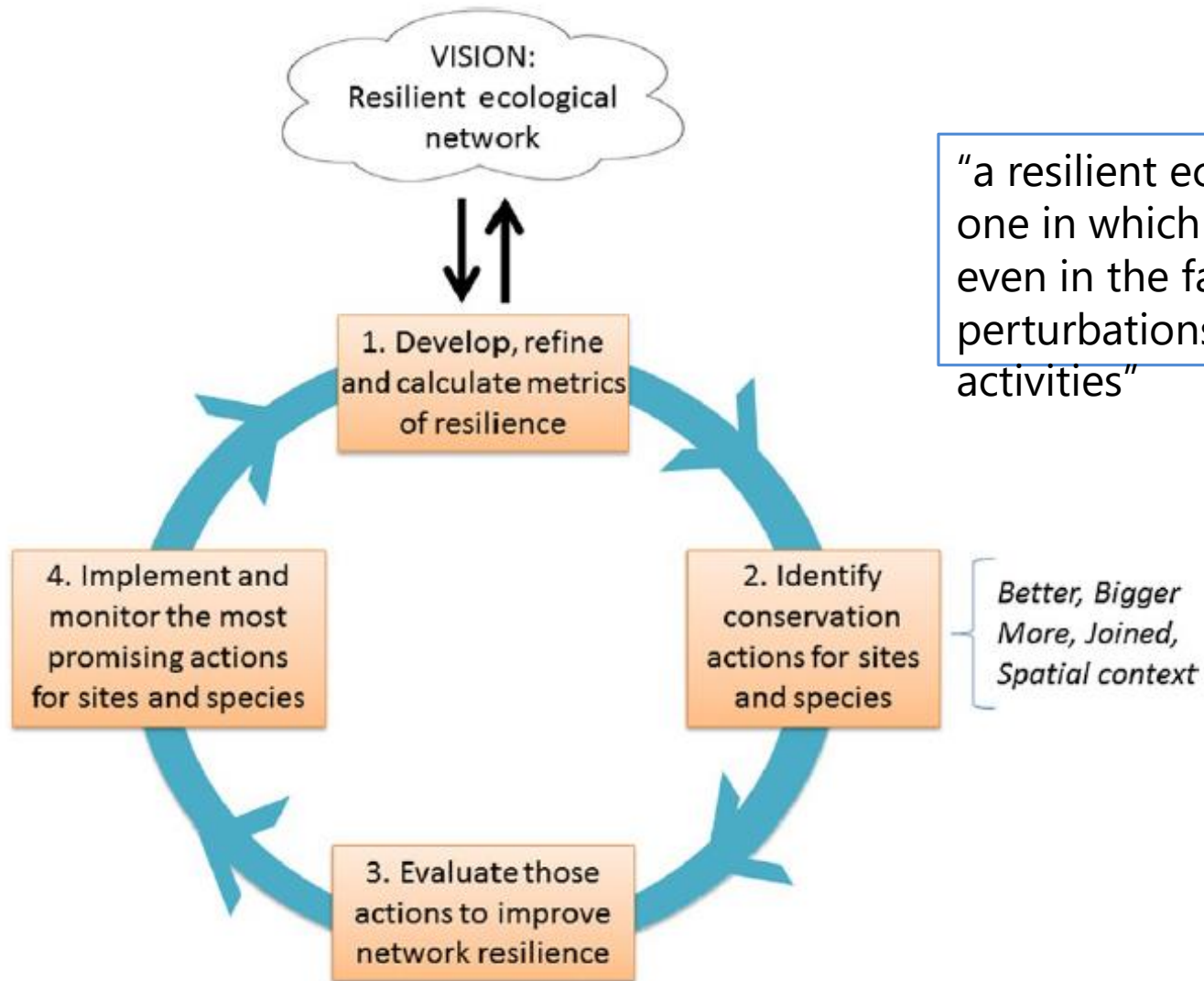


Restoring Ecological Networks for Biodiversity and Ecosystem Services

Photo: iStockPhoto

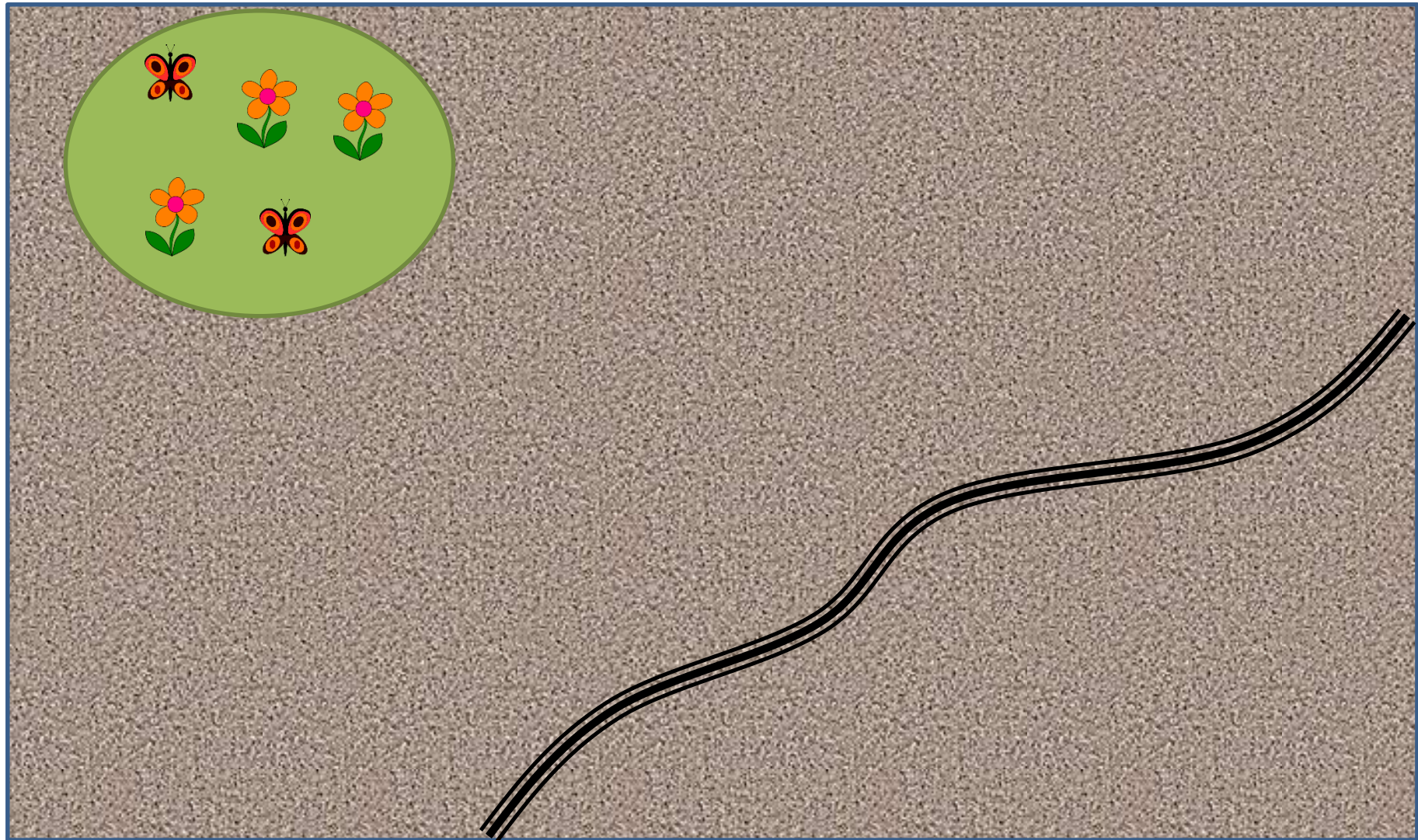
James Bullock
Centre for Ecology & Hydrology

Implementing a resilient ecological network



"a resilient ecological network is one in which species can persist even in the face of natural perturbations and human activities"

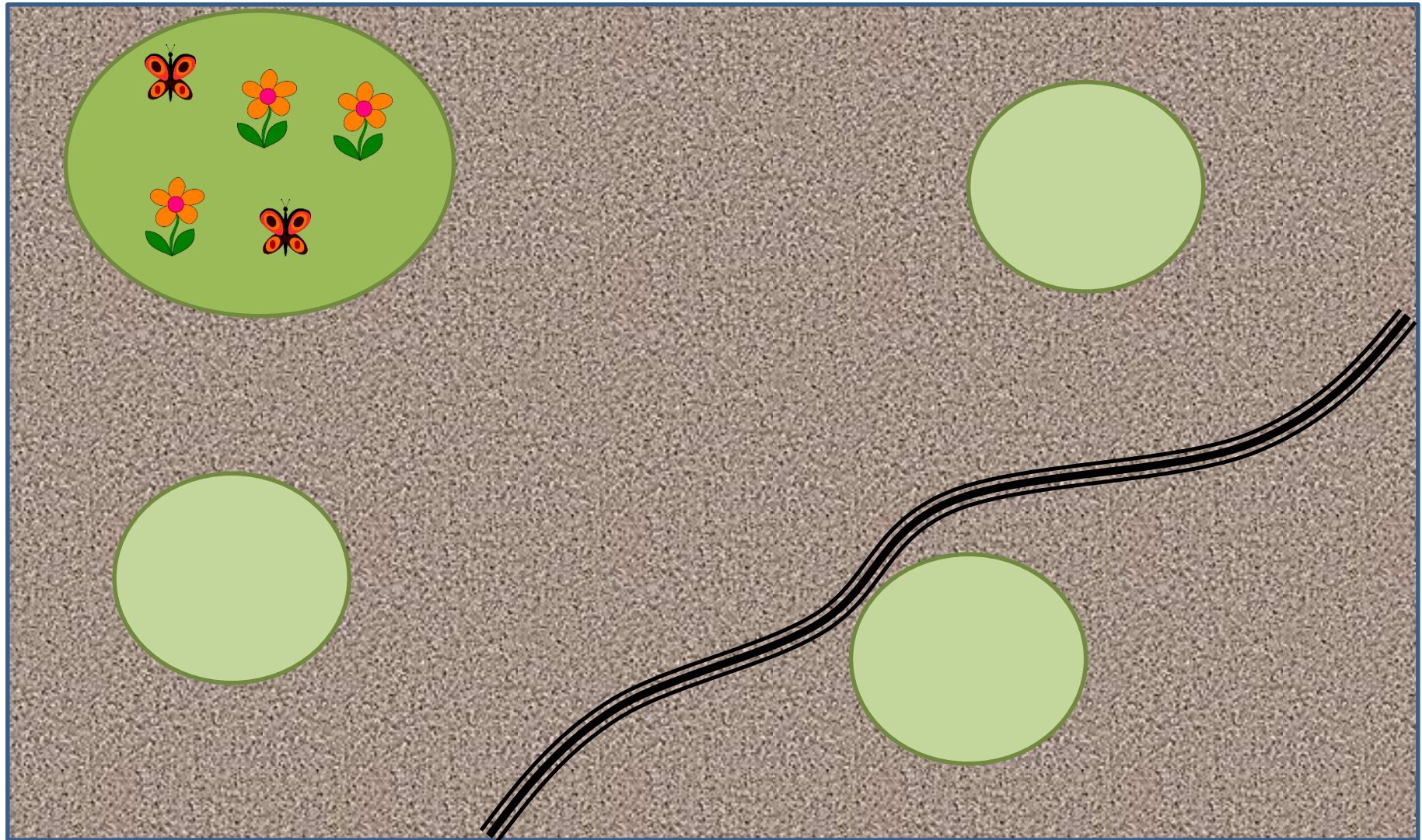
Restoration: not just what & how, but where



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NERC SCIENCE OF THE
ENVIRONMENT

Restoration: not just what & how, but where



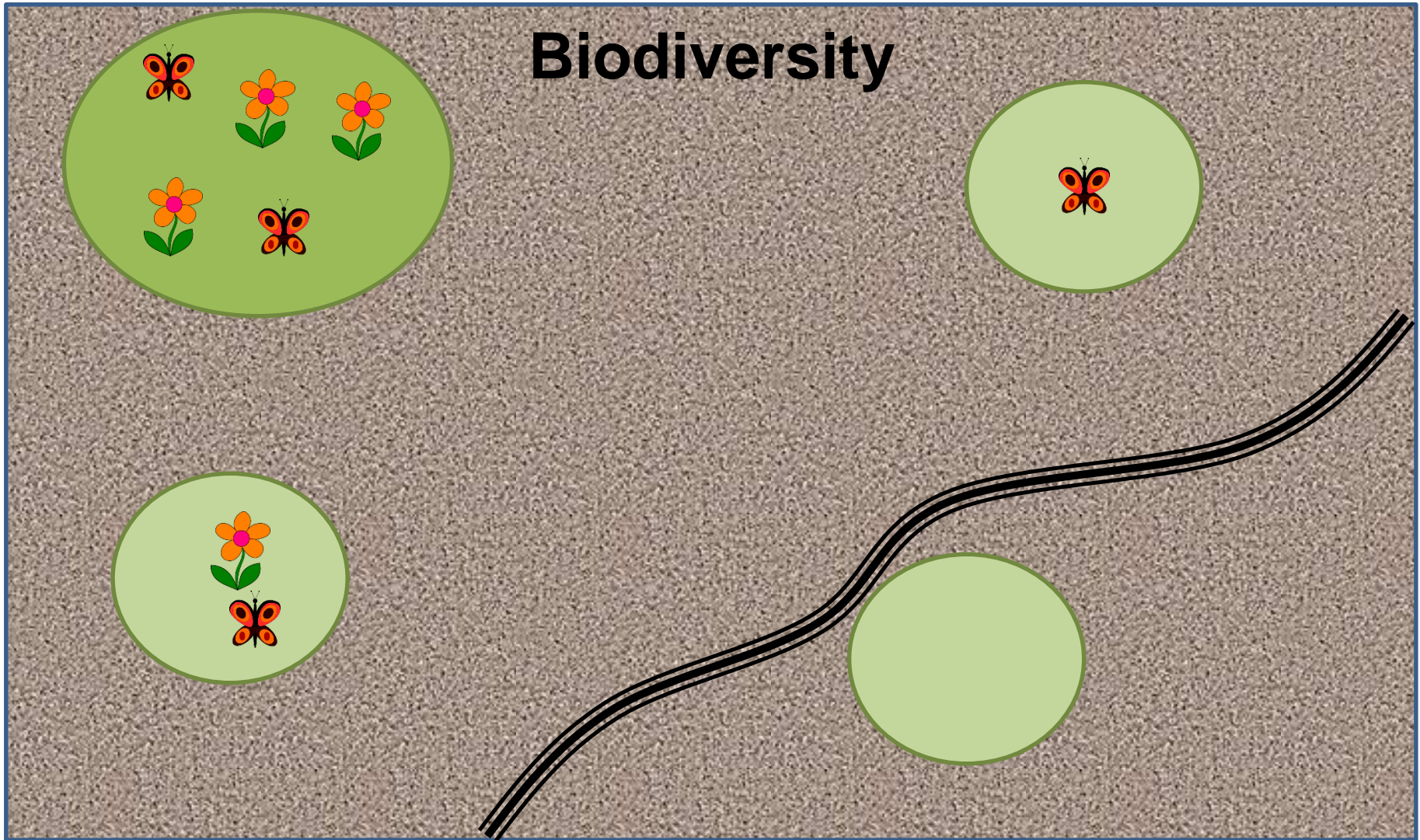
Centre for
Ecology & Hydrology
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SCIENCE OF THE
ENVIRONMENT

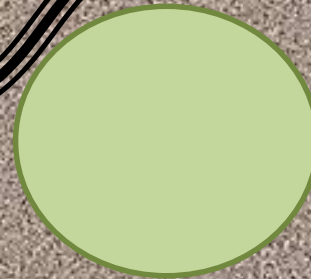
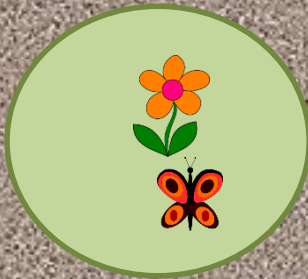
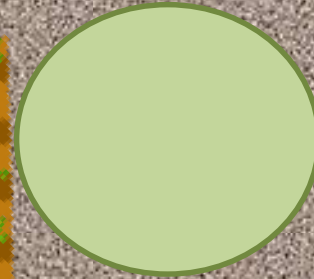
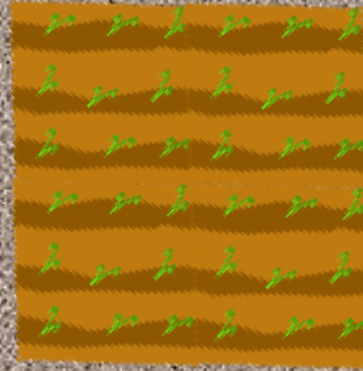
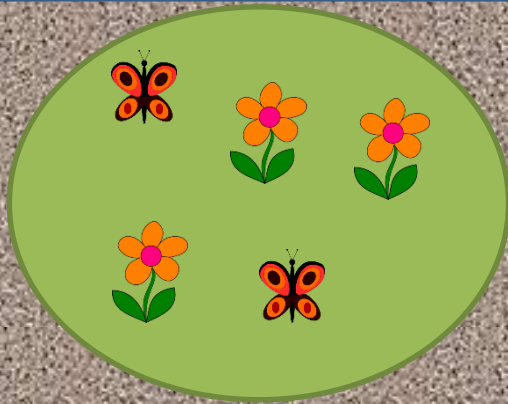
Restoration: not just what & how, but where

Biodiversity



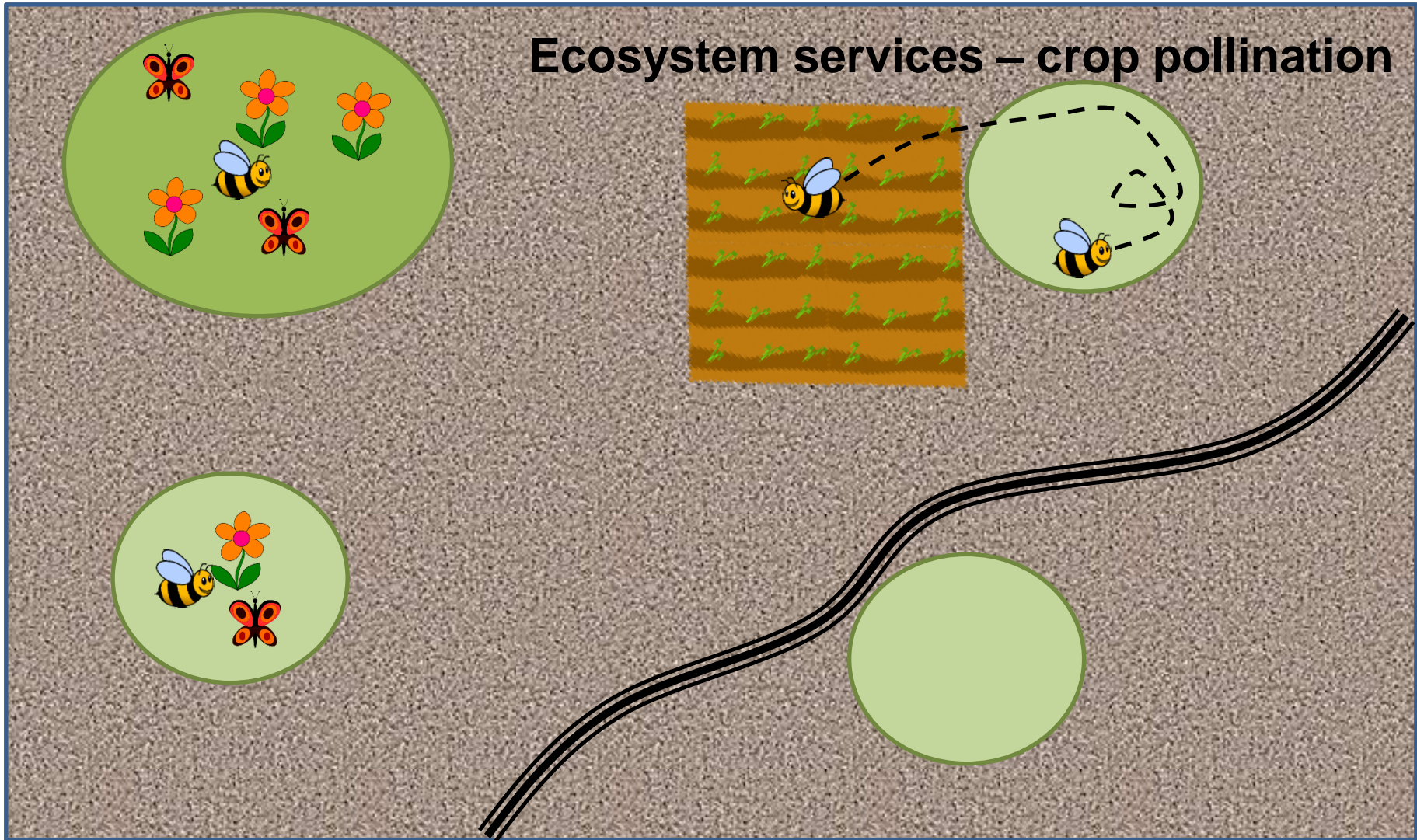
Restoration: not just what & how, but where

Biodiversity



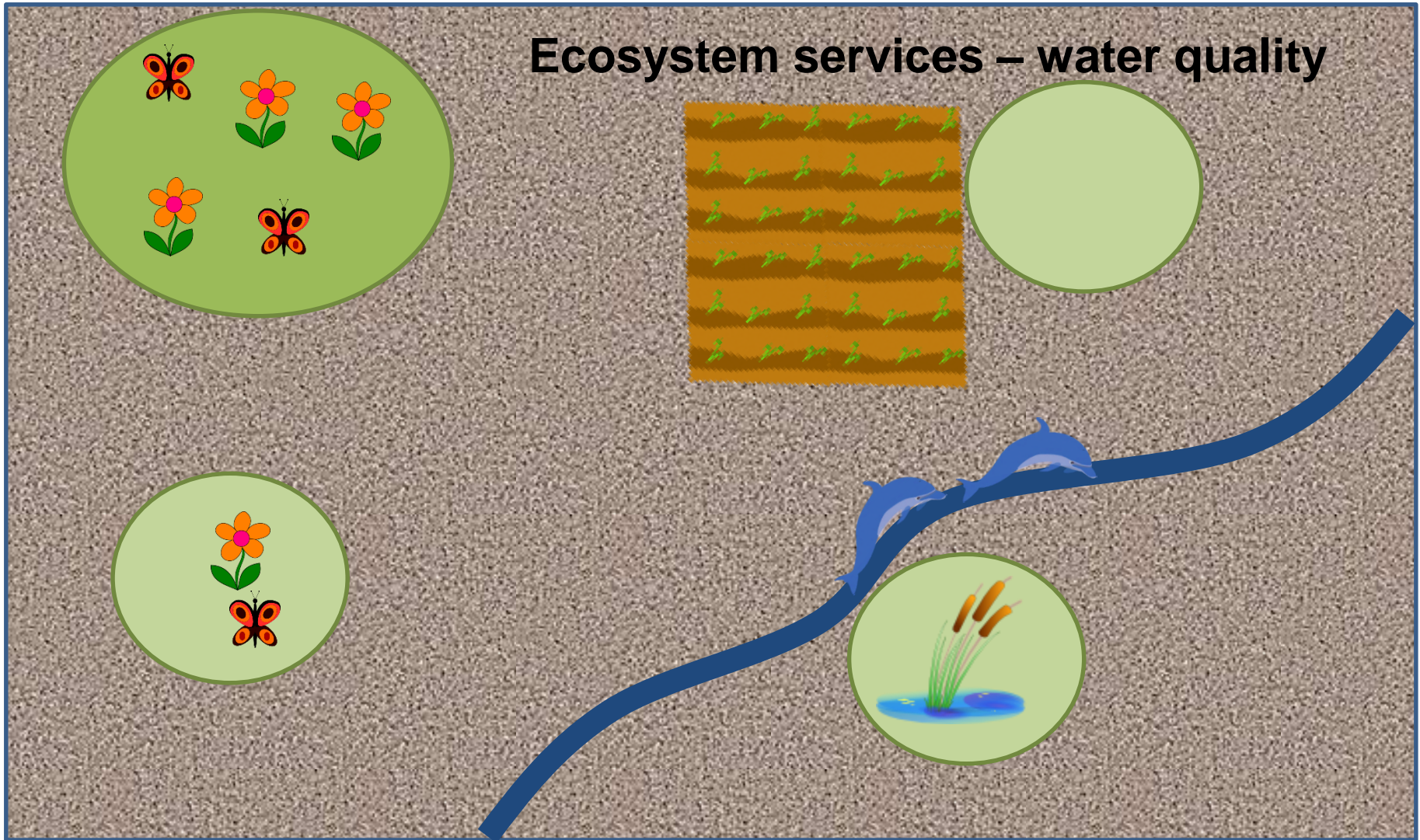
Restoration: not just what & how, but where

Ecosystem services – crop pollination

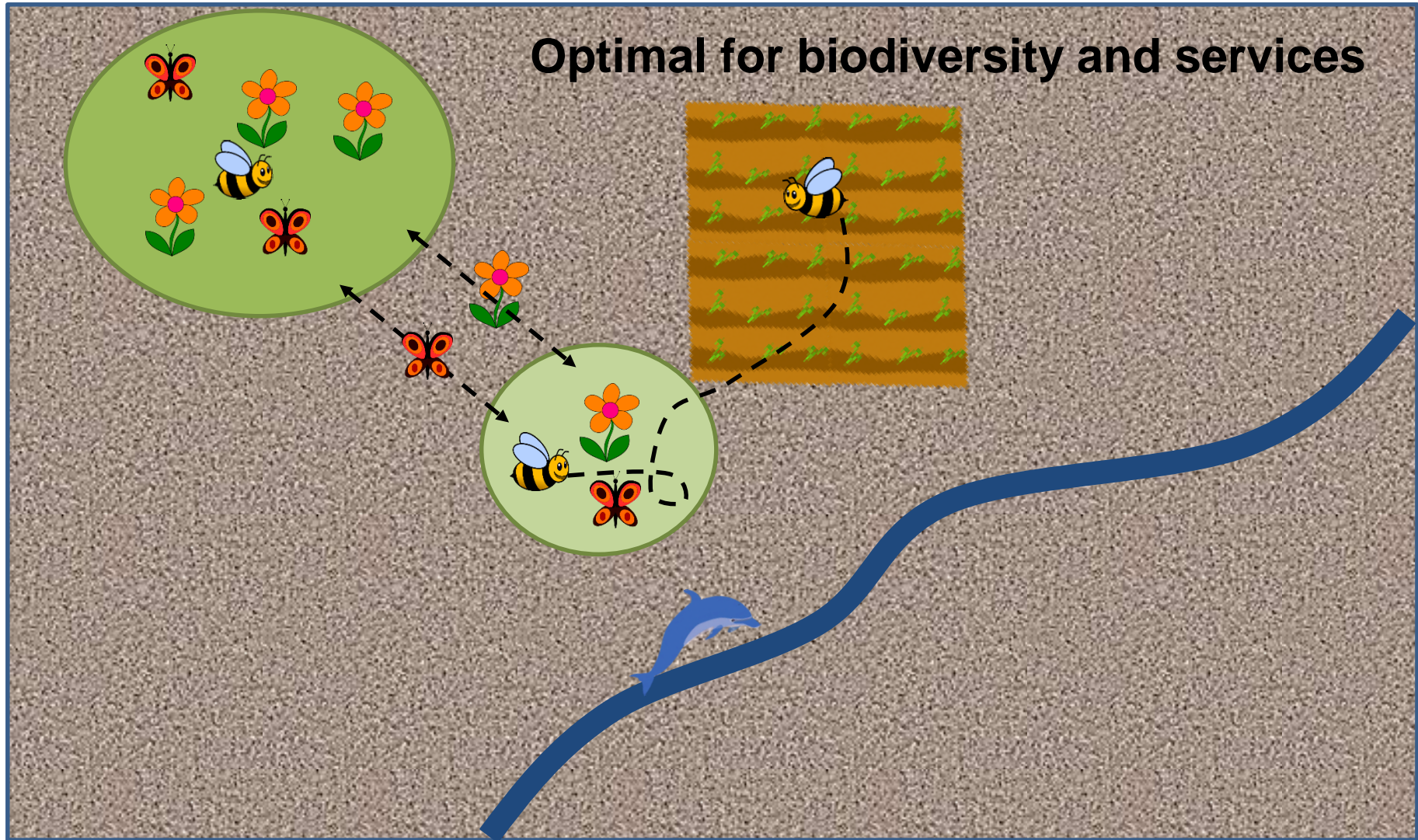


Restoration: not just what & how, but where

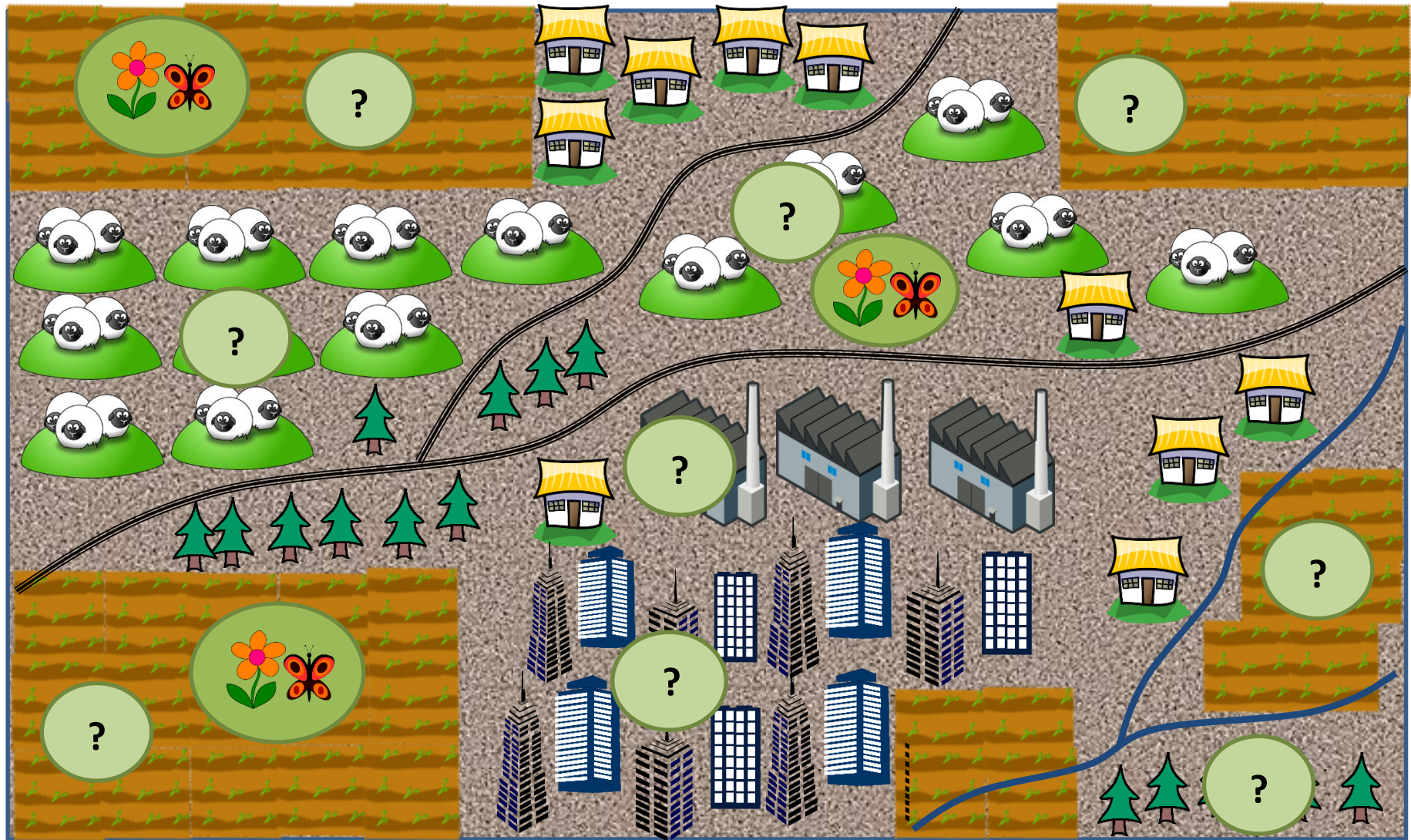
Ecosystem services – water quality



Restoration: not just what & how, but where



Planning restoration for resilient networks

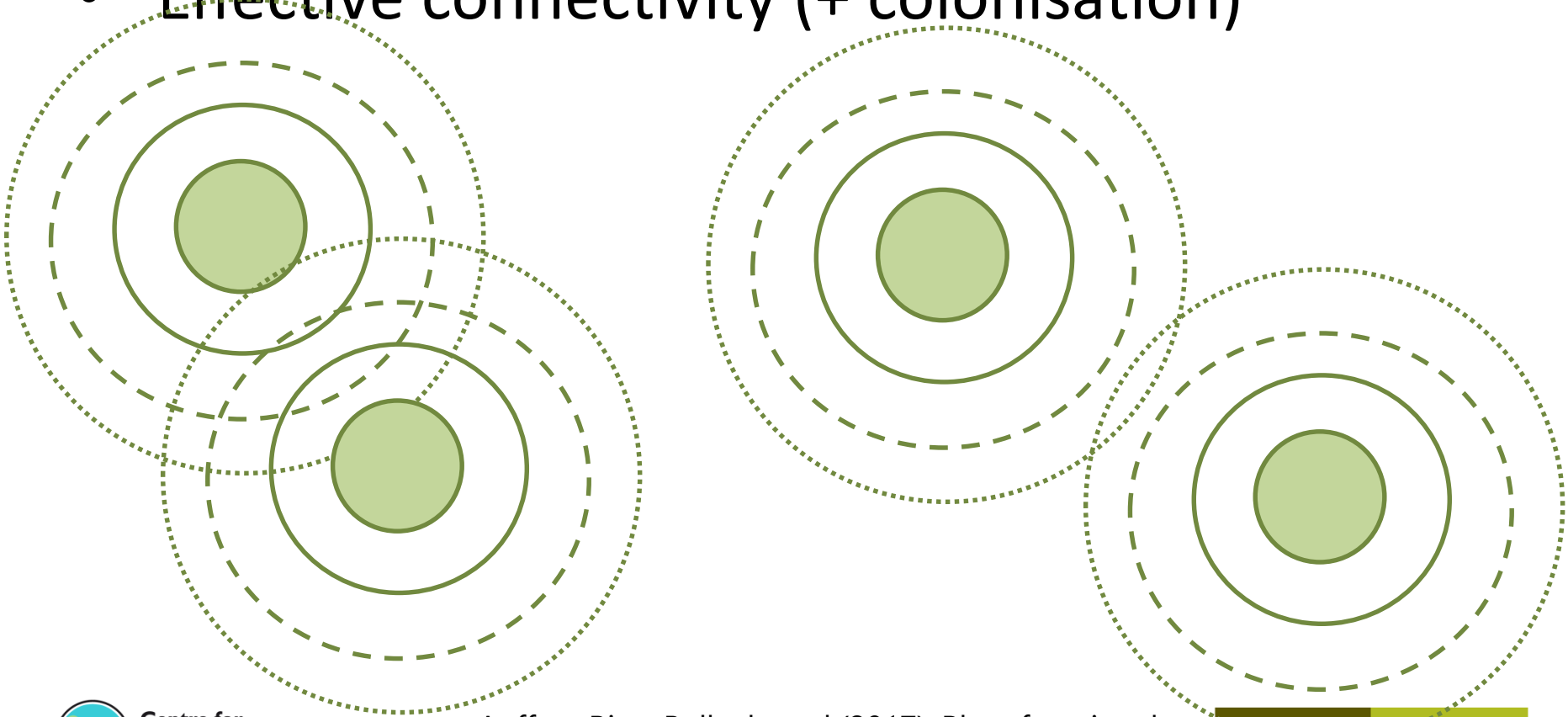


Planning restoration for resilient networks

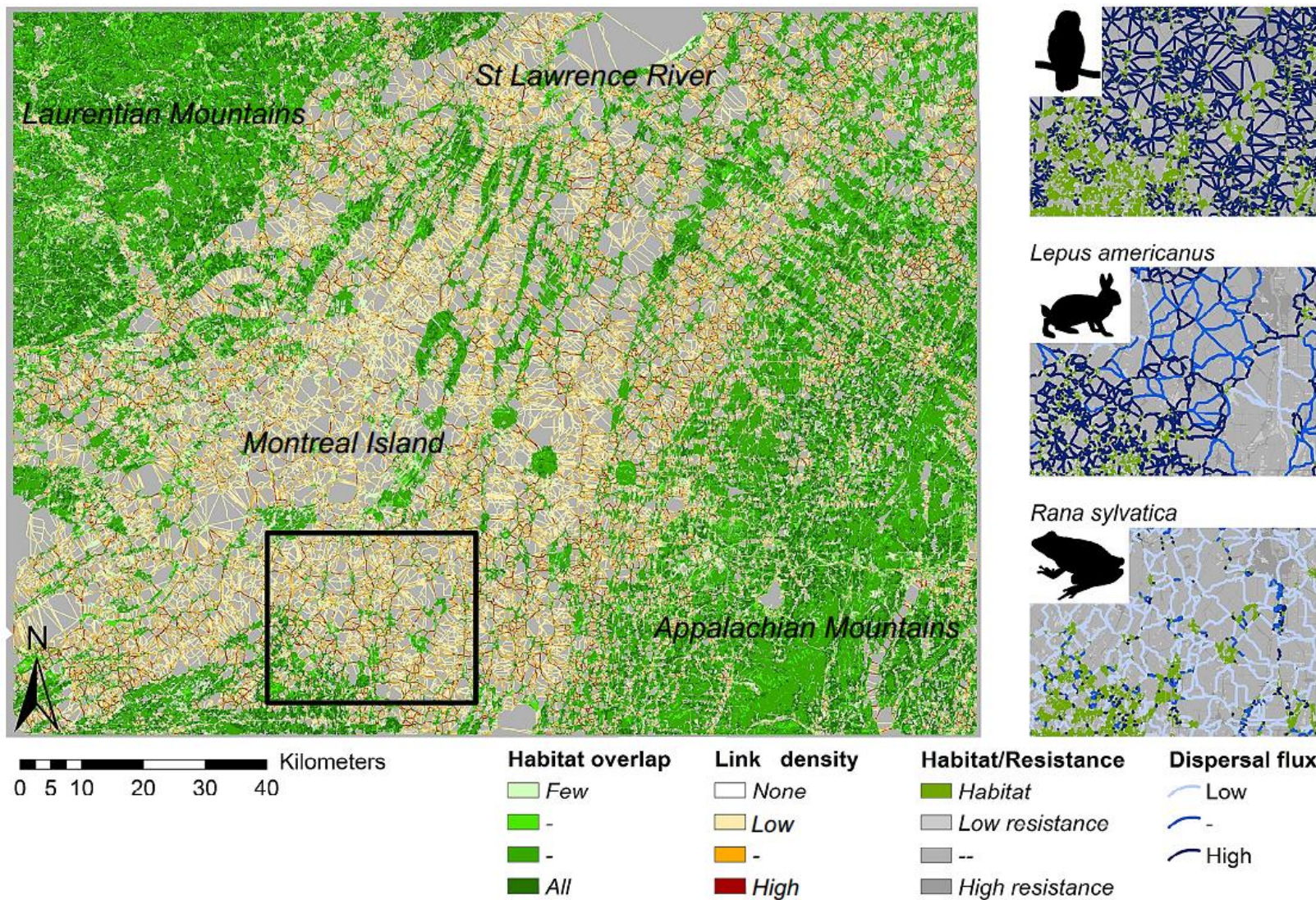


Modelling resilient networks for biodiversity

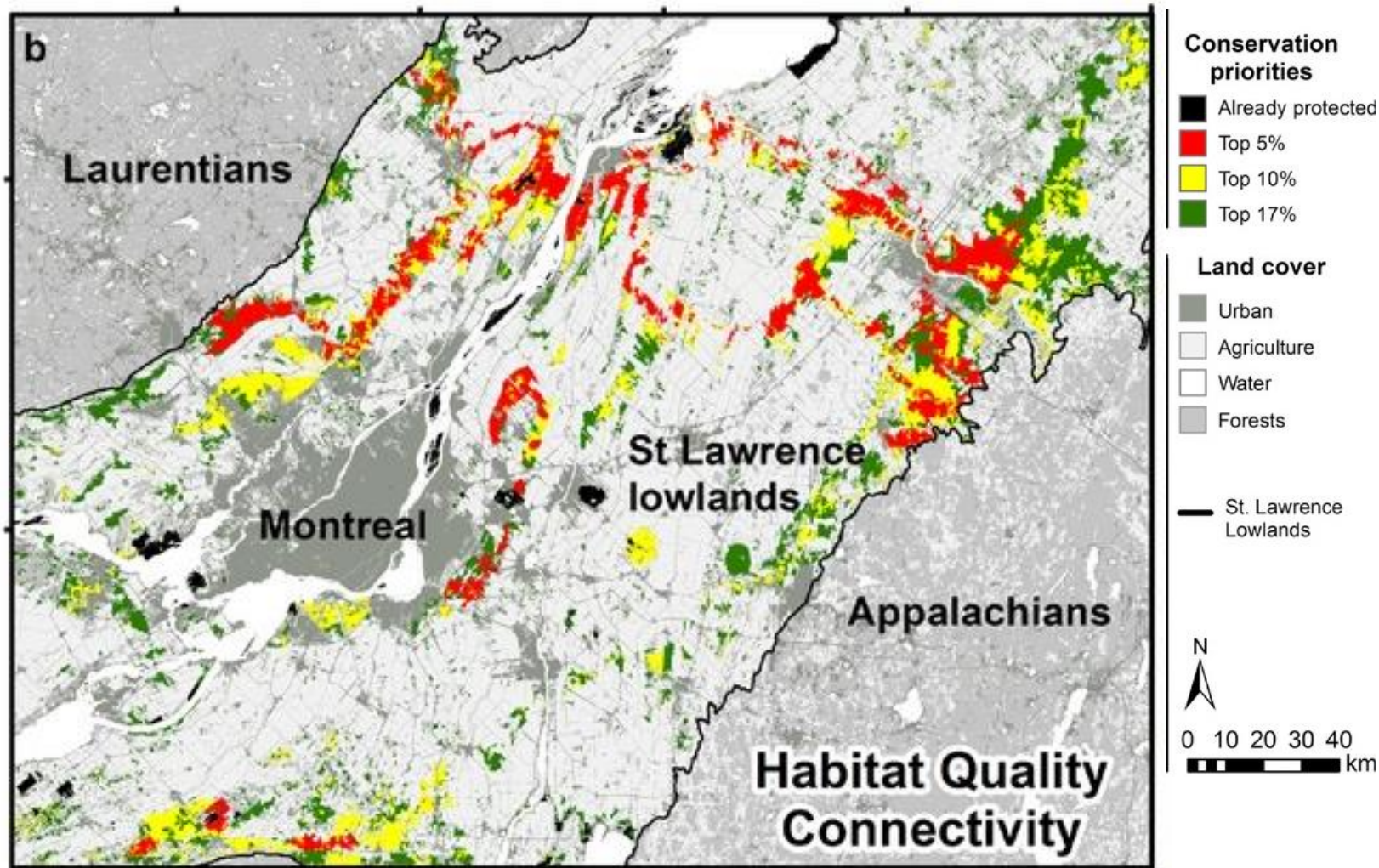
- Structural connectivity (Euclidean distance)
- Functional connectivity (the matrix)
- Effective connectivity (+ colonisation)



Functional connectivity

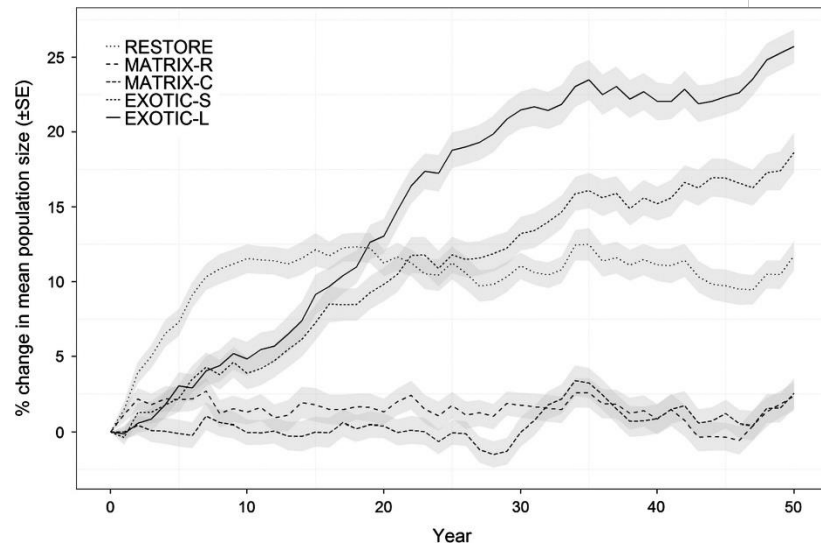
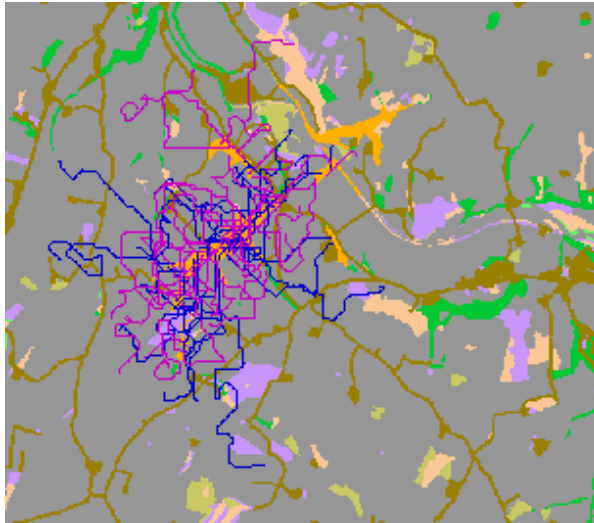


Functional connectivity



Effective connectivity – simulation models

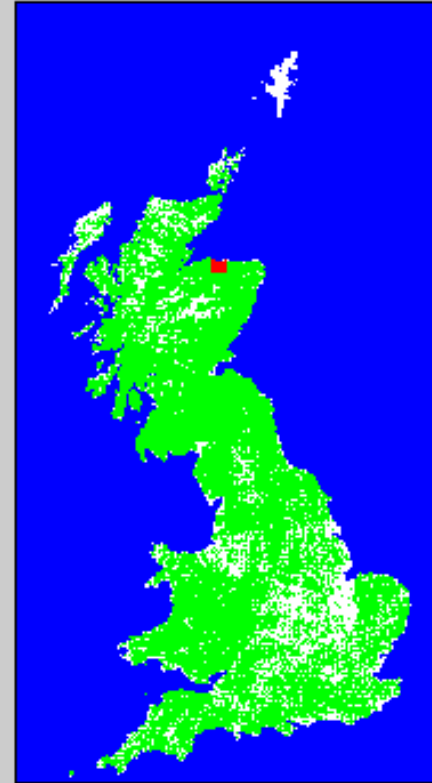
Individual-based



Bocedi et al (2014). RangeShifter: a platform for modelling eco-evolutionary dynamics and species' responses to environmental changes. *Methods Ecol. Evol.*

Mathematical

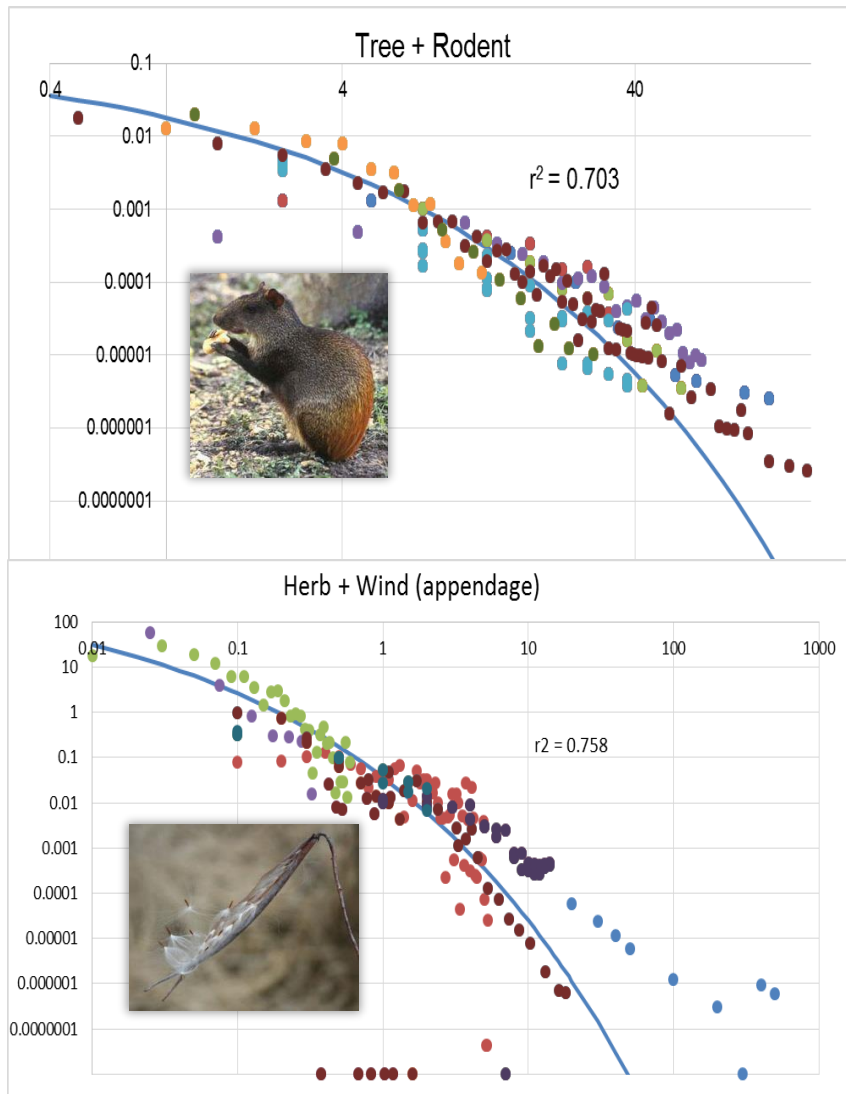
Distribution of an invasive species at $t = 1$



Gilbert, White, Bullock & Gaffney (2017). Speeding up the simulation of population spread models *Methods Ecol. Evol.*

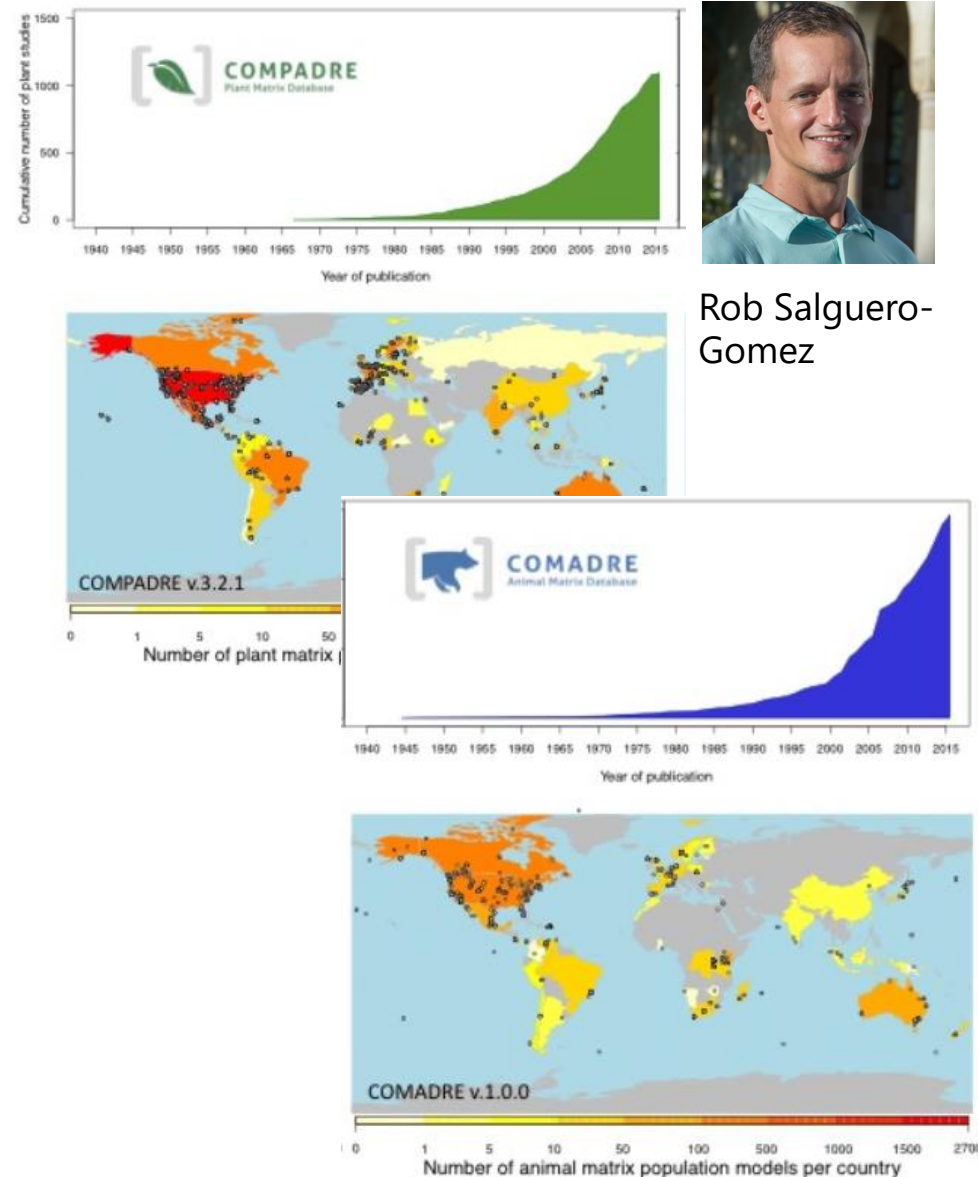
Data for models?

Dispersal/Movement



Bullock et al (2017). A synthesis of empirical plant dispersal kernels. *J. Ecology*

Population ecology



Modelling ecosystem services: InVEST

The diagram illustrates the InVEST ecosystem services modelling framework, showing the flow of information from supporting services to provisioning, regulating, and cultural services. The services are categorized by model tier and linkage type.

Services and Model Tiers:

- Terrestrial/freshwater model: Tier 1 supporting service (Green solid box):** Crop Pollination, Water Purification, Managed Timber Production, Reservoir Hydropower Production, Sediment Retention, Seasonal Water Yield, Agricultural Production, Flood Risk Mitigation.
- Terrestrial/freshwater model: Tier 1 that quantifies service (Green dashed box):** None.
- Marine model: Tier 1 supporting service (Dark Blue solid box):** Marine Water Quality, Habitat Risk Assessment; Biodiversity.
- Marine model: Tier 1 that quantifies service (Dark Blue dashed box):** None.
- Marine model: Tier 0 (Blue solid box):** Aquaculture, Renewable Energy, Coastal Vulnerability, Coastal Protection, Fisheries (including recreational), Overlap Analysis.
- Marine model: Tier 1 that quantifies service (Blue dashed box):** Recreation.

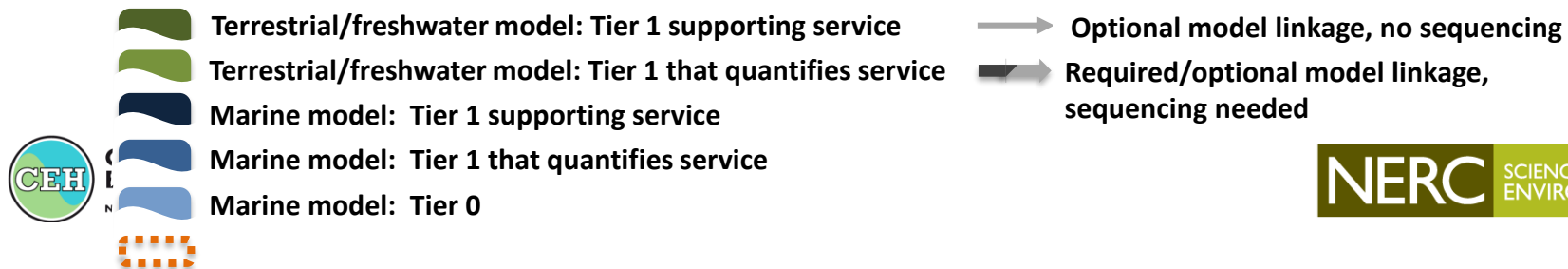
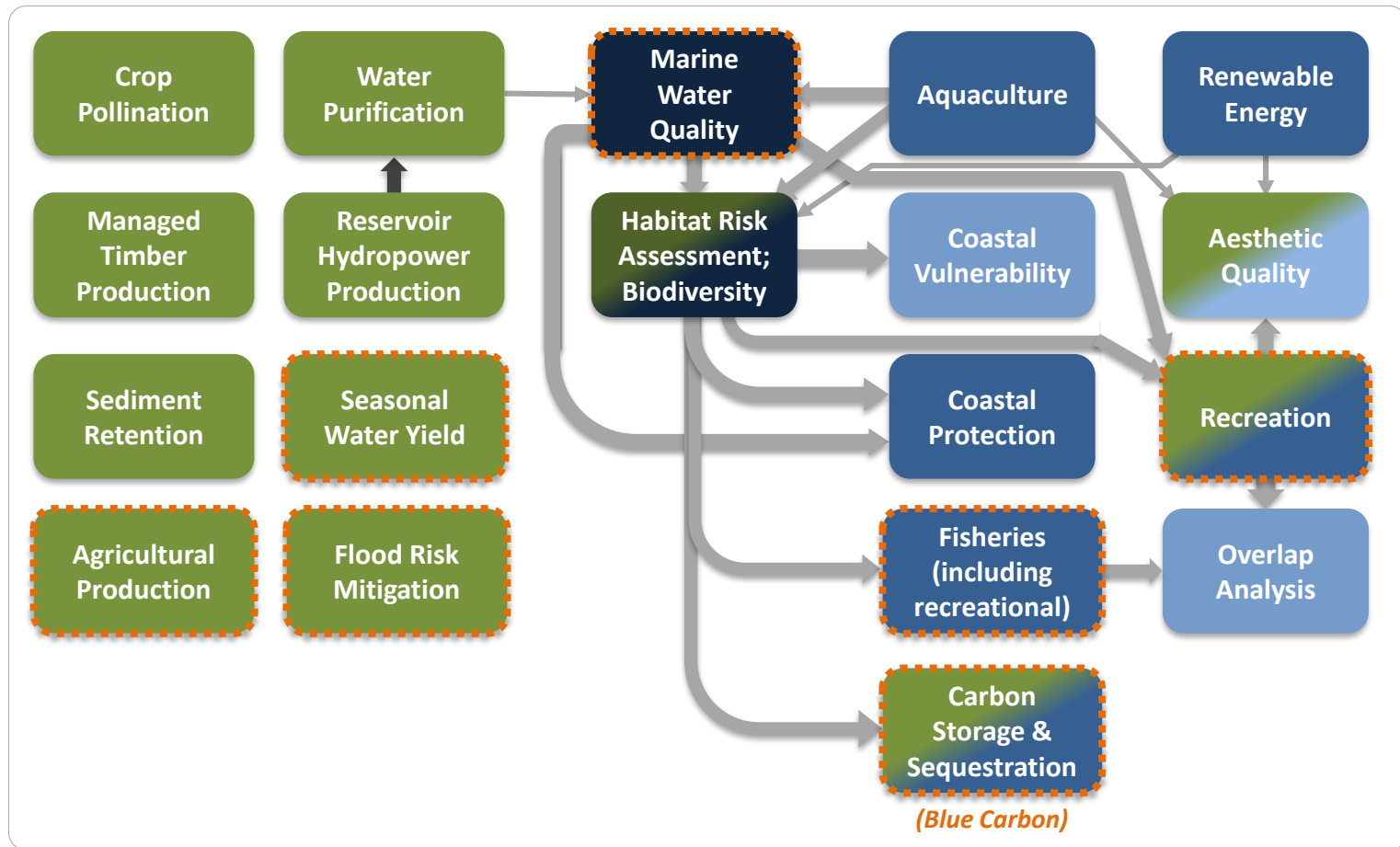
Linkages:

- Optional model linkage, no sequencing (Grey arrow):** From Water Purification to Marine Water Quality; From Marine Water Quality to Aquaculture, Coastal Vulnerability, Coastal Protection, Fisheries, and Carbon Storage & Sequestration; From Habitat Risk Assessment to Coastal Vulnerability, Coastal Protection, Fisheries, and Carbon Storage & Sequestration; From Seasonal Water Yield to Coastal Protection; From Agricultural Production to Carbon Storage & Sequestration; From Recreation to Overlap Analysis.
- Required/optional model linkage, sequencing needed (Thick grey arrow):** From Marine Water Quality to Habitat Risk Assessment; From Habitat Risk Assessment to Marine Water Quality; From Aquaculture to Coastal Vulnerability; From Renewable Energy to Aesthetic Quality; From Coastal Vulnerability to Coastal Protection; From Coastal Protection to Fisheries; From Fisheries to Overlap Analysis; From Carbon Storage & Sequestration to Overlap Analysis; From Aesthetic Quality to Recreation; From Recreation to Overlap Analysis.

Legend:

- Green solid box: Terrestrial/freshwater model: Tier 1 supporting service
- Green dashed box: Terrestrial/freshwater model: Tier 1 that quantifies service
- Dark Blue solid box: Marine model: Tier 1 supporting service
- Dark Blue dashed box: Marine model: Tier 1 that quantifies service
- Blue solid box: Marine model: Tier 0
- Blue dashed box: Marine model: Tier 1 that quantifies service
- Grey arrow: Optional model linkage, no sequencing
- Thick grey arrow: Required/optional model linkage, sequencing needed

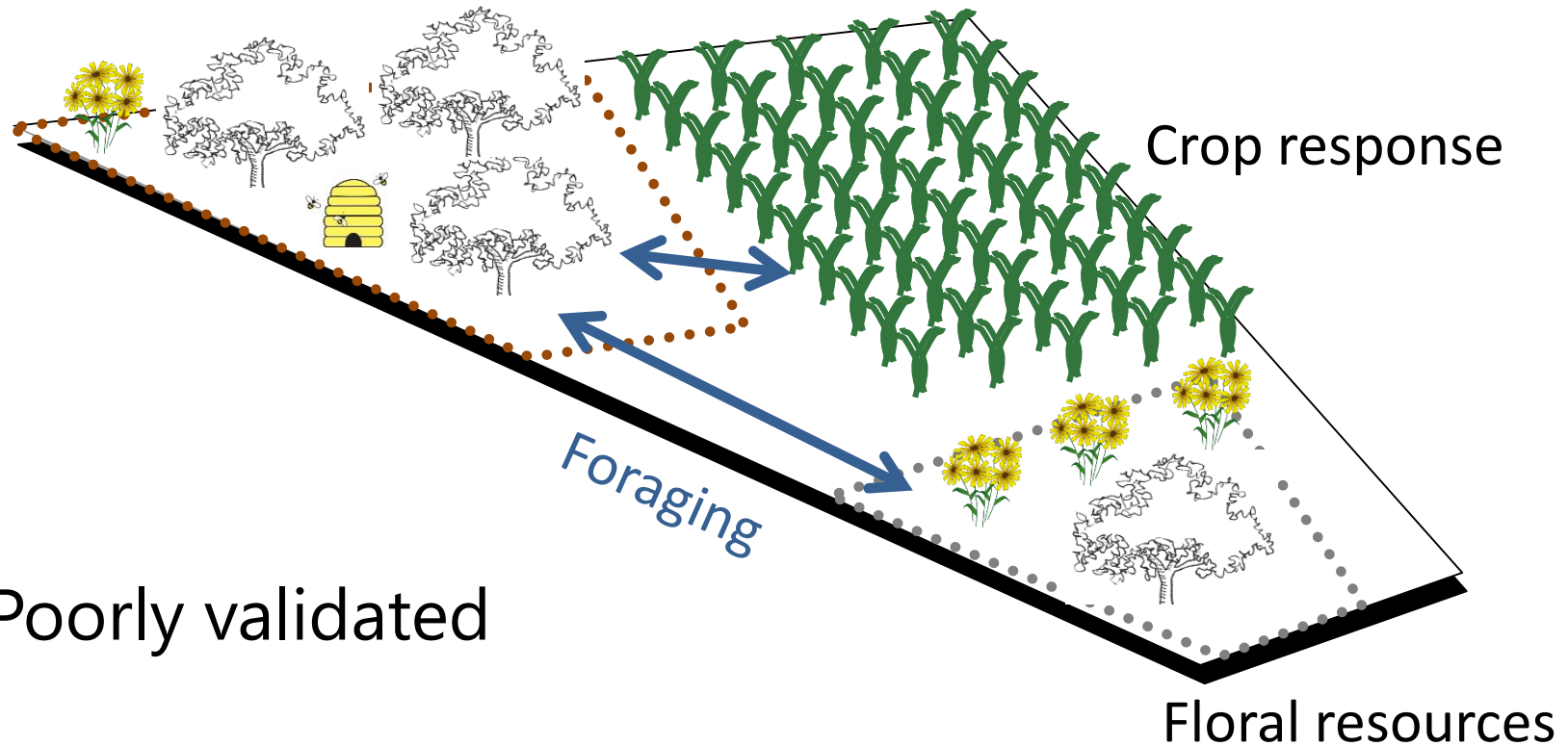
Logos: CEH (Centre for Ecology and Hydrology), NERC (Natural Environment Research Council), SCIENCE OF THE ENVIRONMENT.



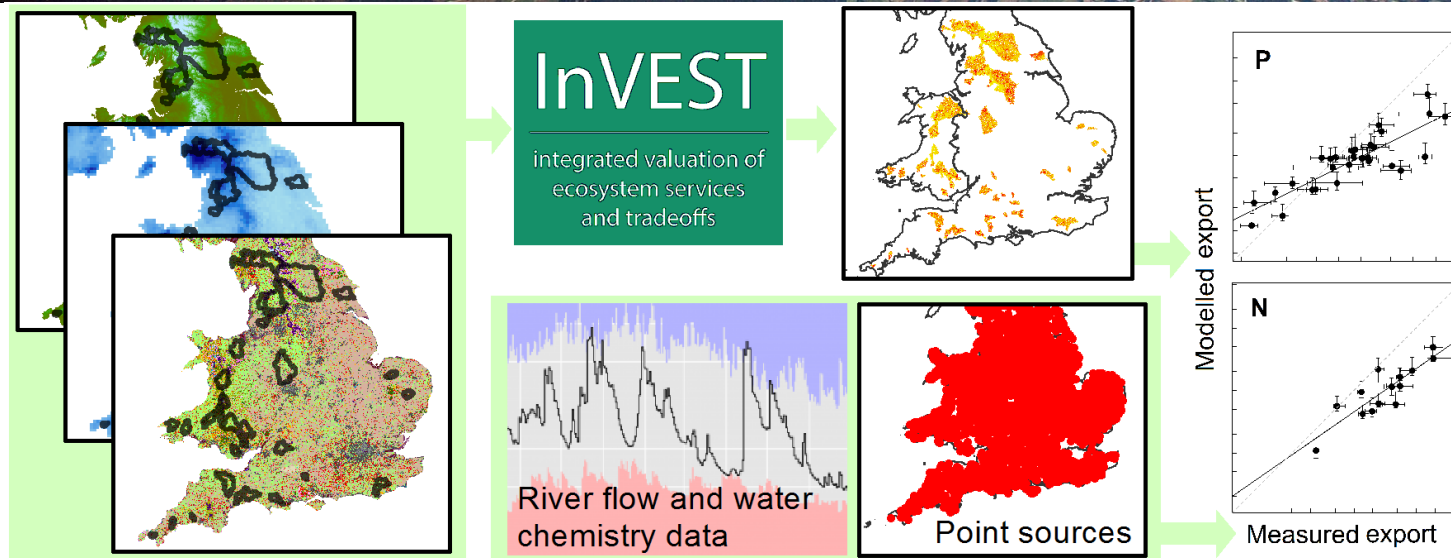
Modelling pollination services: InVEST

Nesting resources

Floral resources

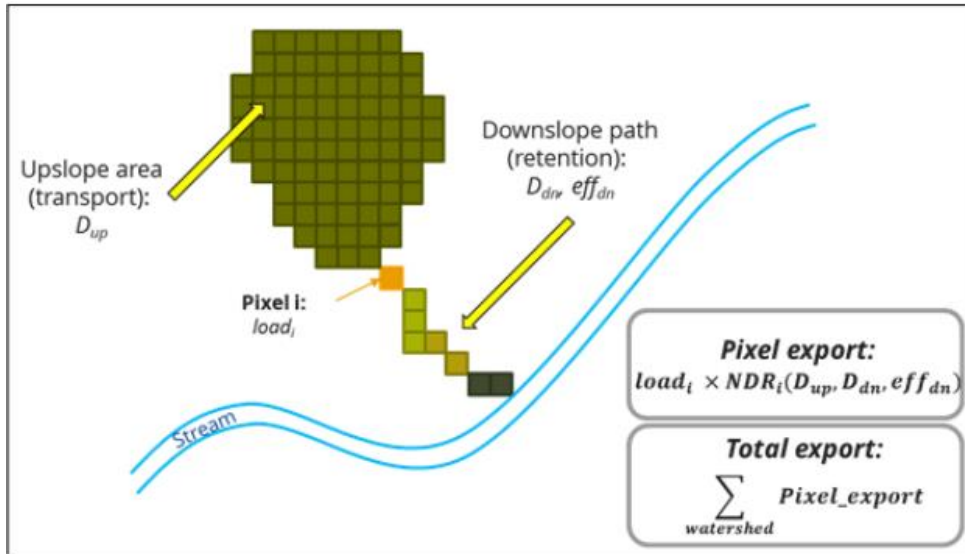


Modelling water purification: InVEST



Validated for the UK – i.e. model matches data

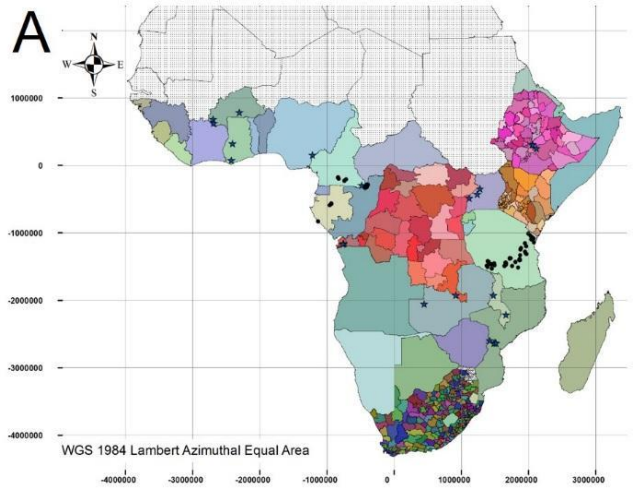
Redhead... & Bullock (2018). National scale evaluation of the InVEST nutrient retention model in the United Kingdom. *Science of the Total Environment*



Restoration & resilient ecological networks

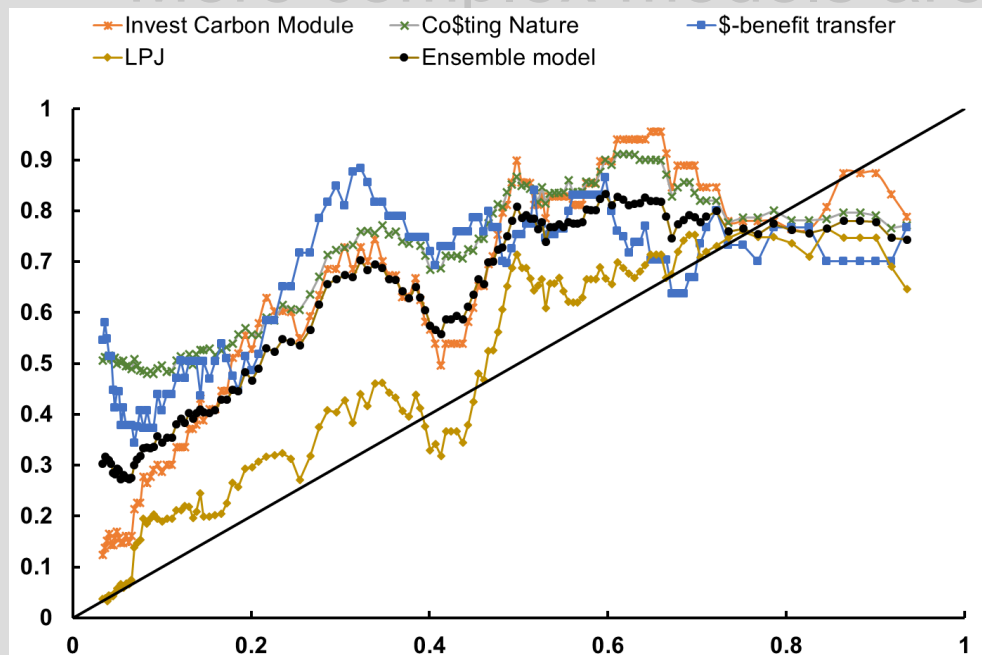
- What is the network for: biodiversity, specific services, multiple outcomes (multi-functionality)?
- There is no one-stop shop for modelling the multiple aspects of a network
- More complex models are more accurate and/or flexible

Restoration & resilient ecological networks



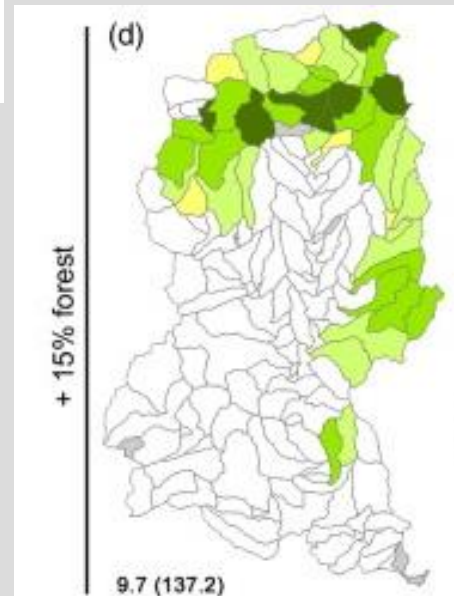
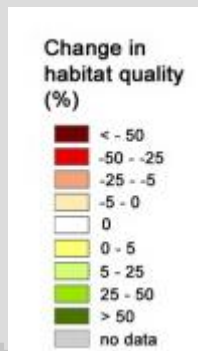
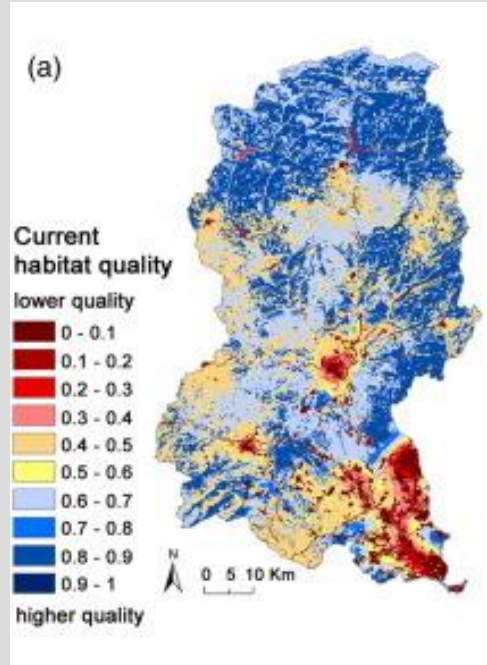
Model accuracy

- Several ecosystem service models tested for accuracy in sub-Saharan Africa
- e.g. carbon stocks
- Process models (e.g. LPJ) best
- Simple benefits transfer worst



Willcock ... & Bullock (in review) A continental scale validation of ecosystem service models

Restoration & resilient ecological networks



Model flexibility

- Models of habitat quality often have no/limited spatial dynamics
- e.g. InVEST Habitat Quality model
- Simple classification of land use to habitat value
- (although some mapping of threat from nearby adjacent land uses)

Terrado et al (2016). Model development for the assessment of terrestrial and aquatic habitat quality in conservation planning. *Science of the Total Environment*

Restoration & resilient ecological networks

- What is the network for: biodiversity, specific services, multiple outcomes (multi-functionality)?
- There is no one-stop shop for modelling the multiple aspects of a network
- More complex models are often more accurate and/or flexible
- But (more complex) models need (more) data
- **Need for concerted and integrated effort among researchers, Gov't, NGOs, industry to:**
 - **Align activities**
 - **Plan and fund data gathering**
 - **Develop and use a consistent set of appropriate models**

Thanks to

Collaborators: Nick Isaac, Georgina Mace, Pete Brotherton, Richard Gregory, John Redhead, Justin Travis, Steve Palmer, Simon Willcock, Felix Eigenbrod, Danny Hooftman, Steven White

Funders: CEH, NERC, ESPA, BESS, EU

