Climate Change and Soil Erosion – a high-resolution projection on catchment scale until 2100

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Multi-model approach

- statistical regional climate model WETTREG
- evapotranspiration model METVER
- physically based soil erosion model EROSION 3D

Event based simulations

- temporal resolution: 5 minutes - catchment scale
- different scenarios with consideration of climate induced changes of soil properties and human activities

reference period: 1998-2007

future periods: 2041-2050 and 2091-2100

1) Do we expect more or/and more intensive rainfall in future?

2) How soils will react on rising temperatures in terms of soil erosion?

3) Are adaption strategies adequate to expected changes?




Regional single event : 350mm in 48h
Returning interval: ~ 30 - 100 years




Lokal single event : 25mm in 30min
Returning interval: ~ 2 years




Erosion is caused by individual single events!

Requirement for soil erosion modelling:

precipitation data

with high temporal and spatial resolution

- **for the present** — measured data
- **for the future climate**

1 - 15 min

Multi-model approach
- statistical regional climate model WETTREG

WETTREG (Enke 2005, Kreienkamp 2009)**:**

- weather pattern consistent climate change projection
- works on basis of longtime measured climate data on local climate stations
- driven by ECHAM5-MPI-OM (**G**eneral **C**irculation **M**odel)

Computation of A1B scenario (IPCC)

Output:

10 equally probable climate simulations 2041-2050 and 2091-2100 for 3 local climate stations in West-, East- and North-Saxony:

→ simulation with the lowest medium rainfall intensity (MIN)
→ simulation with the highest medium rainfall intensity (MAX)

☼ **dated single events > 0.1 mm/min**

+ daily temperature, precipitation, solar radiation

Inputs of METVER

Climate stations in WEST, NORTH and EAST Saxony

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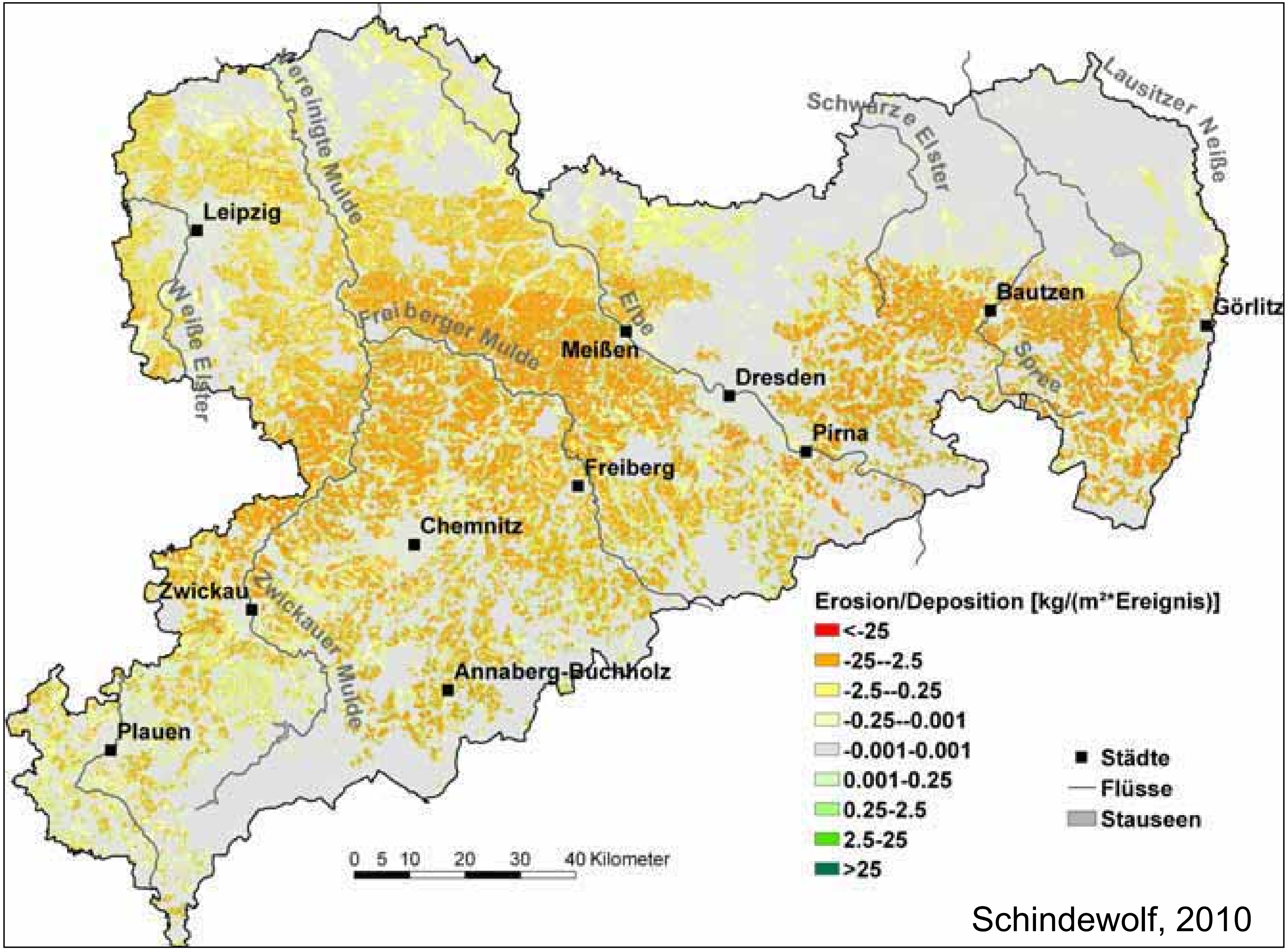
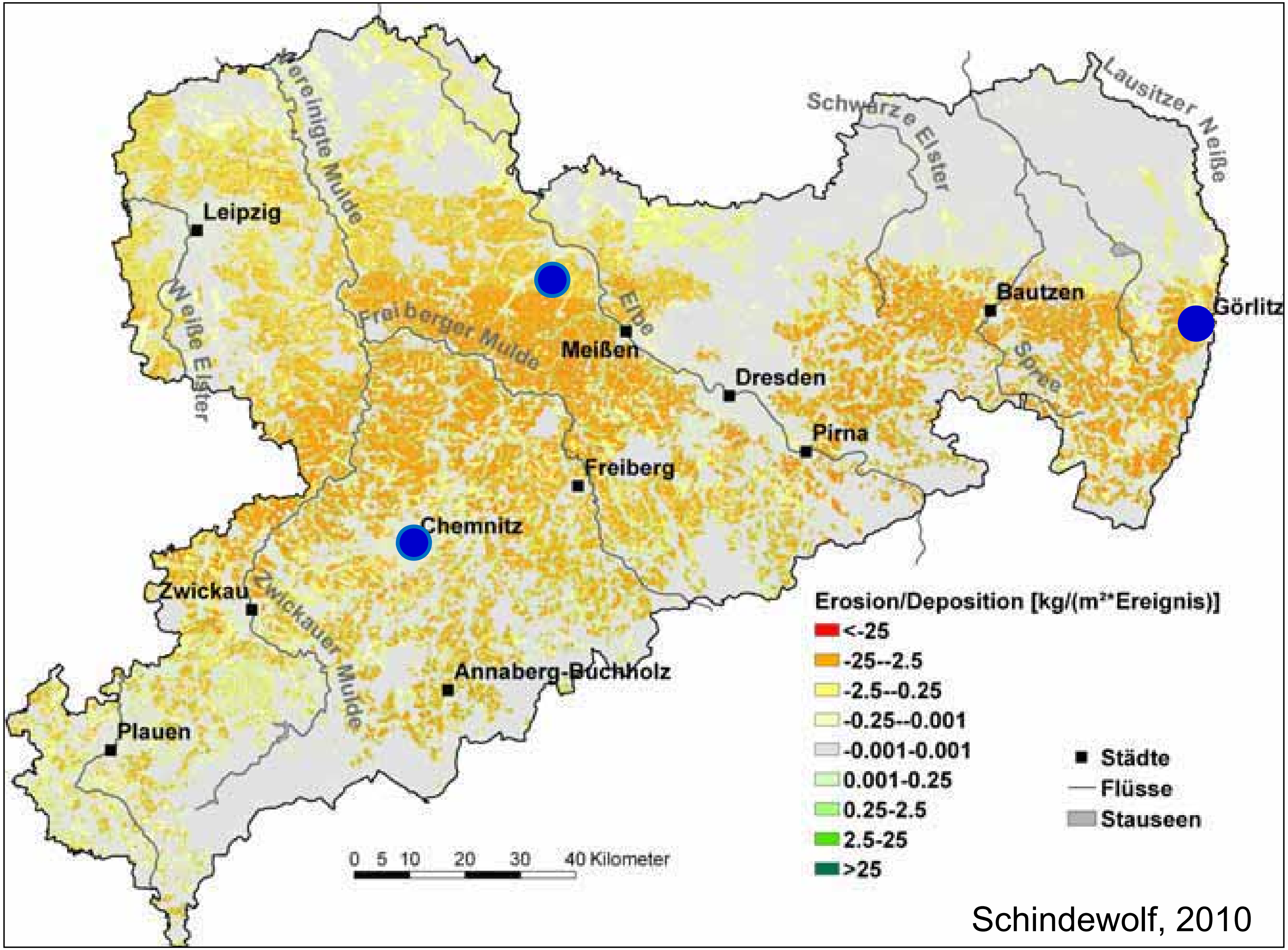


Schindewolf, 2010

Climate stations in WEST, NORTH and EAST Saxony



Schindewolf, 2010

Catchments:

North-Saxony
loess belt

~ 2 km²
~ 88 % arable land
silty soils

West-Saxony
foreland of mountain area

~ 1 km²
~ 56% arable land
sandy-loamy soils

East-Saxony
loess belt

~ 2 km²
~ 74 % arable land
silty soils

Multi-model approach

- evapotranspiration model METVER

Inputs:

= measured data for reference period / outputs of WETTREG

- climate data (daily temperature, precipitation and solar radiation)
- soil-hydrological data
- land use parameters

METVER (Mueller 1987 based on Turc [1961] and Wendling et al. [1991]):

- meteorological evapotranspiration model
- official model of the German National Weather Service

Output:

= daily water contents [Vol.-%] in the upper layer of the topsoil (0-10 cm) for all soils, crops and other land uses within the catchments

= input for EROSION 3D

Multi-model approach

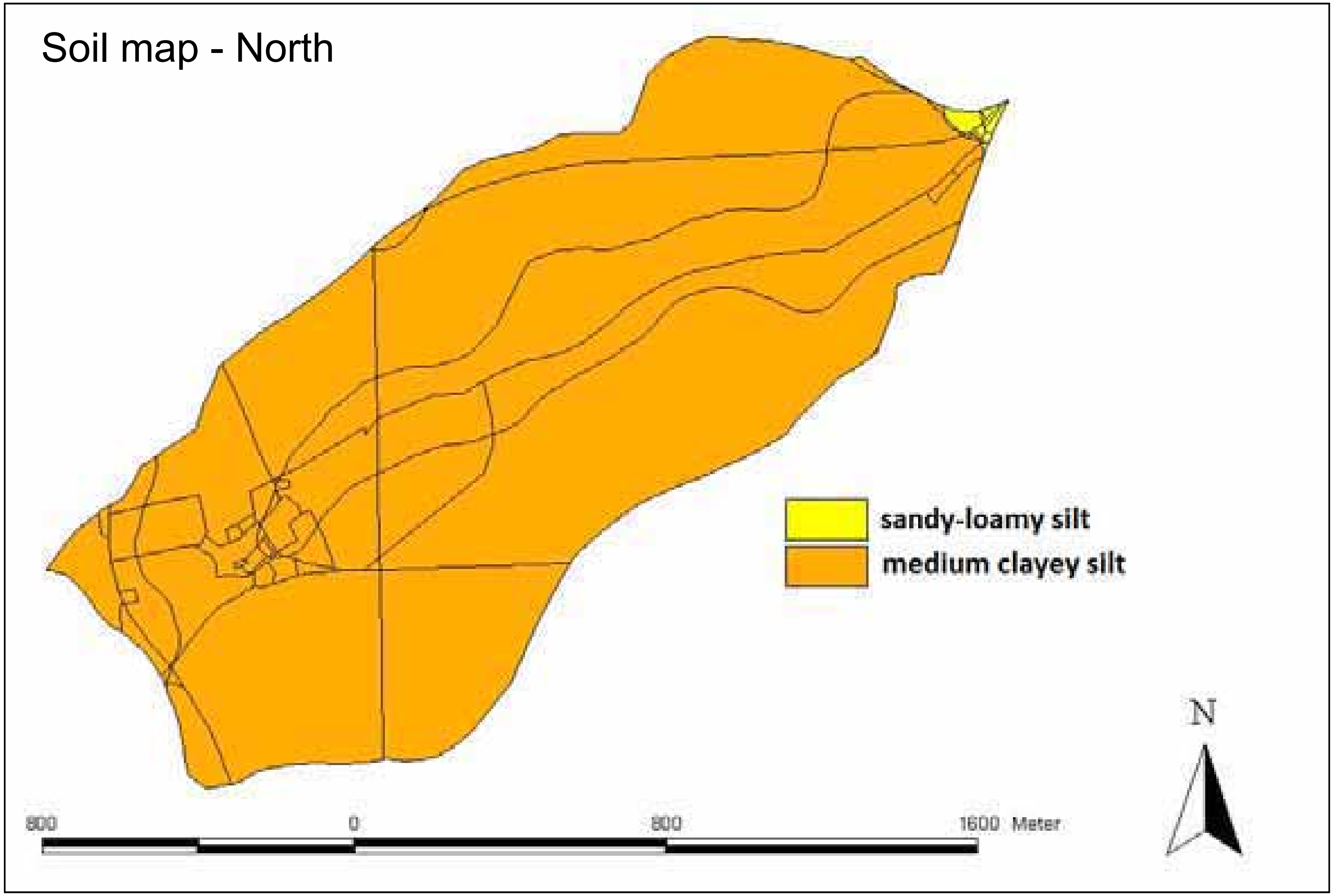
- physically based soil erosion model

Inputs:
- **single rainfall events** = measured data + outputs of WETTREG
- **soil and land use parameters** (texture, bulk density, TOC, cover, erodibility, rouhgness, skinfactor, initial soil moisture) = output of METVER
- **relief parameters** (DGM 10 x 10m)

EROSION 3D (Schmidt 1986, v.Werner 1995):
- event based soil erosion model
- field tested, validated, broad data basis (database)

Outputs:
- netto-erosion for the watershed outlets
- soil erosion map

Intersecting soil map + land use map



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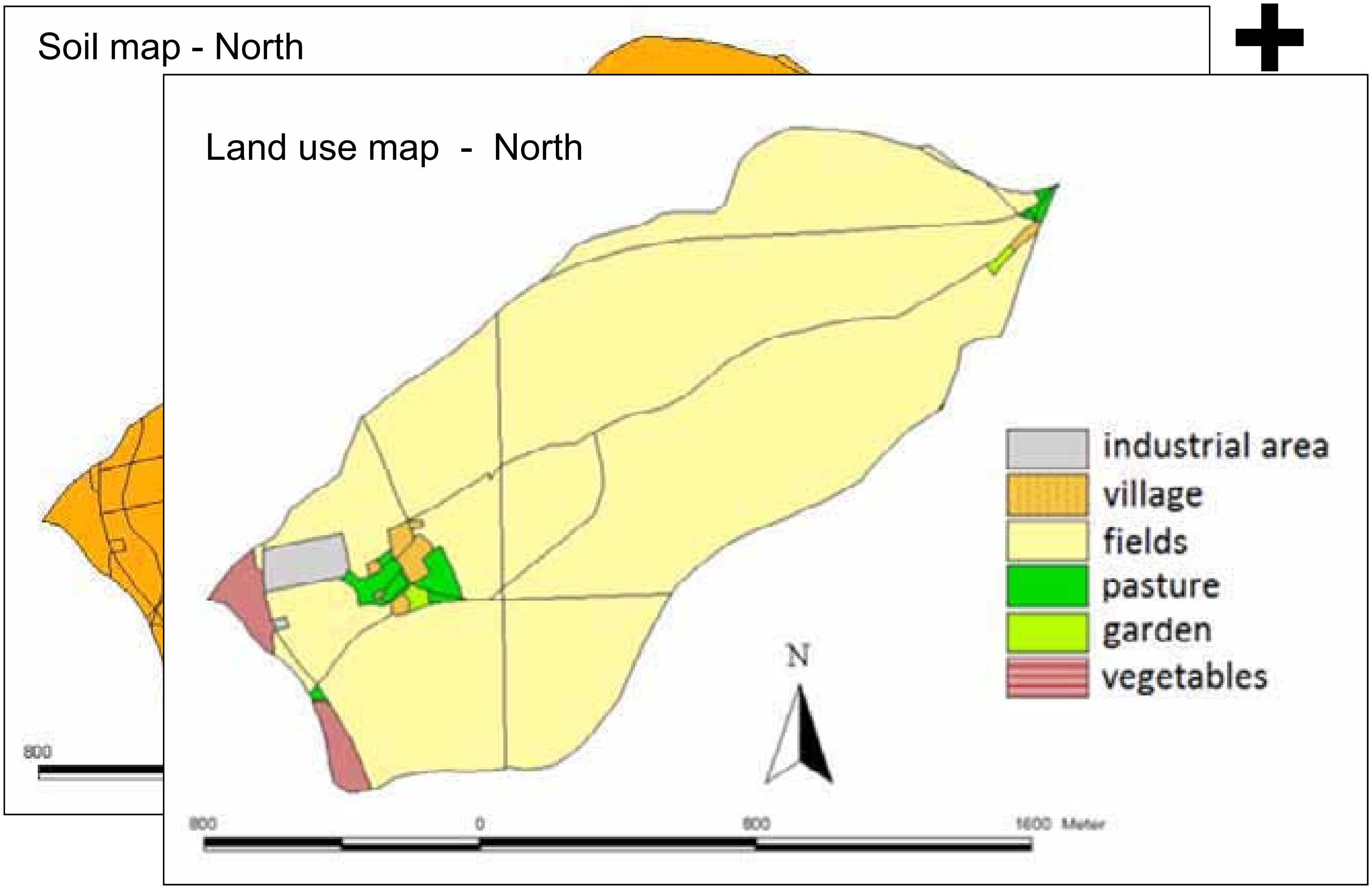
Intersecting soil map + land use map



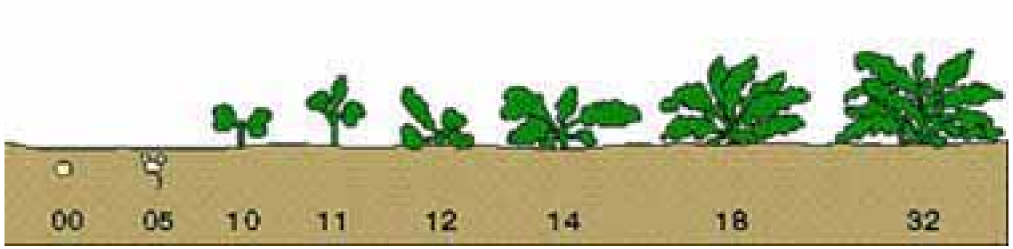
→ polygons with equal land use + soil properties

Each polygon

- **typical 10 year crop rotation:** random distribution of crops

catchment	crop and croprotation
WEST	summer barley - winter wheat - winter barley - winter rape – winter wheat – clover – corn – winter barley – winter rape – summer barley
NORTH	summer barley – winter rape – winter wheat – winter barley – corn – winter wheat – winter barley – winter rape – winter wheat - sugar beets
EAST	summer barley – winter rape – winter wheat – winter barley – corn – winter wheat – winter barley – winter rape – winter wheat - corn

- **growth of plants**



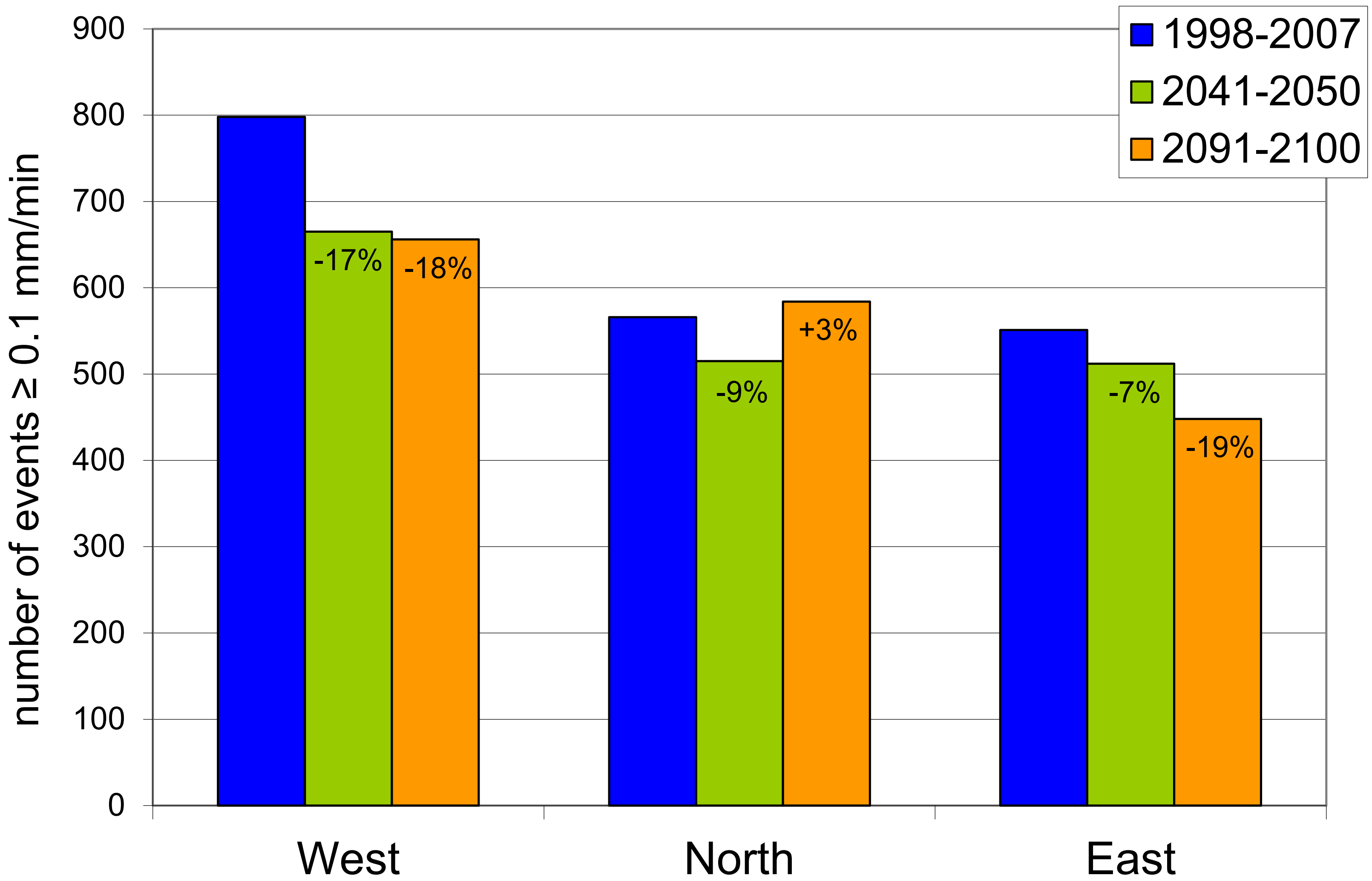
- **soil management (sowing / harvesting / ploughing)**

Results – reference scenario versus future scenarios

1998-2007 ↔ 2041-2050
2091-2100

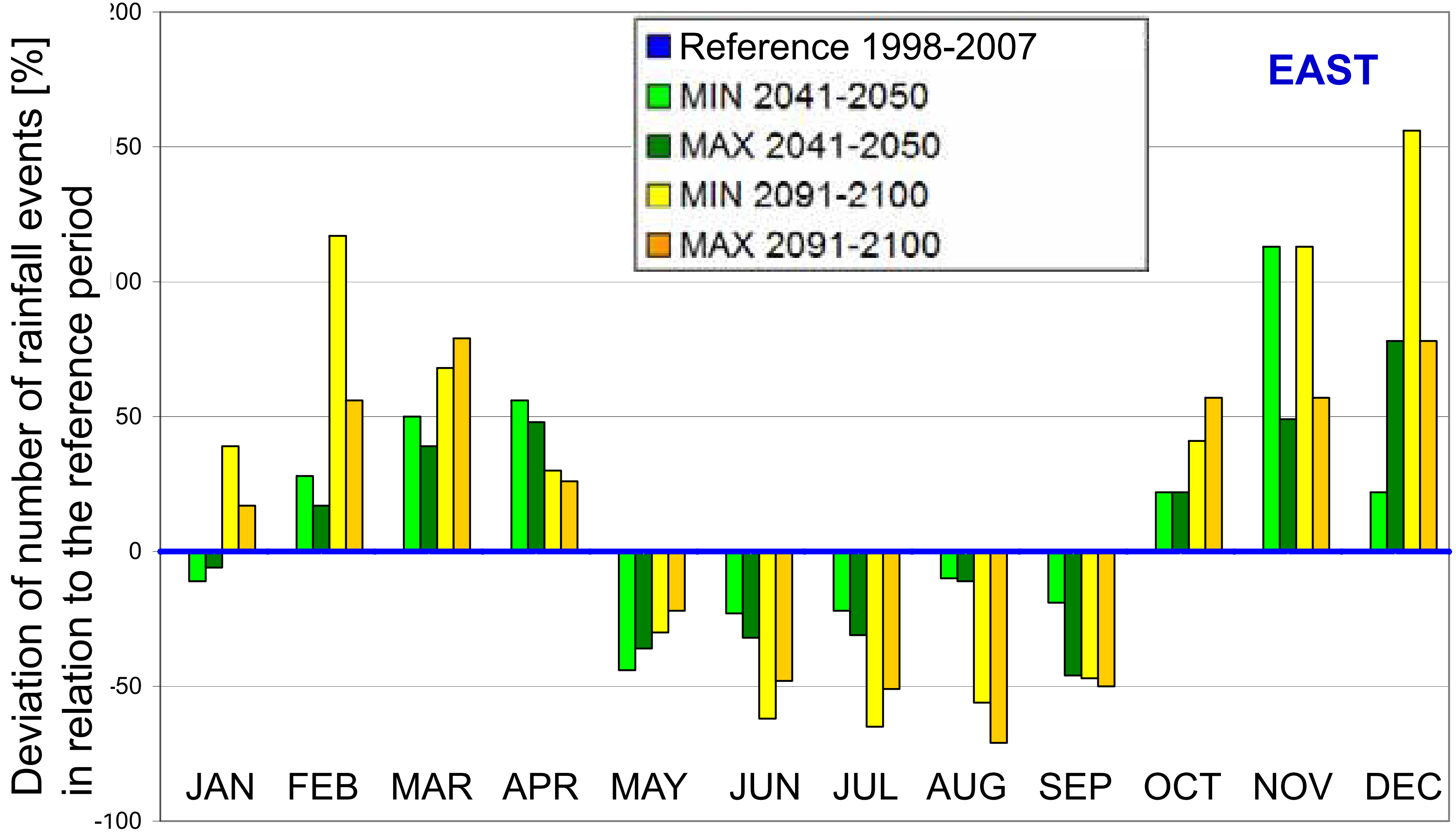
1) **Evaluation of precipitaion data (WETTREG)**
2) **Evaluation of soil moisture data (METVER)**
3) **Evaluation of soil erosion rates (EROSION 3D)**

Results: precipitation – number of events > 0.1 mm/min



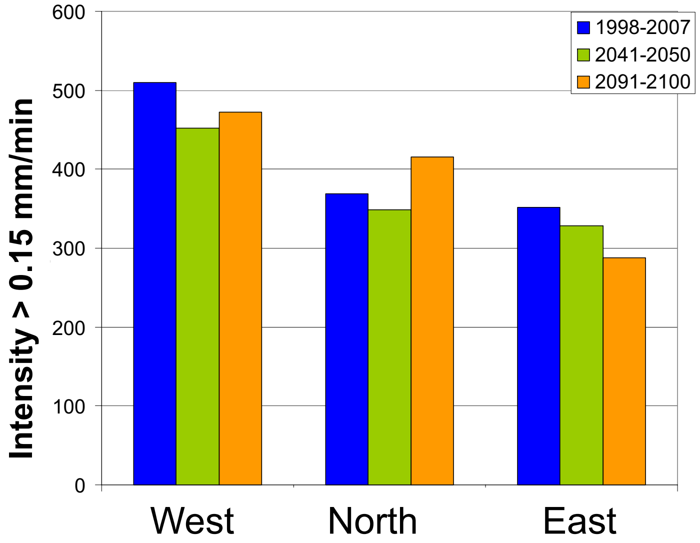
Total number of events > 0.1 mm/min will decrease.

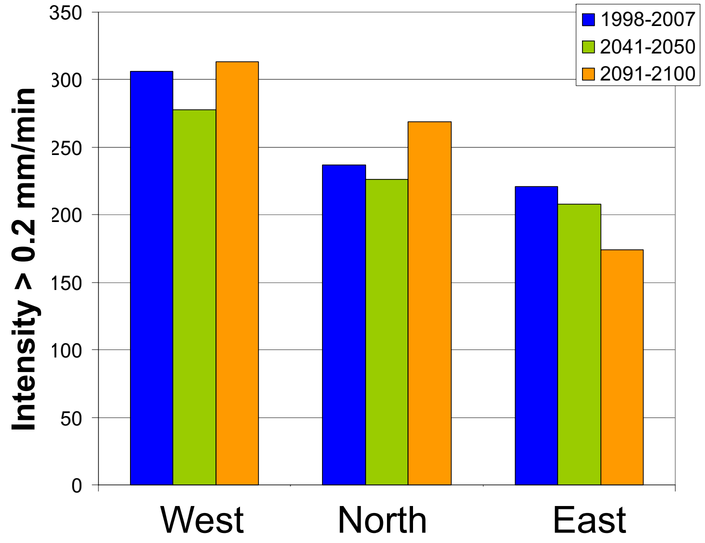
Results: precipitation – spread over the year

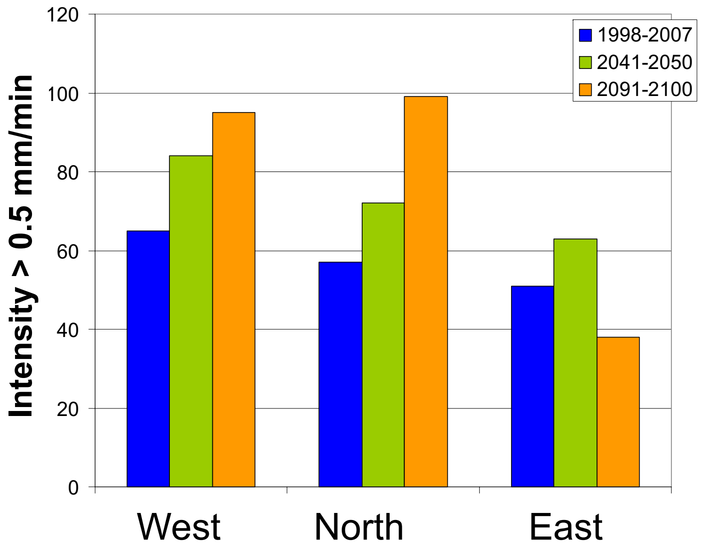


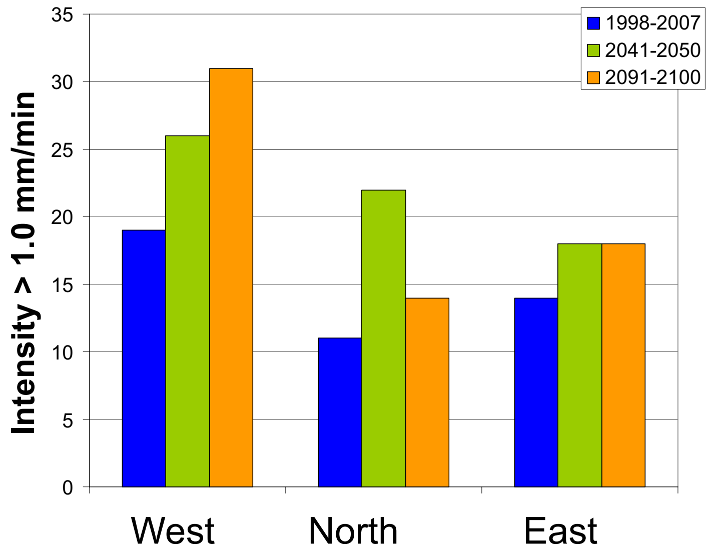
Risk of heavy rainfalls becomes higher in spring and autumn. This trend strengthens until the end of the century.

Results: precipitation - intensities







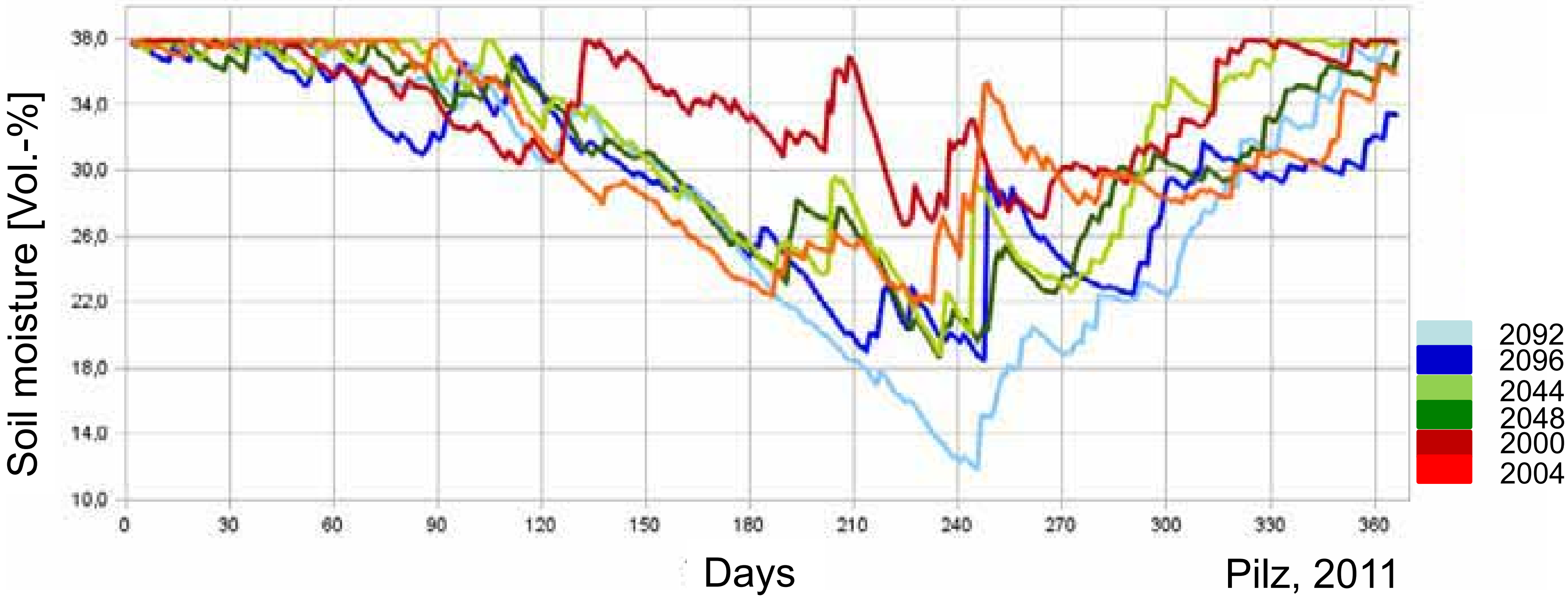


Number of events with low intensities will decrease.
Number of events with high intensities will increase.

Results: soil moisture (METVER)

Annual run of soil moisture

Example: leap years - soil: clayey silt, crop: winterwheat (EAST, MAX)



Pilz, 2011

Soils will become drier in summer, summerly drying period will extend.

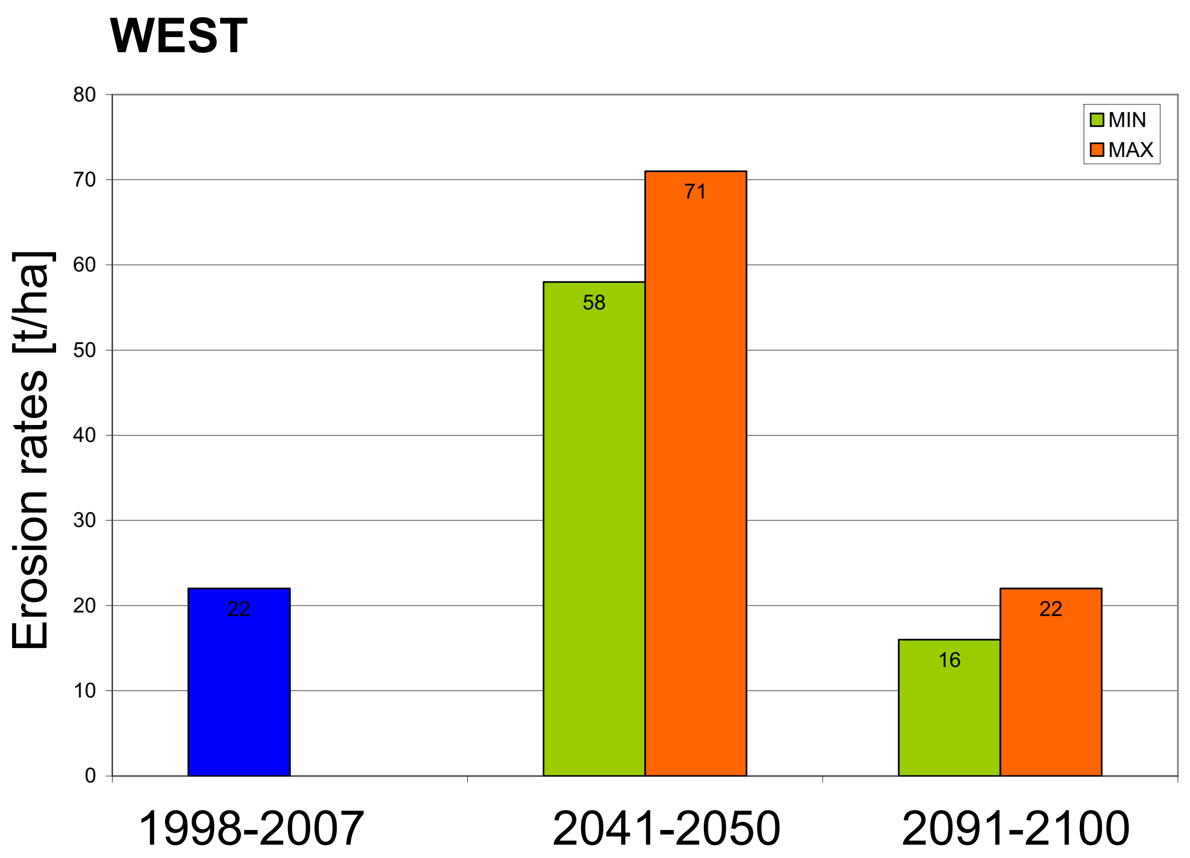
Results: soil erosion rates (EROSION 3D)

Scenarios:

- conventional tillage
- decreasing TOC
- changed phenology
- conservation tillage / no tillage

Results: erosion rates

Scenario: conventional tillage
= pure impact of changed precipitation and altered soil moisture regime



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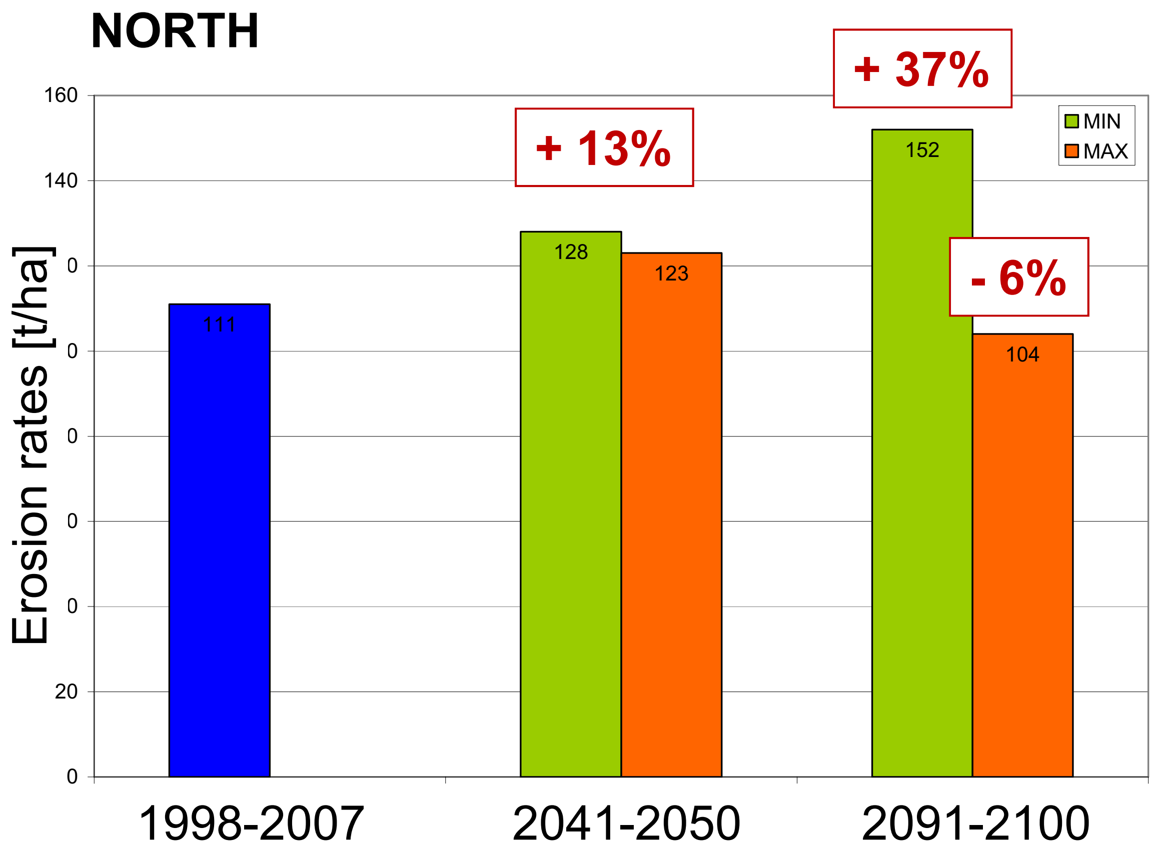

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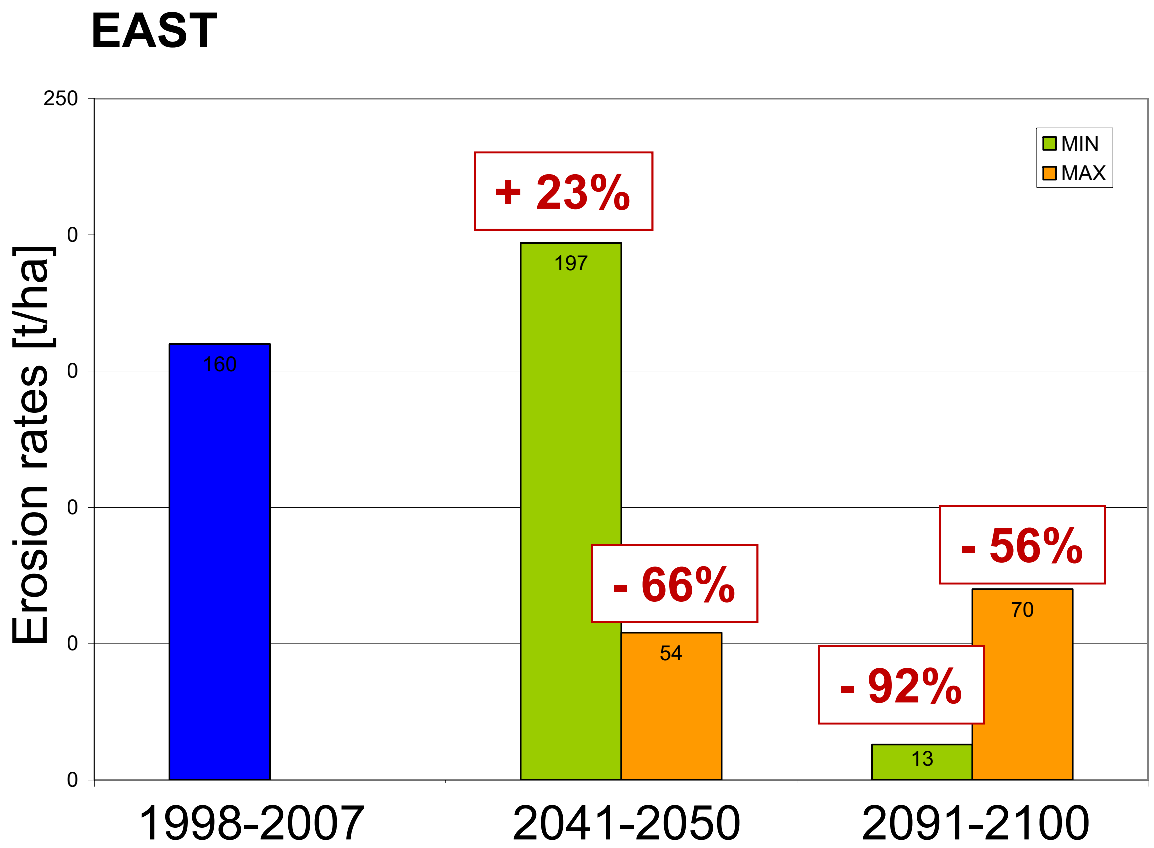
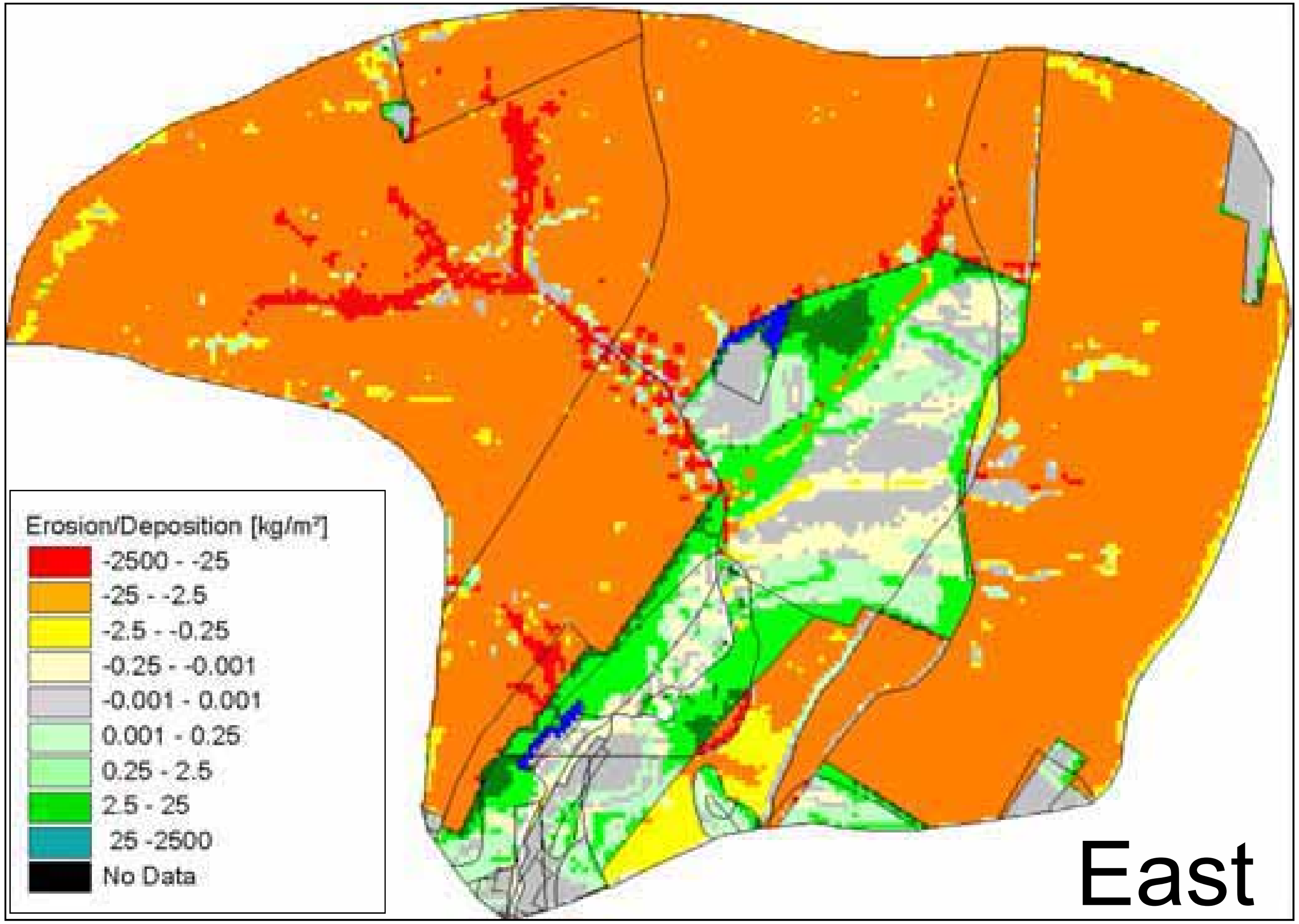


4 single events in March 2098 (MAX)



Soil loss: 58 t/ha

→ **occasionally appearance of very heavy rainstorms**

Results: erosion rates

Scenario: decreasing TOC due to higher biological activity

Future development of TOC-content in topsoils depends on:

- management (conventional – conservation tillage)
- amount and composition of remaining plant residues after harvest
- intercropping, fertilisation, soil texture, soil moisture, …

data from literature (Kolbe, 2009; Nitzsche, 2009):

medium values for conventional tillage:

- 0.1% TOC until 2050 — **additional: +2 to +4%**

- 0.2% TOC until 2100 — **+5 to +14%**

Results: erosion rates

Scenario: changed phenology

data from literature (Chmielewskie et al. 2004; Estrella 2007):

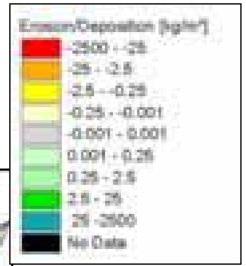
- **no significant shift of sowing (frost periods in spring)**
- **significant earlier harvest**

crop	2050	2100
winter wheat	- 9 days	- 20 days
winter barley	- 5 days	- 11 days
summer barley	- 10 days	- 21 days
corn	- 13 days	- 30 days
rape	+13 days	+30 days

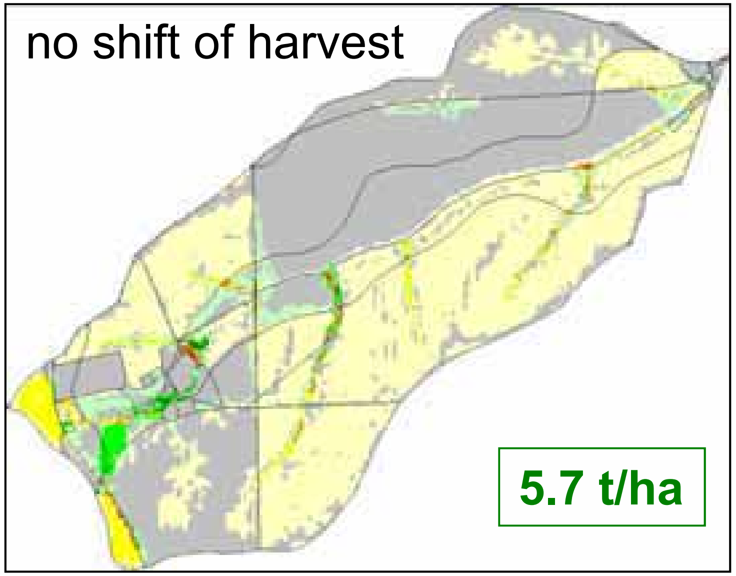
☼enhenced use as oil plant –
not as forage plant

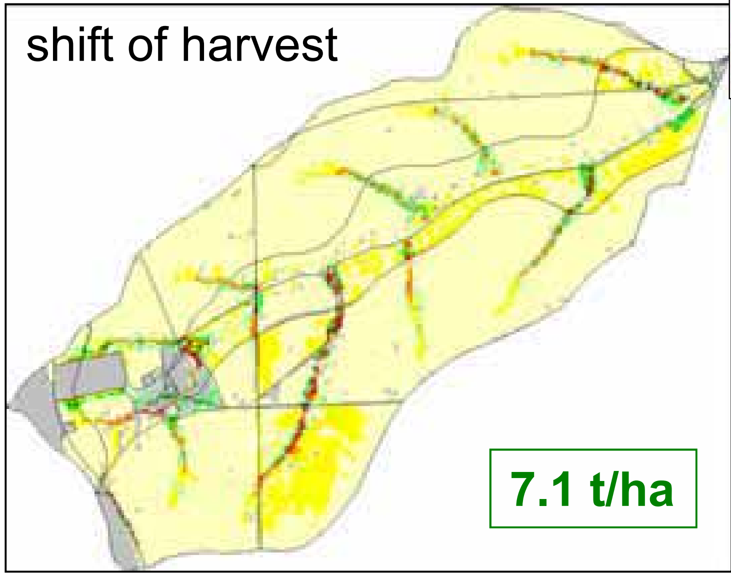
An earlier harvest could lead to higher soil erosion rates (+ 25 to +600 %).

Erosion/deposition September 2043 (North)



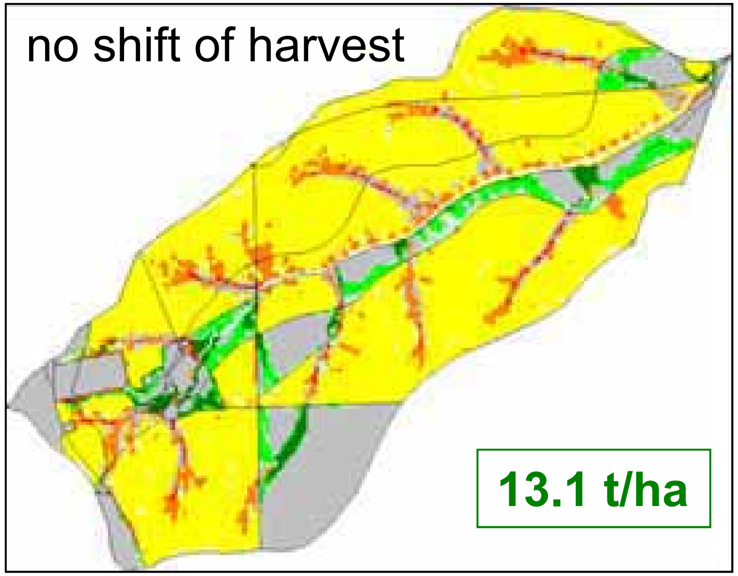
80% plant residues after harvest

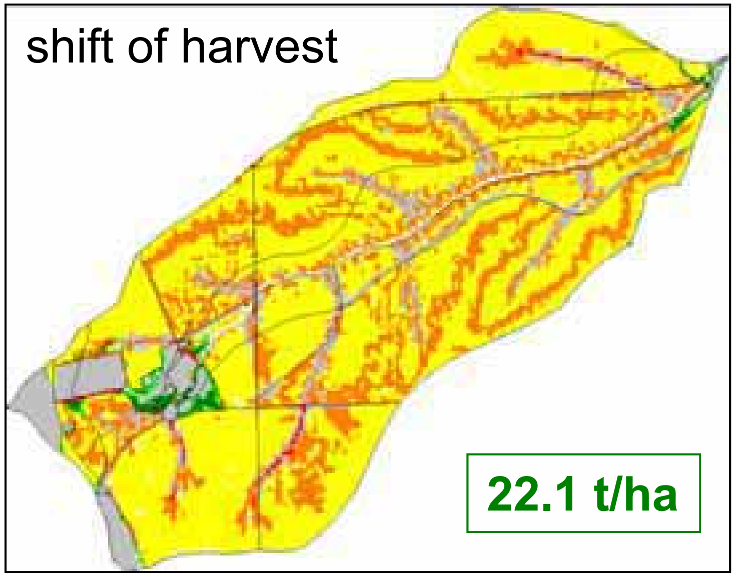




+ 24%

Bare soil after harvest

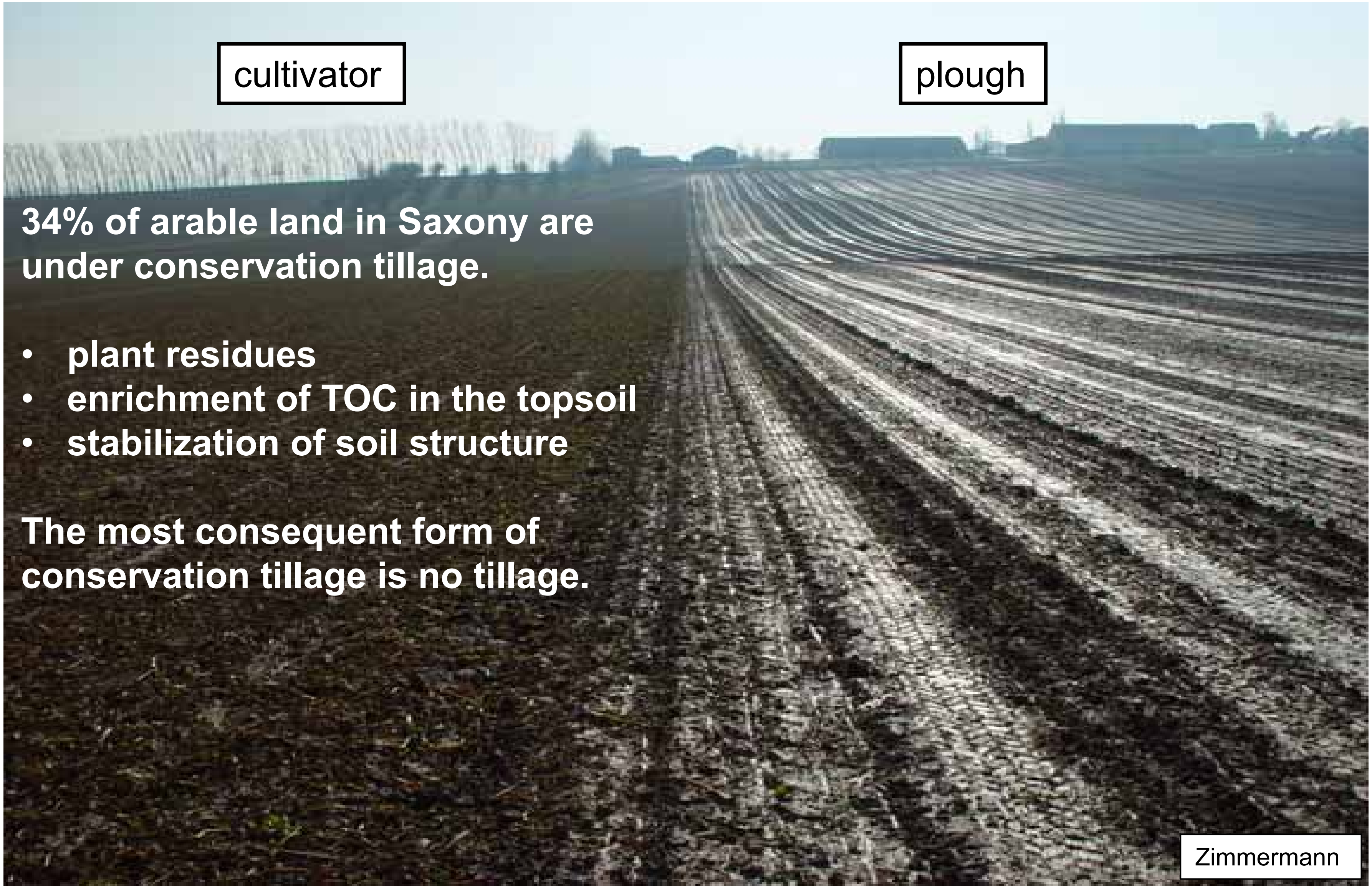




+ 69%

Results: erosion rates

Scenarios: conservation tillage – no tillage



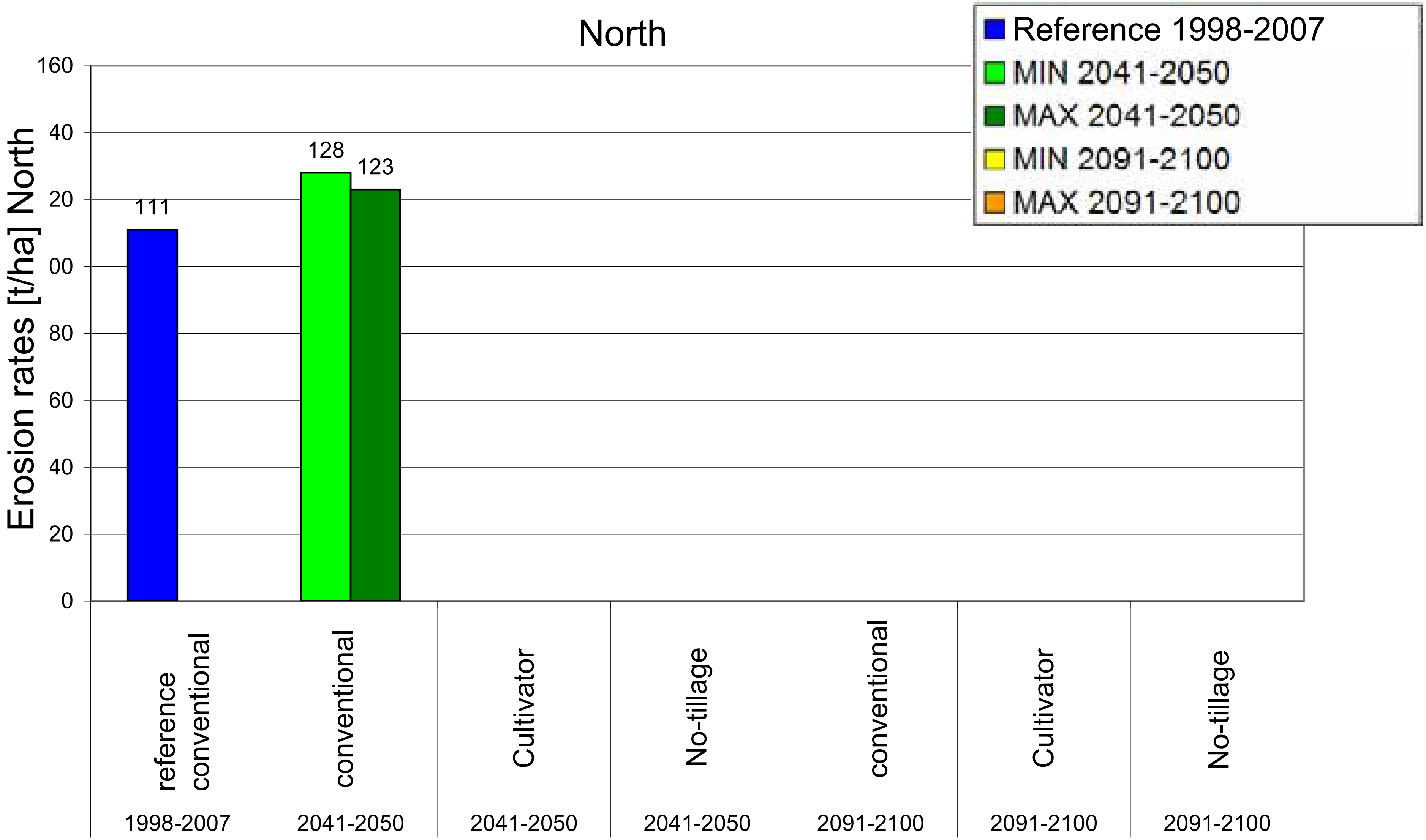
34% of arable land in Saxony are under conservation tillage.

- **plant residues**
- **enrichment of TOC in the topsoil**
- **stabilization of soil structure**

The most consequent form of conservation tillage is no tillage.

Results: erosion rates

Scenario: conservation tillage – cultivator / no tillage



Results: erosion rates

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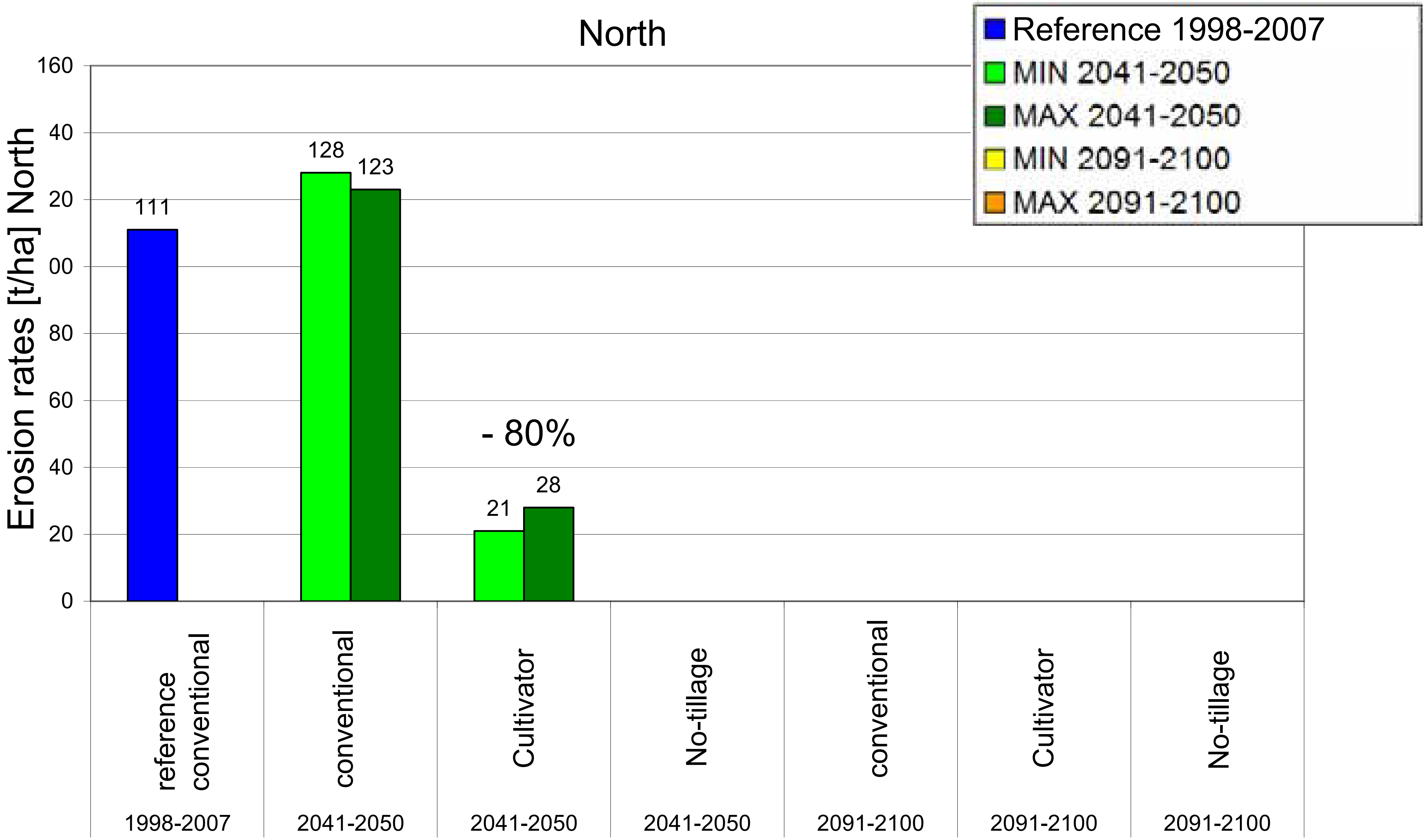

Results: erosion rates

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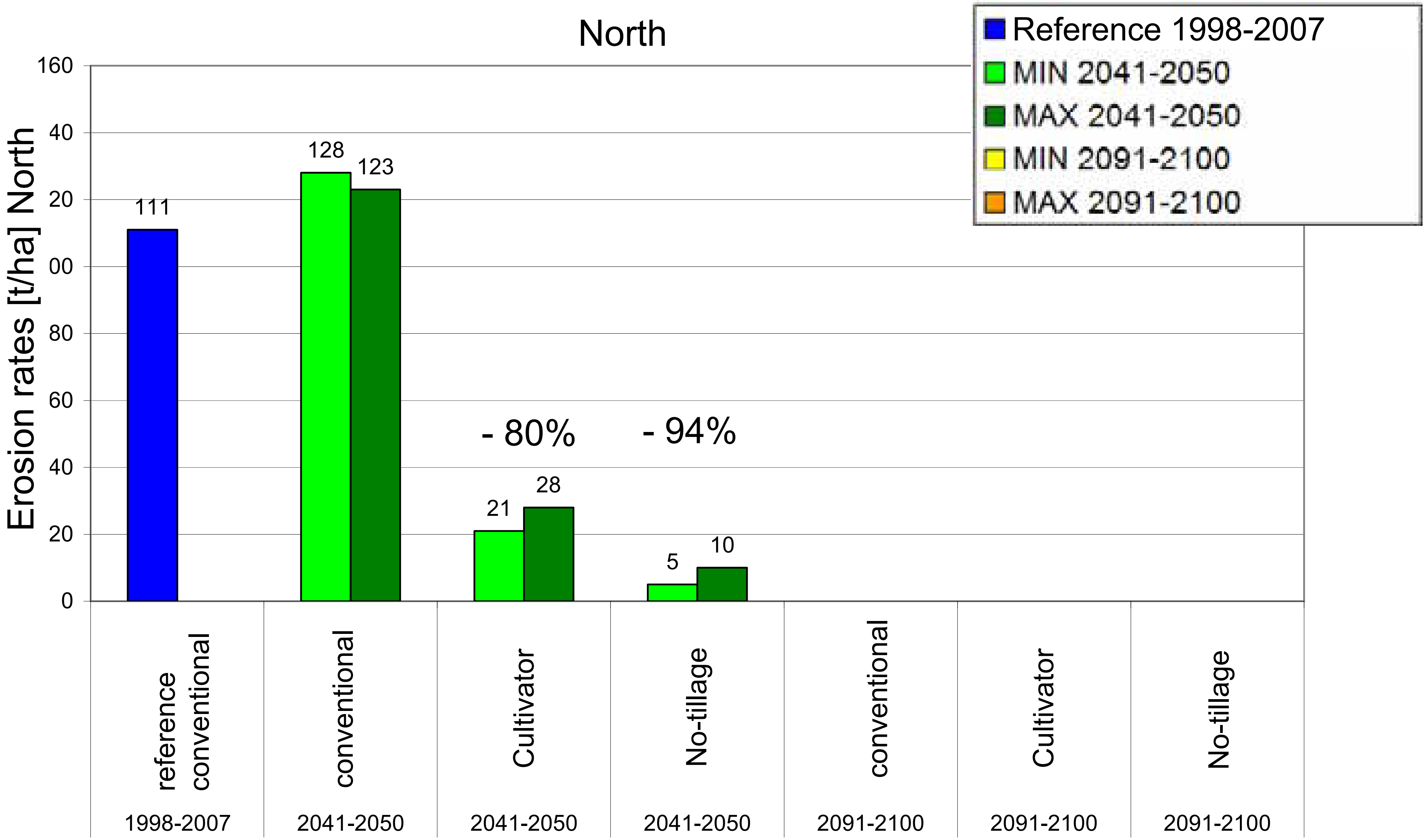

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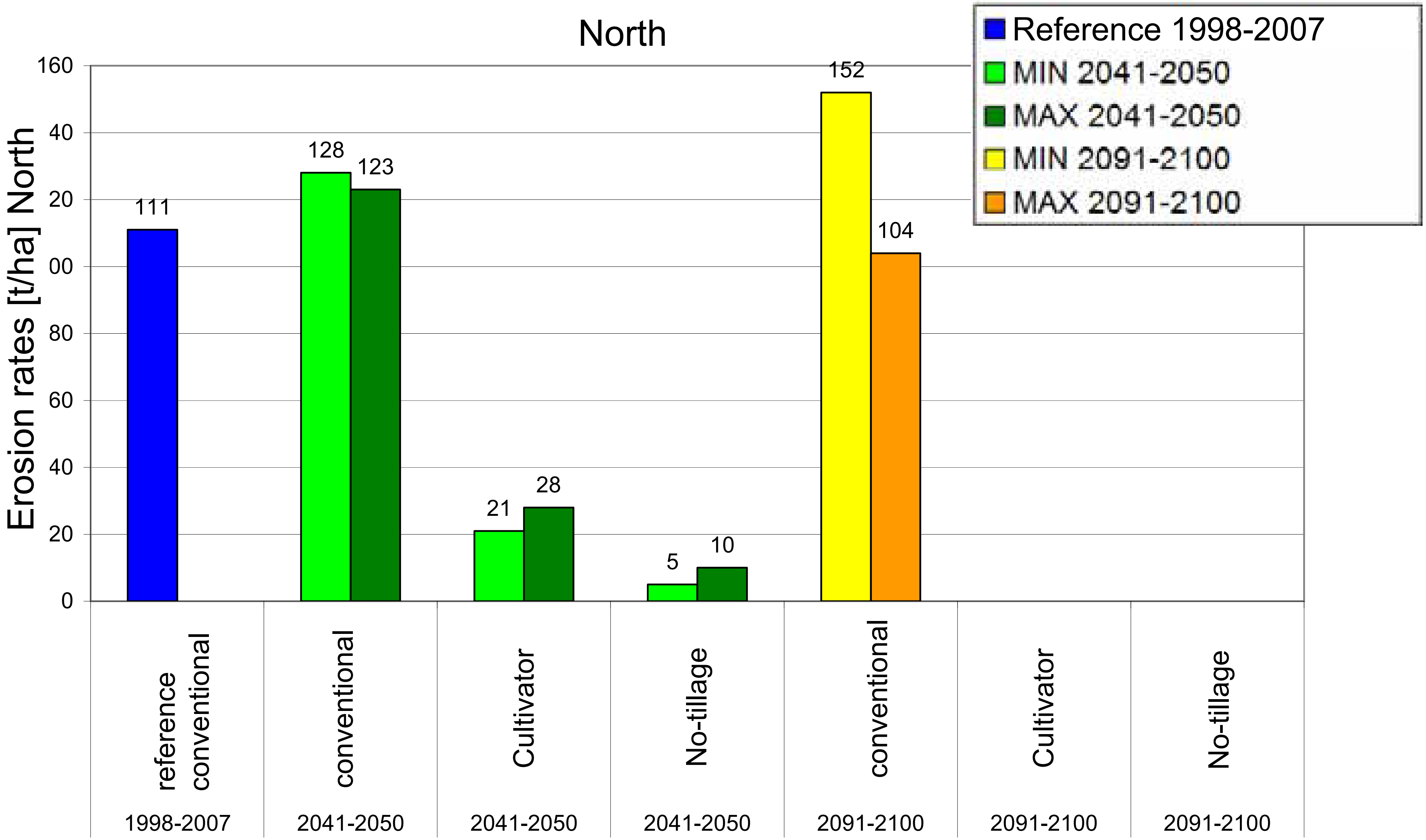

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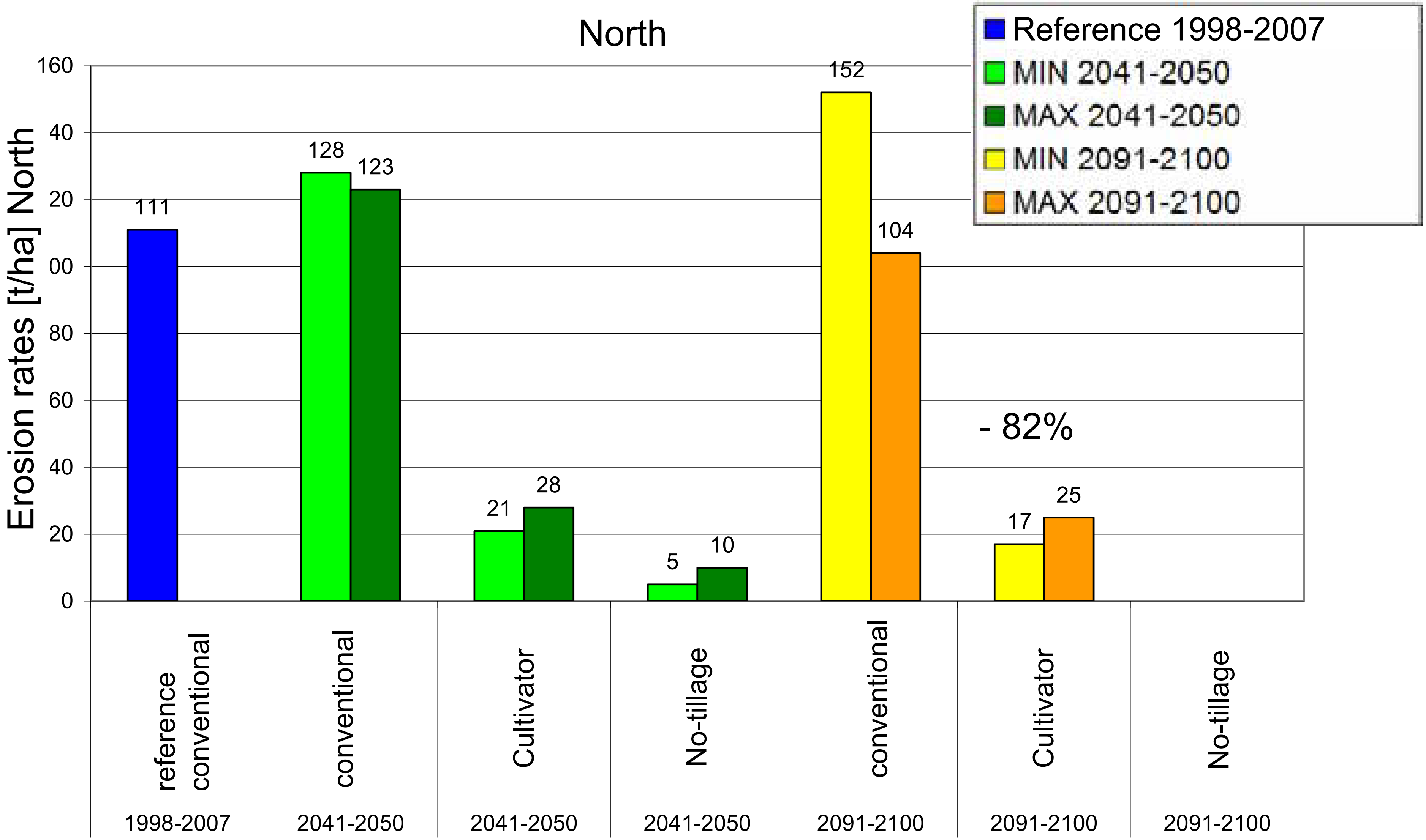

Results: erosion rates

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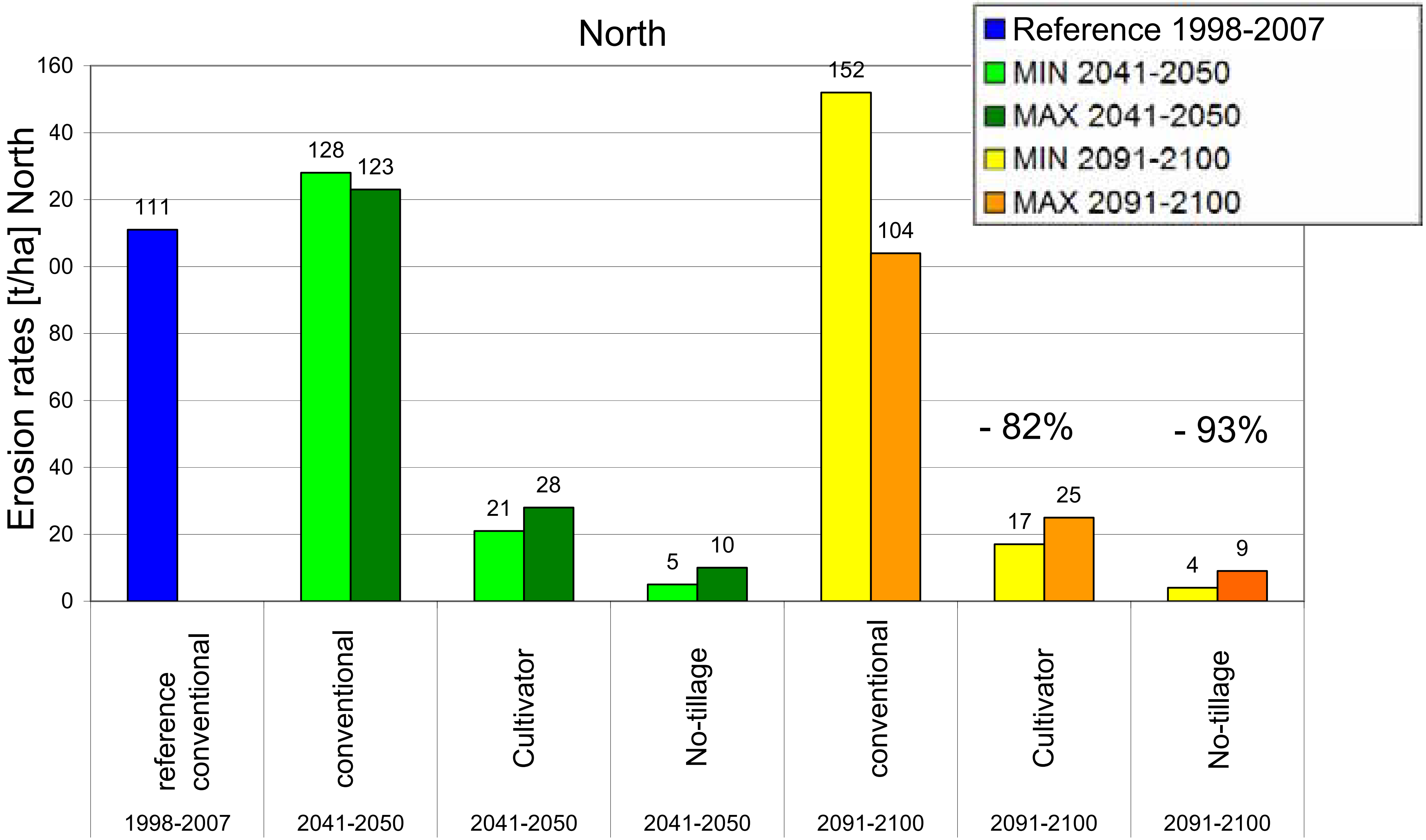
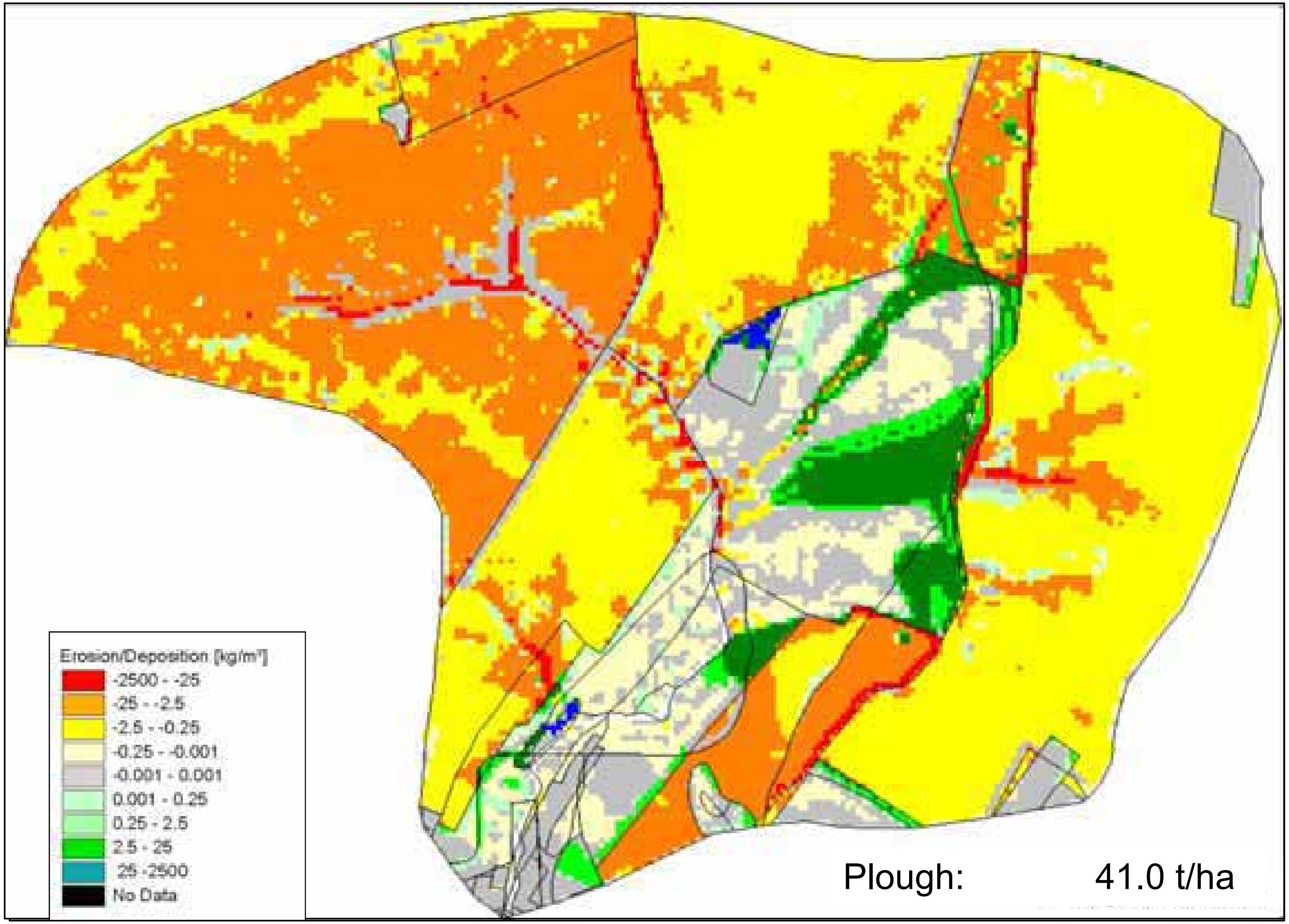
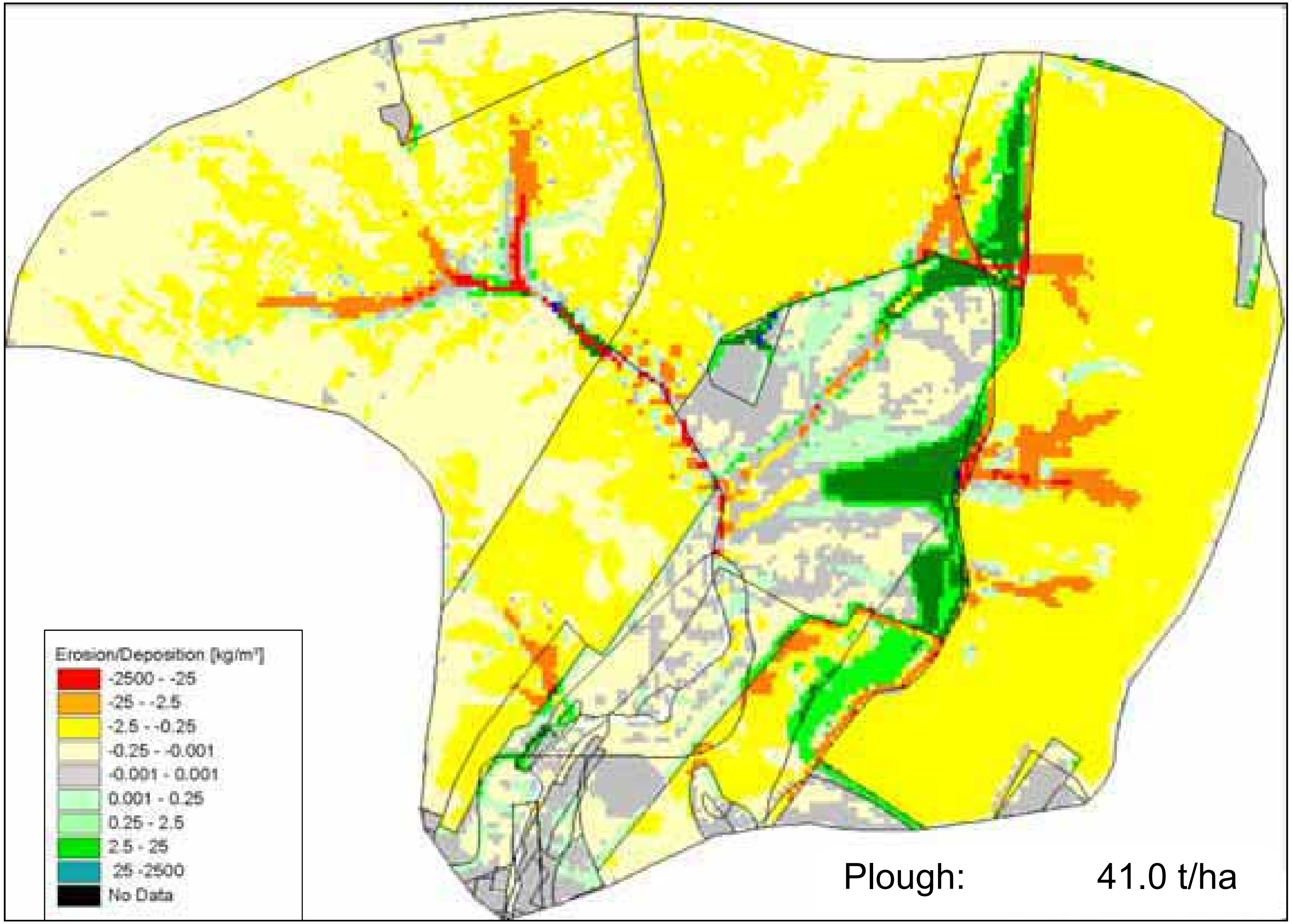


Erosion / Deposition - October 2041 - EAST



Impact of conservation tillage under extreme conditions: field capacity, after harvest

Erosion / Deposition - October 2041 - EAST



Impact of conservation tillage under extreme conditions: field capacity, after harvest

Main impacts of climate change on soil erosion for Saxony:

- higher precipitation intensities
- changed distribution of heavy rainstorms during the year

- decreasing soil moisture
- extention of summerly drying period
- decreasing TOC
- earlier harvest

Essential statement:

- Soil management + tillage practises affect soil erosion rates much more than the impact of the predicted climate change.

- Permanent conservation tillage and no-tillage are `the methods of choise` to protect soils against soil erosion (today and tomorrow).

My findings are open to challenge!