Modelling Scenarios of Land Use Change

-the approach so far

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C3 - Land Transformations – RESAS Research Programme

The Scottish Government
Riaghaltas na h-Alba

Rationale

- Context matters: land use change is the manifestation of **wider** system behaviour- holistic approach needed
- To assess resilience & adaptation: characterisation of **interdependent** impacts to inform adaptation
- High uncertainty justifies the use of scenarios

Aims

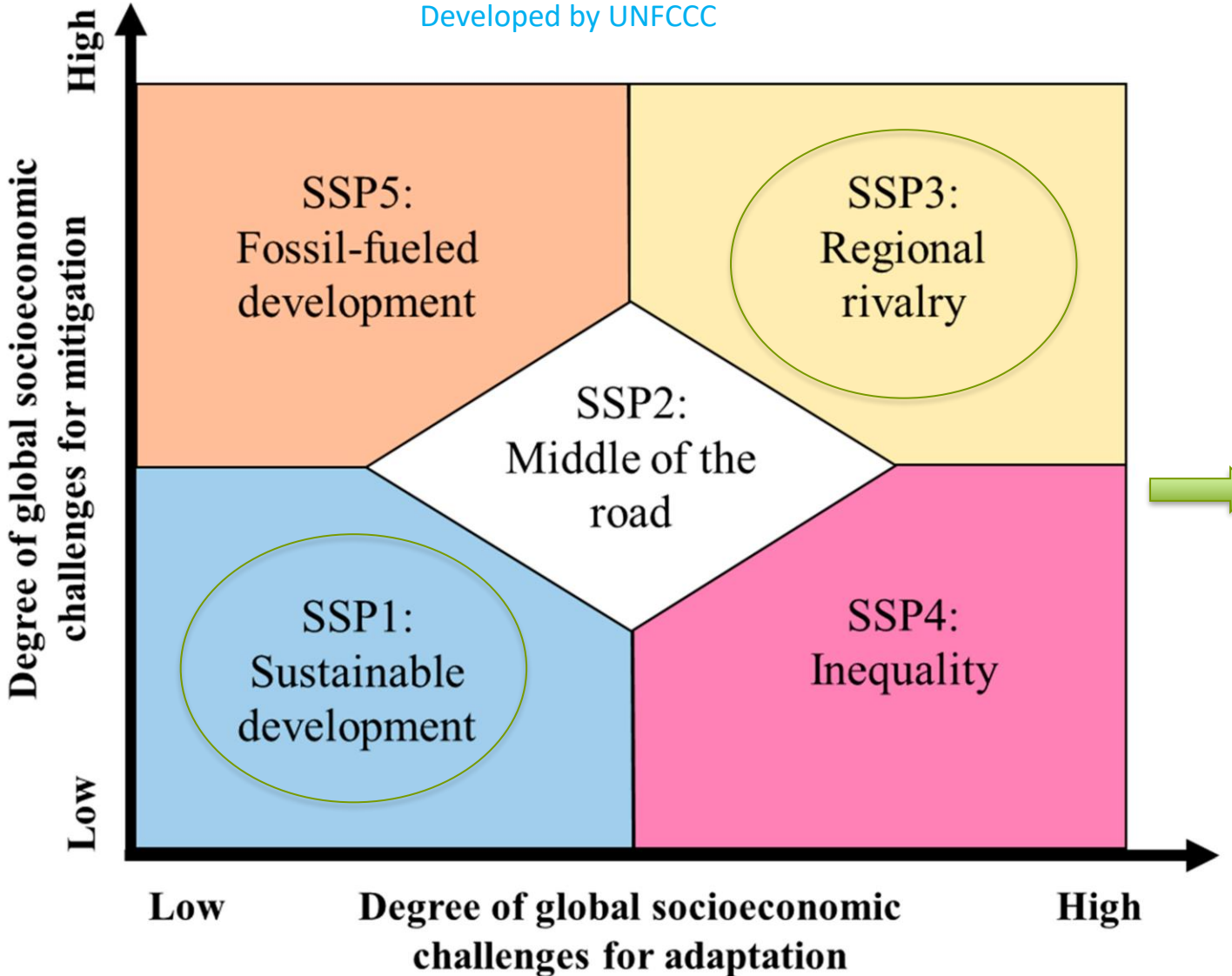
- Understand how land use might respond to societal + climate change: implications for Scotland of wider-scale scenarios -
- **Spatial** understanding of implied LUC and (later) impacts on ESS

Improved national resilience

Shared Socioeconomic pathways (SSPs)

- Intended to span the range of plausible futures
(imply land use futures)

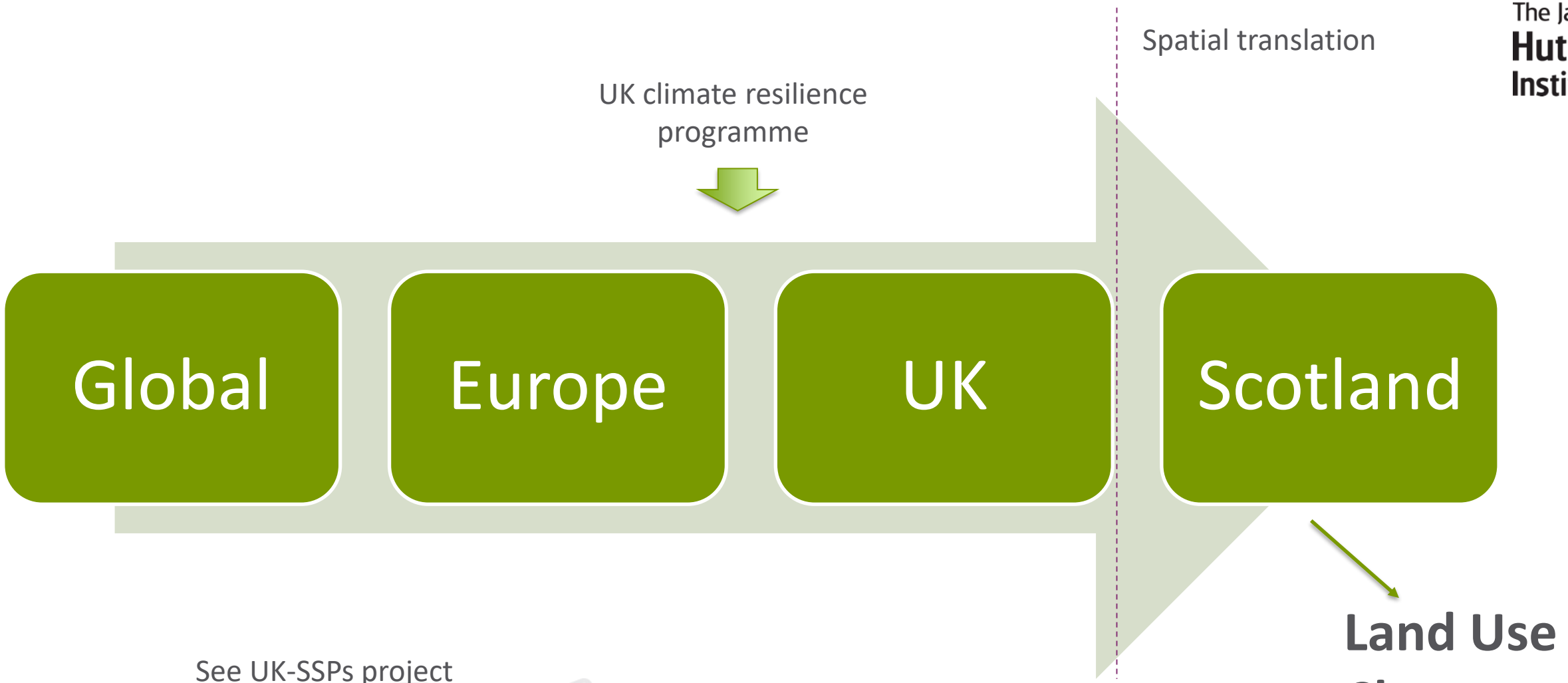
Developed by UNFCCC



Narrative for each

Source: https://www.mdpi.com/1660-4601/15/1/3

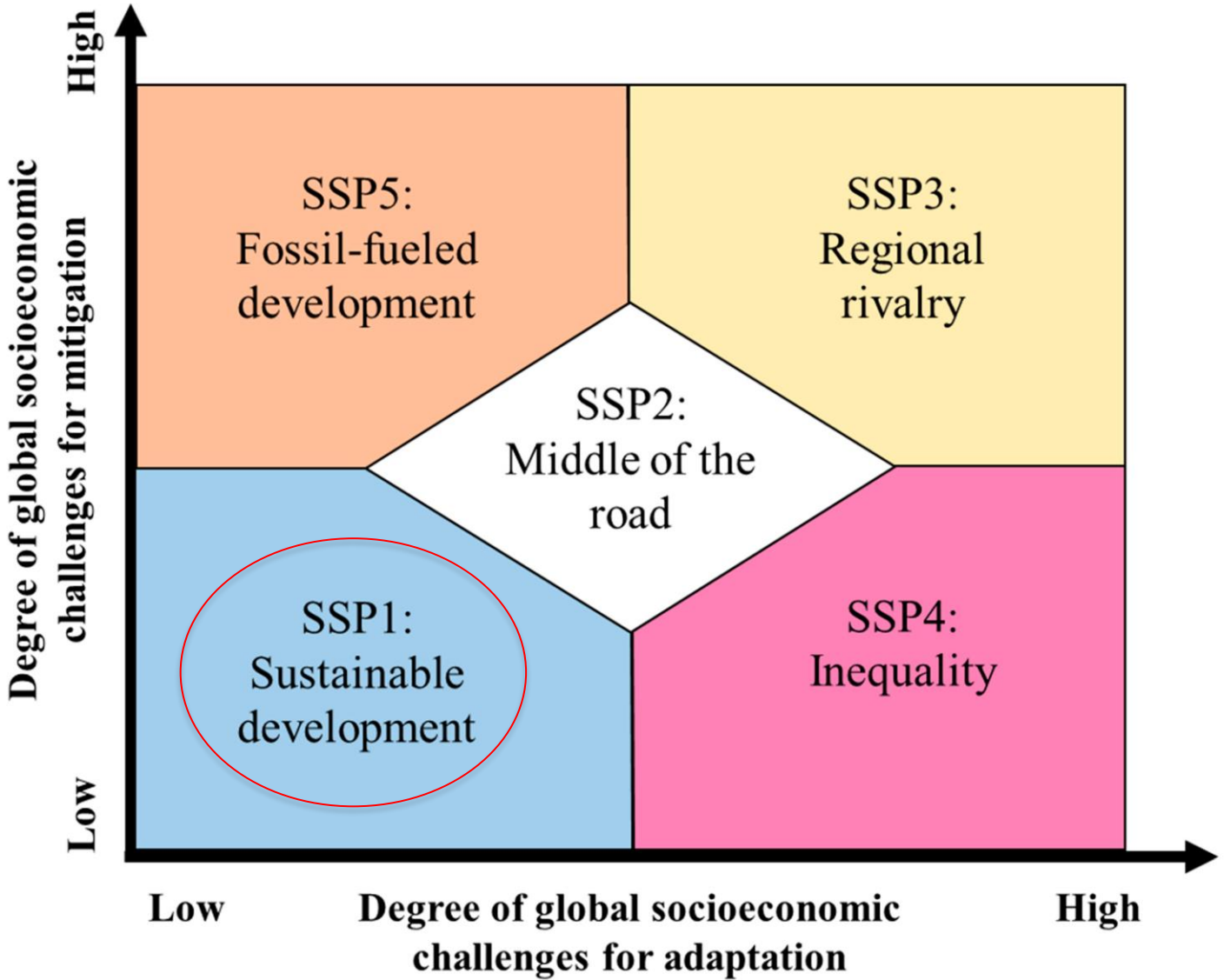
SSPs hierarchy



See UK-SSPs project
https://www.ukclimateresilience.org/products-of-the-uk-ssps-project/

Caveat

UK-SSP1 Sustainability



UK-SSP1 – Sustainable development

Main features

- National cooperation
- Mostly renewable energy
- Strong support for regionalisation
- Green technology
- Low-consumption lifestyles
- Circular economy
- Public support for pro-environmental policies

Sustainable land-use change

LU change modelling approach

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World System Pressures (narratives)

Biophysical constraints and opportunities (includes climate & future *land capability*)

Land Use Change

Improve (change) multiple ESS

Farm types biasing type of change

Spatial relations (opportunity maps) can bias prob. of change

'Satisfy-cing' of objectives (no economic optimisation)

OVERVIEW diagram

Actor/Farm Characteristics

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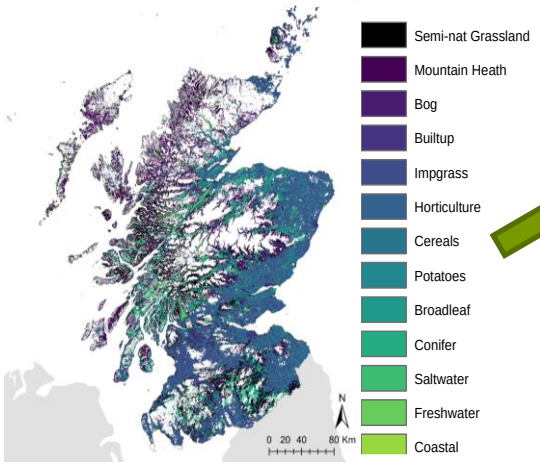
LUC -Tendencies

Define LU change objectives

Opportunity Maps (multiple benefits from LUC)

Baseline Map



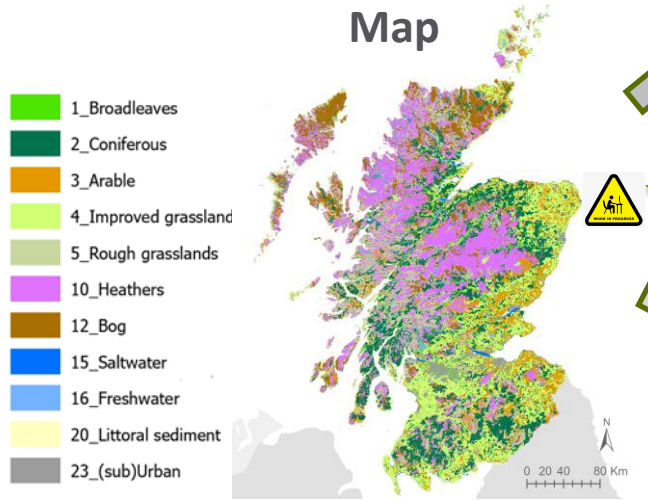
Spatial Allocation Model

Restrictions

A map generated to restrict land use change in designated areas (e.g peatlands)

Model Output

2050 Scenario Map

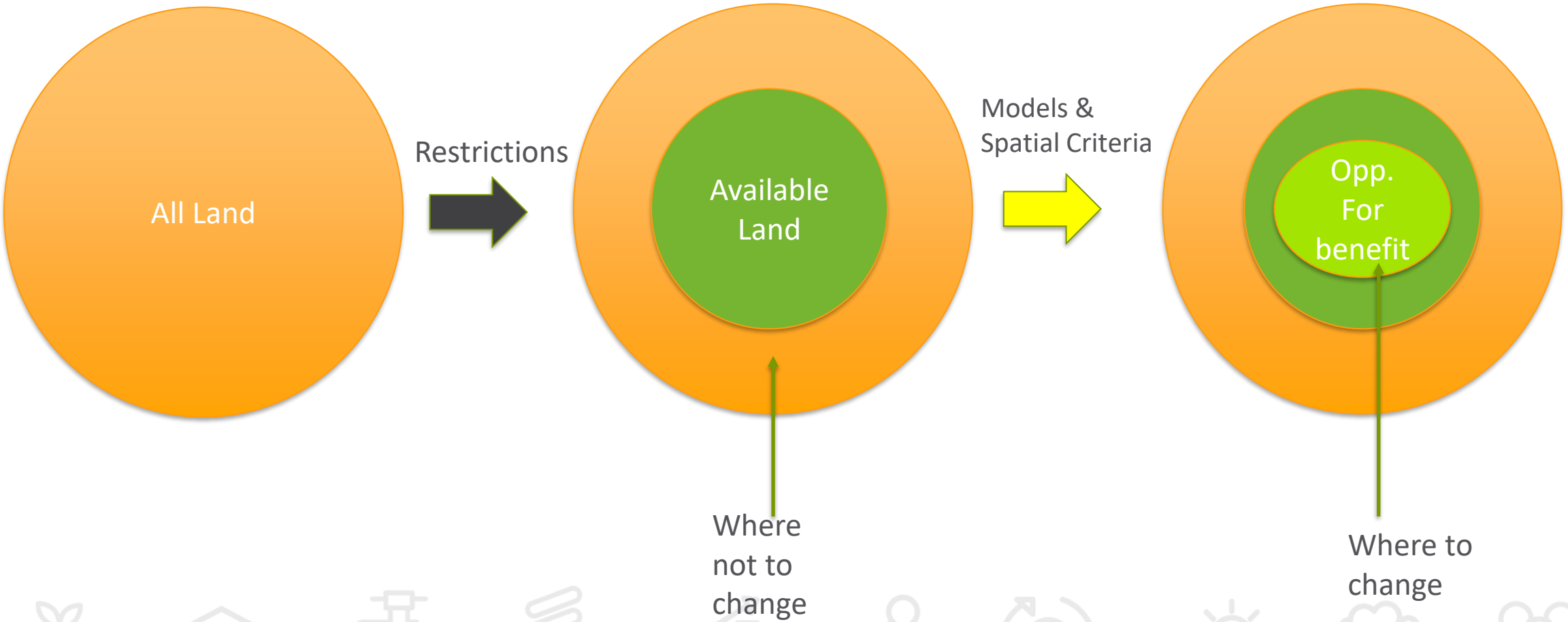


Connectivity analyses

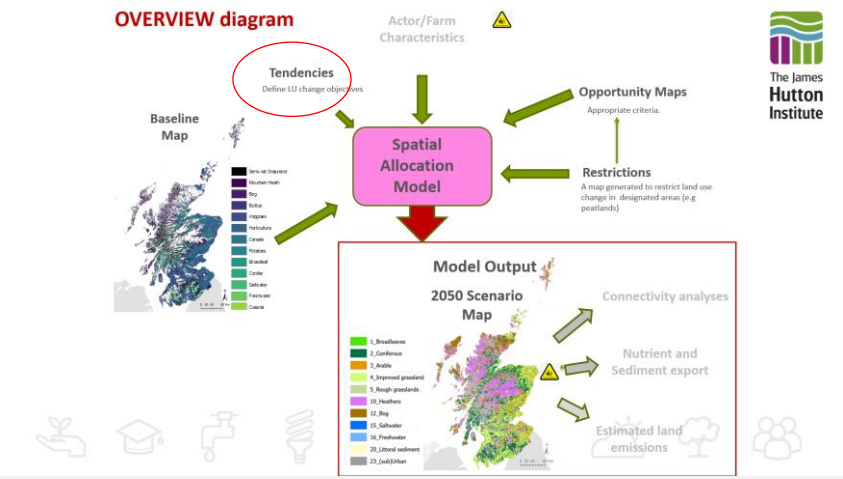
Nutrient and Sediment export

Estimated land emissions

Change to new land use to improve a given benefit/ES : conceptual framework



SSP1-Scotland -Target Land use changes



LUC-tendencies – towards Net Zero

Target Land uses	Trend	Considers ES	Target Ha	How much	source
New Woodlands	Increase	YES	500,000		~ SG compatible
Silvo-Arable	Increase	YES	60,773	**10% of 'Arable' land converted to agroforestry** by 2050	Land use: Policies for a Net Zero UK infographic (theccc.org.uk)
Silvo-Pastoral	Increase	YES	262,619	**10% of farm grasslands** (improved & semi-natural) **converted to agroforestry** by 2050.	Land use: Policies for a Net Zero UK infographic (theccc.org.uk)
Intensive Grasslands (including grazed arable)	Decrease	YES	140,881 - 211,321	20-30% intensive Grasslands stay as they are, the rest, **70-80% intensive Grasslands** (arable, improved and semi-natural) **converted to non-intensive** (reduction of stocking rates).	
Intensive Heathers & bogs	Decrease	YES	15,192 - 22,787	20-30% intensive Heathers & bogs stay as they are, the rest, **70-80% intensive heathers & bogs converted to non-intensive** (reduction of stocking rates).	
Urban (& Suburban)	Increase	NO	46,001	**SubUrban expansion in the countryside** (target of 2.8% build up was chosen for SSP1 using a top-down approach, translating IAP2 total & land use area estimates disaggregated to Scotland level into land use demands for 2040).	(Hewitt et al, 2019)

Land use change considered

From	To
Arable + temp grass (10%)	Silvo-Arable
Improved grasslands (10%)	New woodlands Silvo-pastoral
Semi-natural grasslands (acid & neutral)	New woodlands Silvo-pastoral
Heather & Heather grasslands	New woodlands
Intensively grazed arable, grasslands (improved & semi-natural), heathers & bogs	Non-intensively grazed (grazing pressure below conservation threshold) arable, grasslands (improved & semi-natural), heathers & bogs

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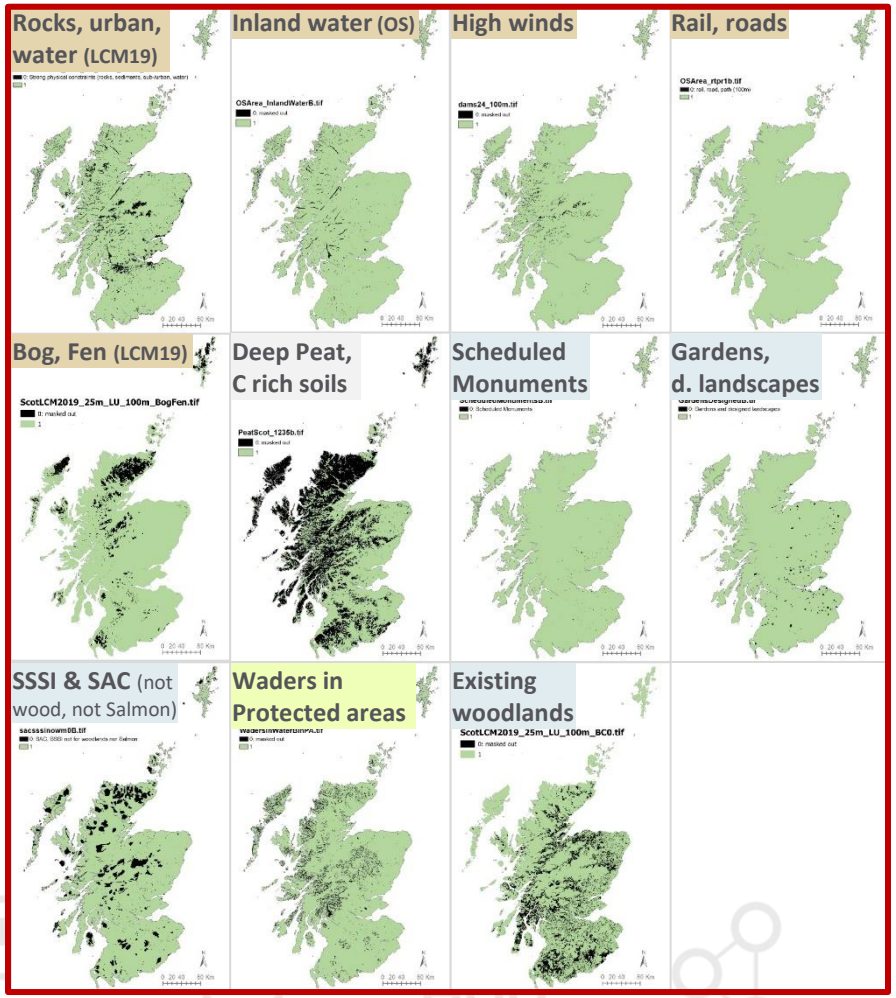
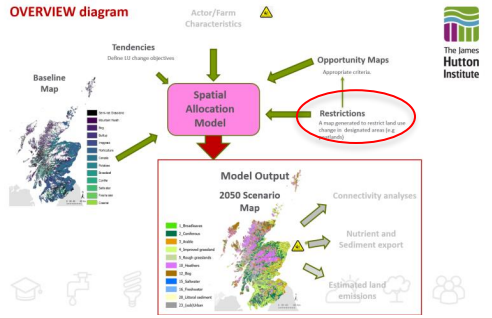
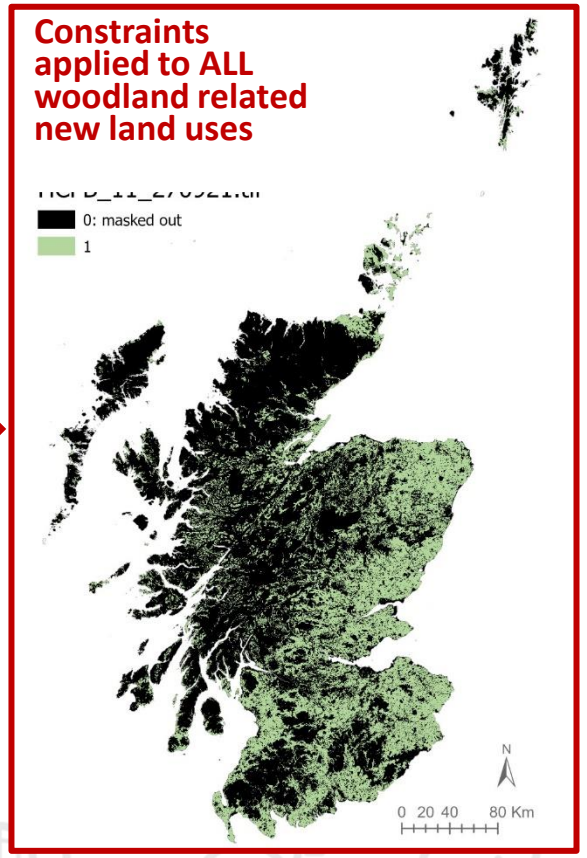
Example –New Woodlands - restrictions (constraints) applied

Topic	Name	
Strong Physical restri-ctions	(sub-)Urban, rocks, sediments, water from LCM19	
	Inland Water (OS)	
	Roads, Railways	
	Bog, Fen from LCM19	
Physical restri-ctions	DAMs score (High winds)	
Policy for Carbon	Deep Peat & carbon rich soils (SNH)	
Policy	Scheduled Monuments	
	Gardens, designed landscapes	
	SSSI & SAC (not wood, not Salmon)	
Conser-vation	Waders in riparian habitat within protected areas	Occurrences
		Riparian habitat
		Protected areas
Existing woodlands from LCM19		







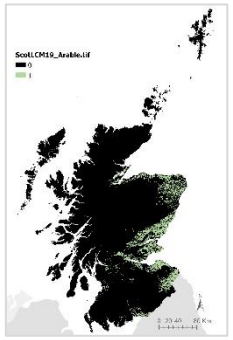
availability for planting

Examples

Silvo-Arable

Original land uses

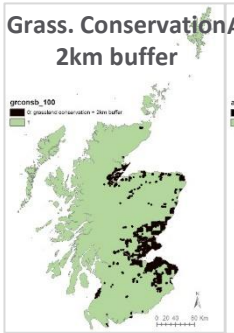
Arable



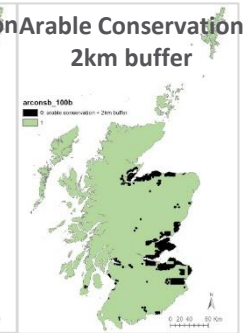
All maps legend :
green: potential locations
black: not allowed

Masked out areas

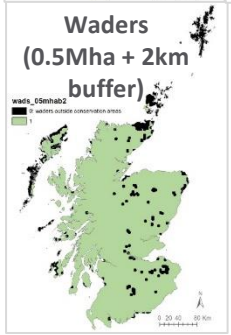
Grass. Conservation 2km buffer



Arable Conservation 2km buffer

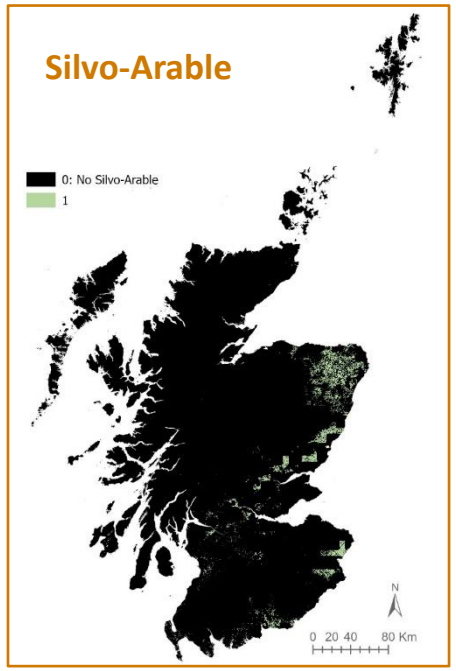


Waders (0.5Mha + 2km buffer)



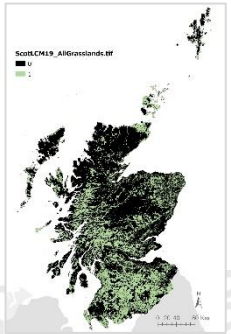
availability map

Silvo-Arable

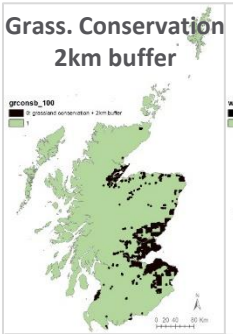


Silvo-Pastoral

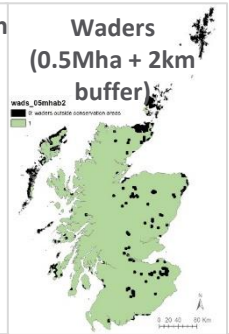
All Grasslands (Improved + semi-natural)



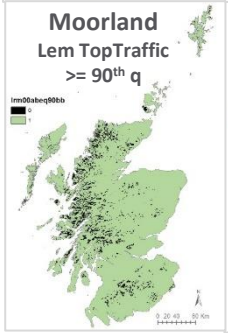
Grass. Conservation 2km buffer



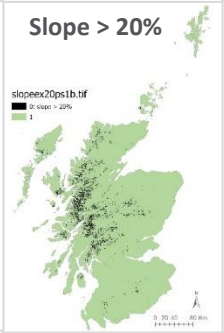
Waders (0.5Mha + 2km buffer)



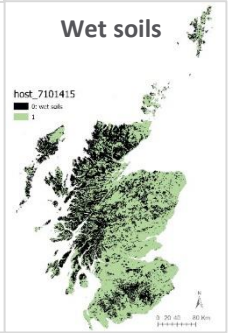
Moorland Lem TopTraffic >= 90th q



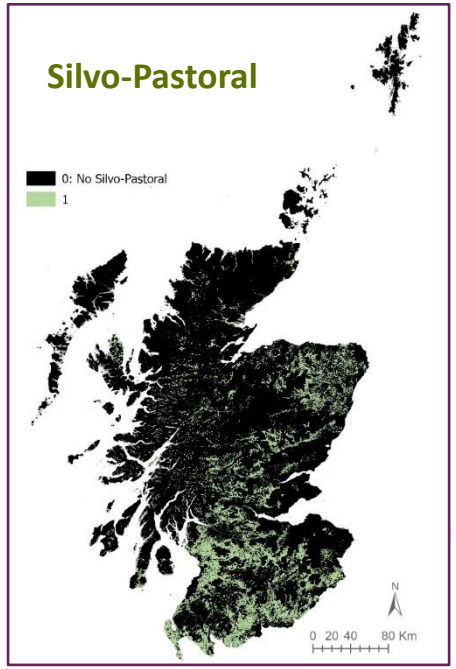
Slope > 20%



Wet soils



Silvo-Pastoral



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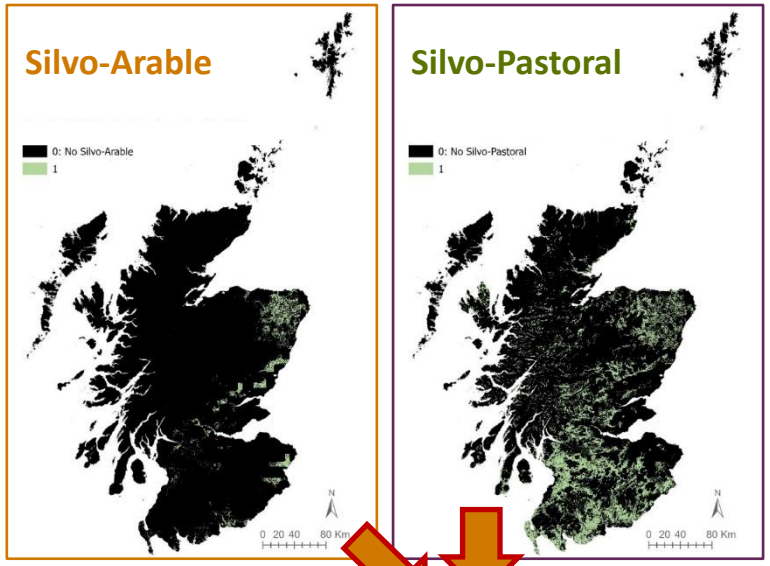
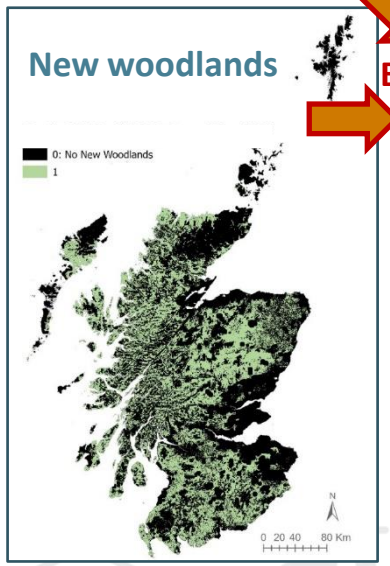
Land availability overview for new/expanded land uses

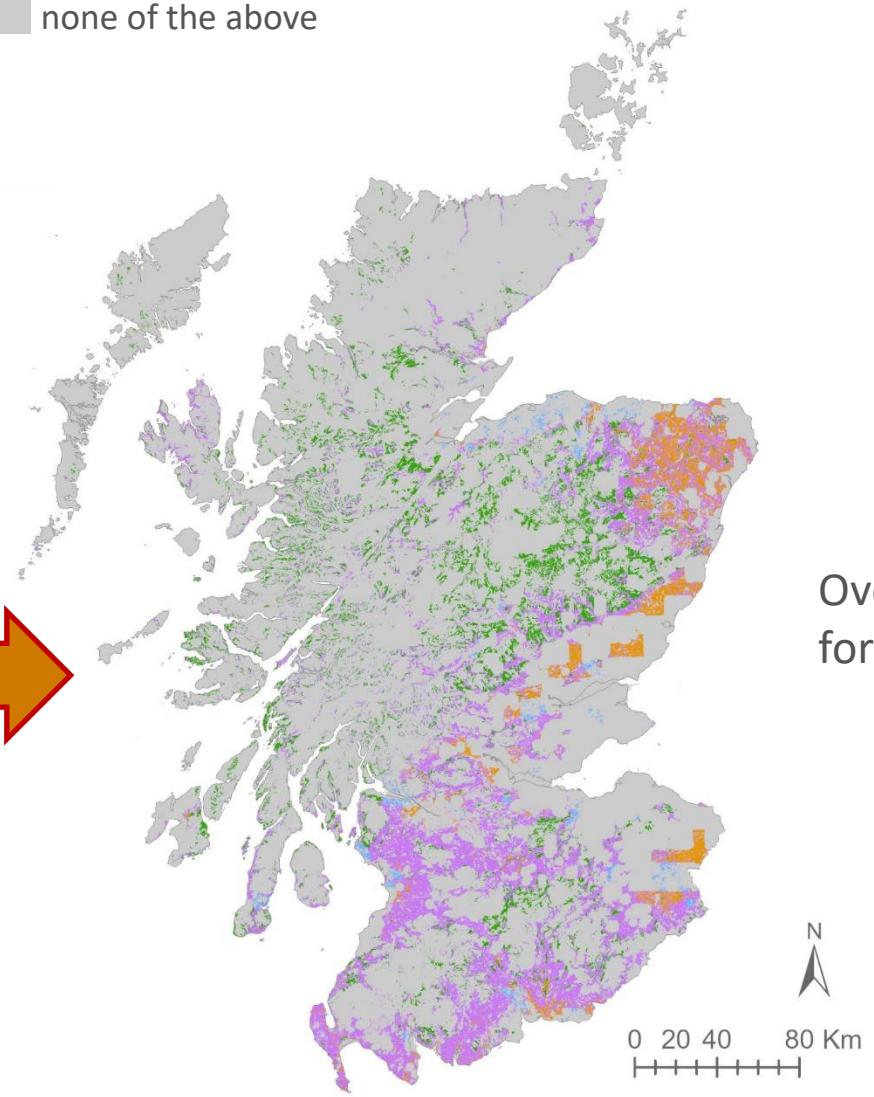
Maps legend. green: potential locations; black: not allowed





Each one is masked by

- **Silvo-Arable** (219,283 ha)
- **Silvo-Pastoral** (46,198 ha)
- **New Woodlands** (583,855 ha)
- **New Woodlands + Silvo-Pastoral** (978,140 ha)
- none of the above



Overall availability for planting trees

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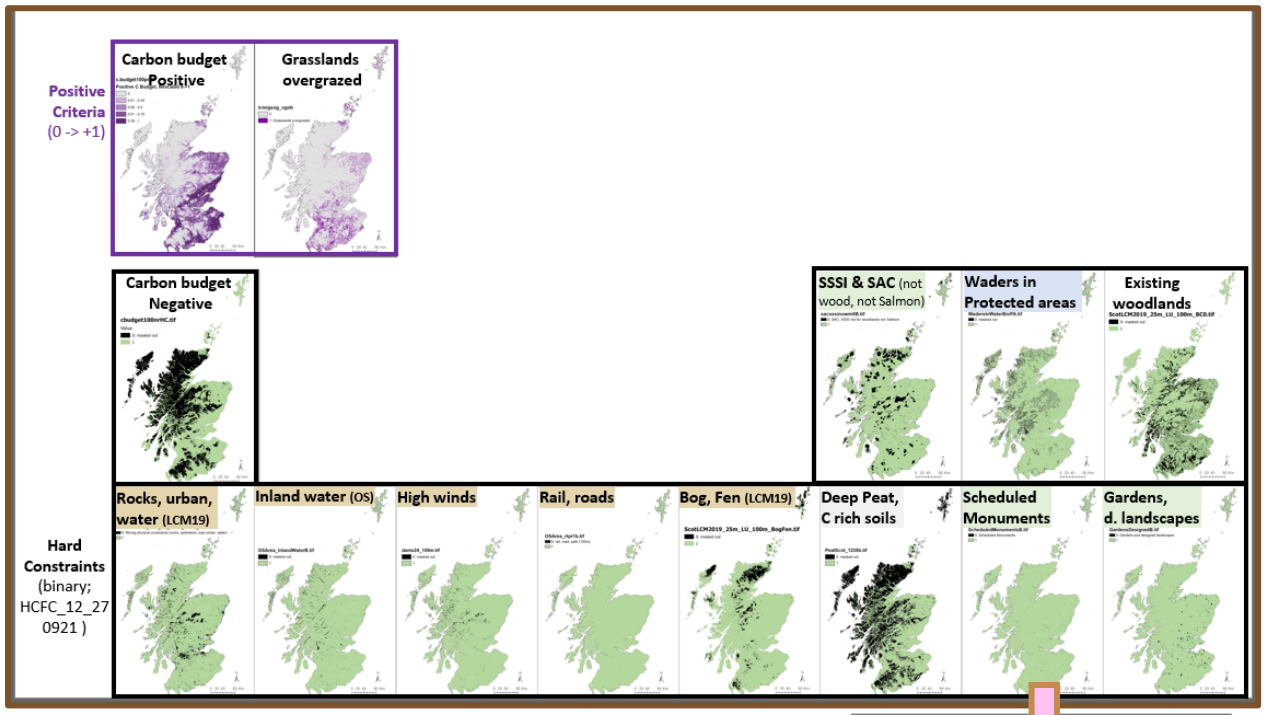
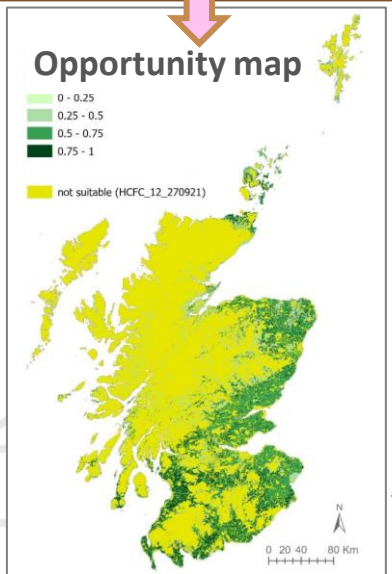
New Trees - Add positive criteria – Carbon storage/negative emissions

Datasets used to create the opportunity map





See also: Baggio et al., 2022, Env. Sci. & Policy

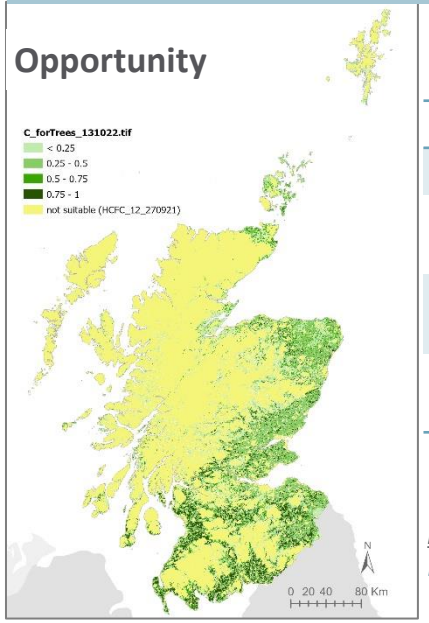
Where should the change occur (or not) ?

Maps legend:
Dark green: highest opportunity
Yellow: not suitable

Overview of opportunities for land use change beneficial to selected ES

ES: Carbon storage through tree planting

Opportunity



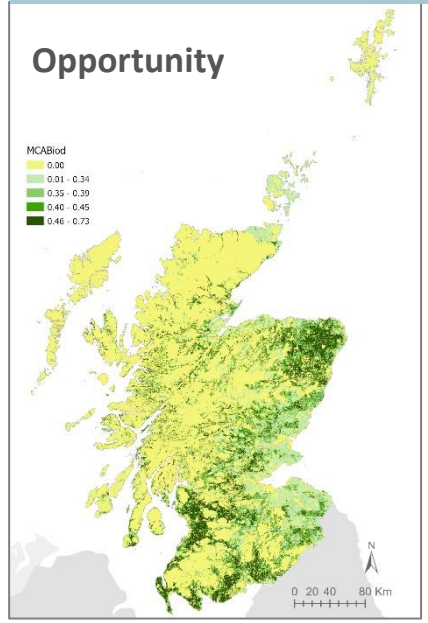
LU changes considered beneficial (ratio: preferences)

From	To
Arable (all)	Silvo-Arable
Improved grasslands	New woodlands (3/4) Silvo-pastoral (1/4)
Semi-natural grasslands	New woodlands (3/4) Silvo-pastoral (1/4)
Heather & heather grasslands	New woodlands

Maps legend:
Dark green: highest opportunity
Yellow: not suitable

ES: Biodiversity through tree planting

Opportunity

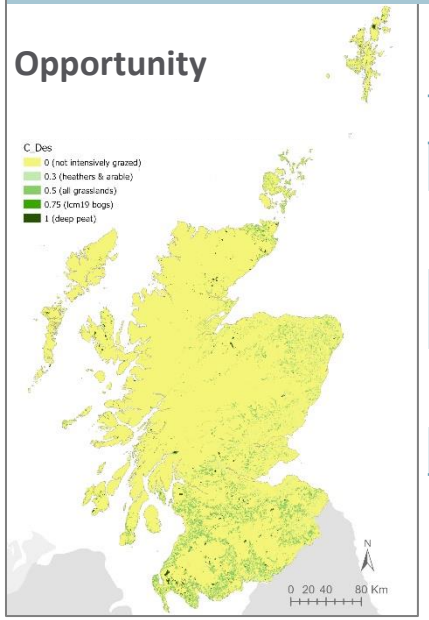


LU changes considered beneficial (ratio: preferences)

From	To
Arable (all)	Silvo-Arable
Improved grasslands	New woodlands (2/3) Silvo-pastoral (1/3)
Semi-natural grasslands	New woodlands (2/3) Silvo-pastoral (1/3)
Heather & heather grasslands	New woodlands

ES: Emission reduction through de-intensification

Opportunity



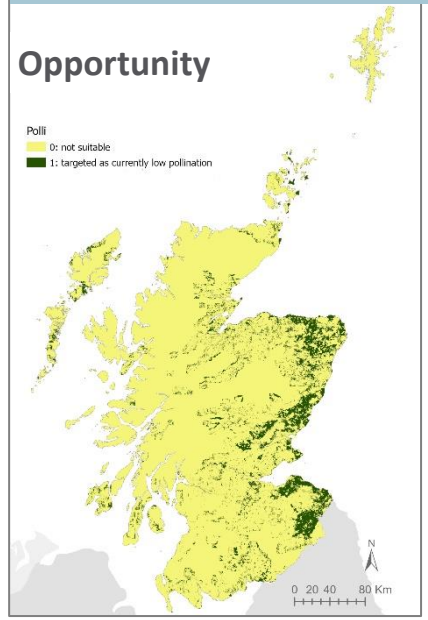
LU changes considered beneficial

From	To
Arable grazed - intensive	-> NOT intensive
Improved grasslands - intensive	-> NOT intensive
Semi-natural grasslands - intensive	-> NOT intensive
Heather & heather grasslands - intensive	-> NOT intensive
Bogs – intensive	-> NOT intensive

All beneficial LU change are derived from NatureScot – SNCAI (2019). Watkinson, P. (2017) Scotland's Natural Capital Asset Index, 2017 model. Scotland's Natural Capital Asset Index - 2019 | NatureScot

ES: Pollination

Opportunity



LU changes considered beneficial (ratio: preferences)

From	To
Arable grazed - intensive	-> NOT intensive (1/2) Silvo-Arable (1/2)
Improved grass. - intensive	–> NOT intensive (1/3) New woodlands (1/3) Silvo-pastoral (1/3)
Semi-natural grass. - intensive	-> NOT intensive (1/3) New woodlands (1/3) Silvo-pastoral (1/3)
Heather & h. grass. - intensive	-> NOT intensive (1/2) New woodlands (1/2)
Bog - intensive	-> NOT intensive

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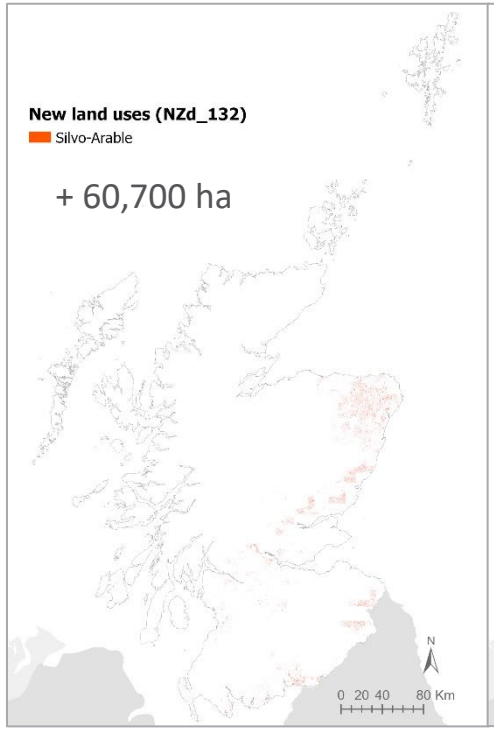
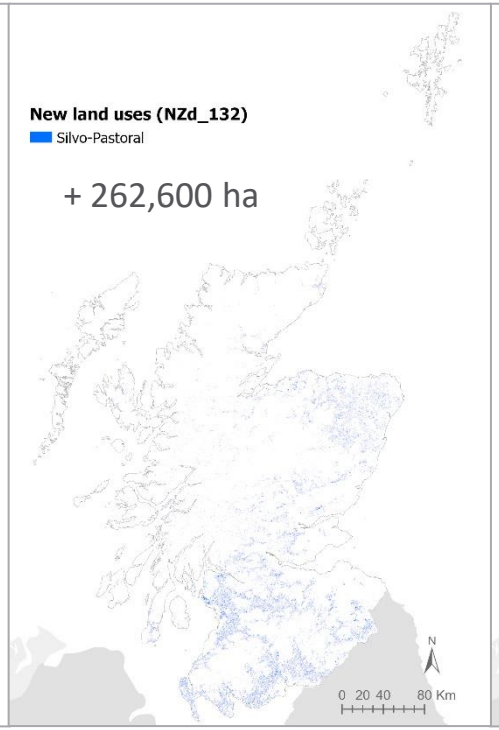
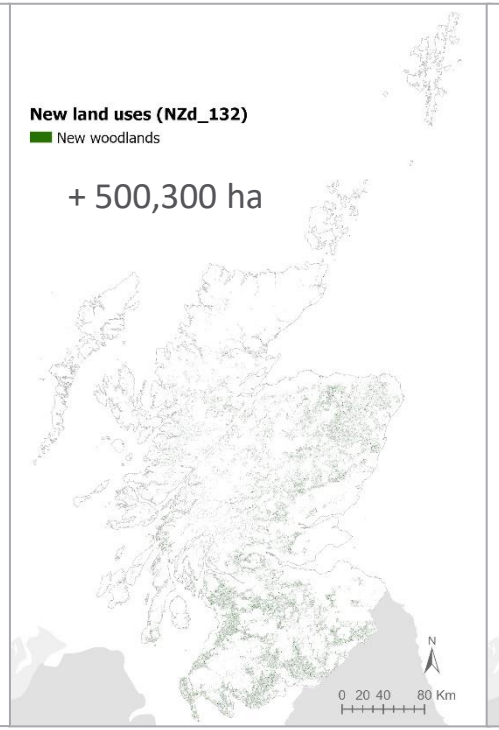
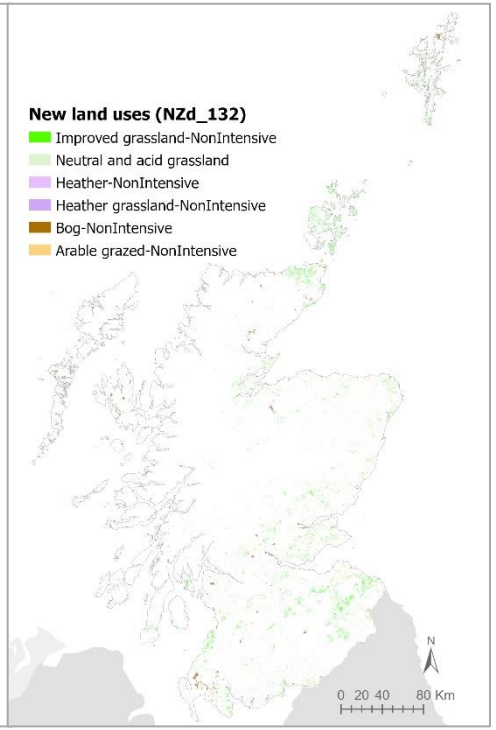
Result: example land uses changes that lower emissions

From narrative to spatial results









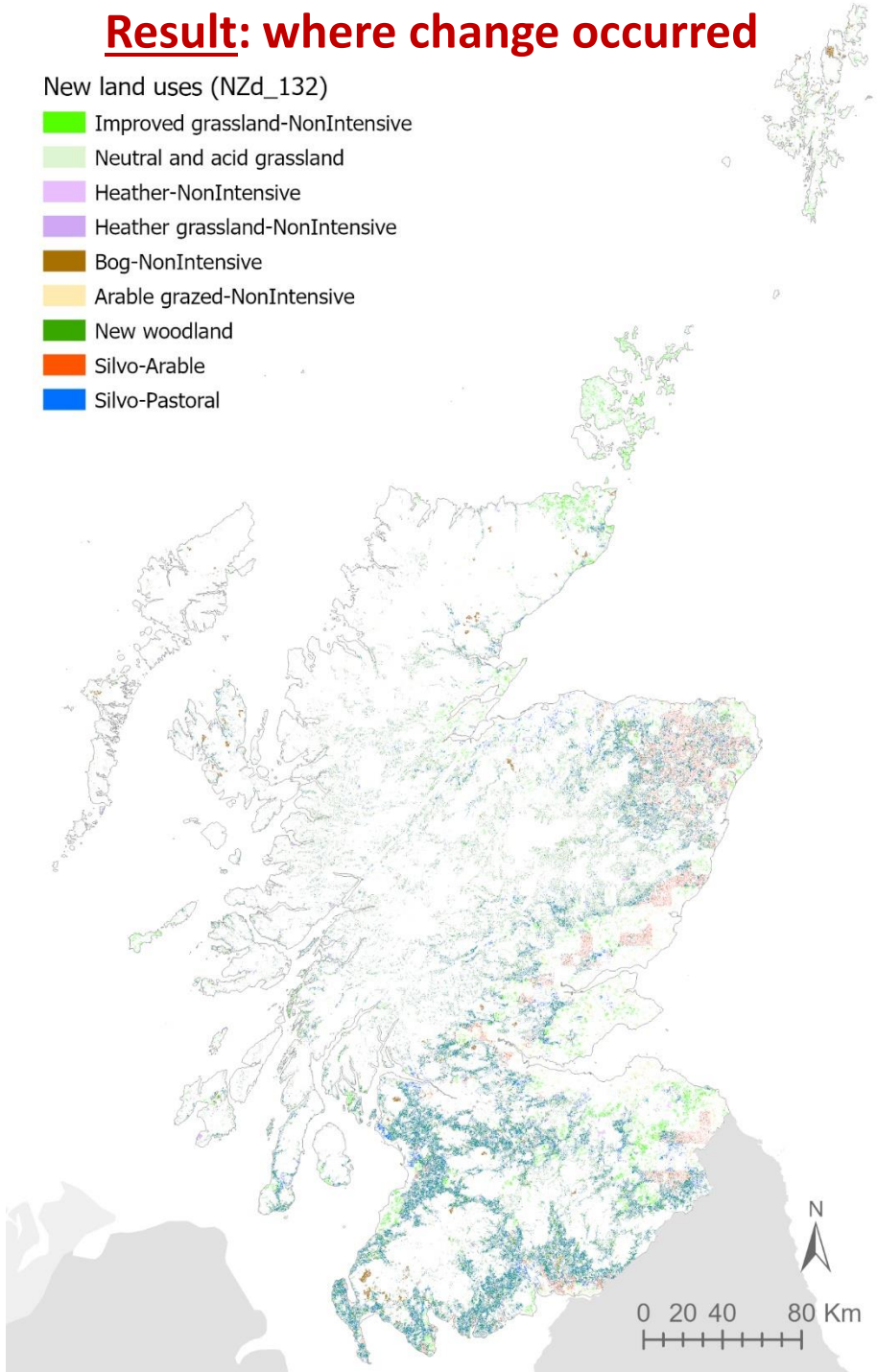
Shrinking of the national herd

LandUse Name	Initial Area Ha	Final Area Ha	Initial Perc	Final Perc
Broadleaved woodland (+new)	424,592	924,827	5.30	11.55
Coniferous woodland	988,482	988,482	12.34	12.34
Silvo-Pastoral	-	262,887	0.00	3.28
Improved grassland-NonIntensive	846,811	785,351	10.57	9.80
Semi-natural grassland-NonIntensive	1,141,450	1,048,195	14.25	13.09
Heather & Heather grasslands -NonIntensive	1,894,417	1,805,963	23.65	22.54
Bog-NonIntensive	645,655	669,976	8.06	8.36
Improved grassland-Intensive	560,858	125,233	7.00	1.56
Semi-natural grassland-Intensive	77,070	21,592	0.96	0.27
Heather & Heather grasslands -Intensive	42,396	13,546	0.53	0.17
Bog-Intensive	33,562	9,241	0.42	0.12
total desintensified land		*239,865*		*2.99*
Arable and horticulture	519,430	474,249	6.48	5.92
Arable grazed - NonIntensive	21,820	49,919	0.27	0.62
Arable grazed - Intensive	66,476	21,811	0.83	0.27
Silvo-Arable	-	61,747	0.00	0.77
sum all arable	*607,726*	*607,726*	*7.58*	*7.58*

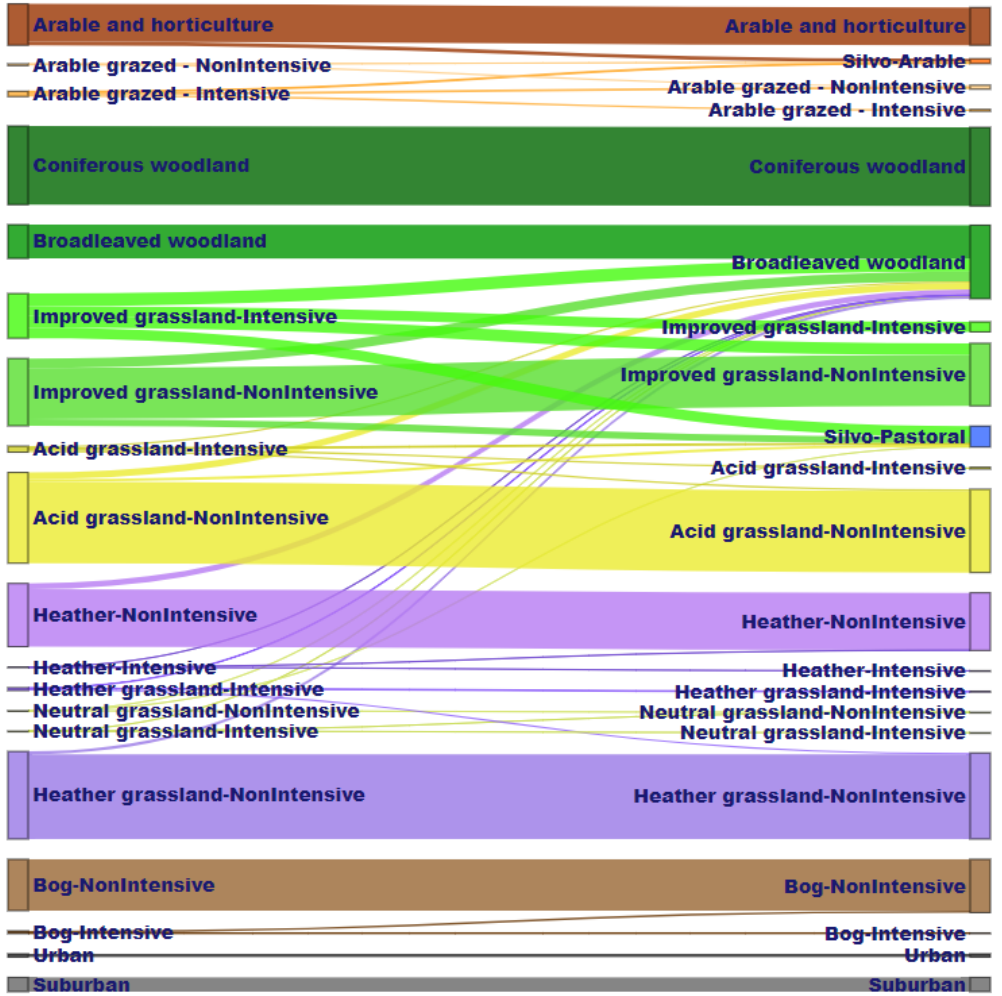
70-80% intensive grassland to non-intensive grazing use
(reduction of stocking rate)
+ 239,865 ha

Ca 27% of Scotland ‘tree-rich’ landscapes

Result: where change occurred



All low emissions land use changes (Ha)



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Future work

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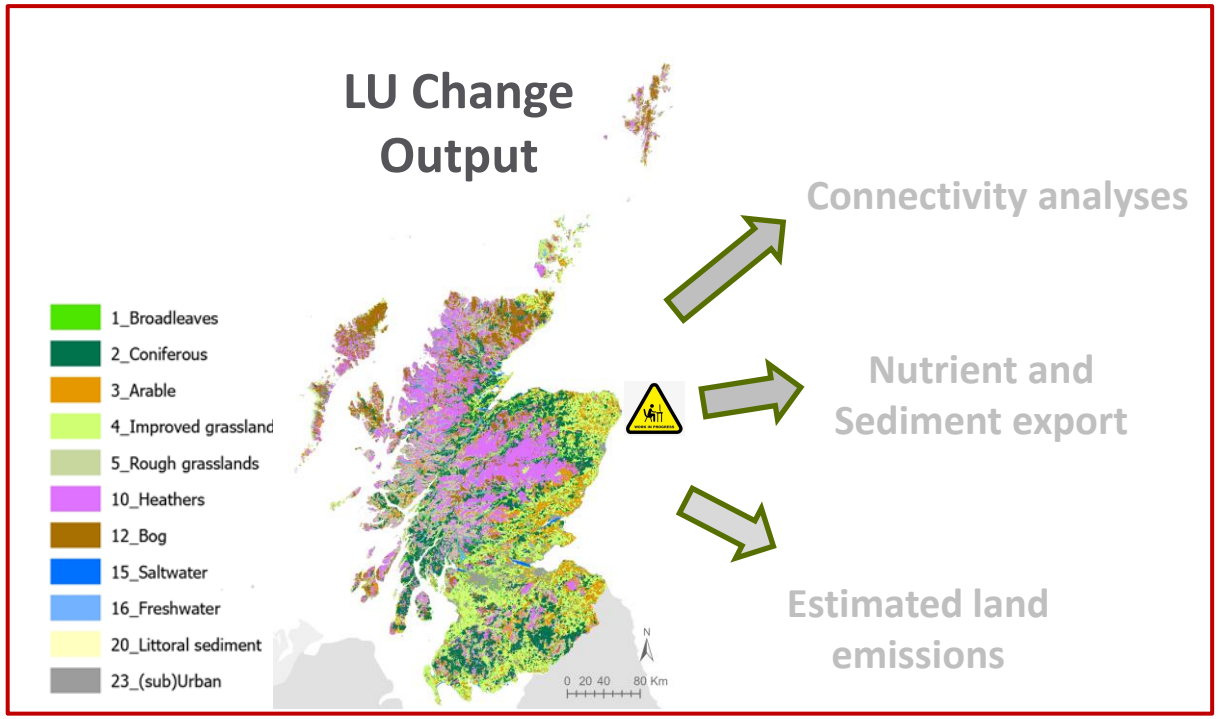
For each scenario:



Conclusions

- Our approach allows to:

  Account for the fact that land use change is likely to be embedded in wider societal evolution

  BUT also :

  Type of change constrained by *detailed* biophysical landscape attributes => from non-spatial to spatial scenario

to do so we can

  ingest output of other models as constraints and opportunities

  compare ESS-impacts (and trade-offs) of different scenarios

Implications

Better risk management, resilience and preparation for adaptation

Thanks for your attention

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