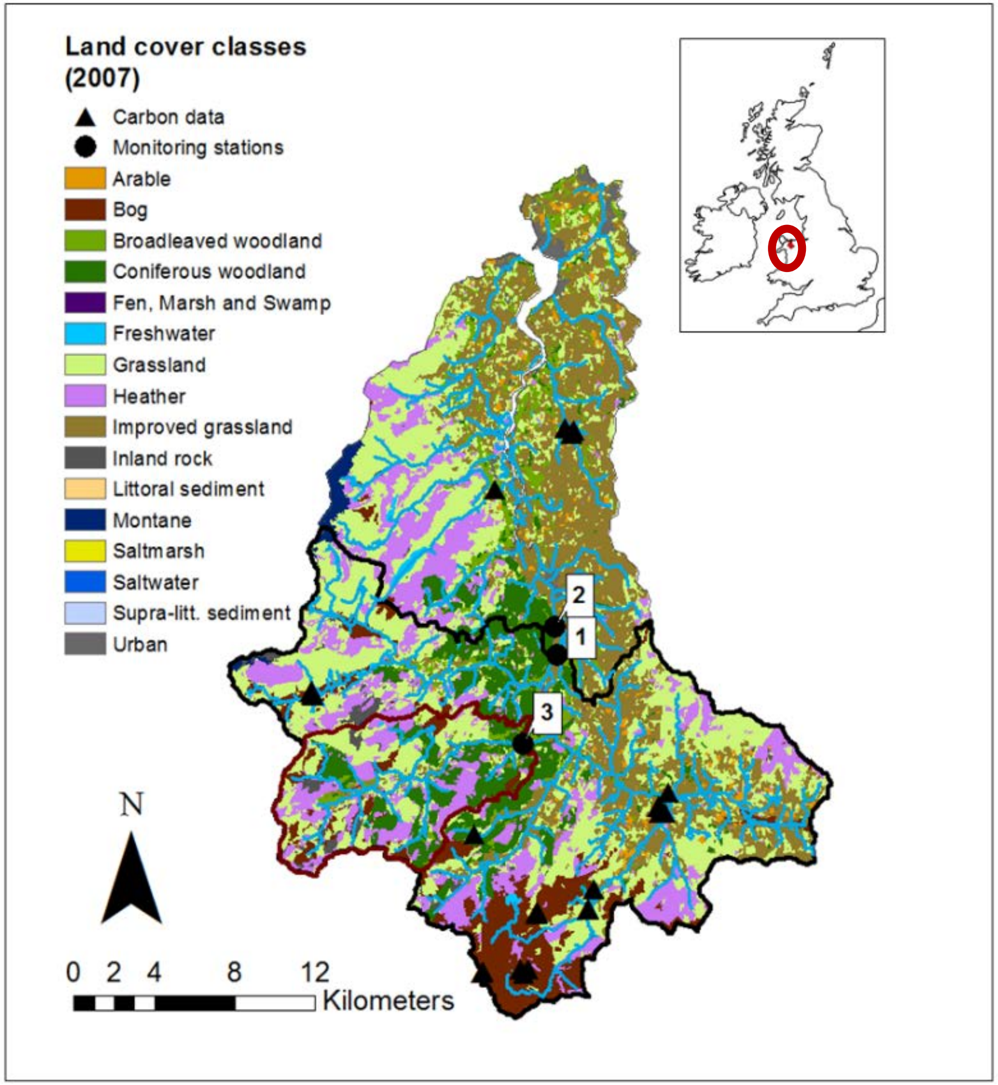
LUCI — Land Utilisation & Capability Indicator

Incorporates biophysical processes, applying topographical routing for hydrological and related services, and using lookup tables where appropriate (e.g. carbon model). Also has a unique trade-off tool. Available for public use in 2017.

ARIES — ARtificial Intelligence for Ecosystem Services

Developed as an online platform to allow model building. Can use probabilistic methods (Bayesian networks) if insufficient local data available. Easy to use online tool is under development.

Study system



Conwy catchment, North Wales, UK.

Small catchment in global terms (580 km^2)

Diverse range of:

- elevation (0-1060m)
- climate
- geology
- land use

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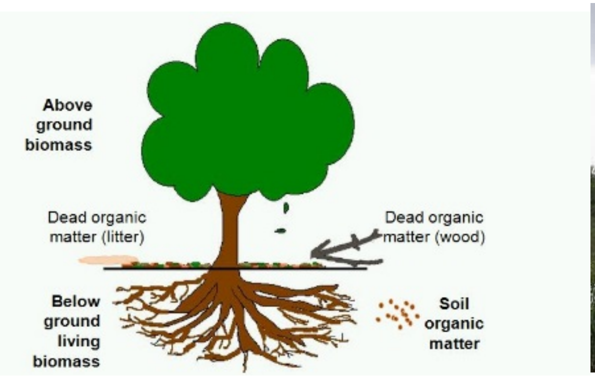
Ecosystem services modelled

Water supply

Carbon stocks



Nutrient retention (N & P)

- Models were parameterised for the UK and then applied to the study catchment.
- Validated using empirical data from the catchment:
  - Flow data from 2 sites within catchment (in UK gauging station network).
  - Soil carbon, above and below-ground biomass data collected from 18 sites within catchment.
  - Water quality data from 1 site within catchment.

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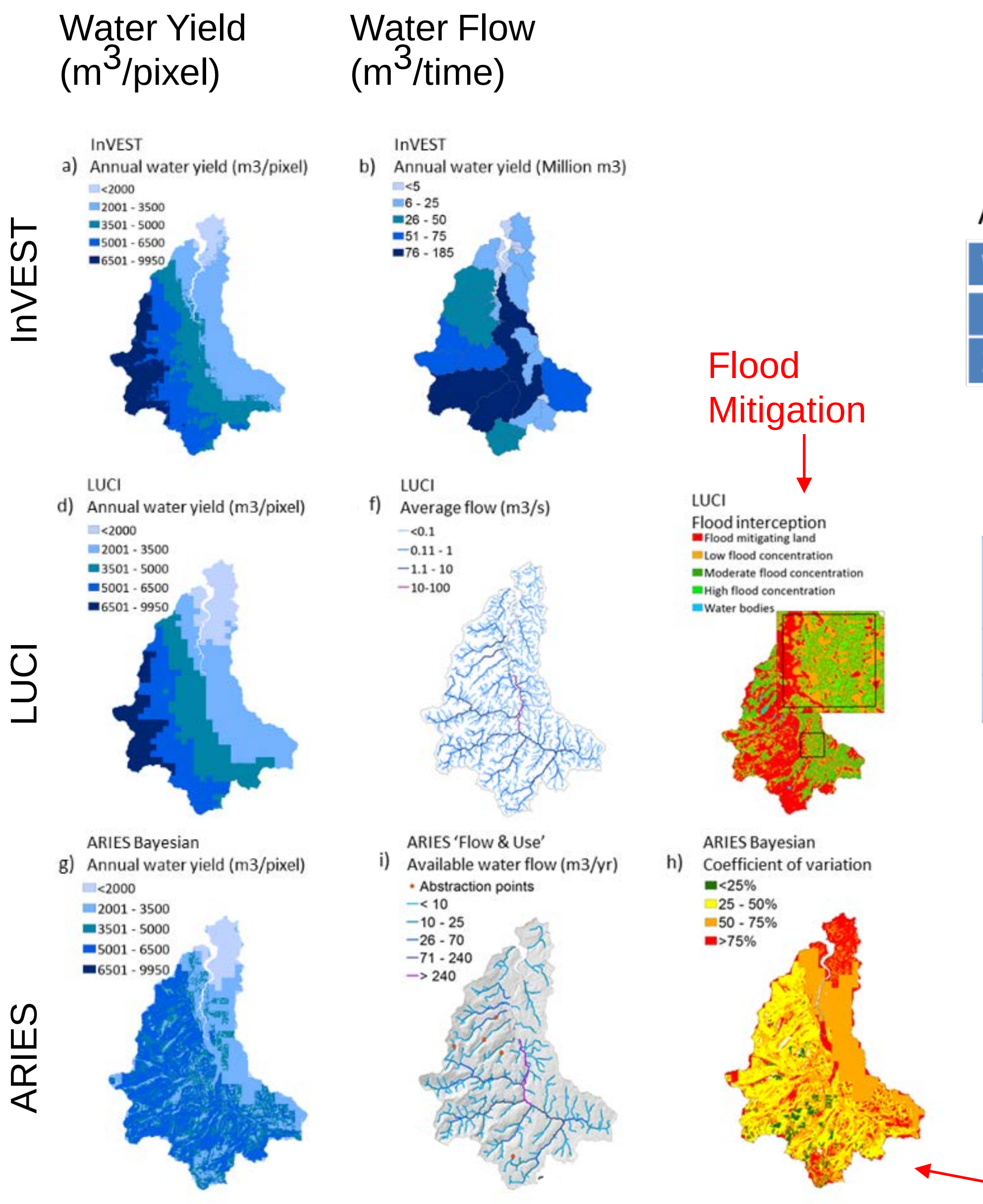
Water supply



Coefficient of variation

Model validation

Actual measured flow

Watershed	Gauging station flow (m^3/y)
1) Cwm Llanerch	648, 070, 000
2) Lledr	161, 790, 000

% difference between modelled and measured flow

Watershed	ARIES BAYESIAN	ARIES 'Flow & Use'	InVEST	LUCI
1)	-7%	+1%	+7%	+1%
2)	-17%	+7%	+12%	+6%

The water models performed well when compared with measured data from the catchment.

Carbon stocks

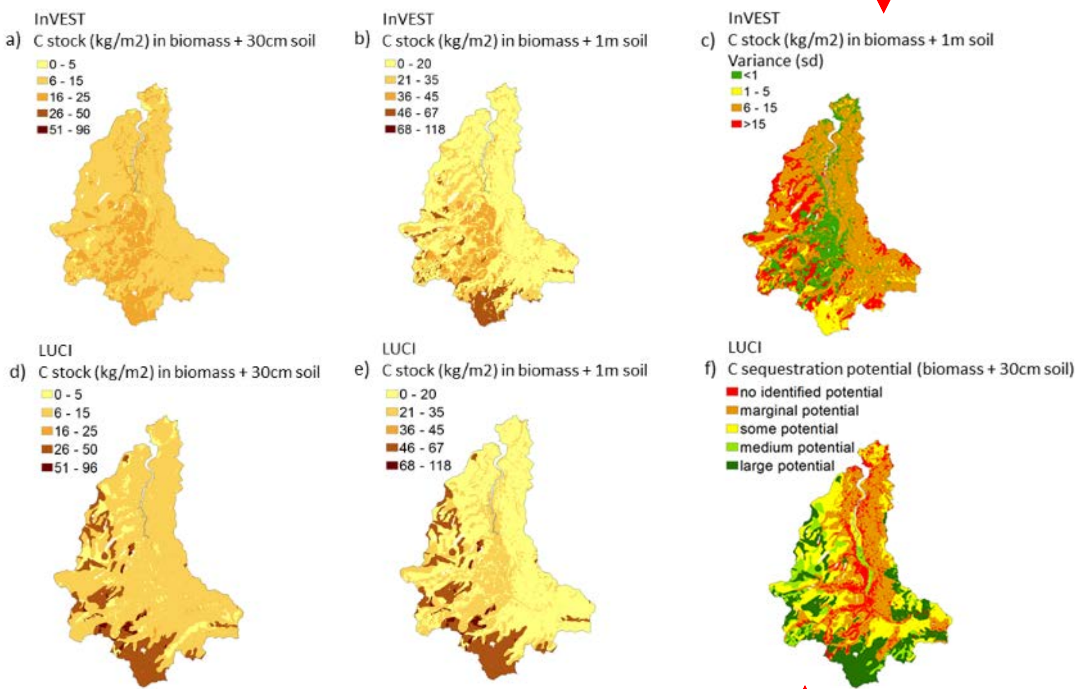
Carbon stock (kg/m^2)
Biomass + 30 cm soil

Carbon stock (kg/m^2)
Biomass + 1 m soil

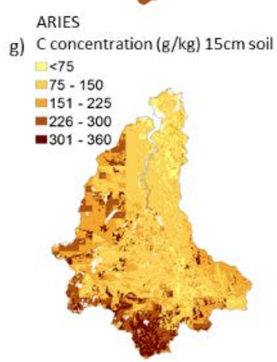
Variance

InVEST

LUCI



ARIES



ARIES modelled C conc (not stock) and top 15 cm of soil only (no biomass)

C sequestration potential

Model validation

Estimated total C in the catchment using measured data

	Catchment C stock (t)
Biomass +30cm soil	5,153,042
Biomass +1m soil	10,475,968

Modelled total C
(% diff. between modelled and measured)

	Total carbon stock (t)
	Biomass + top 30cm soil
InVEST	8,020,377 (+56%)
LUCI	8,070,546 (+57%)

	Total carbon stock (t)
	Biomass + top 1m soil
InVEST	14,596,360 (+39%)
LUCI	15,488,110 (+48%)

- InVEST and LUCI similar (10%)
- Both biased high (50%)
- “Measured” is estimate

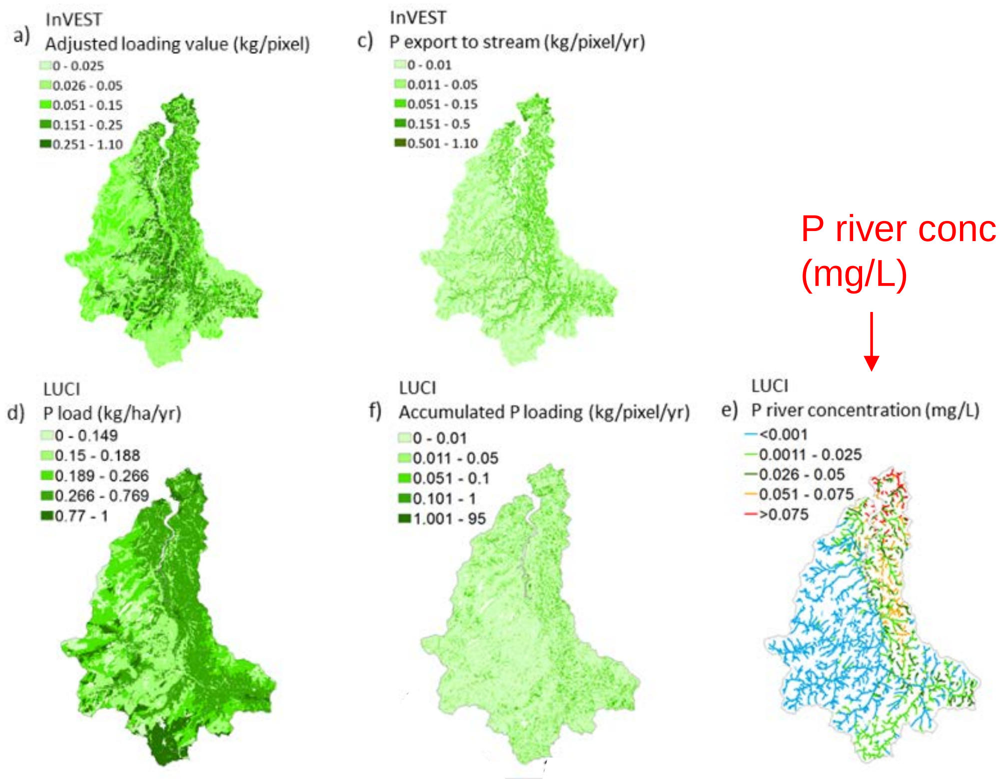
Nutrient retention

P loading (kg/pixel)

P export to stream (kg/pixel)

InVEST

LUCI



Spatial patterns similar for N

Model validation

Annual load calculated from measured concentrations

Nutrient	Average annual load (kg/year)
Nitrogen	253,800
Phosphorus	8,590

Modelled loads from InVEST and LUCI (% diff between modelled and measured)

	InVEST (kg/year)	LUCI (kg/year)
Nitrogen	49,400 (-81%)	196,000 (-29%)
Phosphorus	4,990 (-42%)	5,200 (-40%)

Overall, models did not perform well, (difficulties in assigning export coefficients)

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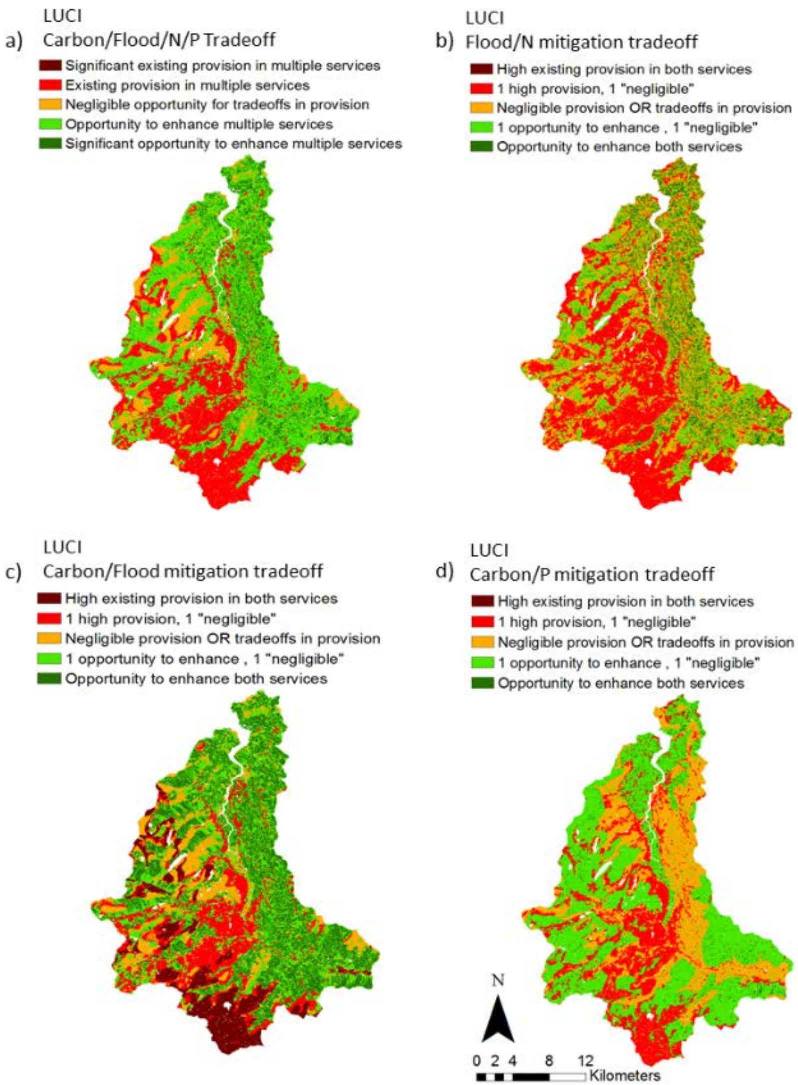
Trade-offs



Using the LUCI trade-offs tool, can investigate appropriate placement of interventions and protective measures.

When all modelled services were considered, there is opportunity to enhance multiple services, particularly in east of catchment.

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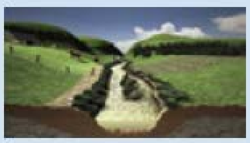
Managing future risk – scenarios & planning

What does the future hold?

DURESS future scenarios for Wales

From an analysis of drivers of change, and a review of historic changes in the uplands since World War 2, we have considered four possible scenarios to 2050:



Agricultural Intensification

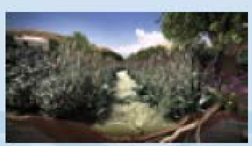
Maximising food and fibre production becomes crucial to meet the challenges of food security and increasing global demand.

Managed Ecosystems

Ecosystem integrity is pro-actively enhanced to safeguard water, carbon and nature through either public funding of agri-environment schemes or because the market value of these services increases.

Business as Usual

Publically funded agri-environment continues to deliver social benefits and ecosystem services.



Abandonment

Land becomes abandoned as a result of market or regulatory failure of the other three scenarios, leading to rapid decline in production and unmanaged development of quasi-natural habitats.

Duress

DURESS scenarios created by:

- Appraising drivers of change in expert workshops representing all appropriate sectors (farming, forestry, water, communities, nature…)
- Identifying plausible land management responses to each driver of change, called projections.
- Analysing possible interplay among these projections to construct the four storylines.

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Scenarios

We tested the sensitivity of all 3 models to land-use change of varying severity.

Grassland → **Woodland (GW)**

(5, 10, 30% catchment)

DURESS Diversity in Upland Rivers for Ecosystem Service Sustainability

The DURESS scenarios were developed through discussions with stakeholders and experts on current and future drivers of land-use change in Wales.

"**Managed ecosystems**" scenario

Scenario results

Tool	Water		% difference from baseline output		
	Output	**Watershed**	**GW 5**	**GW 10**	**GW 30**
ARIES	Water yield	Cwm Llanerch	-0.19	-0.62	-2.34
		Lledr	-0.31	-0.65	-2.01
InVEST	Water yield	Cwm Llanerch	-0.26	-0.55	-1.67
		Lledr	-0.18	-0.36	-1.11
LUCI	Area mitigated	Whole catchment	1.9	-2.7	-27.4
	Area mitigating	Whole catchment	10.9	23.9	82.5

Tool	Carbon	% difference from baseline output		
	Output	**GW 5**	**GW 10**	**GW 30**
ARIES	C concentration of top soil (15cm)	-1.49	-2.8	-9.17
InVEST	C stock in biomass + 1m depth soil	3.67	7.33	23.88
LUCI	C stock in biomass + 1m depth soil	1.8	4.0	13.6

Tool	Nutrients	% difference from baseline output		
	Output	**GW 5**	**GW 10**	**GW 30**
InVEST	Average annual N load	-3.19	-6.13	-20.18
	Average annual P load	4.00	7.53	22.25
LUCI	Average annual N load	1.91	0.35	-7.49
	Average annual P load	3.39	2	-9.61

Recommendations and guidance for implementation

Using three well-known ES models, we demonstrate:

ES models can provide quantitative and mapped outputs for services within a study catchment. Outputs for different scenarios of land-use change can be compared and trade-offs between services can be visualised. Therefore these models are extremely useful for planning purposes.

When the three models were compared:

- The models provided broadly comparable quantitative outputs.
- There is a wide variety of possible outputs for each service.
- Each tool has unique features and strengths.
- InVEST has detailed documentation and example data, therefore would be useful for those with time constraints. This tool also produces economic valuation.
- LUCI would benefit users seeking fine scale outputs or interested in mapping trade-offs.
- ARIES allows the customisation of models and is particularly useful when data is scarce.

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Thanks for your attention

https://gmep.wales/

This work ‘Location, Configuration, Distribution: the Role of Landscape Pattern and Diversity in Ecosystem Services; NERC project NE/K015508/1; CEH Project NEC05059’ was funded with support from the Biodiversity and Ecosystem Service Sustainability (BESS) programme.

LUCI modelling work was funded through the Glastir Monitoring and Evaluation Programme (GMEP), contract reference: C147/2010/11), NERC/Centre for Ecology & Hydrology (CEH Project: NEC04780). LUCI Mapping derived from soils data © Cranfield University (NSRI) and for the Controller of HMSO 2011.