Global Land Change and soil-landscape dynamics

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With contributions of:

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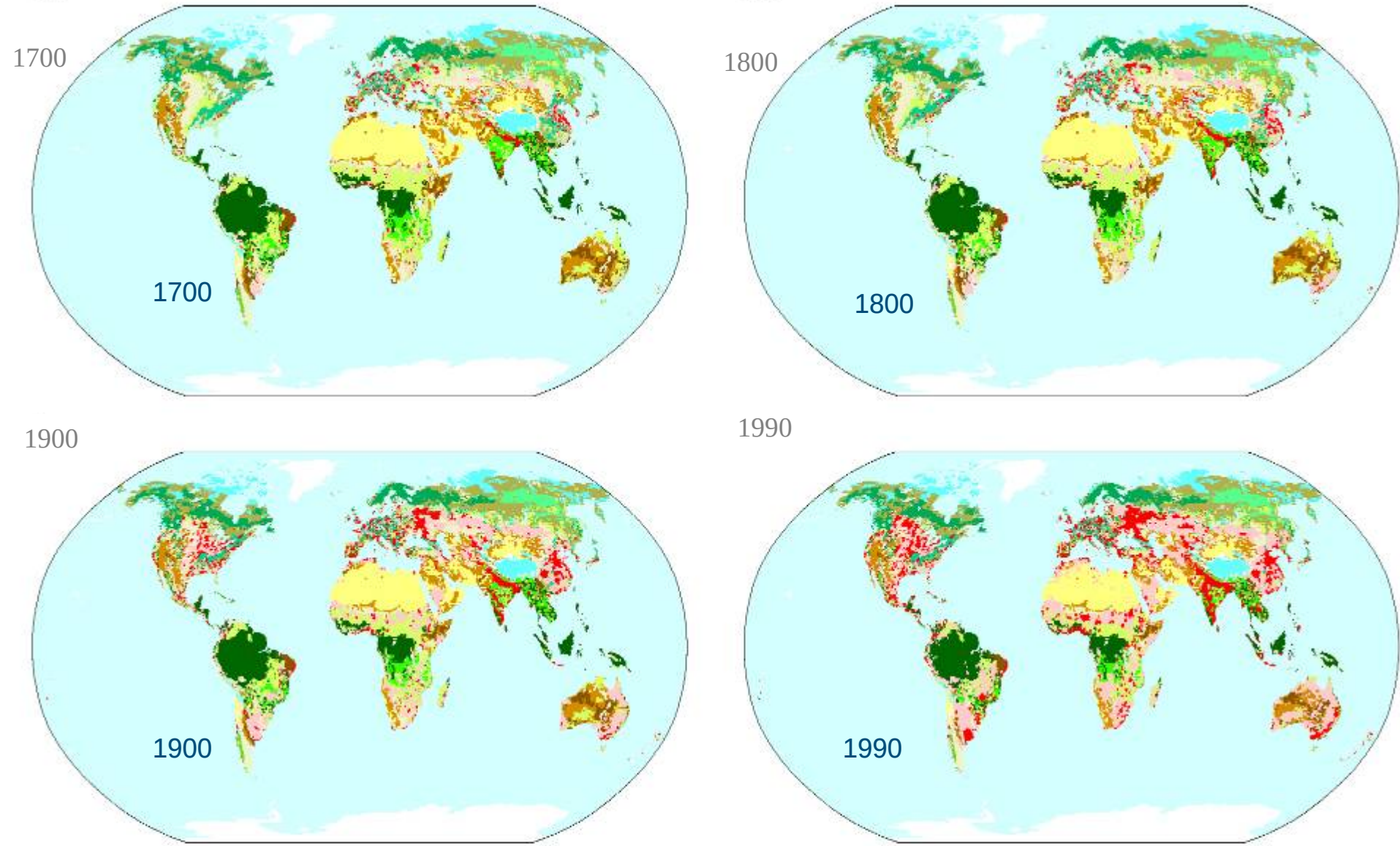
40 years ISRIC

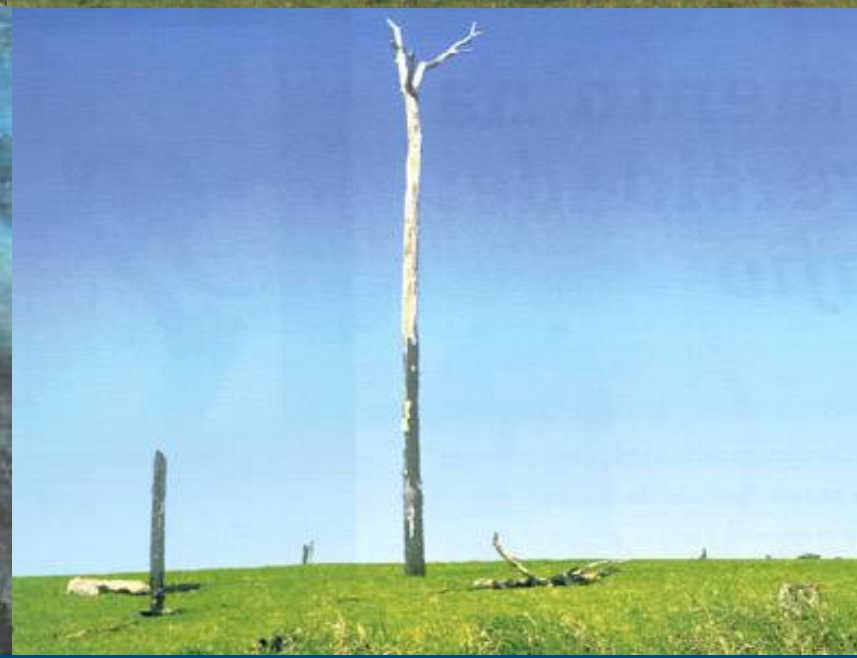


Global Historical Data

Klein Goldewijk: HYDE (2001)

Main global Land use/cover changes

- Deforestation
- Desertification
- Agricultural expansion
- Agricultural intensification
- Abandonment of agricultural land
- Urbanization



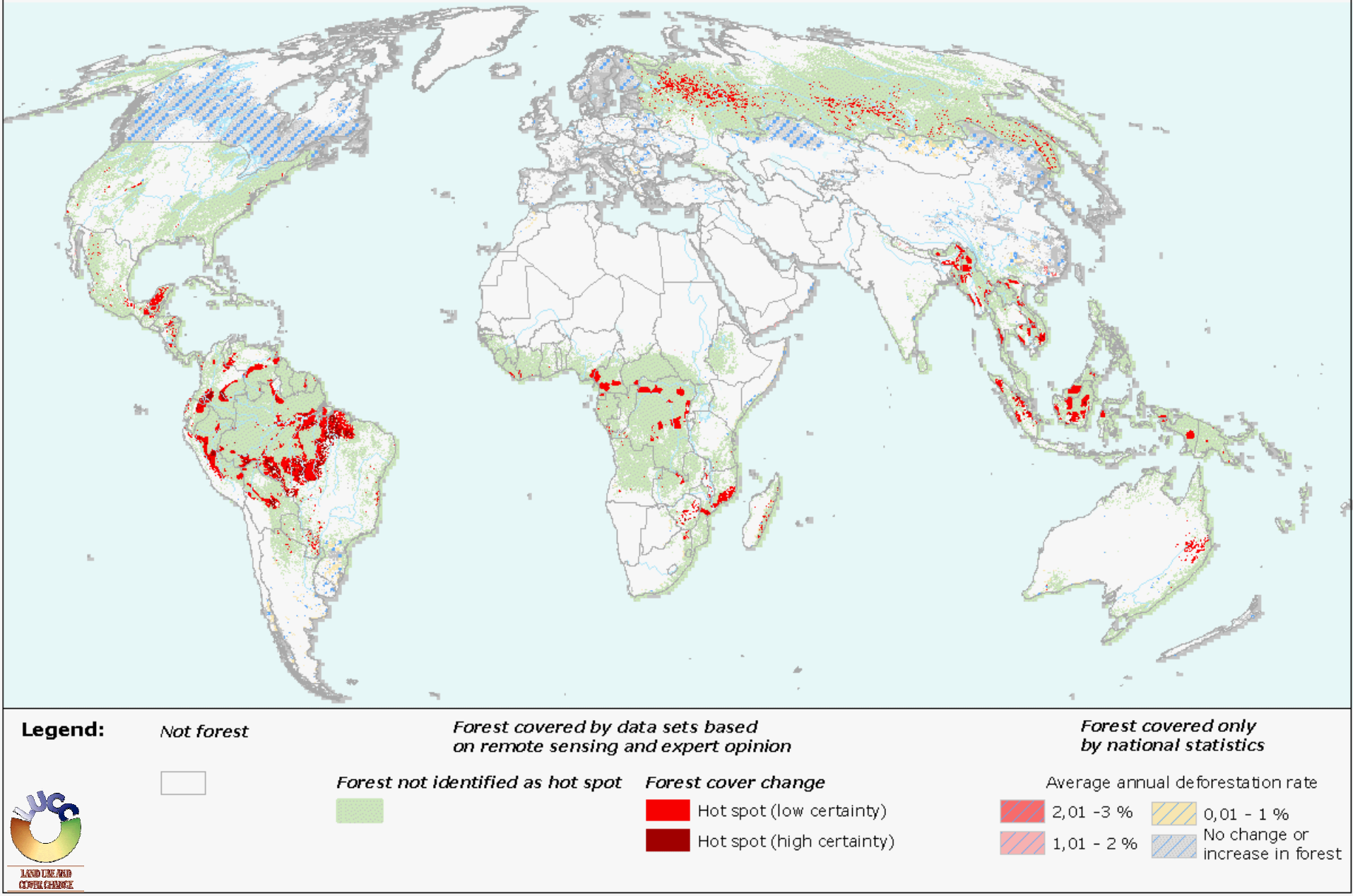
GLOBAL
IGBP
CHANGE

Deforestation

Deforestation: a change in forest to a state with tree crown cover <10% for developed countries and <20% for developing countries (FAO)

Different terms leads to confusion on extent of regional and global deforestation practices

"...AAAAEEEEIIIIAAAARRRGGGHHHH!!!"



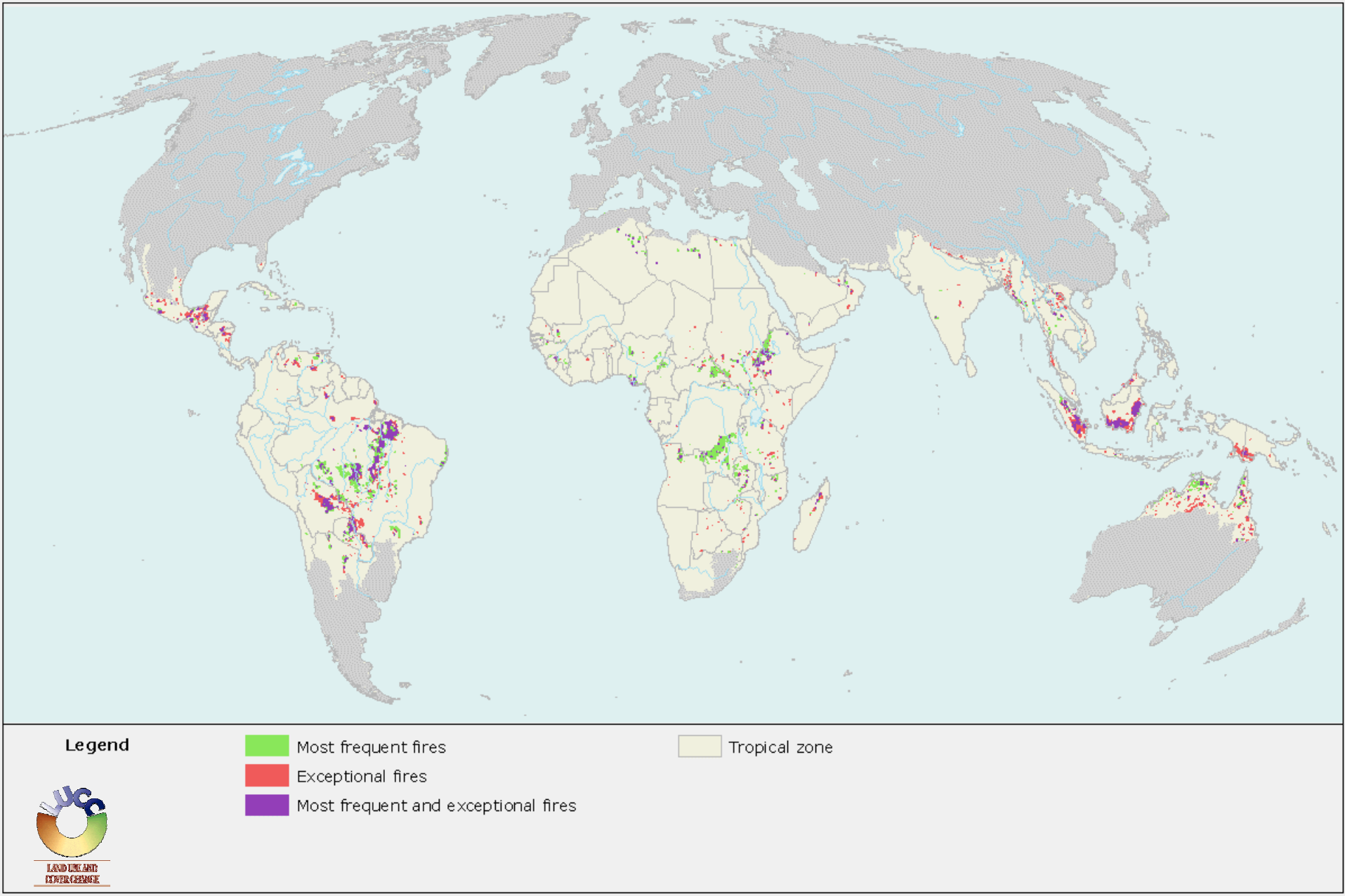
Main areas of forest cover change over the last twenty years (1980-2000)

Types of deforestation

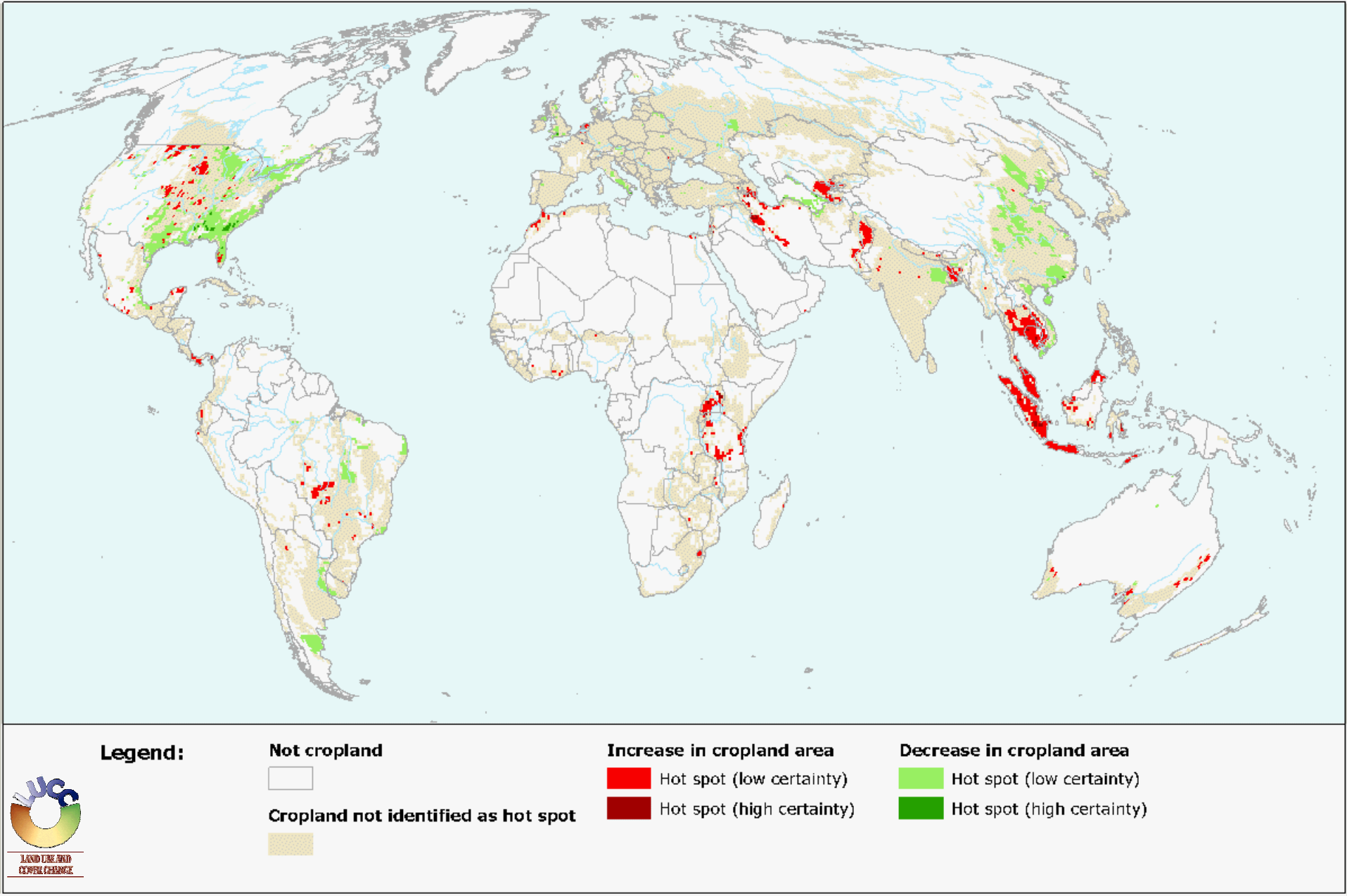
Deforestation: a change in forest to a state with tree crown cover <10% for developed countries and <20% for developing countries (FAO)

Different terms leads to confusion on extent of regional and global deforestation practices

- Clear-cutting (agricultural expansion, commercial logging)
- Shifting cultivation & regrowth
- Forest degradation/fragmentation (selective logging)
- Forest destruction by fire



Most frequent and exceptional fire events in the tropics (1997 - 2000)



Main areas of change in cropland extent (1980-1990)

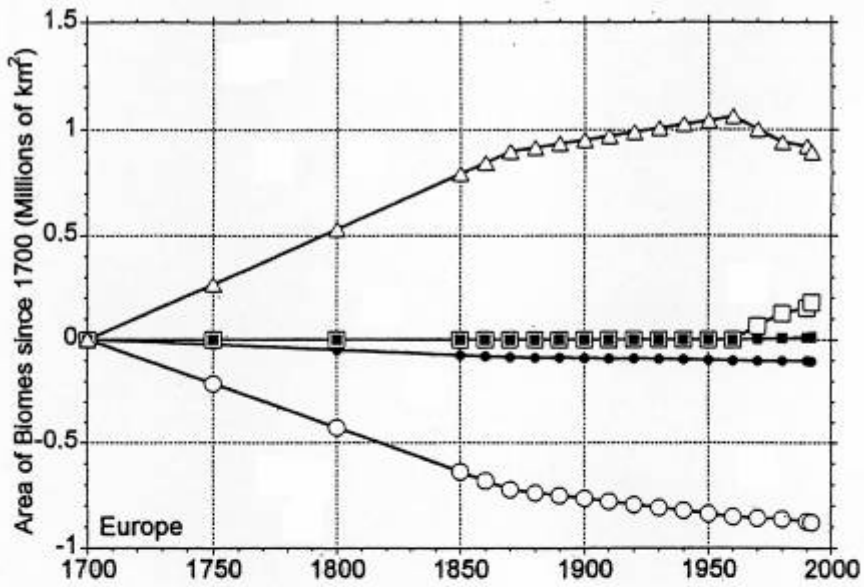
Regional differences

Historical changes in:

- **Forest/woodlands & savannas** (circles)

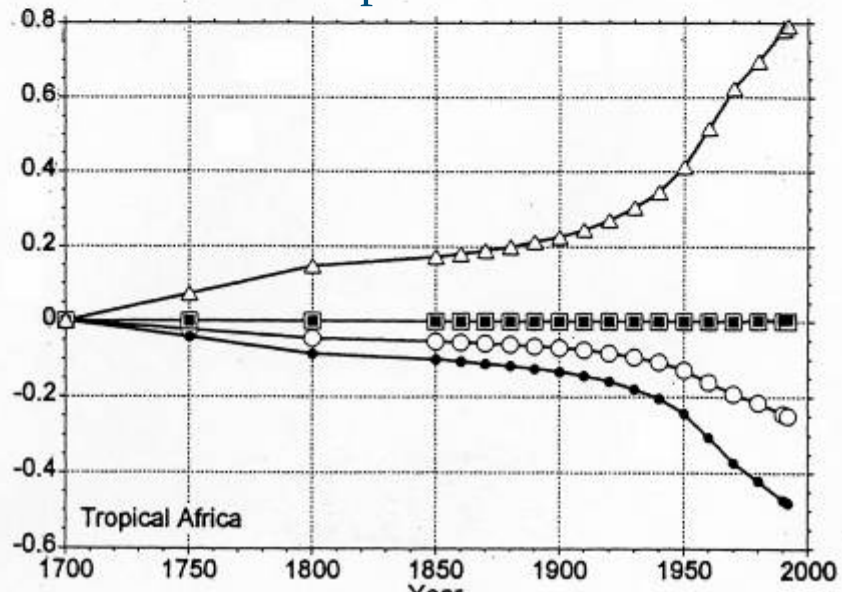
- **Croplands** (triangle)

- **Abandoned cropland** (squares)



Europe

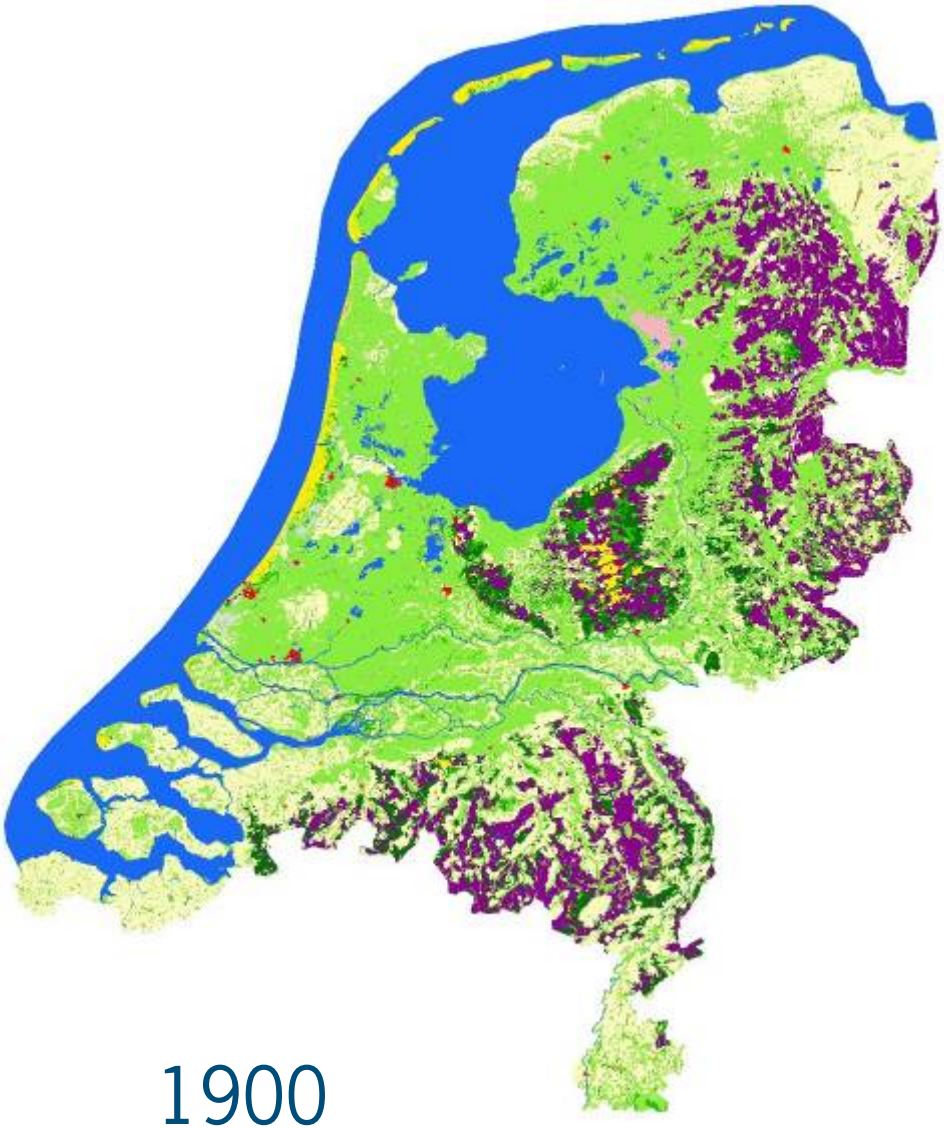
Tropical Africa



Ramankutty and Foley, 1999

Night image Europe

Land use change in the Netherlands: 1900-2000



1900

2000

Urban expansion (red) into “prime” agricultural land and intensification of grassland and arable land

LAND as coupled human-environmental system

Alternatively ‘Socio-Ecological Systems’ is used

Relationships contain feedback loops

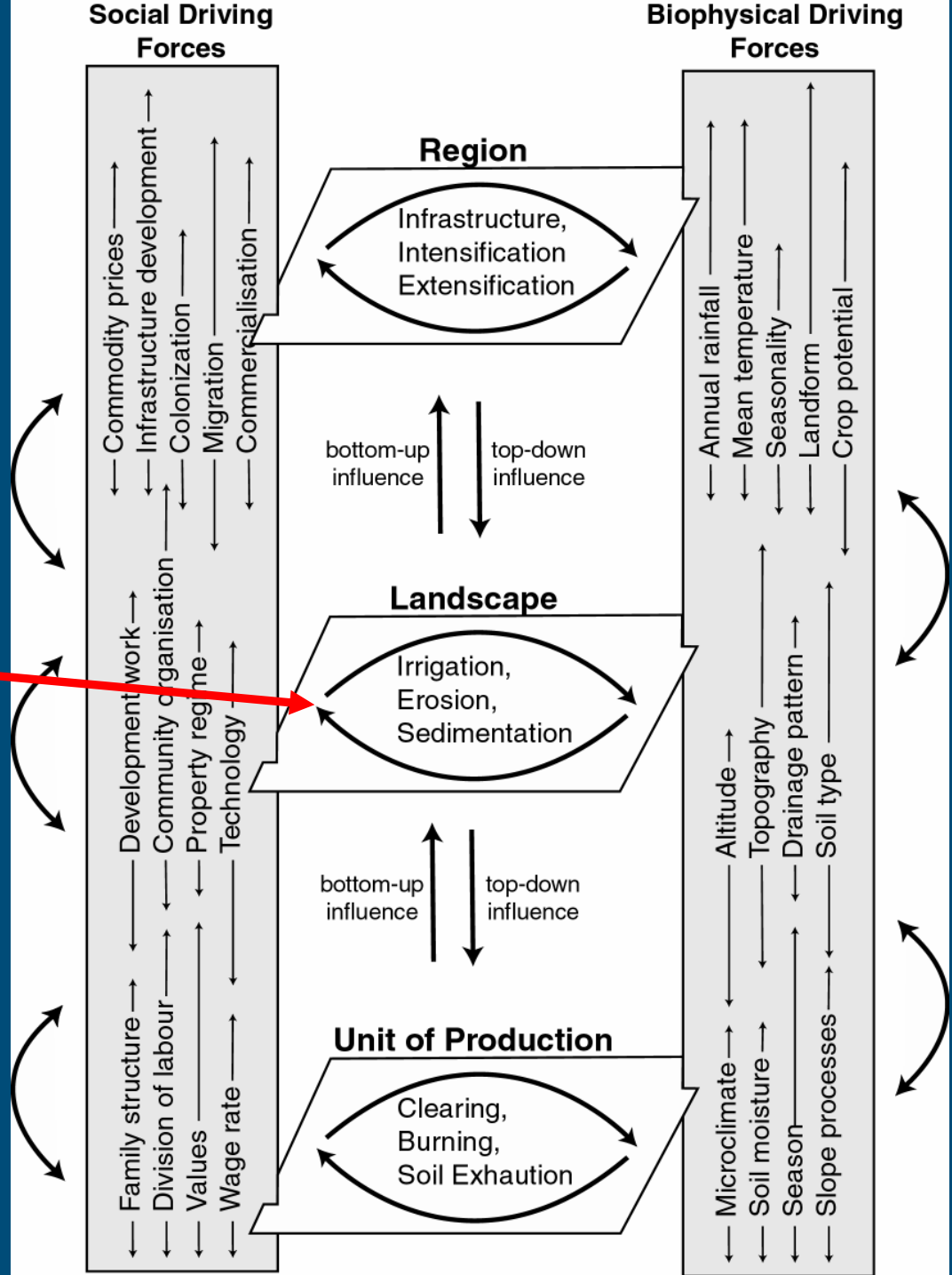
LAND systems are:

I. **Functionally complex**

Multiple driving forces of land change

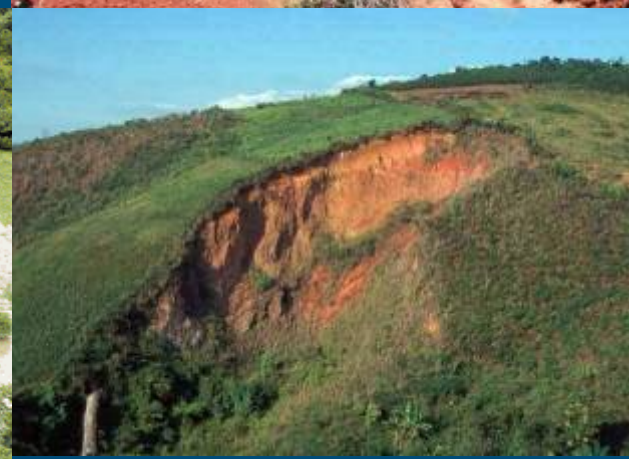
II. **Structurally complex**

Scale issues

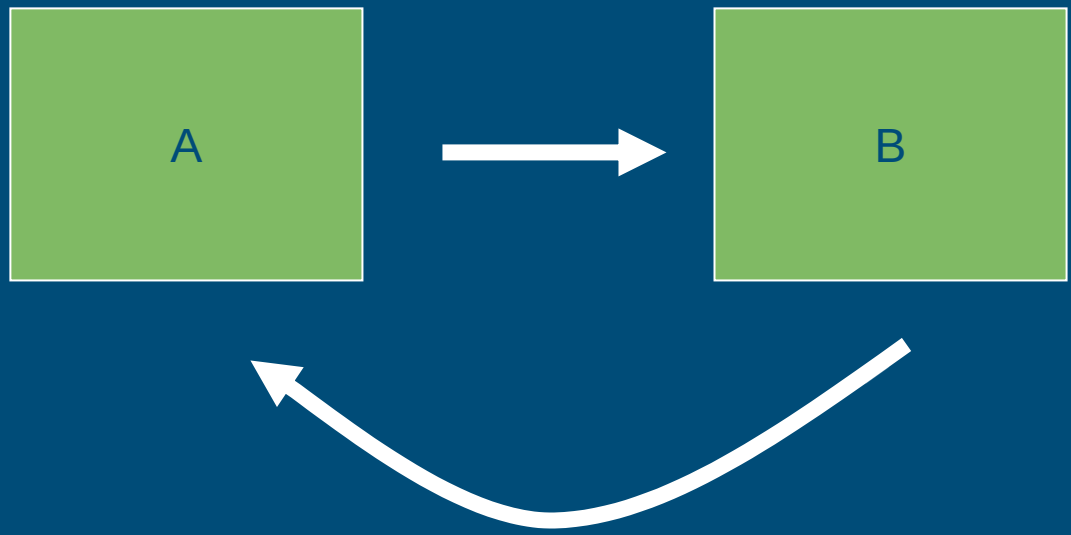


Coupled human-environmental systems

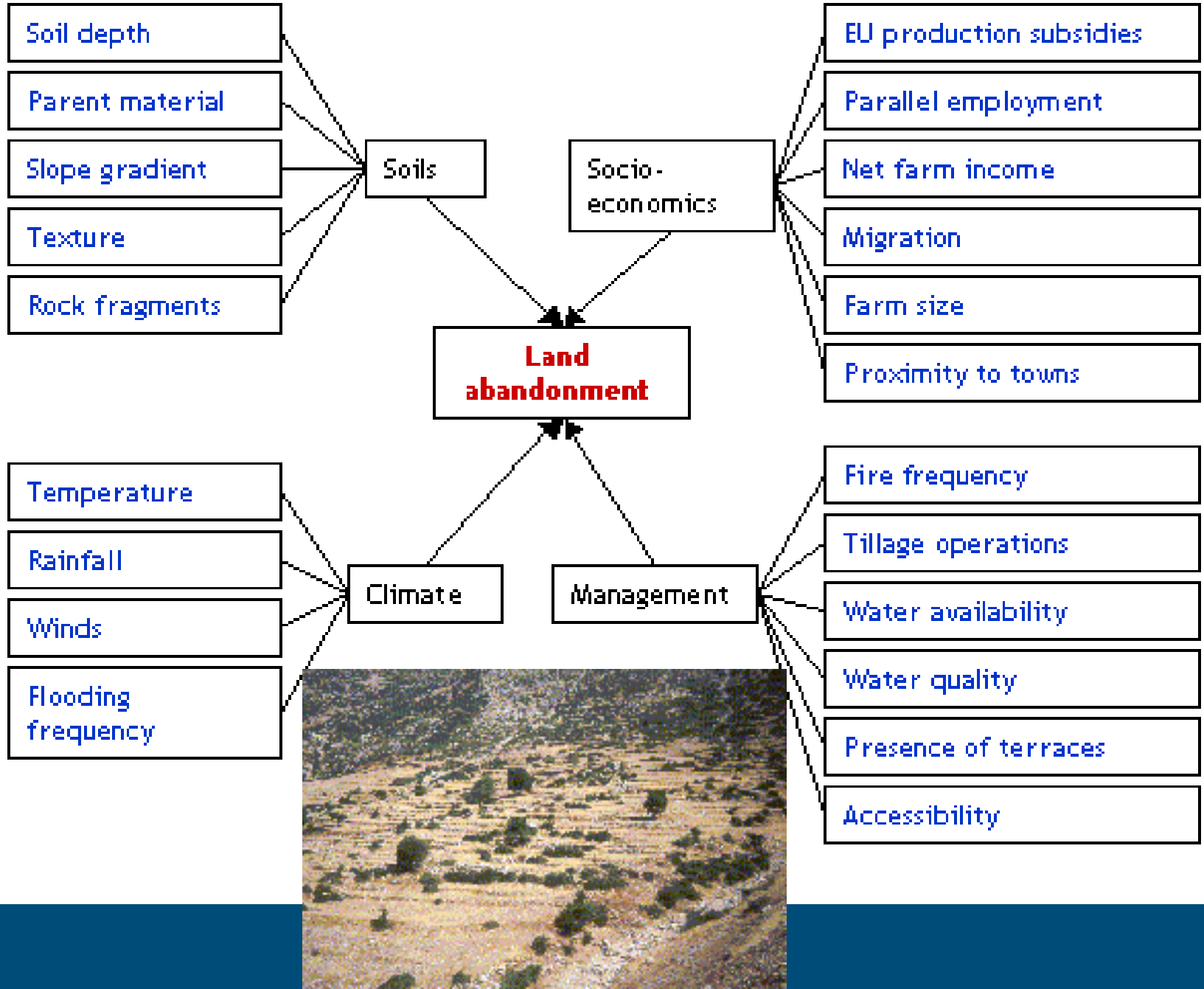
- Human decisions and actions affect the environment. This typically happens at landscape level



Coupled human-environmental systems

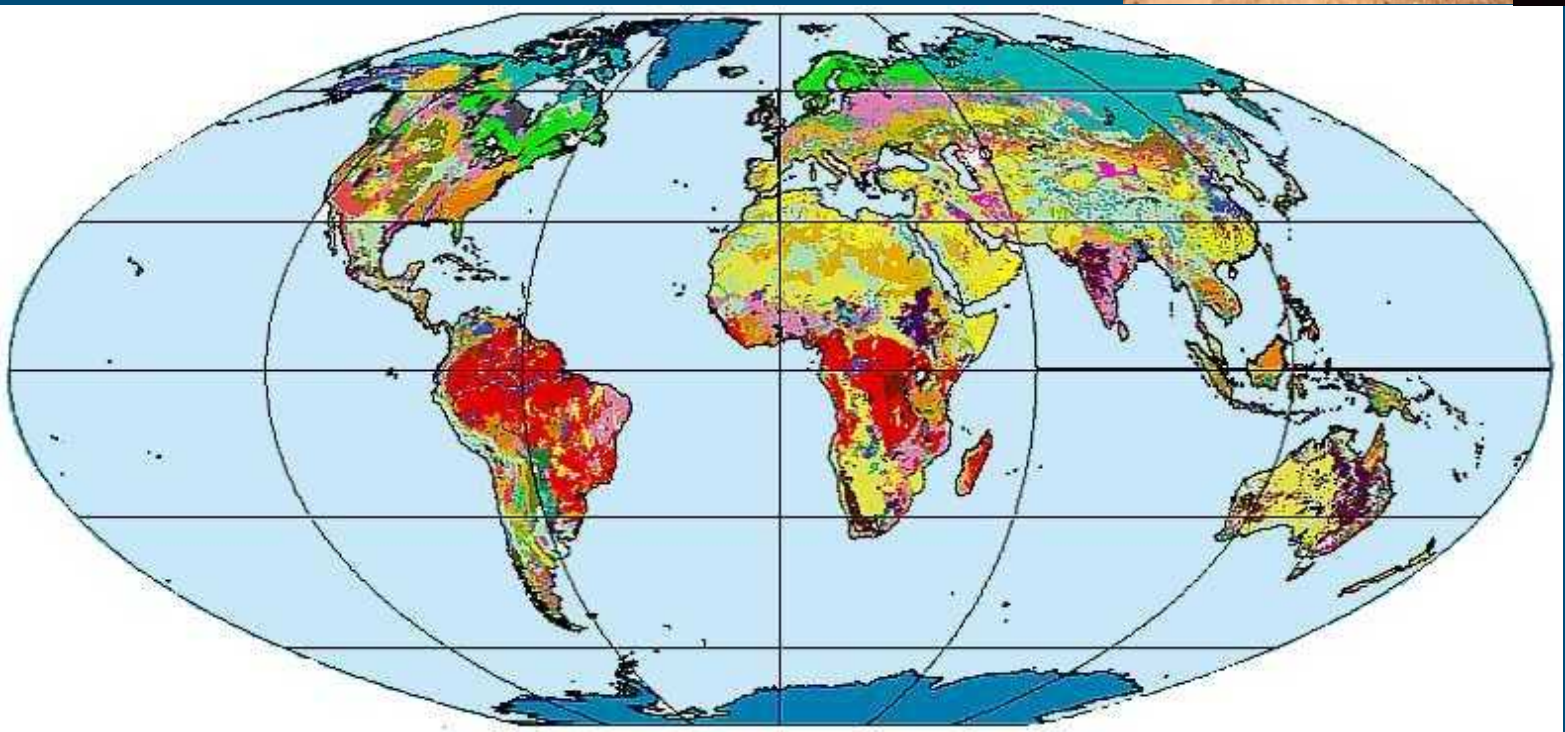


- Changed environmental properties affect decisions future use
- Perceived changes in the environment are at least equally important .

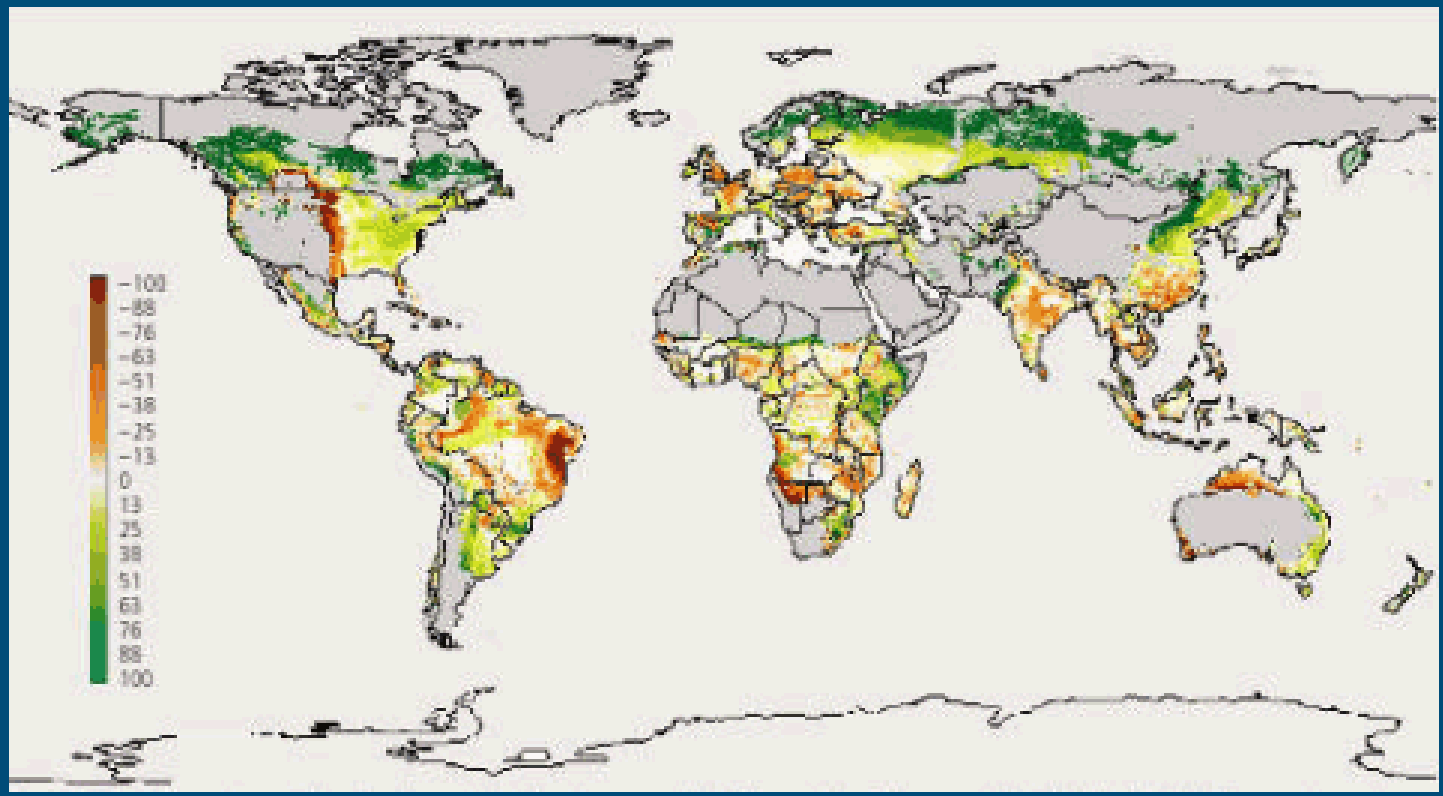

Soil depth
Parent material
Slope gradient
Texture
Rock fragments
Soils
Socio-economics
EU production subsidies
Parallel employment
Net farm income
Migration
Farm size
Proximity to towns
Land abandonment
Temperature
Rainfall
Winds
Flooding frequency
Climate
Management
Fire frequency
Tillage operations
Water availability
Water quality
Presence of terraces
Accessibility

How static are soils??

World Soil map (FAO)



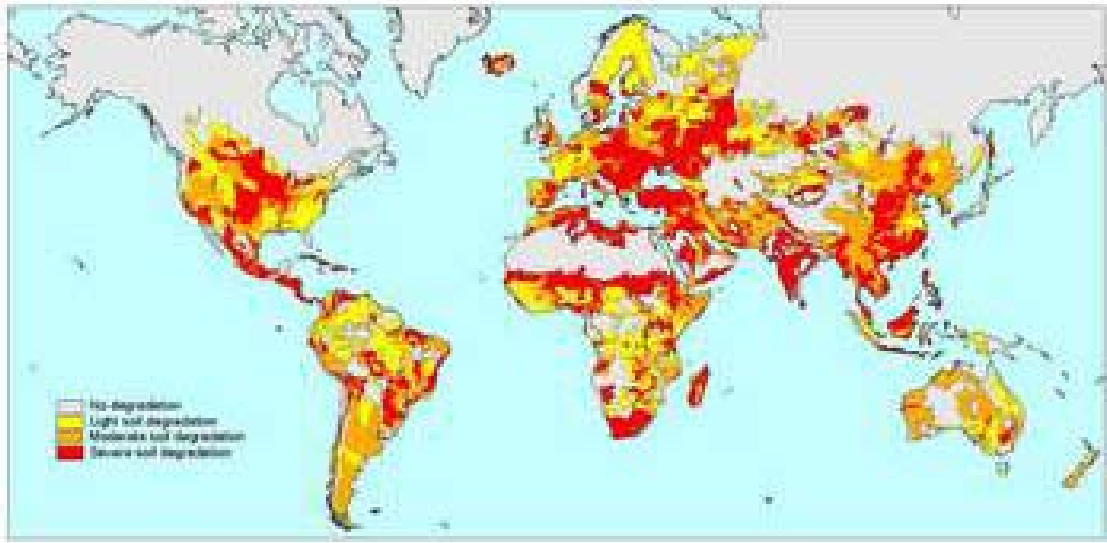
In many global assessments climate change is linked to a static soil (pedon) data base.



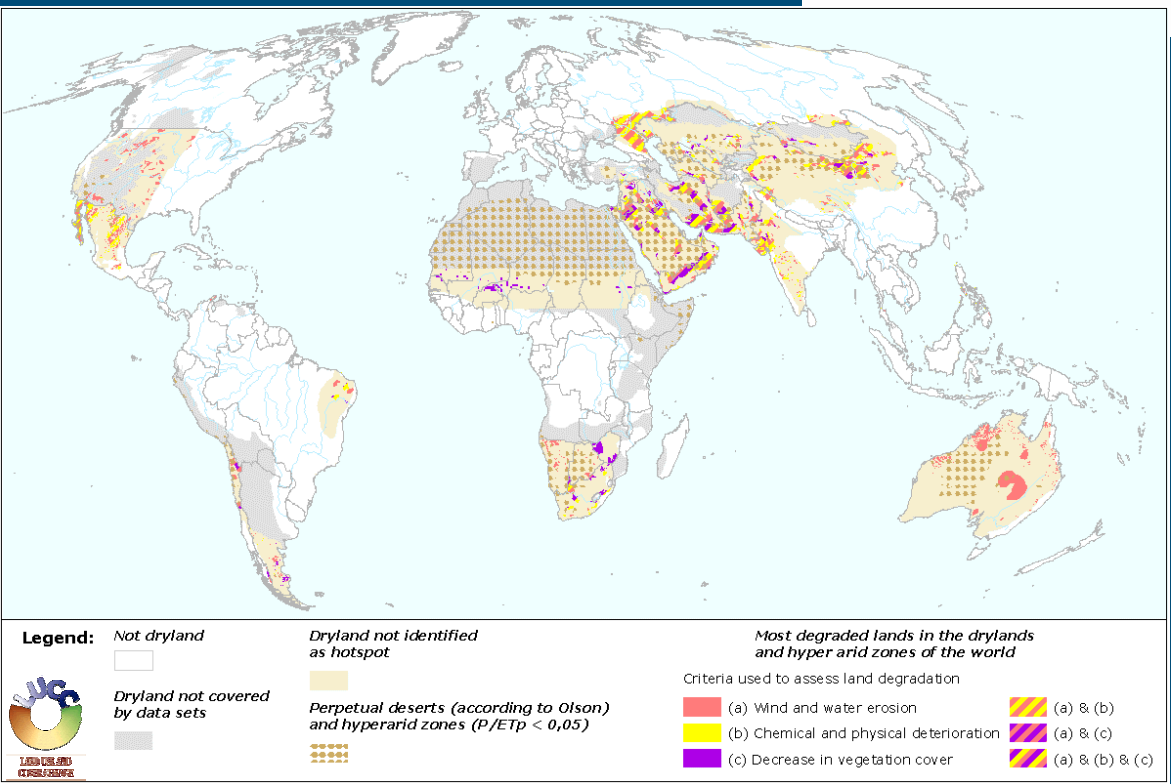
Impacts of Climate Change on Cropping Production Potential of Rain-fed Cereals. Source: Fischer, et al., IIASA.

We do know that soils are

Changing ‘degrading’



ISRIC



Main areas of degraded land in the drylands and hyper-arid zones of the world over the last twenty years (1980-2000)

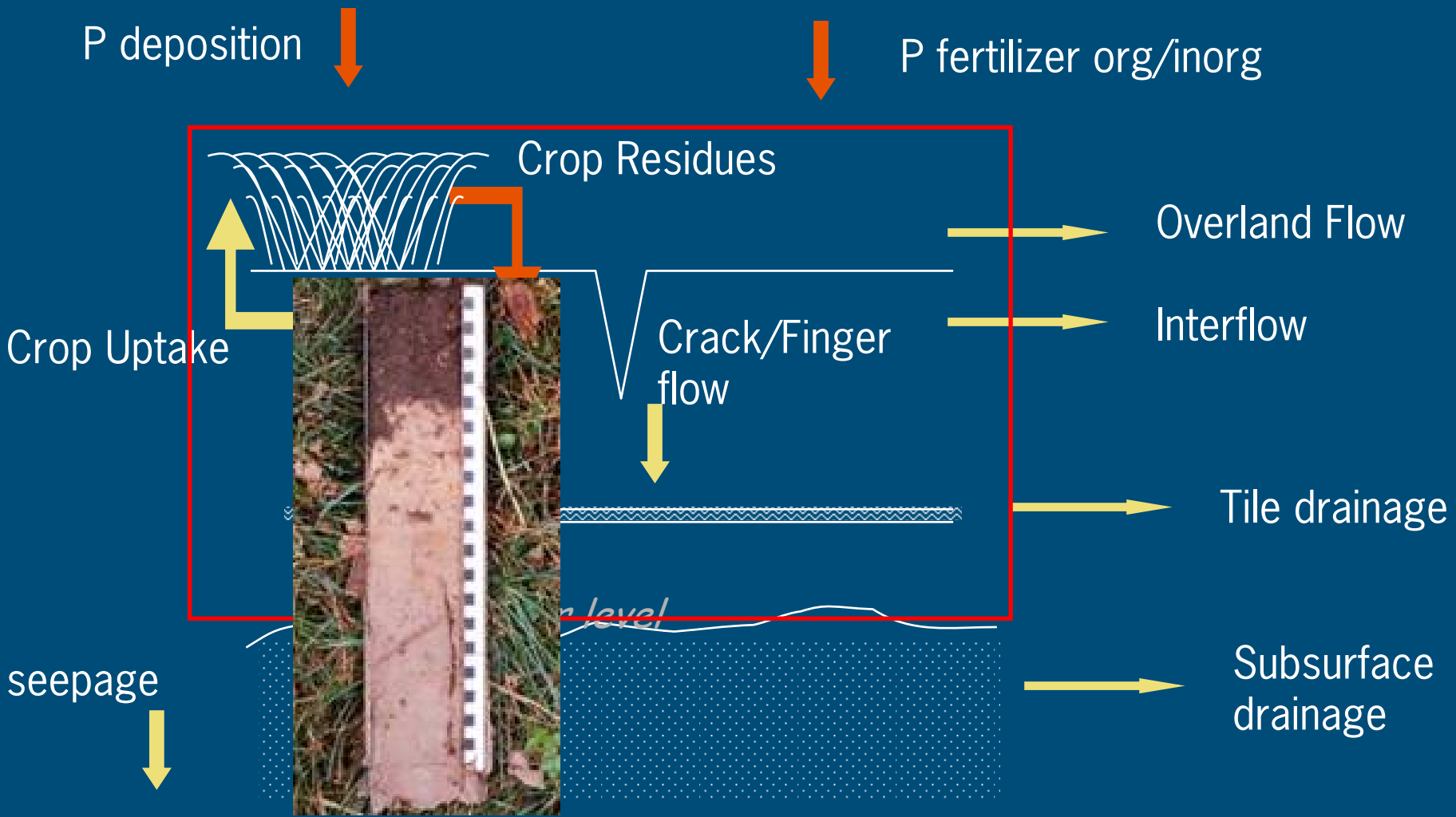
Main cause of changes in soils:



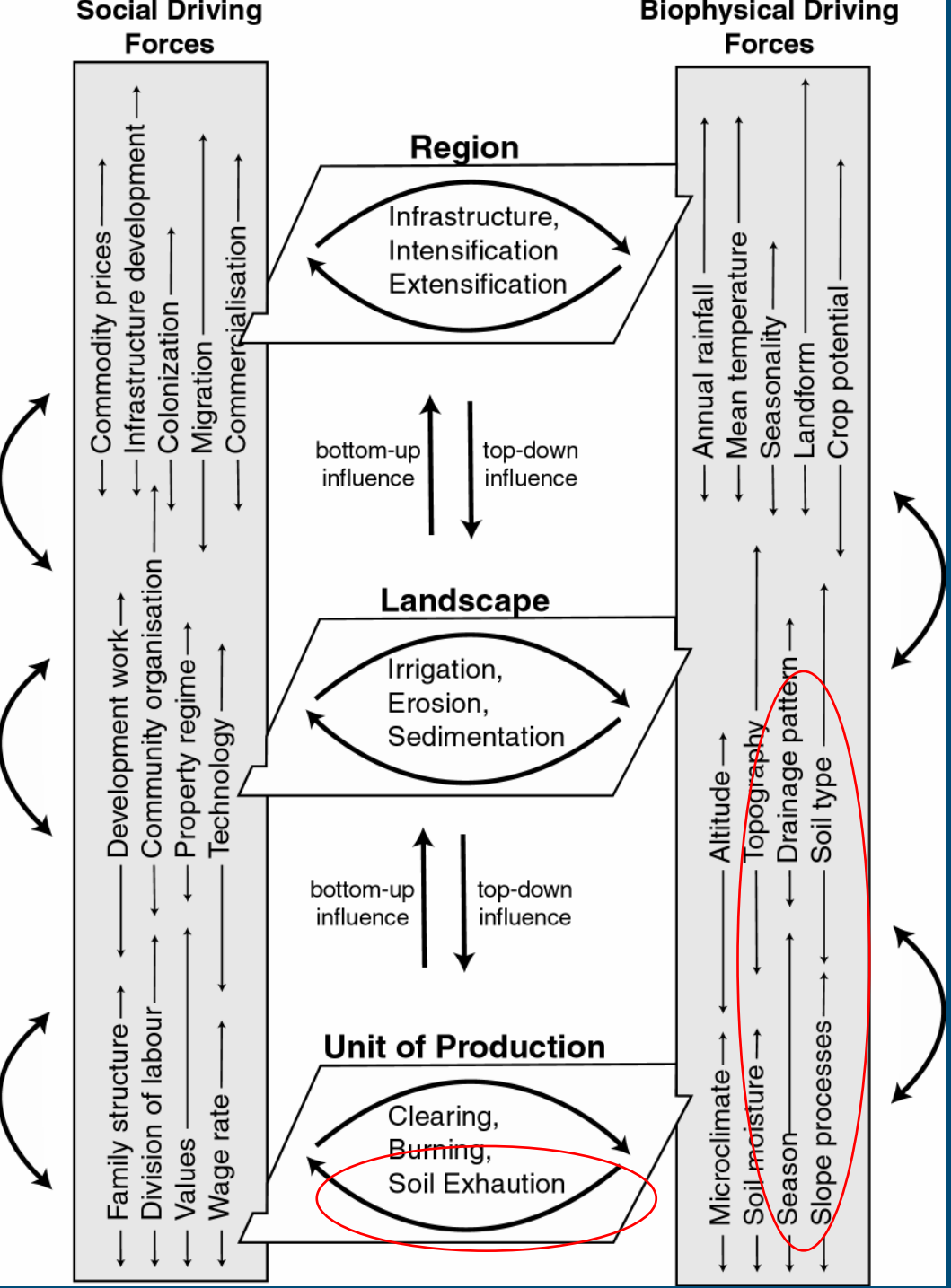



- Human actions (direct and indirect)
  - By converting or modifying the land cover
  - By changing the management (land use)

The soil box!! : example for P pathways Processes



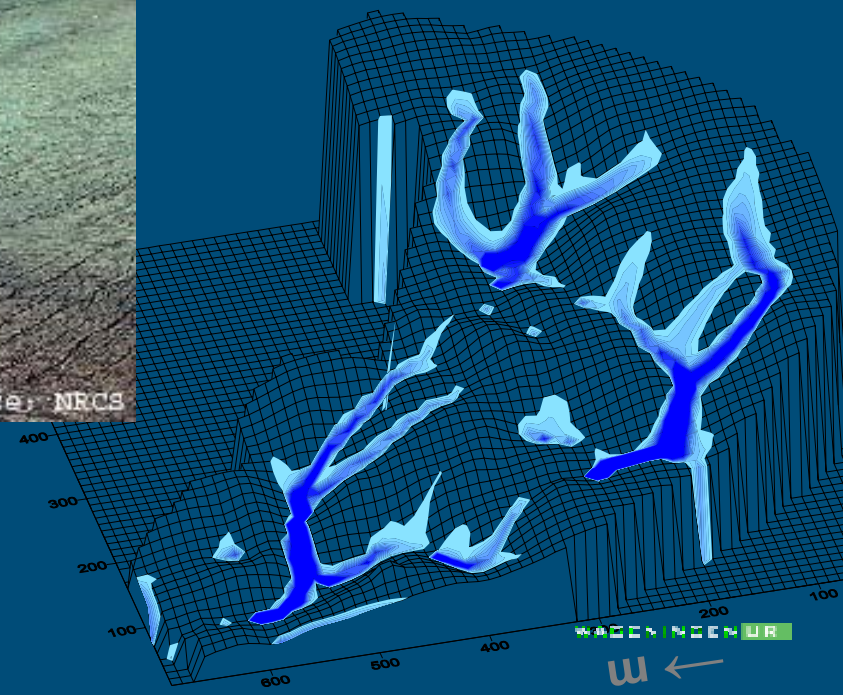
By focusing on the pedon (profile) soil science has lost touch with the scale level where soils interact and where they are managed: Landscape



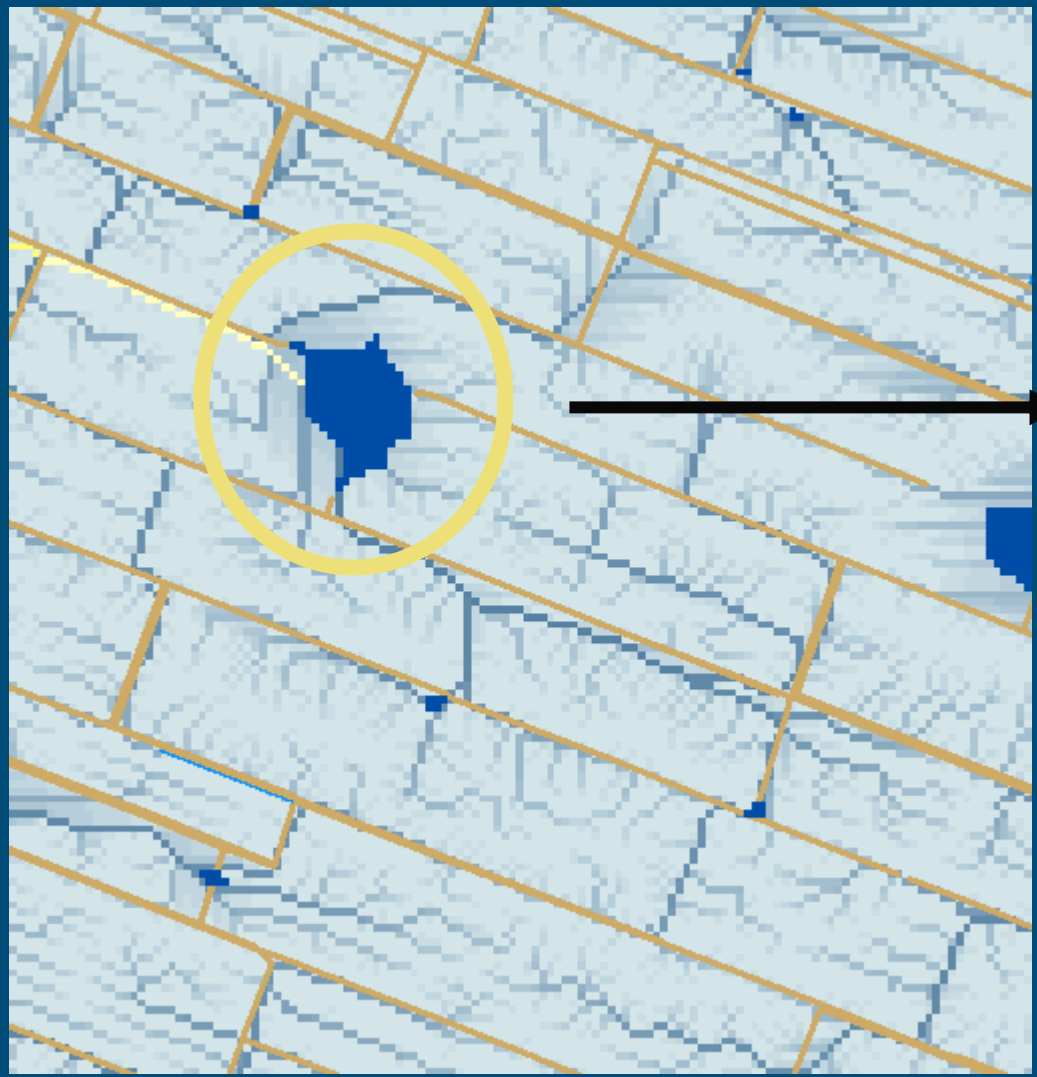
Soils have to scale up to landscape level

Soils have to come out of the box

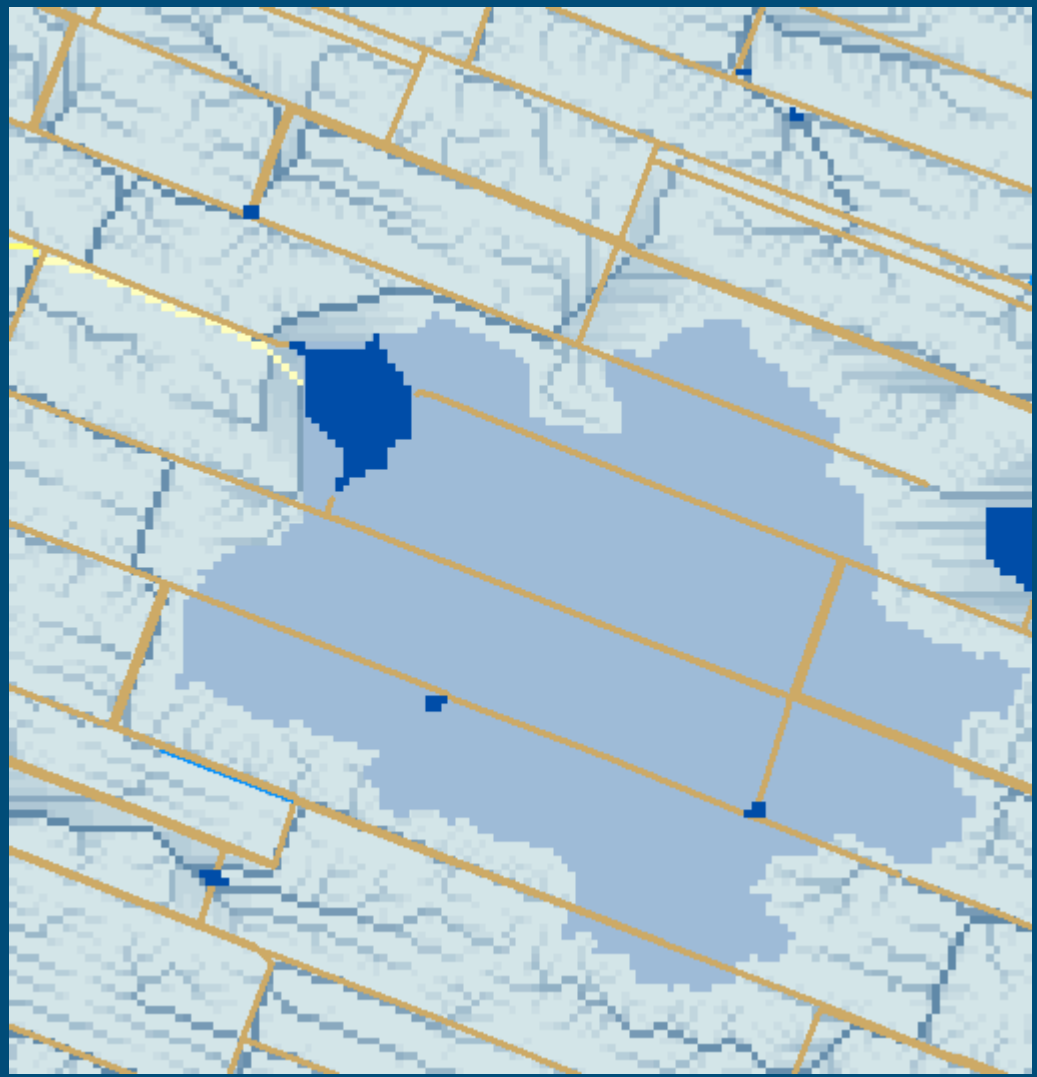
Soils connect in landscapes by interacting processes: tillage and water related soil redistribution



East Friesland (Northern Netherlands)
Also here soils are connected in the landscape



Local bottom land: 5000 m^2

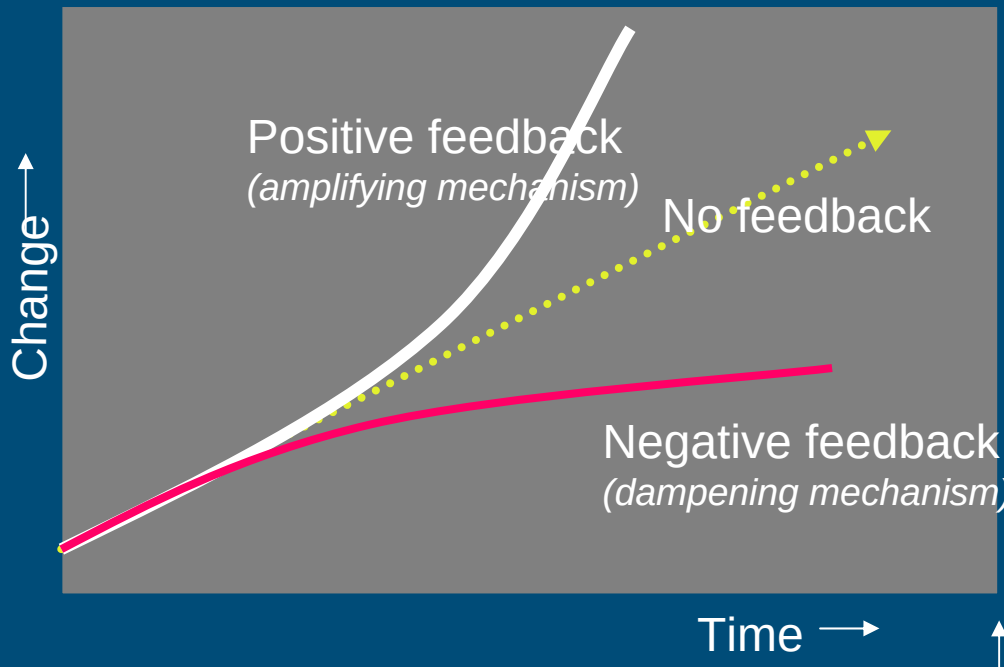


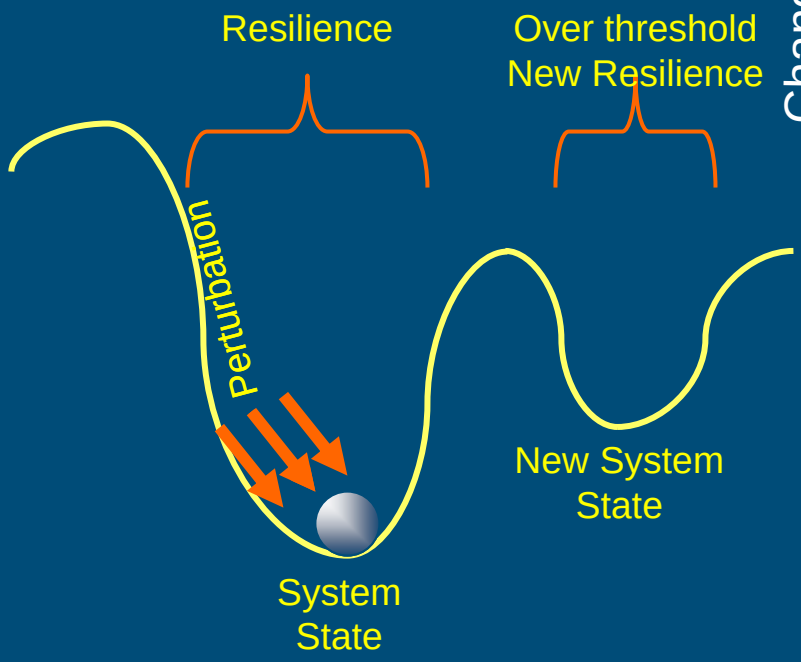
Total Contr. Area:

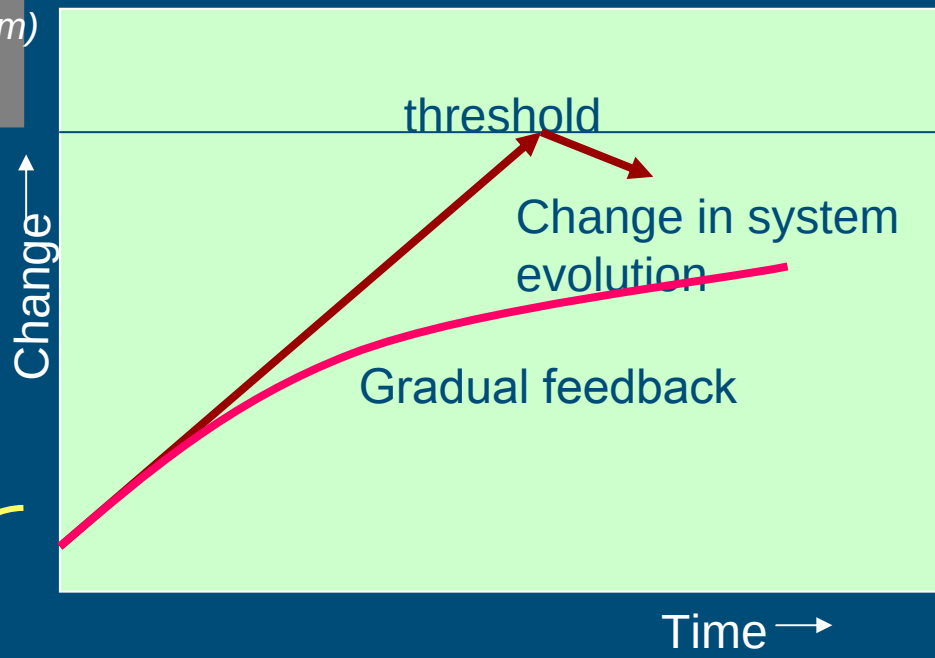
140,000 m^2 (14 ha.)

Soil use and its effects can only be addressed at the landscape level.

Feedbacks and system change







Ball in the cup system concept

Adapted from Manuel Winograd

Studying the interaction of soil-landscape and land use/cover systems

- First modeling experiments
- Linking a land use/cover change model (CLUE) and a dynamics soil-landscape model (LAPSUS)

What is CLUE?

CLUE is methodology to model near-future changes in land use patterns

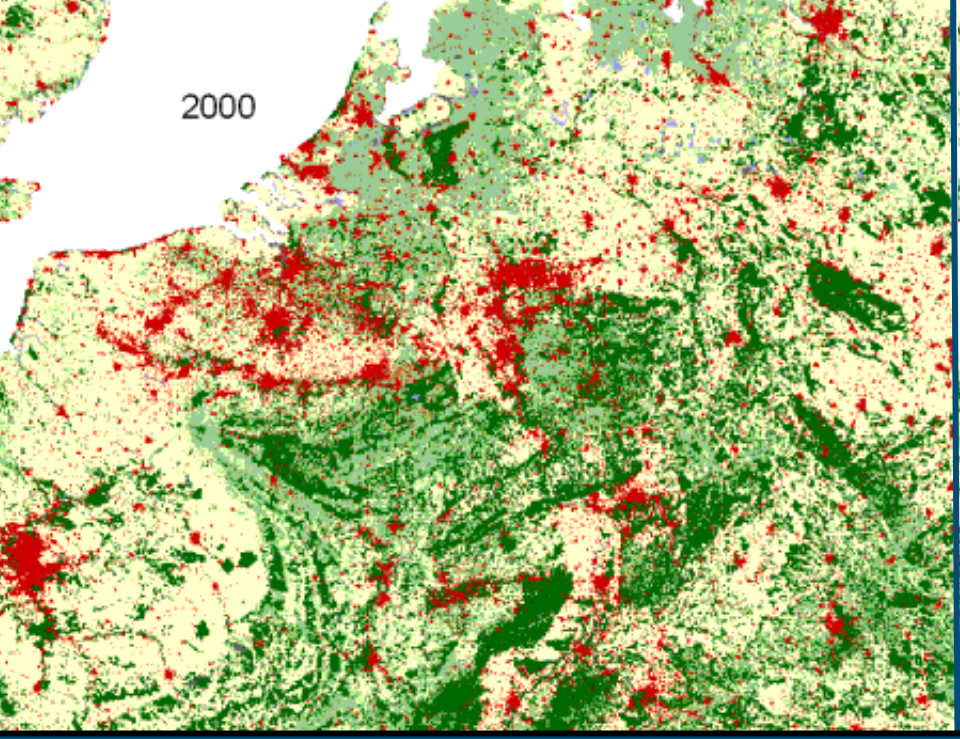
CLUE is a hybrid methodology, combination of:

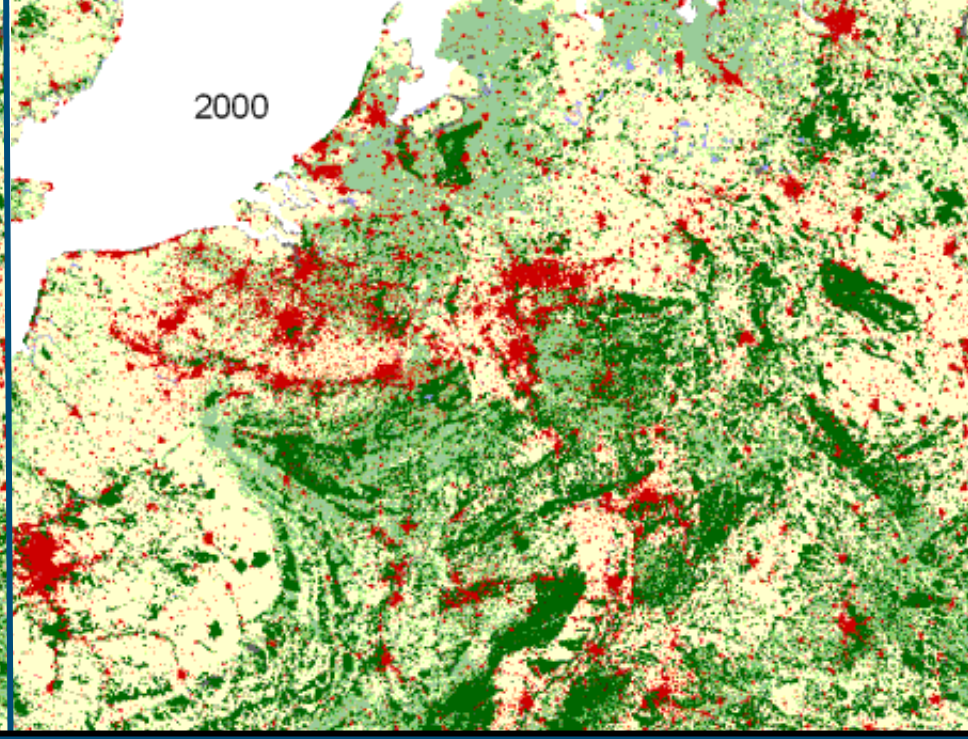
- Cellular Automata
- Markov Chains
- Decision Rules
- Statistical Analysis

Specification dependent on scale, land use processes, case study

http://www.cluemodel.nl

CLUE case-studies





A1: Global Economy

B2: Regional Communities

CLUE Model
www.cluemodel.nl

Land use dynamics 1km^2 resolution for EU 25 differ by scenario:

- Quantity of change
- Spatial pattern of change

CD Available

EURURALIS

VALUE
Urban/Residential/Mining/Industrial/recreation/airports
Non-irrigated arable land
Pastures
Forest/nature/natural grasslands
Inland wetlands
Static land use types
Irrigated arable land (incl rice fields)
Abandoned land

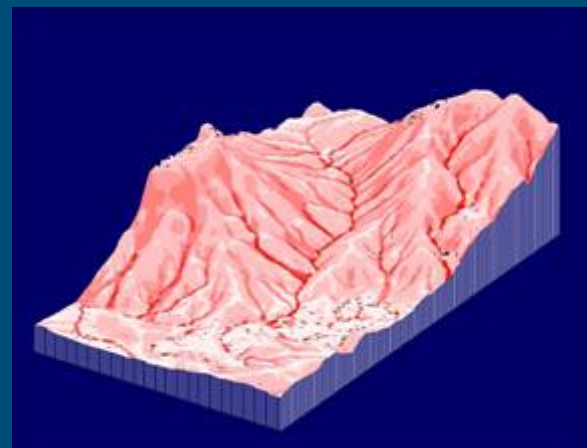
LAPSUS Modelling framework

'LandscApe ProcesS modelling at mUlti dimensions and scaleS'

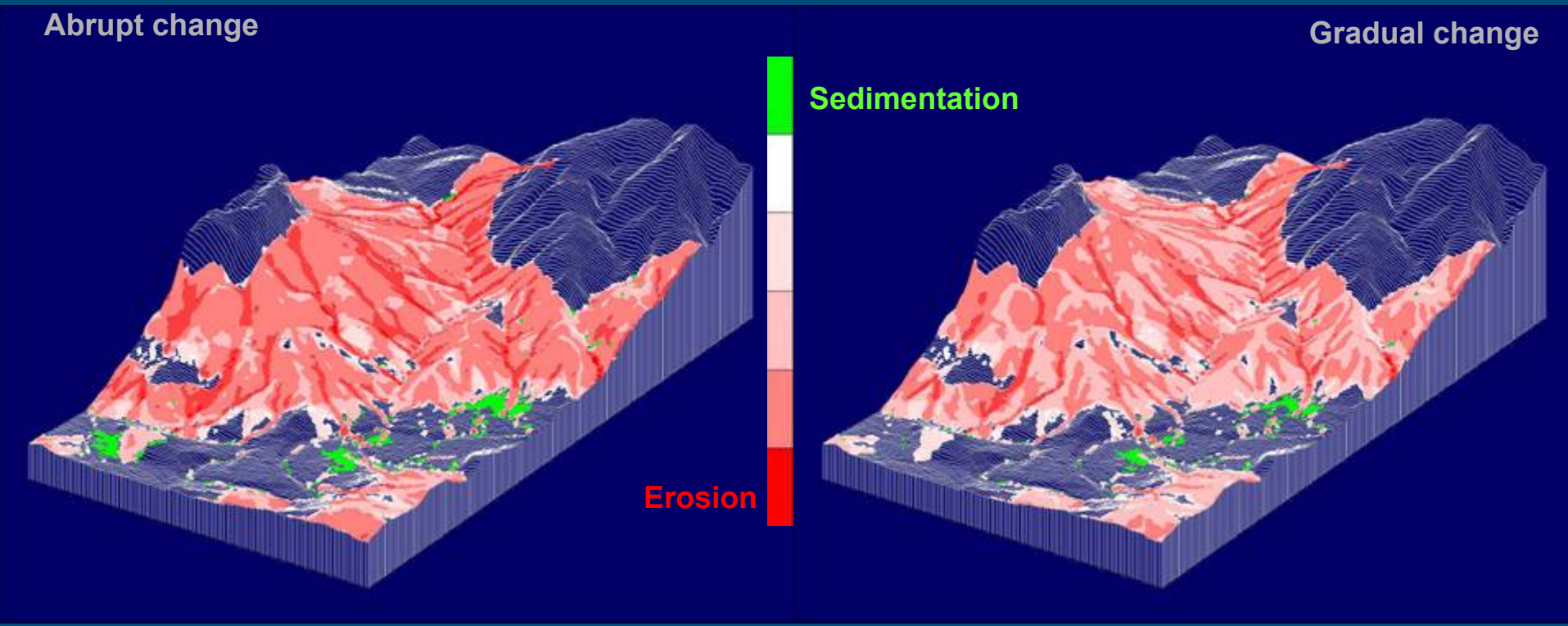
→ Simulation of erosion and sedimentation:

- surface water run-off -on
- tillage translocation
- land slides and mudflows

→ Dynamic, adaptation of DEM and soil properties between time steps



Dealing with temporal dynamics: Effect of rate of land use change



LAPSUS

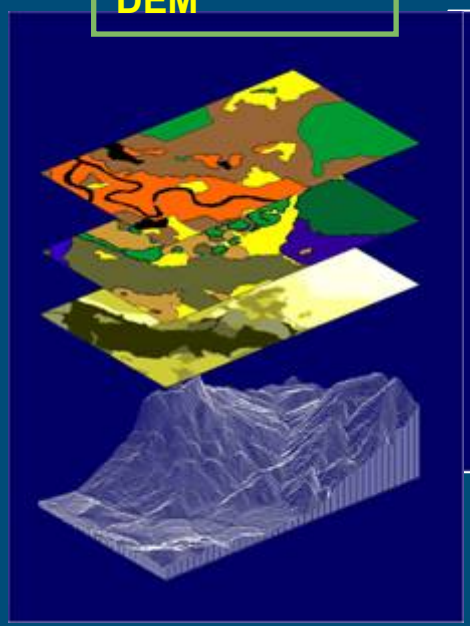
CLUE simulates land use change

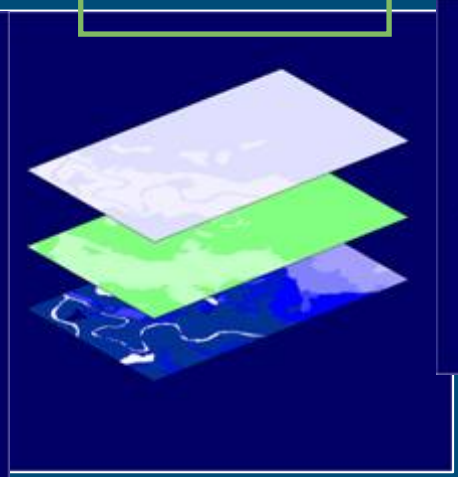
Land use
Geology
Soil type
Soil depth
DEM

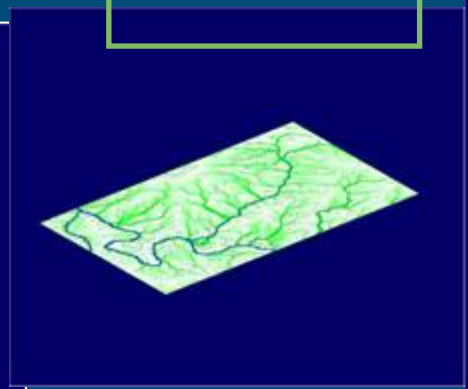
Rainfall
Erodibility
Infiltration

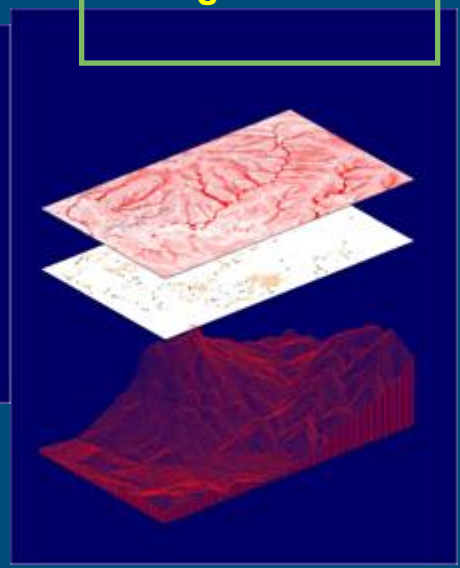
Discharge /
Overland flow

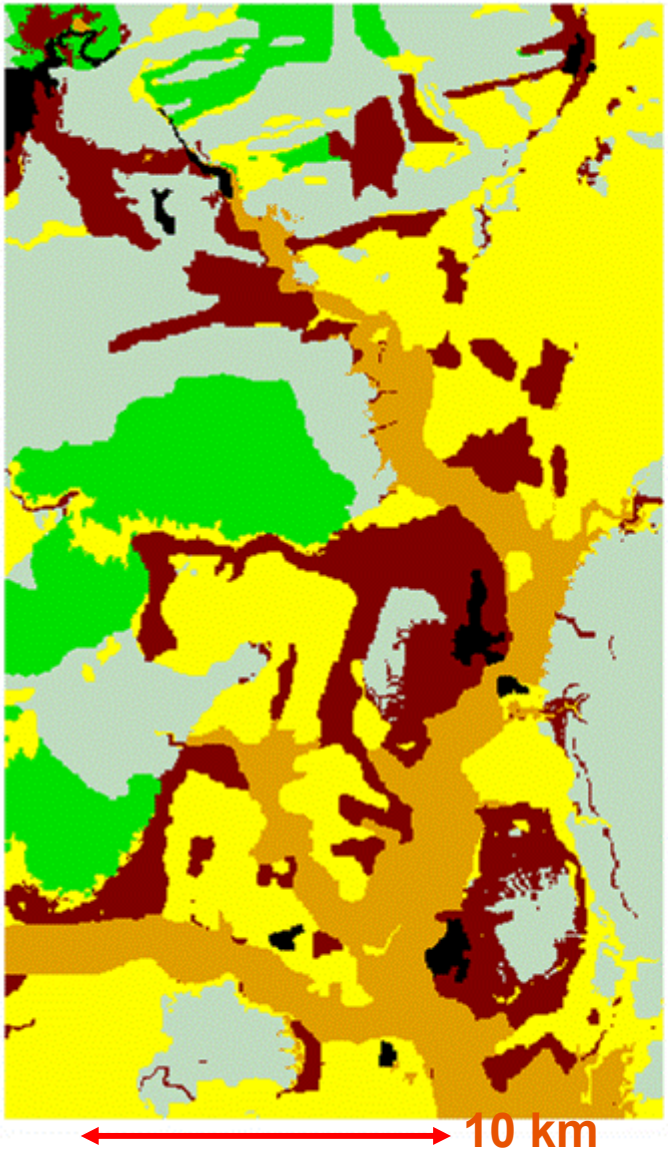
Erosion
Re-sedimentation
Changed DEM

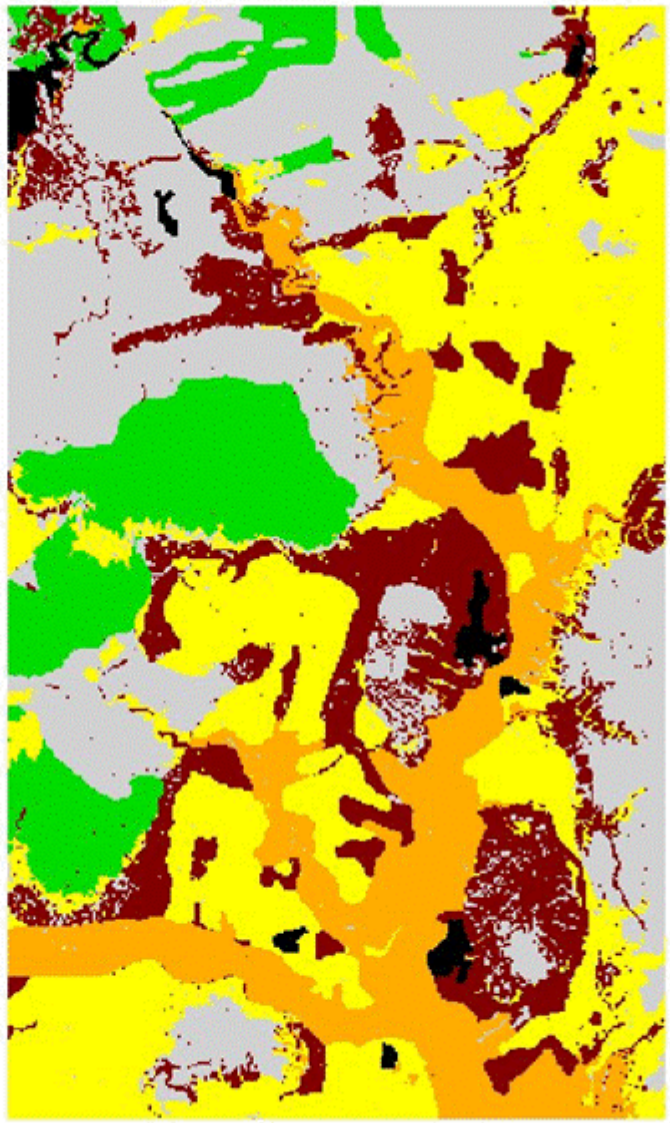












The effect of

15 y feedbacks

Soils depth

Erodibility

Olives

Cereals

Irrigated (citrus)

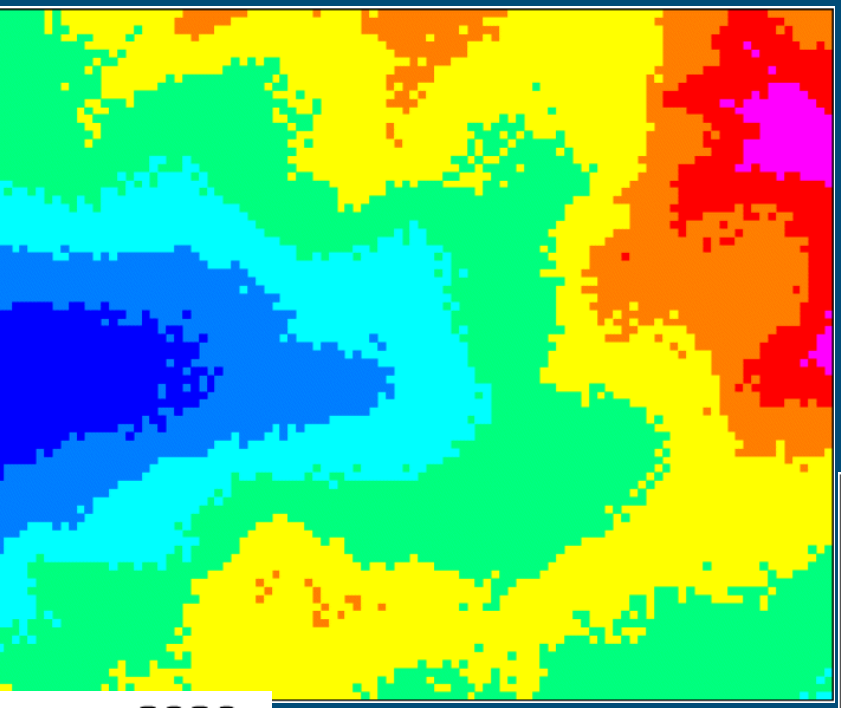
Forest

Abandoned

Others (Urban, Water)

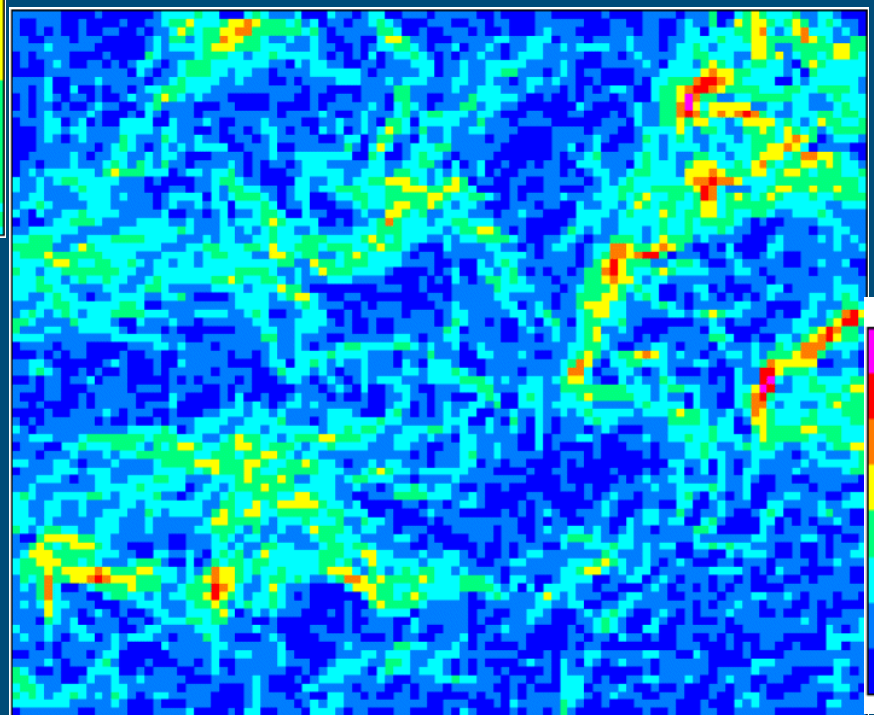
Comparison without (left) and with soil feedbacks mechanisms

Effects of uncertainties in for example DEM: Based on Monte Carlo Simulations



2620
2510
2400
2280
2170
2060
1950
1840
1730

Altitude
m



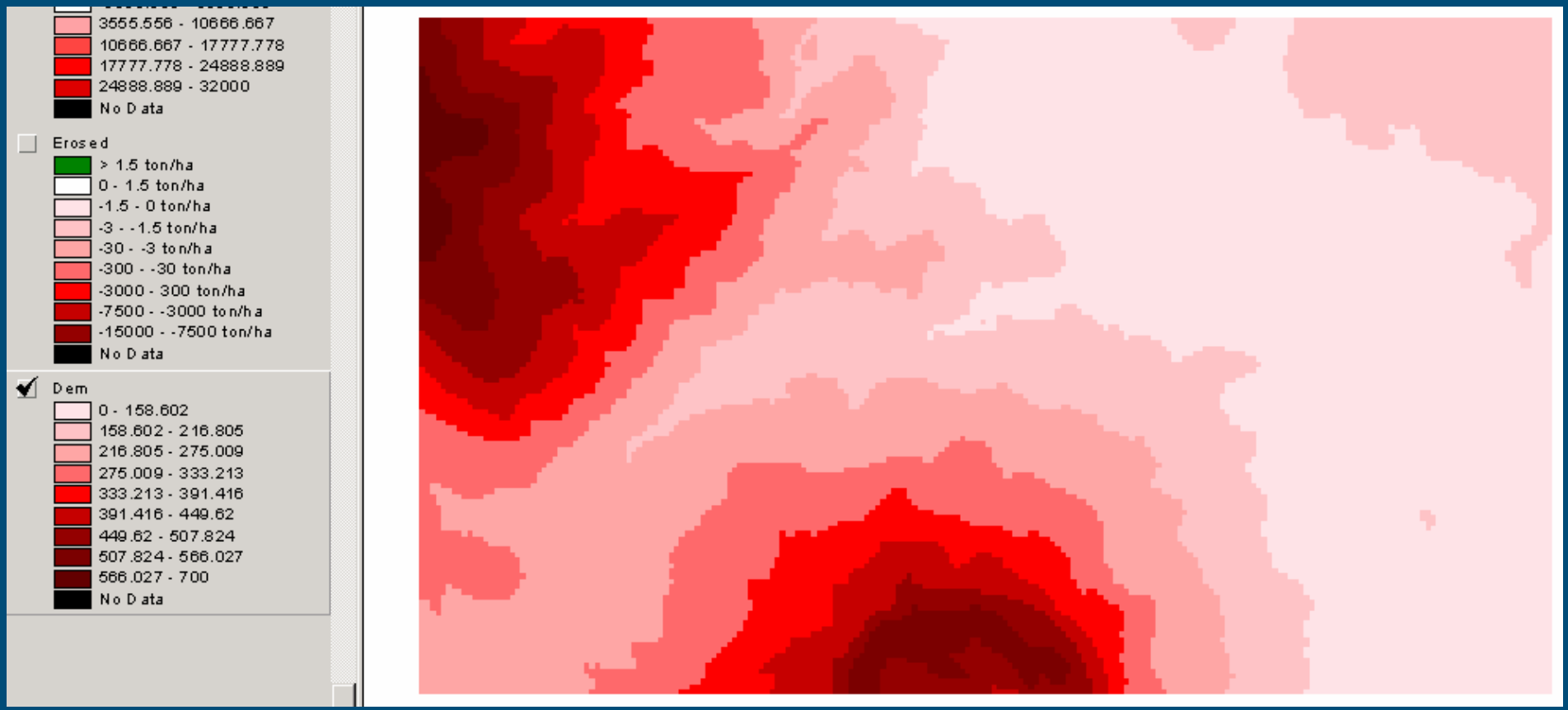
Slope
%

44
39
33
28
22
17
11
6
0

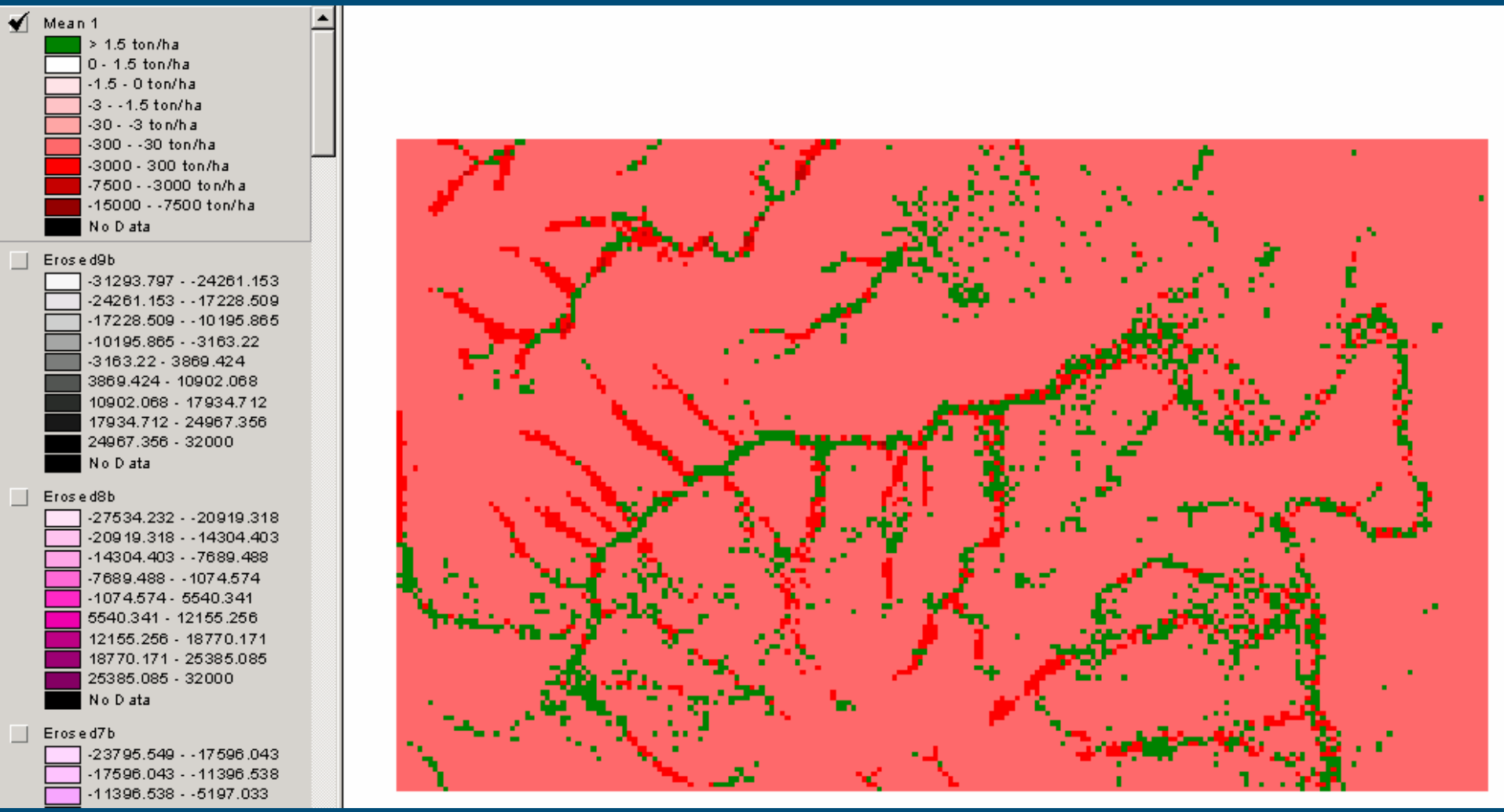
Heuvelink 2004

LAPSUS and uncertainty propagation

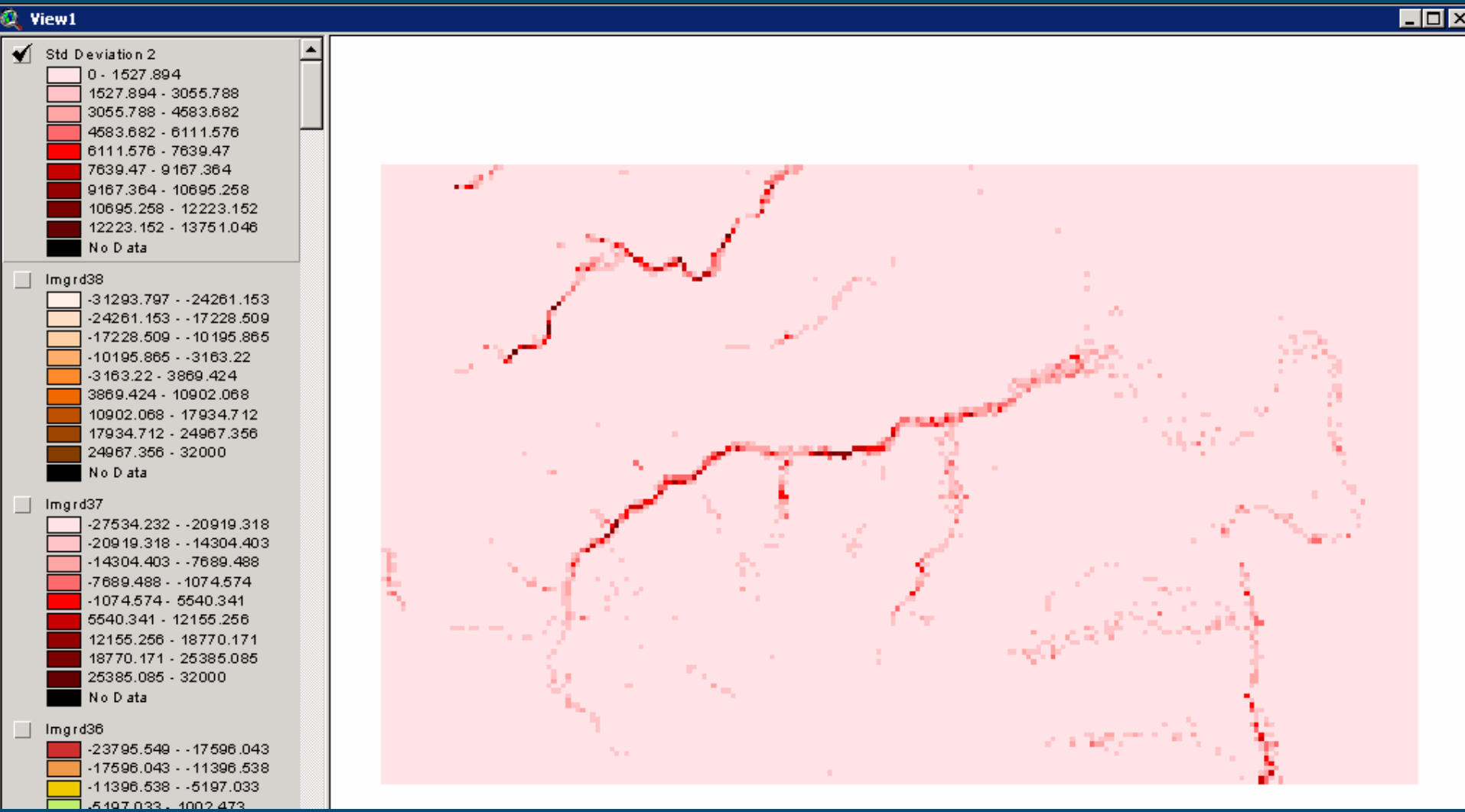
‘Standard’ LAPSUS run, DEM



Mean of the 30 calculated erosion maps



Standard Deviation of the 30 erosion maps



Preliminary results

- Endogenous feedbacks can be very important in determining the spatial pattern of land use and soils
- This enhances the path dependency
- Uncertainty and error propagation matters

- New research is needed to research these endogenous feedbacks in the land system

Conclusions

- Dynamic linkages between land use/cover system and landscape systems is necessary to understand and characterize soil/land systems
  - Landscape processes interact dynamically with land use and soil systems and shape them.
  - Global land change can be linked to soil change at the landscape level
  - Feedbacks need to be explored including uncertainty issues!!
- ISRIC could make a functional dynamic link between soil and land use/cover dynamics by addressing land change and landscape processes.

http://www.sil.wur.nl/UK