Implications of ecosystem services and regime shifts for economic models; some preliminary thoughts

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Personal Introduction

- MSc Environmental Sciences (1994); PhD Environmental Sciences - Env. Economics (2005)
- 1994-1997: Researcher at Science, Technology and Society Group, Utrecht University
- 1997-2002: Environmental Expert, FAO/World Bank Investment Centre, Rome
- 2002 – present: Associate Professor, Environmental Systems Analysis Group, Wageningen University
- 2007 – 2010: Shell International (part-time): Senior Environmental Consultant.
- Research Interests: Ecosystem Dynamics, Ecosystem Services, Resource Optimisation, Climate Change Impacts and Adaptation

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Contents of the presentation

- Scales and Dynamics of Ecosystems
- Ecosystem Dynamics and Ecosystem Services Supply
- Case Studies
  - Forest Ecosystem
  - De Wieden Wetland
  - The Ferlo rangeland

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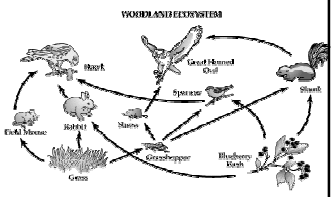
(1) Scales and Dynamics of Ecosystems

- Ecosystem are defined by
  - Components
  - Structure
  - Processes
- Ecosystems occur at a range of geographical scales, e.g.
  - A local pond
  - A river
  - The North Atlantic Ocean
- The Ecosystem is characterised by strong internal functional relations, and weaker external relations ("a functional unit")



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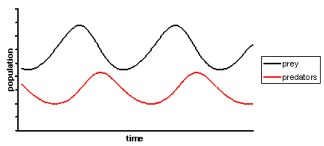
Modelling ecosystem dynamics

- Ecosystem may be modelled as a (*homogeneous*) functional unit, driven by management and external drivers that influence the composition and processes taking place in the ecosystem.
  - Lotka-Volterra models



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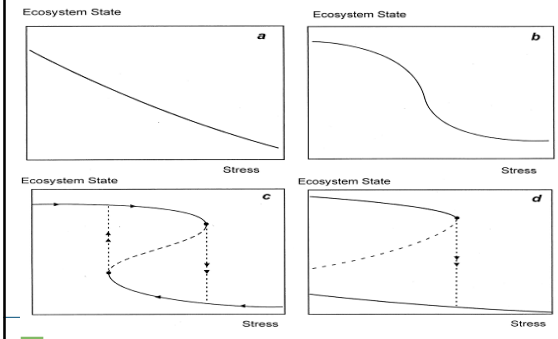
Ecosystem response to stress (figure taken from Scheffer et al., 2001). Feedback mechanisms



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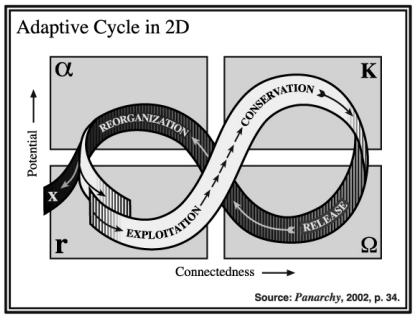
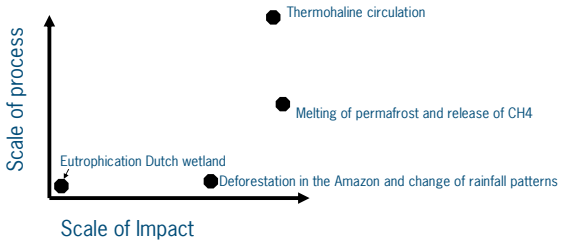
Ecosystem Dynamics: Adaptive Cycle



Scales of Impacts and Processes of Ecological Dynamics

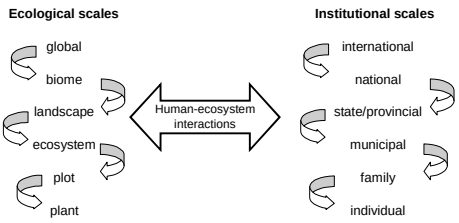


Defining ecological thresholds at coarse spatial scales

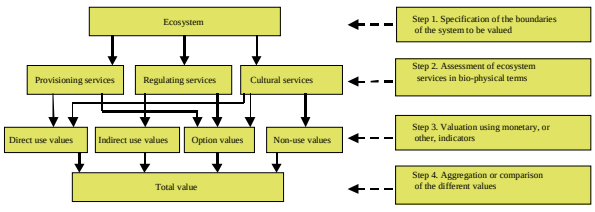
more pronounced Thresholds

- Case 1. Large Scale Processes and Impacts (e.g. Thermohaline Circulation). Threshold results from changes in single process and can easily be defined (though not necessarily easily predicted).
- Case 2. Large scale impact as a result of cumulative impacts of a single or homogenous process (melting of permafrost). Thresholds can often be defined and may be predicted.
- Case 3. Large scale impact as a result of the cumulative impact of activities influencing a range of interconnected processes (e.g. deforestation Amazon, driven by local land use change, influencing atmospheric water balances, hydrology, albedo, and climatic response at a coarse scale). Another example: impacts of climate change on biodiversity in Europe. Temperature and rainfall patterns will change, influencing species, food webs, animal and flora behaviour, etc. Thresholds (forest cover, temperature change) will occur but are very difficult to define and predict.

Ecological and Institutional Scales

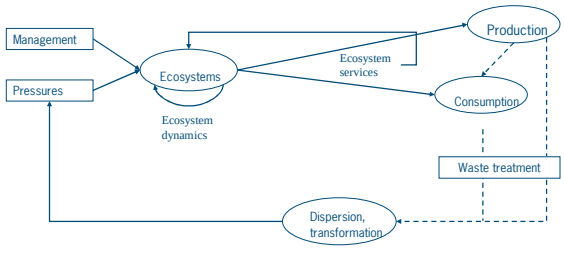


(2) Ecosystem dynamics and ecosystem services



'Static' approach: valuation of ecosystem services

Ecosystem Services in a Dynamic Context



Scale is a key factor in incorporating ecosystem services and dynamics in economic models

- National/Sector
  - Variable prices as a function of (i) ecosystem dynamics and subsequent changes in ecosystem services supply; and (ii) a host of other factors
  - General Equilibrium / Econometric Models
  - Difficult to incorporate feedbacks and complex dynamics
- Local
  - In specific cases, exogenous prices may be assumed
  - Dynamic Systems Modelling ('flows and stocks' – models)
  - Feedbacks and complex dynamics can easily be included

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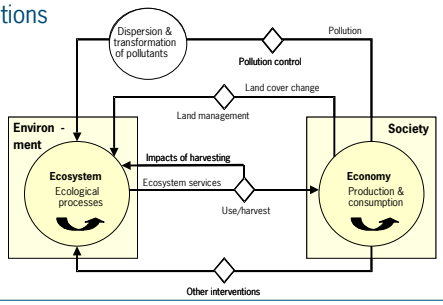
Ecosystem Services in Economic Models

- Framework for Modelling Ecosystem Management Options



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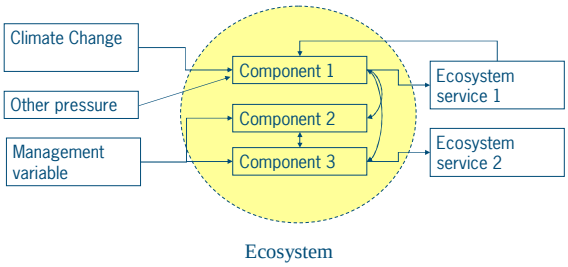
Dynamic systems modelling



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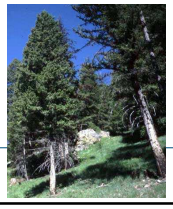
Case study 1: Hypothetical forest ecosystem (North-western US Douglas fir)

- 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°)



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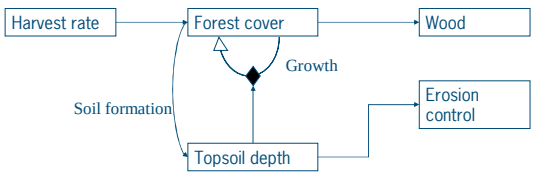
Case study 1: the model structure



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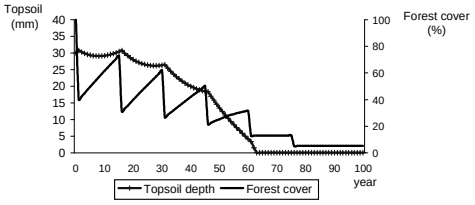
Profit maximisation (felling cycle = 15 years)



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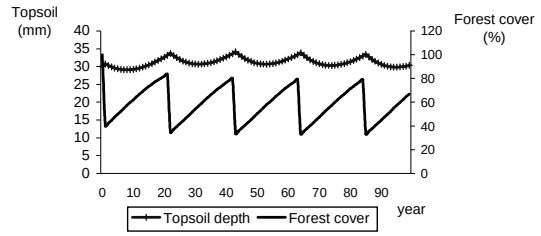
Sustainable management (felling cycle = 21 years)



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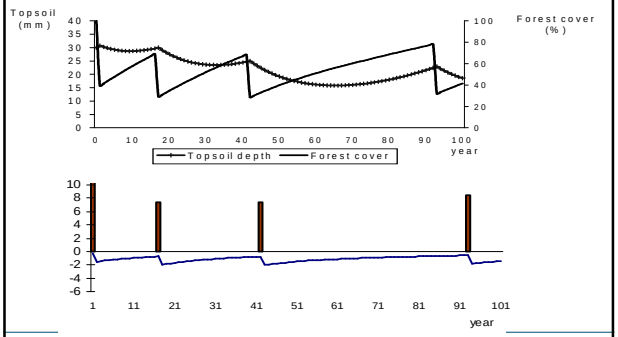
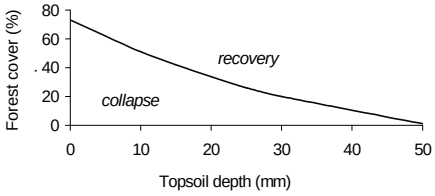
Maintaining minimum sustainable stocks



Modelling complex dynamics



- Irreversible response and threshold are not 'forced' upon the ecosystem but follow from the modelled processes (i.e. feedbacks)

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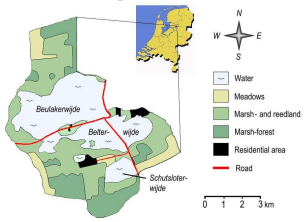
Case study 2: De Wieden wetland

- Lowland peatland ecosystem; mix of forests, lakes, extensive agricultural land
- Subject to high inflow of nutrients, mainly from agriculture, in the past
- Question: what is the optimal level of pollution control in De Wieden ?



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Ecosystem services of De Wieden

- Fisheries
- Reed cutting
- Recreation (boating, beach recreation)
- Nature conservation (habitat service)

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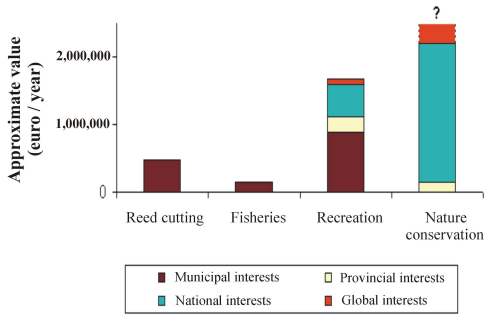
Ecosystem services of De Wieden



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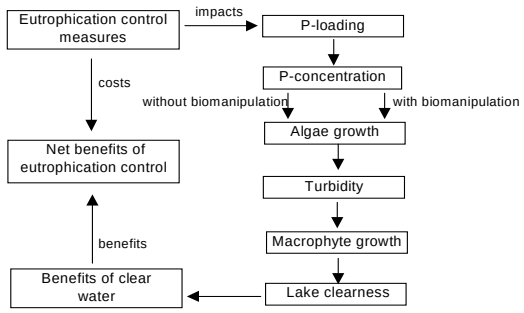
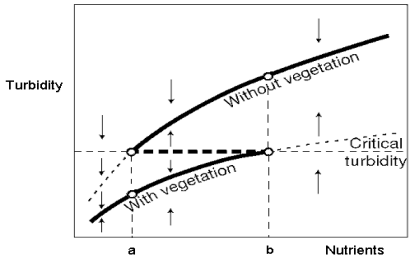
Model to analyse impacts of nutrient pollution control



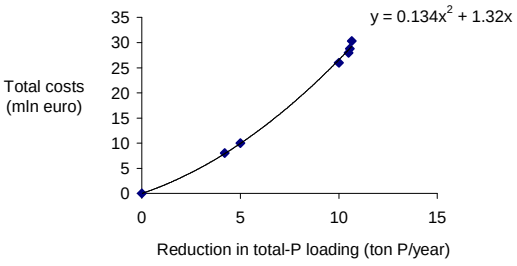
Lake dynamics in De Wieden



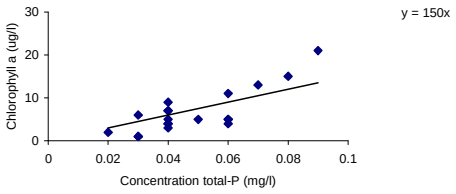
Constructing the abatement curve (1)

Measure	P-reduction (ton/yr)	Costs (NPV) (mln euro)	Cost-effectiveness (mln euro/ton P)
1. Diverting eutrophic polder water	4.2	8	1.90
2. Enhancing sewage treatment plant Steenwijk	0.8	2	2.50
3. Phosphorus reduction inflowing surface water	5	16	3.20
4. Increased connection to sewage system	0.5	2	4.00
5. Enhanced sanitary facilities for tourists	0.06	0.8	13.33
6. Reduction sewage spill-over	0.1	1.5	15.00
Total	10.7		

Constructing the abatement curve (2)



Functional relations in the model – an example

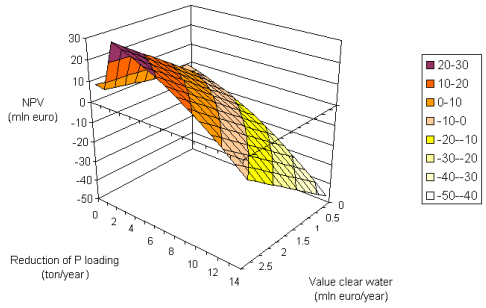


- Relation between nutrient concentrations and algae growth

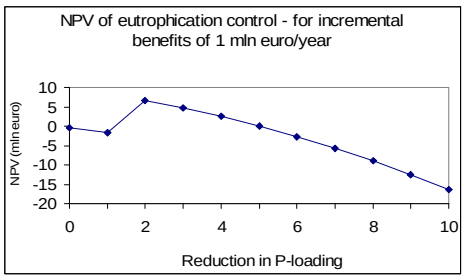
Impacts of reduced nutrient loading on ecosystem services supply

Fisheries	Neutral: eel is relatively insensitive to turbidity and nutrient concentrations
Reed harvesting	Neutral
Recreation	Enhanced value for swimmers and people on boats
Nature conservation	All threatened (red-list) species would benefit, none would suffer

Results (1)



Results (2)



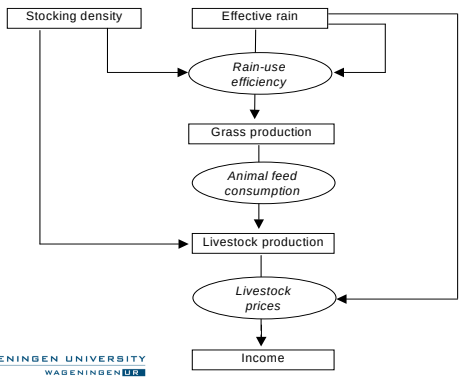
Optimal nutrient pollution control in De Wieden

- The model allows analysis of the impacts and benefits of different eutrophication control measures
- Calculation of the costs of measures necessary to obtain clear water (around 2 mln euro)
- Calculation of economic cut-off point: reducing nutrient concentration become efficient if the incremental benefits are valued at at least 0.2 mln euro/year
- Calculation of the optimal eutrophication control level

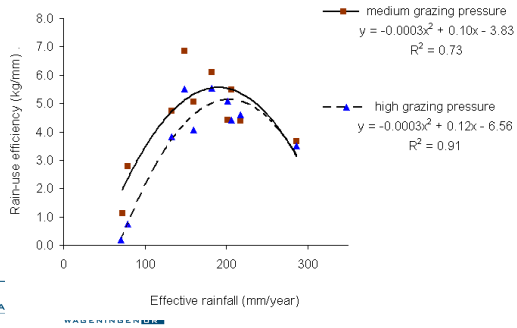
Case study 3: The Ferlo (Senegal)

- In the Ferlo, livestock grazing is the main source of income; but sustained, heavy grazing pressures have an impact on the vegetation. This impact depends to a large extent on the annual rainfall.
- Question: what is the optimal grazing pressure in the Ferlo (in terms of livestock units/hectare) ?

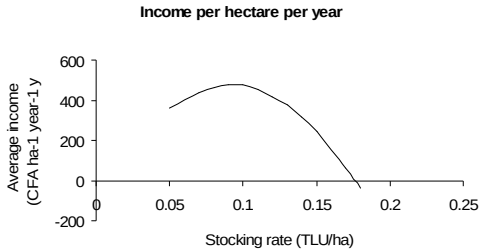
Case study 3: The Ferlo - the model



Rainfall and grazing as drivers for productivity



Case study 3: Income opportunities in the Ferlo



- Current income: 240 CFA/ha/year; highest income: 460 CFA/ha/year

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Case study 3: Rainfall forecasts for the Ferlo 2050 (from the IPCC datacenter)

	A1F	A1B	A1T	A2	B1	B2
HadCM3	-0.52			-0,52, -0.30, -0.26	-0.43	- 0.43, -0.26
CCCma				-0.09		-0.18
CSIRO		-0.35		-0.18	-0.18	-0.09
ECHAM4				-0.30		-0.22
GFDL99				-0.22		-0.22
NIES99	0.09	-0.06	-0.01	0.08	0.17	0.08

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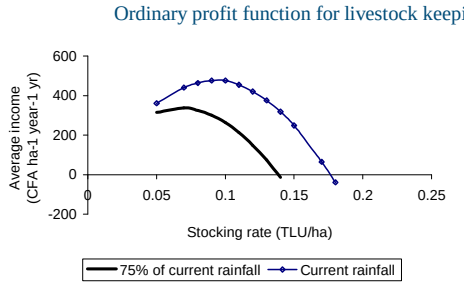
Case study 3: impacts of climate change in the Ferlo



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Potential avenues for further research

- Analysing the occurrence of ecological thresholds at higher spatial (and temporal) scales
- Integrating thresholds and feedback mechanisms in macro-economic (optimisation?) models
- Defining optimal responses in the face of uncertainty and strategic behaviour of stakeholders

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