Modelling in the context of ecosystem accounting

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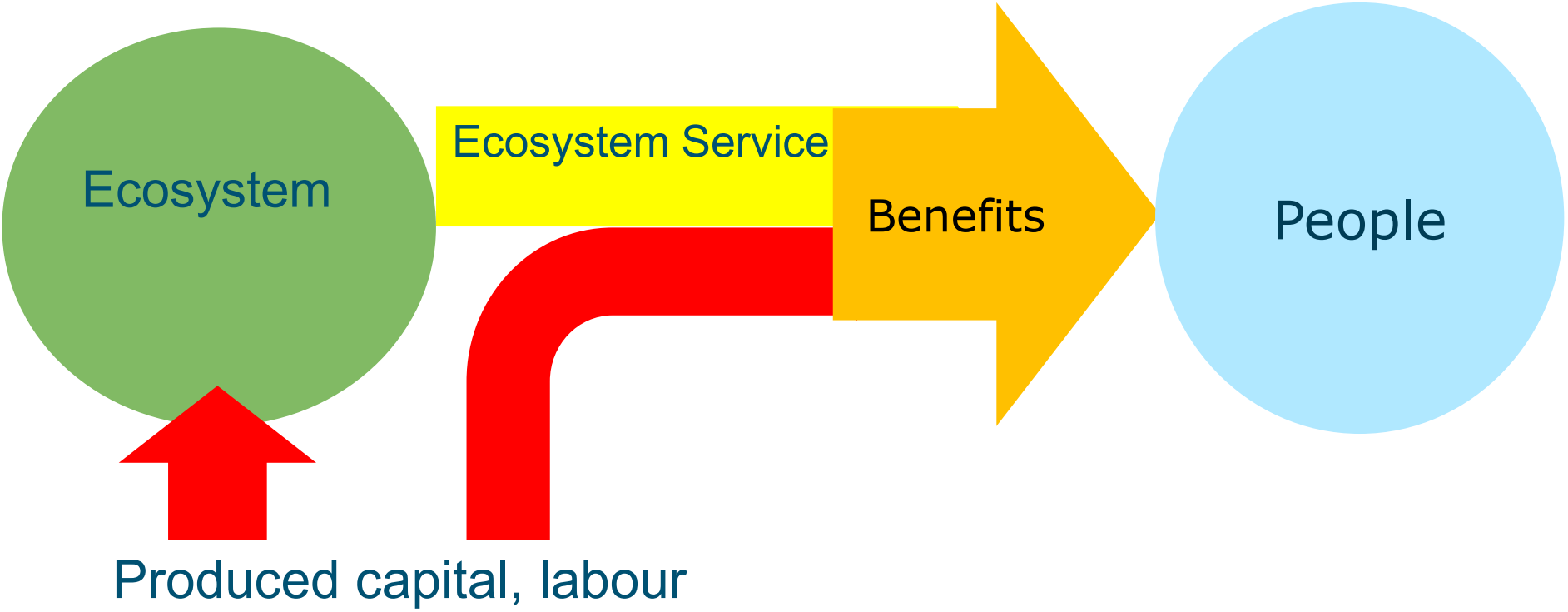
Defining Ecosystem Services

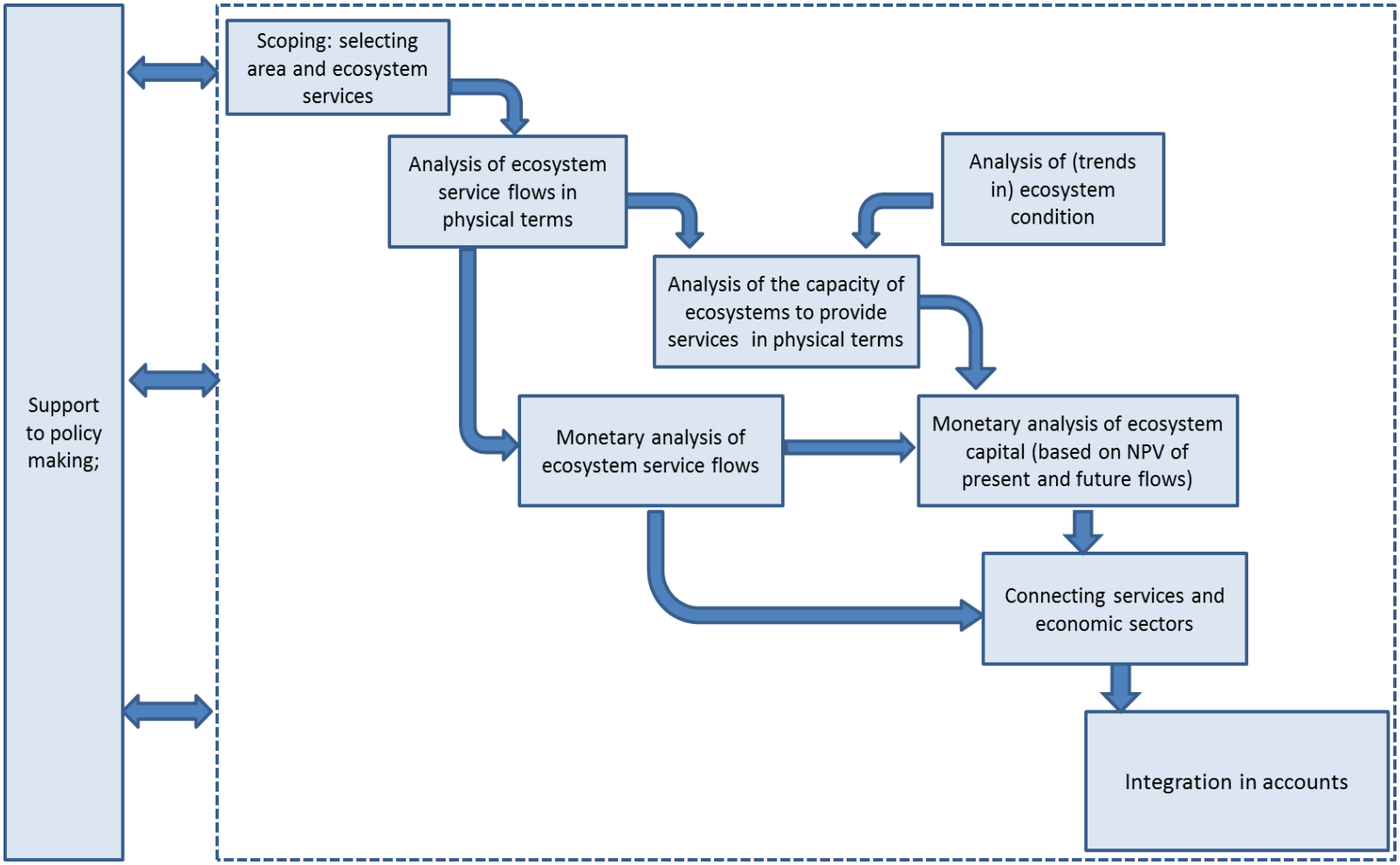


Ecosystem accounting aims to record the flow of ecosystem services

How to define the service crop production ?

1. SEEA: The contribution of the ecosystem to crop production, i.e. providing substrate, supply of water and crop nutrients, and retention of water and nutrients:
    - Input of the ecosystem is often small compared to human inputs
    - Defined in this way it is not a flow indicator
    - Very difficult/impossible to measure, what unit to use?? How to quantify ??
2. The crop yield (just before it is harvest) can be used as indicator for the service. In the valuation step the human inputs (e.g. fertilizer input) are deducted
    1. But: the use of inorganic fertilizers also contributes to the (physical) ecosystem services supply
    2. Strawberries picked in a forest is the same (physical) service as strawberries picked in a greenhouse

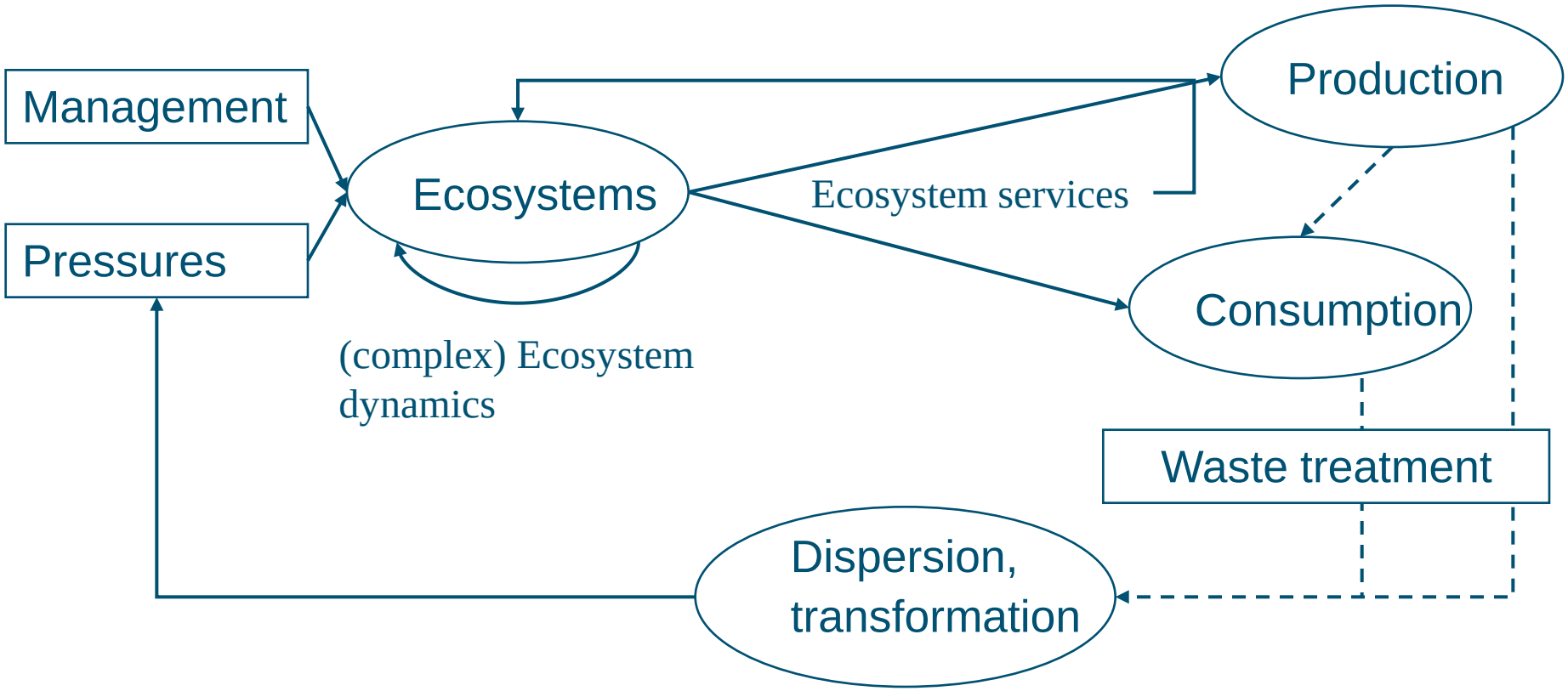
Temporal Modelling is required for analysing changes in ecosystem capacity



Temporal modelling involves 2 basic steps

- Step 1: Model changes in ecosystem condition
  - How will ecosystem condition change as a function of
    - Management (including harvesting)
    - Ecosystem processes
    - External drivers (e.g. climate change)
- Step 2: Analyse changes in ecosystem capacity to generate services over time as a function of changes in ecosystem condition

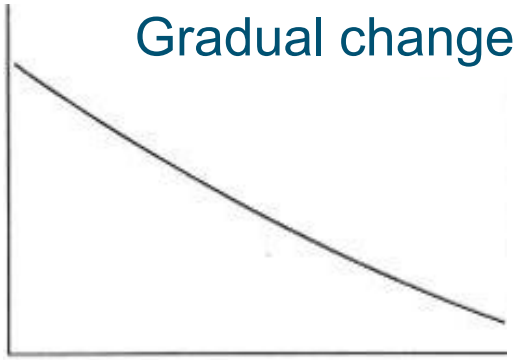
Modelling framework



Complex ecosystem dynamics

State

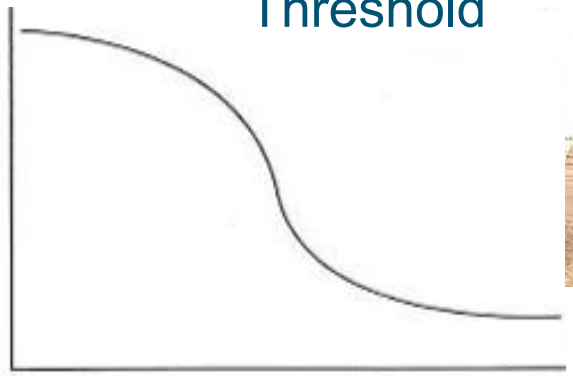
Gradual change



Pressure

State

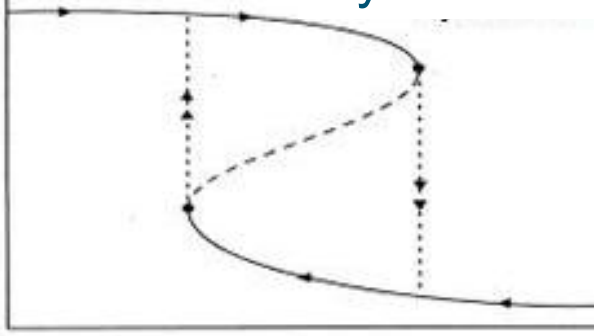
Threshold



Pressure

State

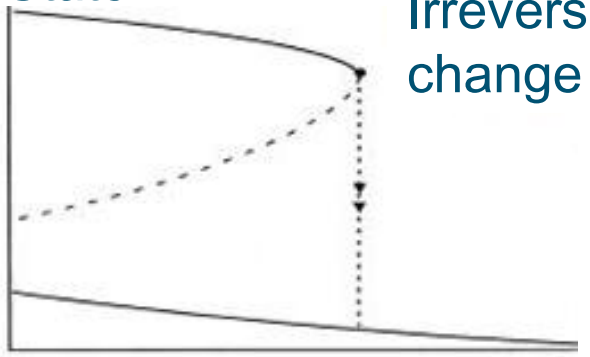
Hysteresis



Pressure

State

Irreversible change



Pressure

How to model complex dynamics ?

- Systems approach, using differential equations, for instance a logistic growth curve:

$$\frac{dP}{dt} = rP\left(1 - \frac{P}{K}\right)$$

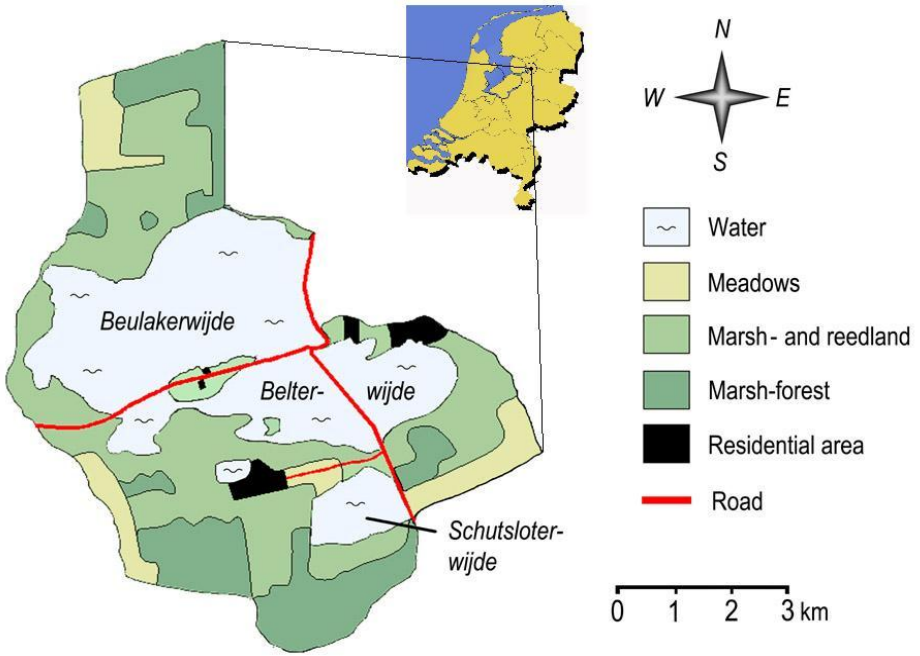
- The carrying capacity (K) may be related to environmental factors (condition indicators), introducing **feedback mechanisms**
- These relations may be found using regression analysis provided that data are available
- Regulating services (except carbon) often depend on spatial relations, spatial-temporal modelling is required

Case study (efficiency versus sustainability): Forest

- Modelling of irreversible responses to overharvesting
- Analysis of two ecosystem services: wood and erosion control
- Modelled for a hillside plot (30 by 30 meter) with a uniform slope (20^{o})

Case: Pollution in De Wieden wetland

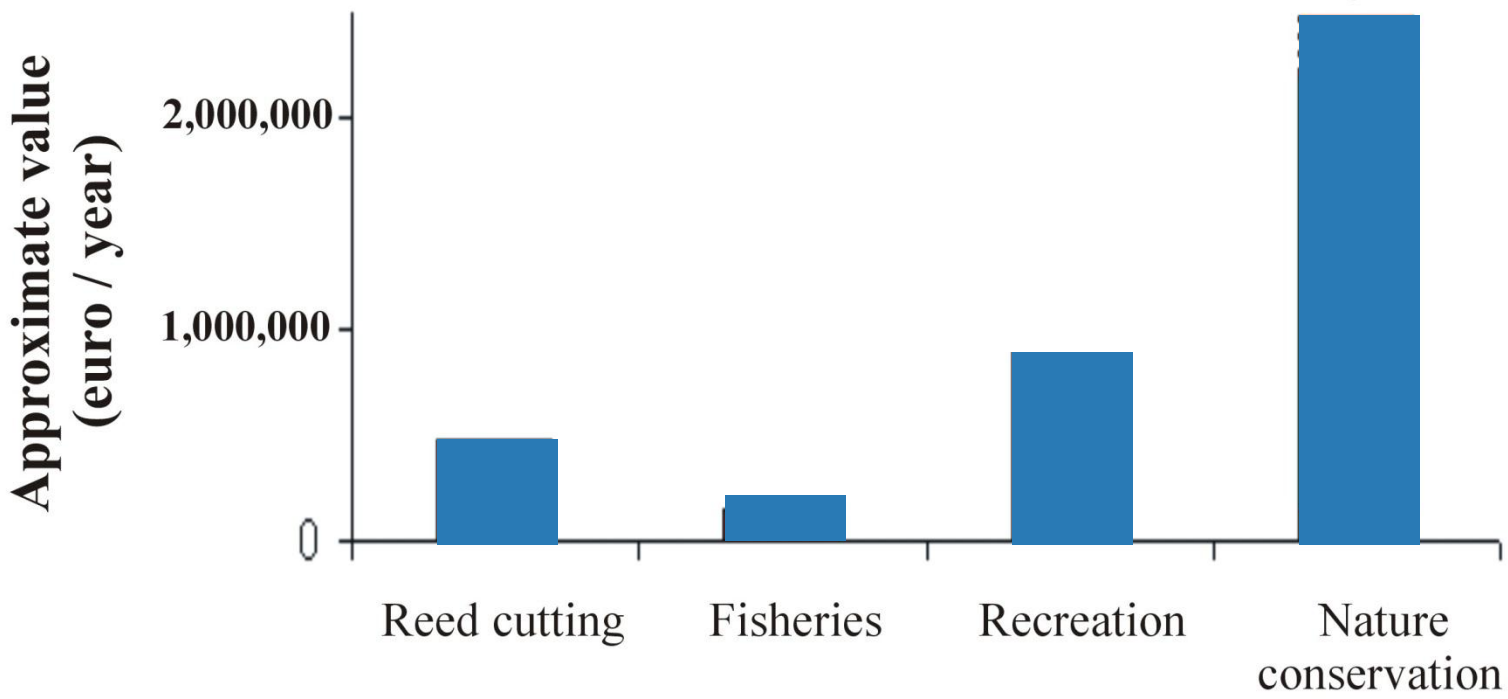
- The De Wieden wetlands have been subject to eutrophication since the early 1970s. Water quality has improved but the lakes remain eutrophic and turbid.
- Case study was conducted in support of eutrophication management, what are implications for Ecosystem accounting ?



Biophysical quantification ecosystem services of De Wieden

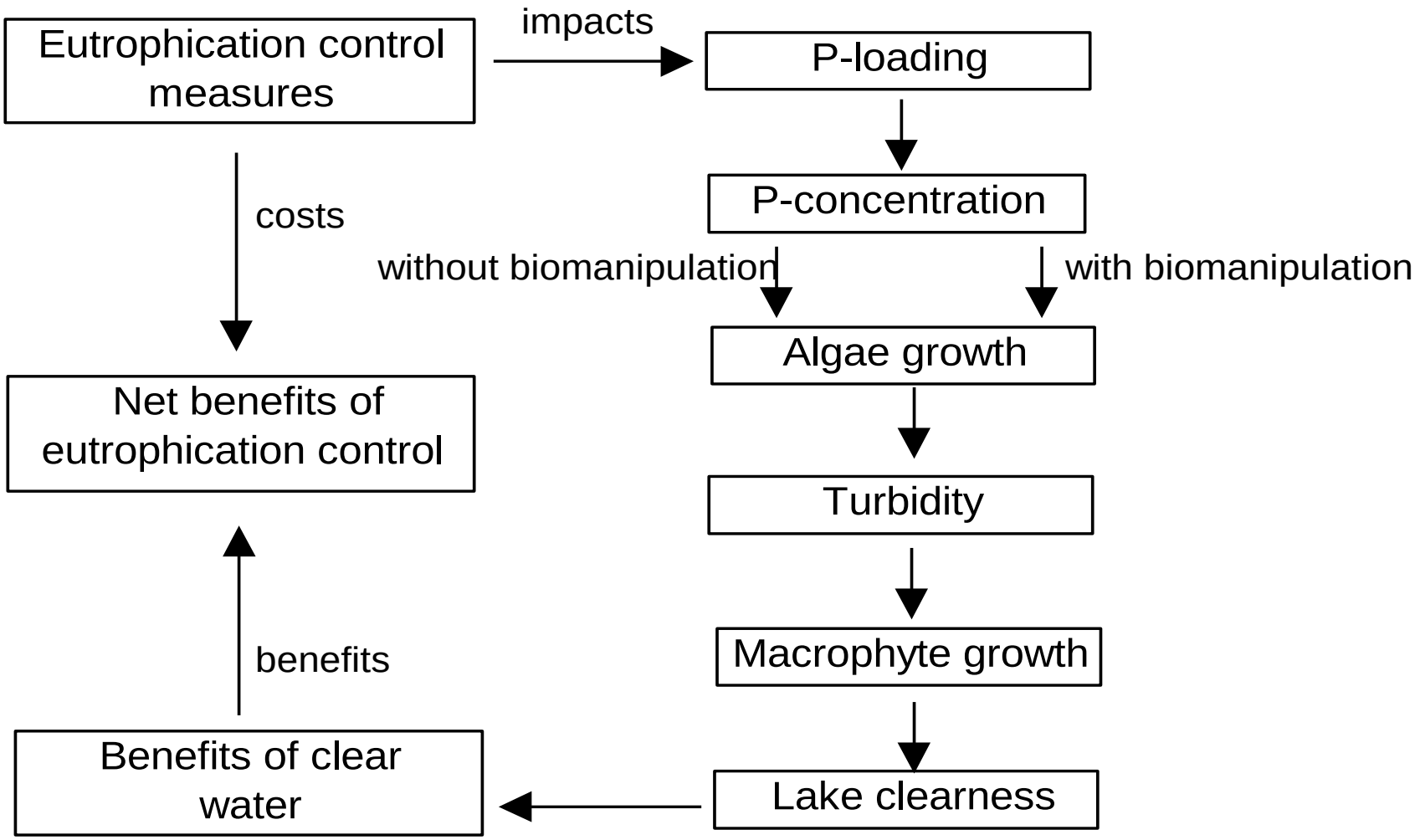
- Fisheries : type and amount of fish caught
- Reed cutting : amount of reed cut
- Recreation : number of visitors and their activities
- Nature conservation : number of red list species

Ecosystem services of De Wieden

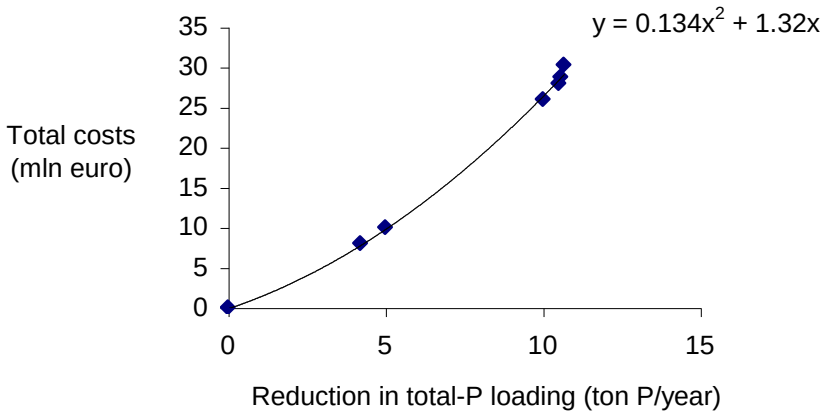


- The ecosystem services of De Wieden generate around 600 euro/ha/year, around 50% more than the value generated by cropland

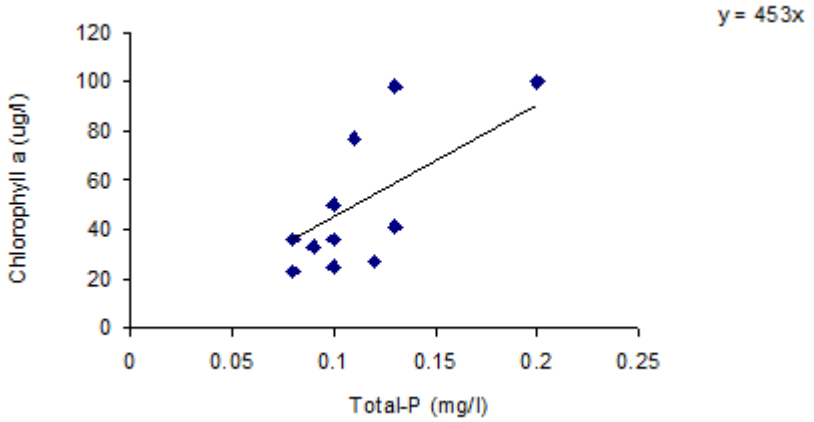
Model to analyse impacts of nutrient pollution control



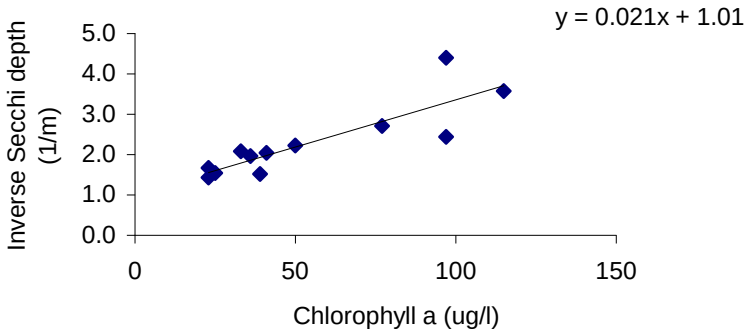
Modelling ecosystem processes



Costs of eutrophication control

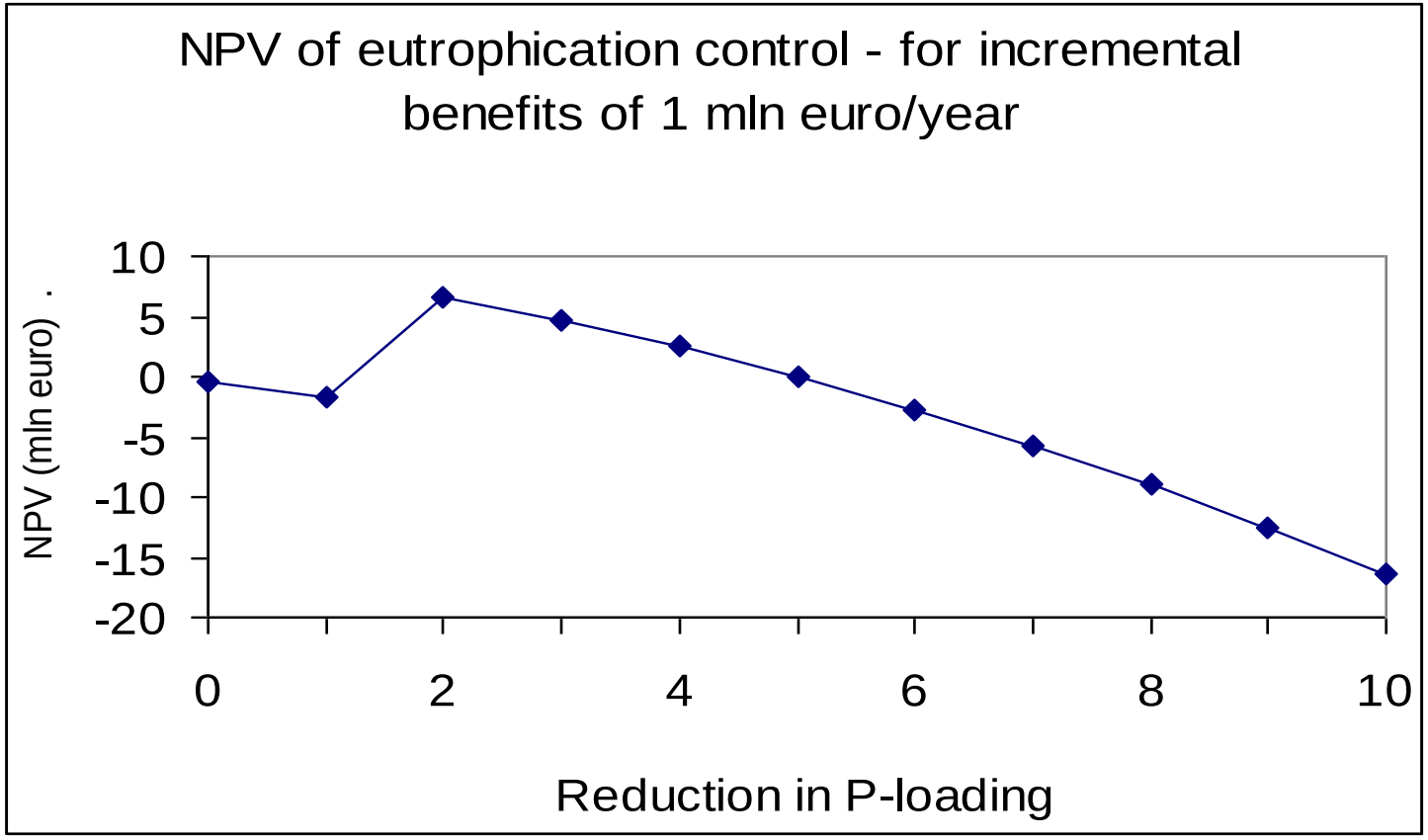


Relation between total-P and chlorophyll a



Relation between Chlorophyll a and the inverse Secchi depth

Benefits of pollution control in De Wieden



Capacity, flows and pollution

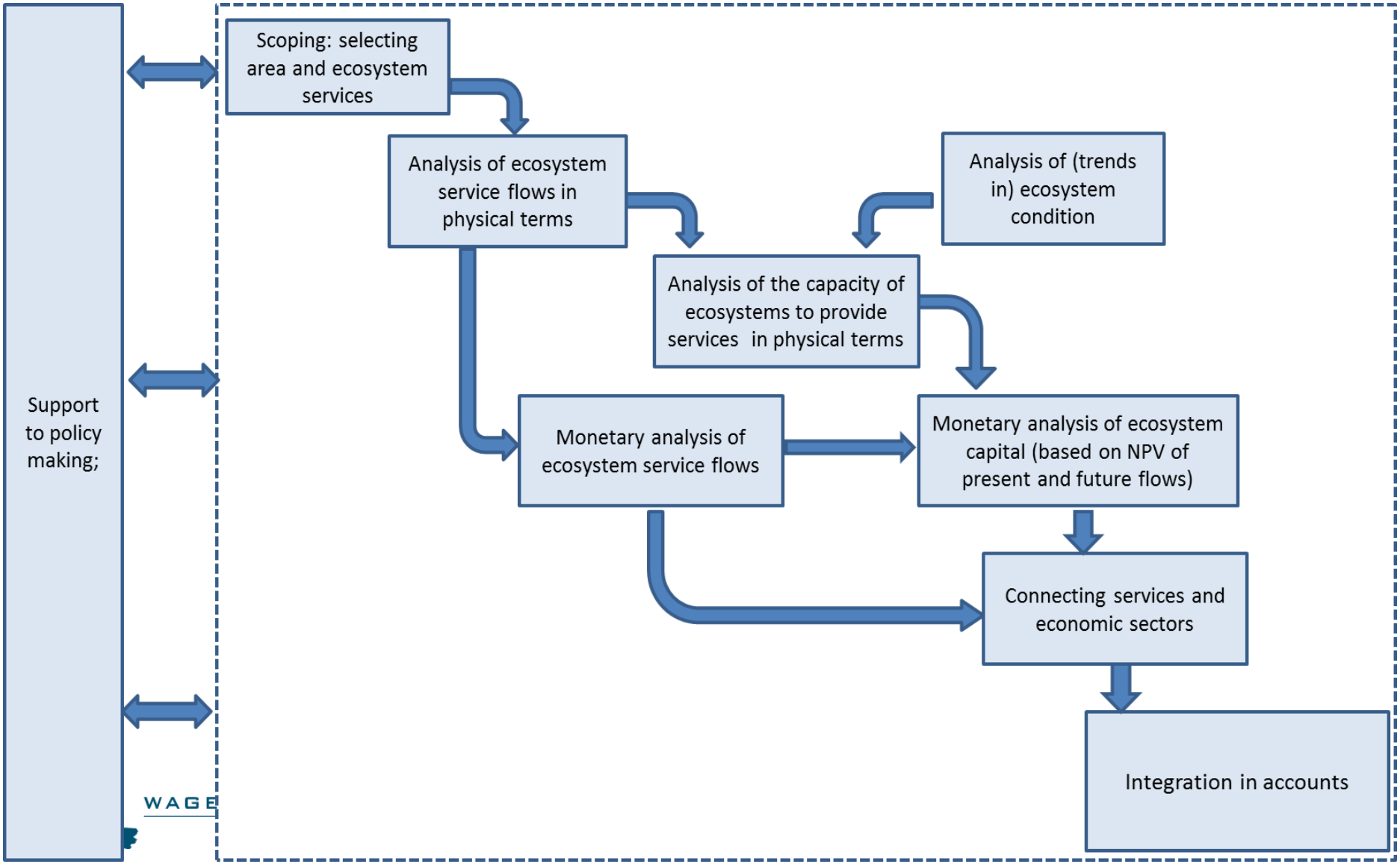
- Increased pollution levels, or clean-up of waterways will be reflected in year-to-year changes of ecosystem accounts.
- Pollution may change the capacity of ecosystems to provide services, the flow of services itself, or the value of these services (e.g. more effort needed to harvest, or lower quality product)
- Trends (but not potential policy measures) can be considered...however often difficult to anticipate effects of changes in pollution loads on ecosystem services

Spatial modelling

Spatial modelling involves combining spatial datasets (maps, remote sensing images), point data and statistical data for administrative units to estimate ecosystem services flow and capacity. It can be used:

- For calculating flow and capacity of specific data points
  - Look-up tables
  - Geostatistical interpolation (e.g. kriging)
  - Statistical approaches
  - Process based modelling (e.g. USLE)
- For modelling spatial aspects of ecosystem services (in particular regulation services except carbon sequestration)
  - E.g. hydrological services, air filtration

Key elements of Ecosystem Accounts



How to define capacity ?

	Ecosystem service capacity	Ecosystem service flows
Provisioning services	Capacity to provide the products (overharvesting may occur)	Amount of products extracted / harvested
Regulating services	Regulating impact of ecosystems on physical environment	Regulating impacts on people
Cultural services	Depend on service	Depend on service

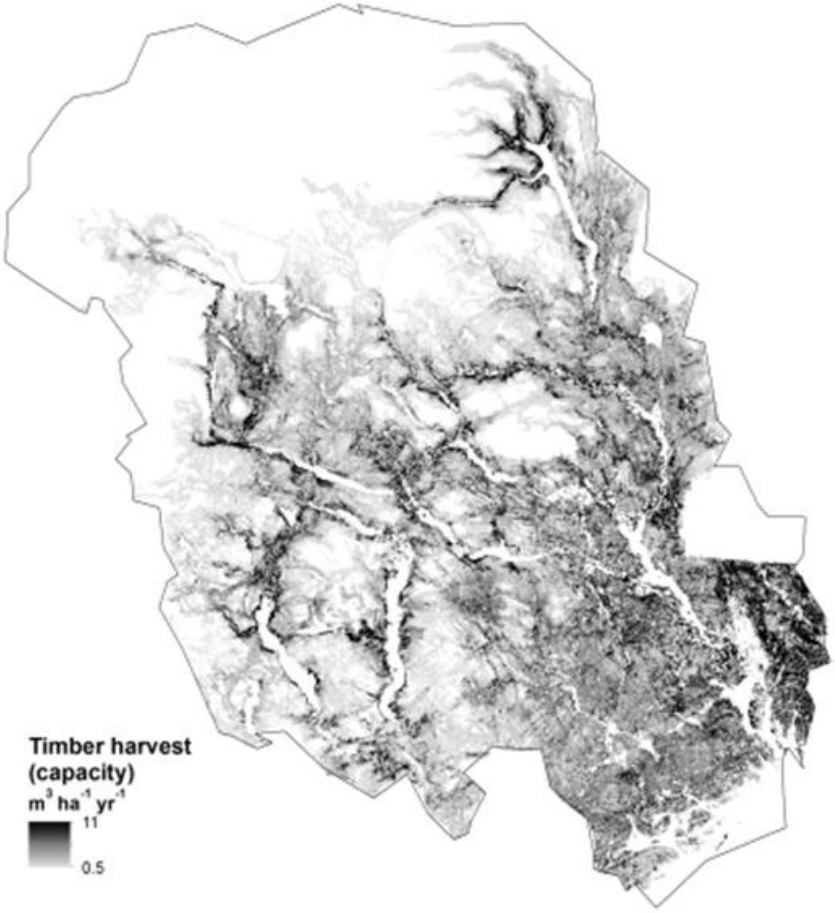
Mapping techniques

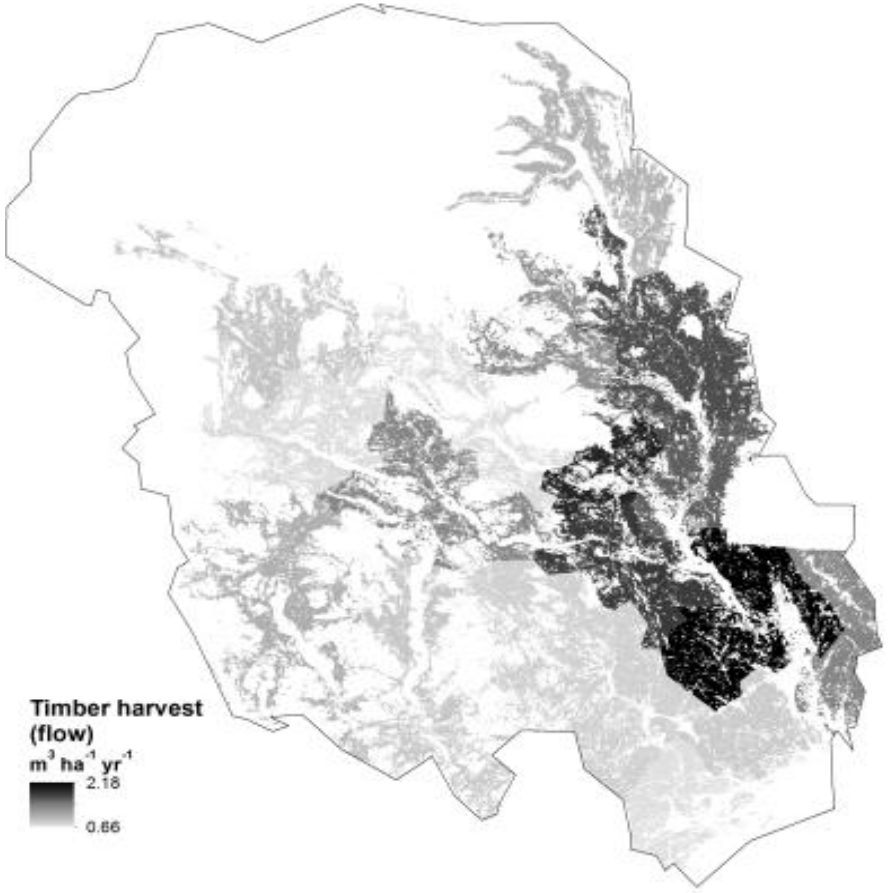
- **Look-up tables**. A specific value for an ecosystem service or other variable is attributed to every pixel in a certain class,
- **Geostatistical interpolation**. Use of statistical algorithms to predict the value of un-sampled pixels on the basis of nearby pixels in combination with other characteristics of the pixel. (e.g. kriging).
- **Statistical approaches**. For instance Maxent analyses the likelihood of occurrence of a species (or other services) as a function of predictor variables, based on an analysis of the occurrence of that species in those data points where the species occurrence has been recorded.
- **Process based modeling**. This method involves predicting ecosystem services flows or other variables based on a set of environmental properties, management variables and/or other spatial data sources.

Mapping approaches

Mapping Approach	Basic characteristic	Mapping techniques applied
Dedicated ecosystem services mapping tool such as InVEST;	Predefined modules for mapping ecosystem services	Mostly based on Look-up Tables, predefined techniques for specific services.
Modeling framework such as ARIES	Enables designing specific algorithms for individual ecosystem services in a dedicated GIS environment, using predefined modules where appropriate	Flexible, different mapping techniques are supported in ARIES.
Using ArcGIS or a freeware GIS programs.	All services need to be modelled individually	Flexible, all mapping techniques can be used.

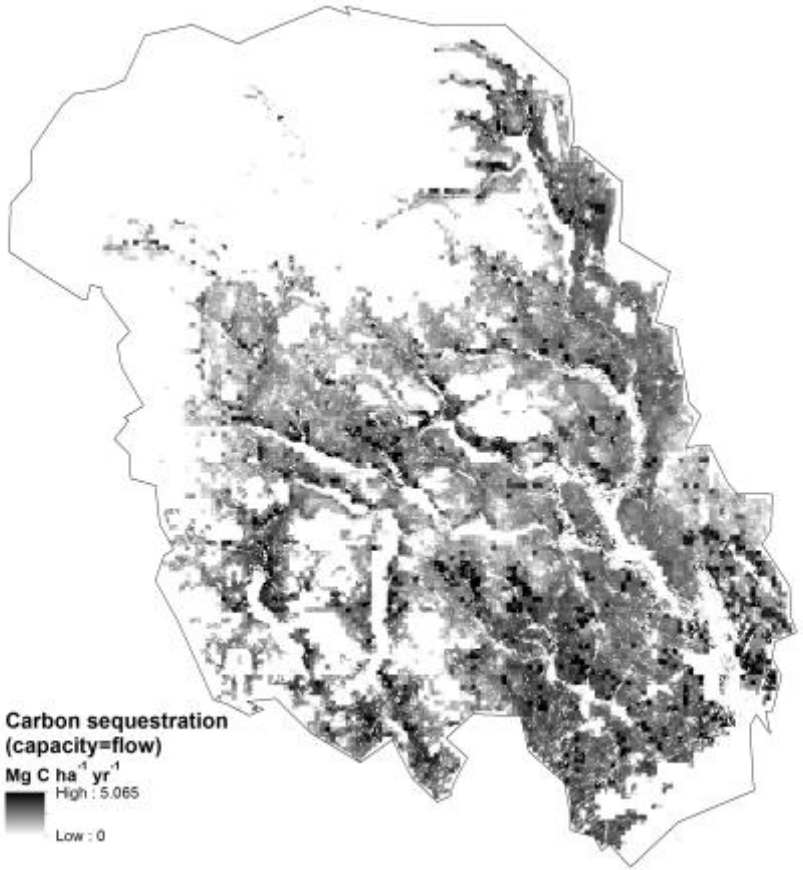
Timber harvest

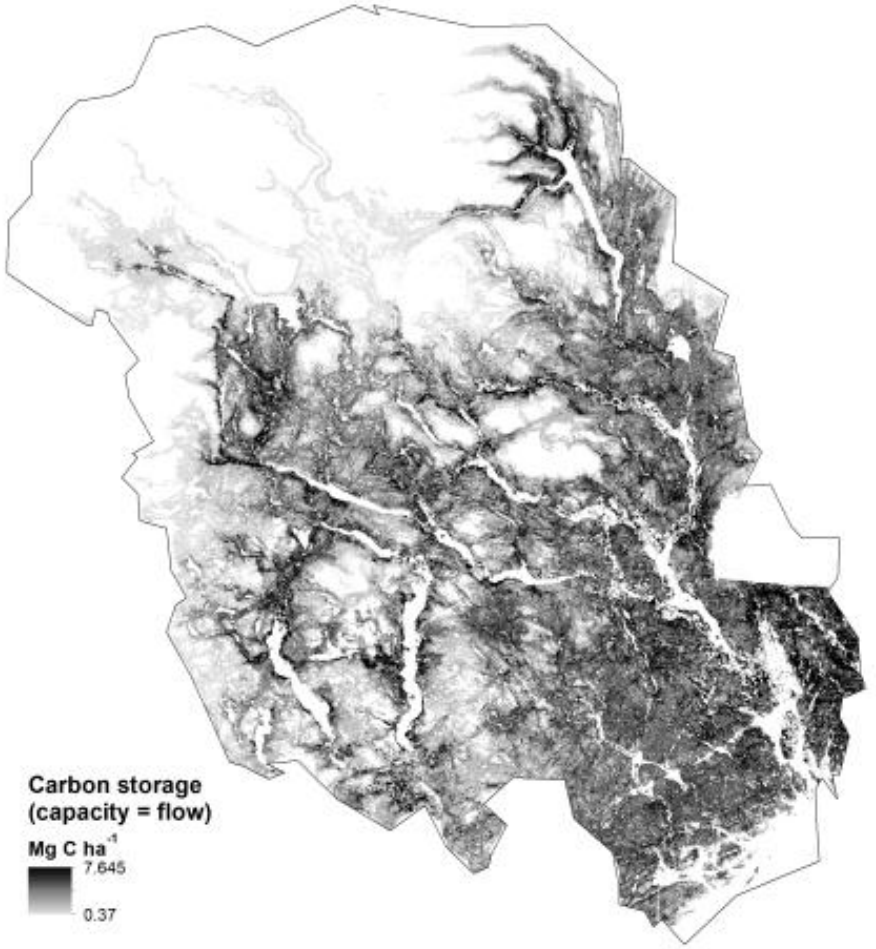




Source: Schröter et al., 2014

Carbon sequestration and storage





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