Joint Research Centre

The EPIC model: current status and CCAT implementation

Marijn van der Velde

A FARM OF THE FUTURE

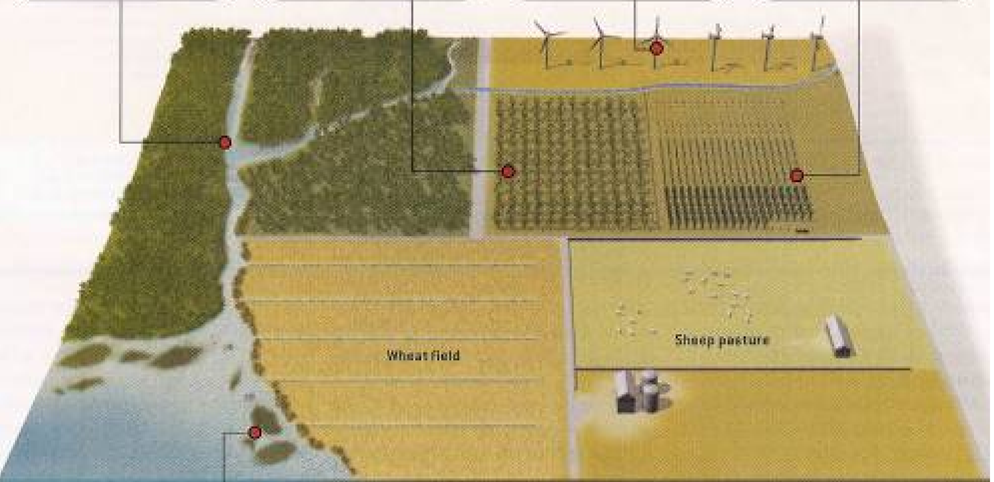
Ecosystem services previously taken for free could generate perhaps half the income of a farm, if markets for various kinds of environmental credits take off as hoped. Farmlands in the future may have a diverse portfolio of ecosystem services to offer to a wide range of customers.

BIODIVERSITY CREDITS
Conservation organizations are leasing development rights from the owners of undisturbed forests and other habitats that host threatened endemic species and fast-vanishing ecosystems.

CO_2 OFFSET CREDITS
When landowners plant new forests and promise never to cut or burn the trees, they can receive carbon dioxide offset credits that industries will buy to help them comply with restrictions on greenhouse gas emissions.

RENEWABLE ELECTRICITY
Wind farms generate nonpolluting electricity that commands premium prices in deregulated power markets. The turbines can also garner tax credits that subsidize their capital and operating costs.

CERTIFIED SUSTAINABLE TIMBER
Sustainably harvested timber is now one of numerous "eco-labeled" products that are certified as ecologically sound and sold at a premium in specialty markets.



WATER CREDITS
Careful management of water and wetlands is economically valuable for many reasons. Urban water authorities purchase water filtration credits to protect the quality of their watersheds; wetland owners can also receive compensation from government agencies for flood-control services, from conservation organizations for the preservation of migratory waterfowl breeding areas, and from agricultural cooperatives for the prevention of soil salinity increases caused by overdrawn groundwater aquifers.

COMMODITY	PERCENT OF FARM'S INCOME	CUSTOMER
Biodiversity credits	5	Conservation trust
CO_2 offset credits	10	Steelmaker
Renewable electricity	15	Power market
Certified sustainable timber	20	Specialty market
Water credits	20	Urban water market
Wheat	15	World market
Wool	15	World market

Scientific American's *Vision of the Future Farm*

Scientific American, Special Issue
September 2005

<u>Soil</u>

The first filter…

Production & Protection

Only 30% revenue from world markets

Half of the income from 'ecosystem services'!

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Valuing Environmental Services

"… the city government of New York realised that changing agricultural practices meant it would need to act to preserve the quality of the city's drinking water.

One way to have done this would have been to install new water-filtration plants, but that would have cost $4-6 B up front, together with annual running costs of $250 M.

Instead, it is spending $250 M on buying land to prevent development, and paying farmers $100 M a year to minimise water pollution".

'Rachel Carson meets Adam Smith'

The Economist 375, 8423:
pp 9; 74-76, April 23, 2005

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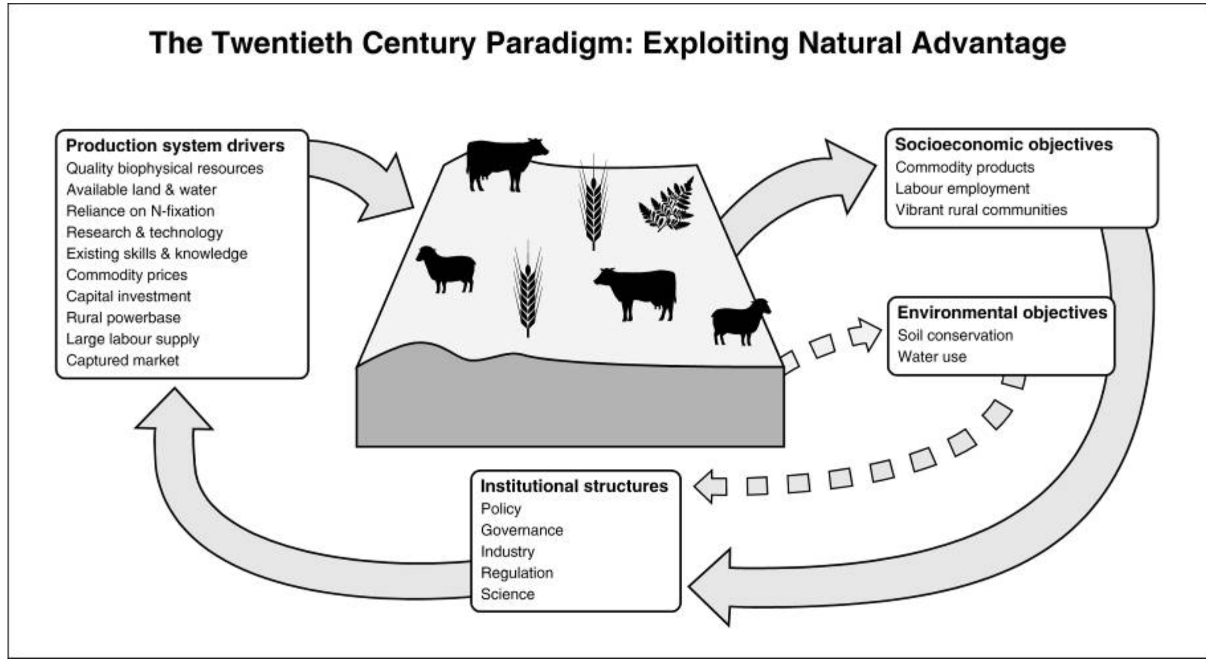
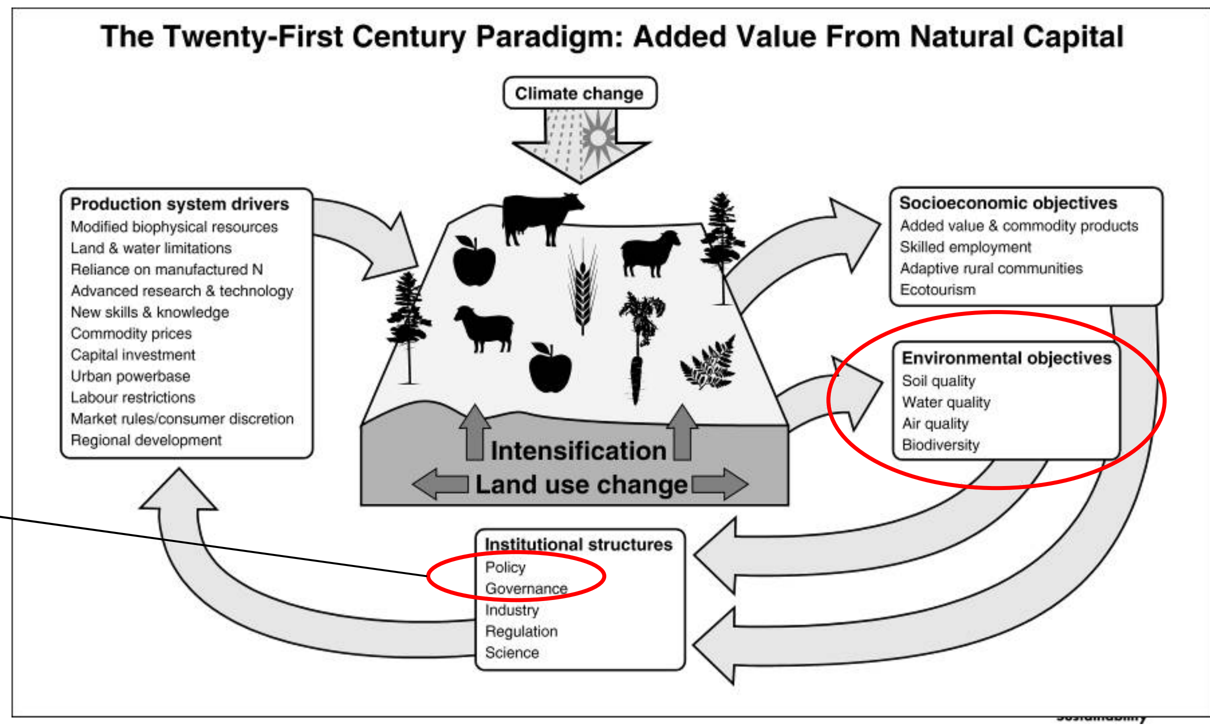
The 20th Century Paradigm…

Agriculture & Land-Use of Today & Future

€'s for the Environment



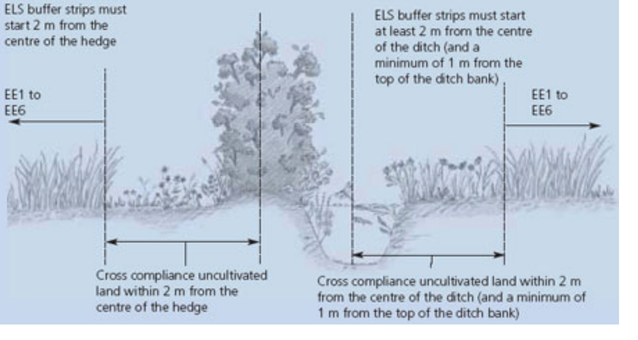


Cross Compliance

A policy tool that seeks to improve the environmental performance of agriculture in the EU.

- Made compulsory in the 2003 CAP reform
- Since 2005, farmers have been required to meet a range of environmental standards or risk losing some of, and in severe cases, all of their subsidy payment.

1. Statutory Management Requirements (SMRs) are derived from 18 European Union (EU) Regulations and Directives, including the wild birds, habitats and nitrates Directives. These SMRs also include EU legislation relating to food safety and animal welfare.
2. The other set of standards relates to 'Good Agricultural and Environmental Condition' (GAEC), where Member States have defined nationally specific standards relating to soil and habitat maintenance.



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SMR and GAEC

1. SMR

    1. Groundwater
    2. Nitrate
    3. Sewage Sludge

2. GAEC

    1. Soil erosion
    2. Soil organic matter
    3. Soil structure

Objectives

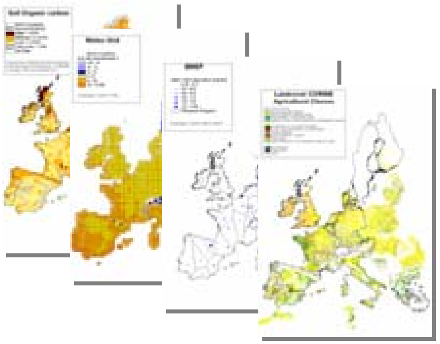
Overall goal: to define EPIC metamodels to evaluate selected SMR and GAEC policy measures

Broad research question:

• What are the consequences across Europe when key cross-compliance measures are implemented on the environmental (and economic performance) evaluated with EPIC?

Framework of the FATE project

Concept: Agrochemicals fate are studied at the **relevant scale**, making best use of **readily available data** at European level



Europe-wide Harmonized Geographical Database

Policy

Nitrate Directive
WFD
Groundwater Directive
PPPs Directive
Soil Thematic Strategy

Recommendations

Assessment

Modelling
Continental
River basin
Local, field
Monitoring

Scenario Analysis

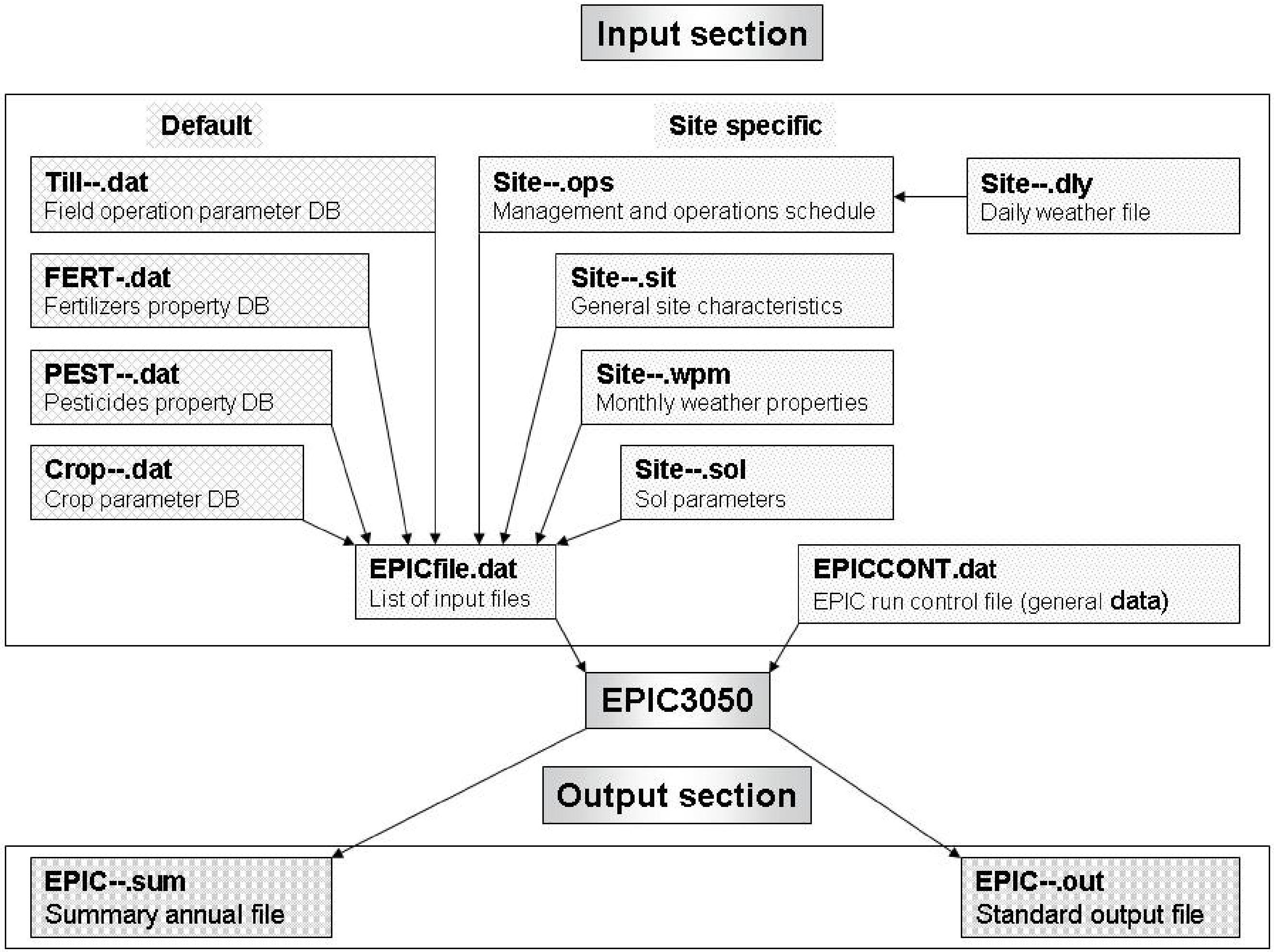
European Agrochemicals Geospatial Loss Estimator:

EAGLE

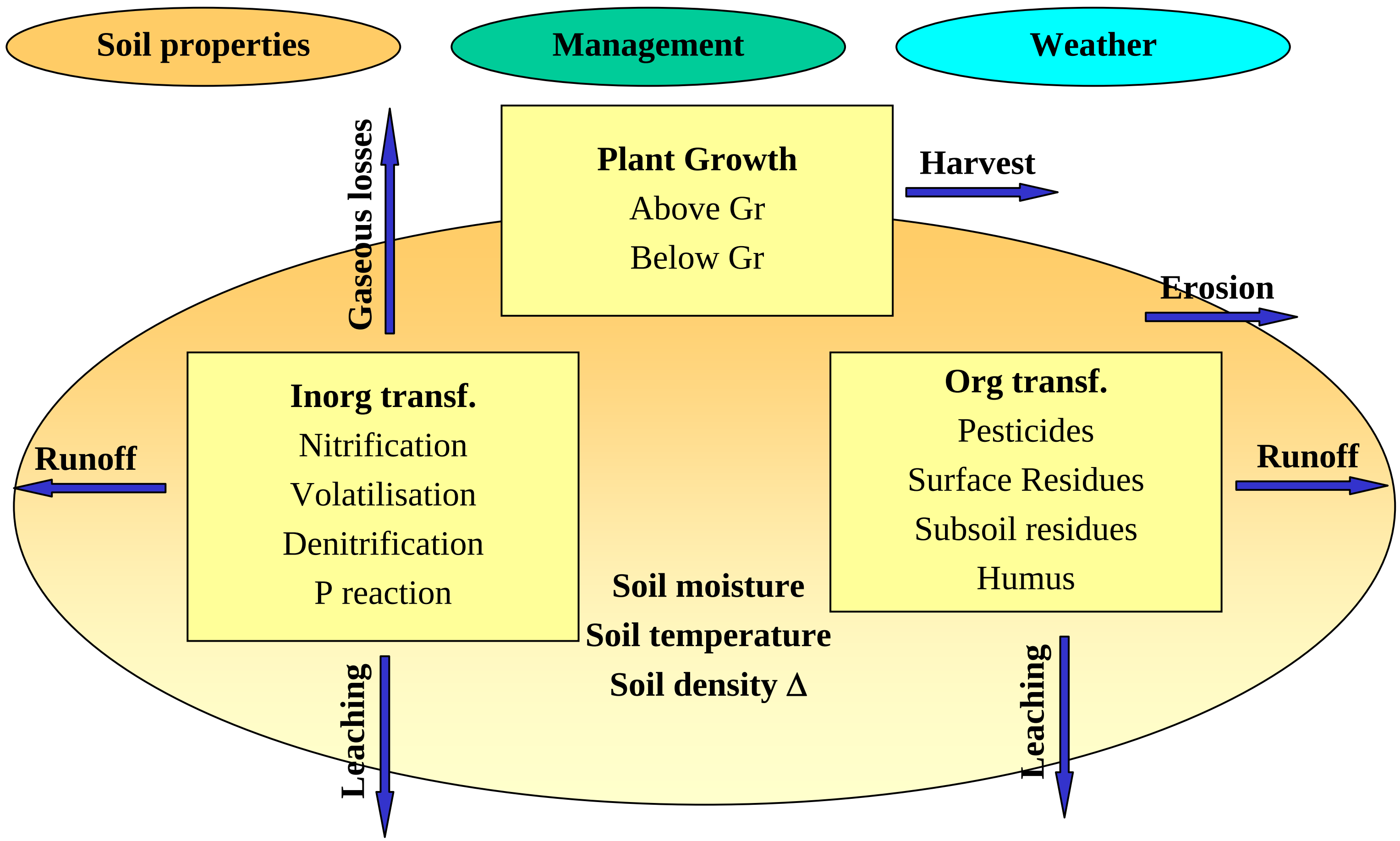
EAGLE is composed of three components:

1. EPIC model (Williams, 1995) EPIC is a continuous simulation model that can be used to determine the effect of management strategies on agricultural production and soil and water resources
2. Database. The EAGLE European geodatabase holds all the necessary data (soil, meteorological, crop management, etc.) to perform EPIC simulations to formulate and evaluate various management scenarios
3. GIS Interface. This is an ESRI ArcMap customization that allows the use of EPIC using data stored in the previously described geodatabase through an intuitive GIS interface.

EPIC -model structure

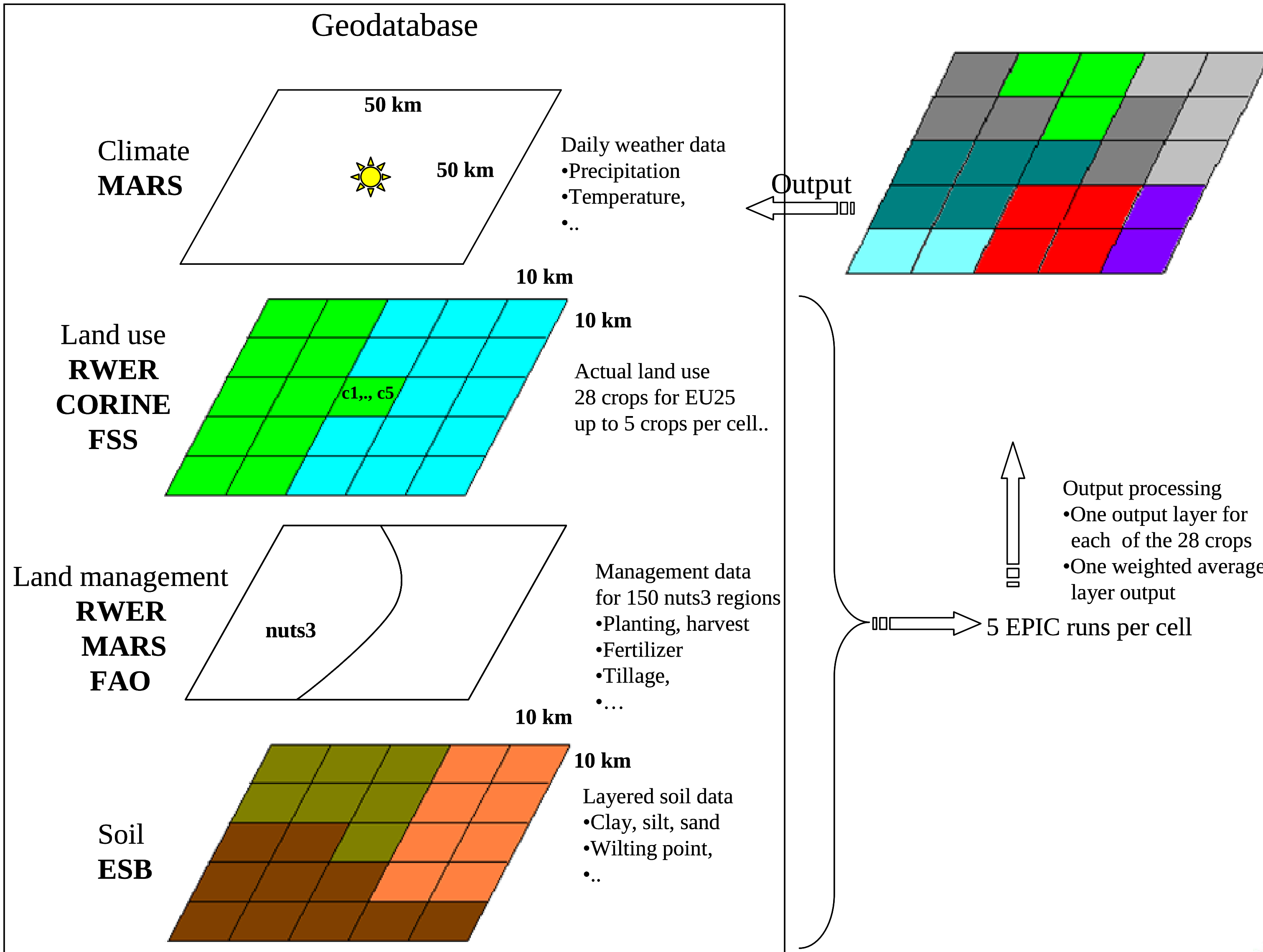


EPIC -model structure

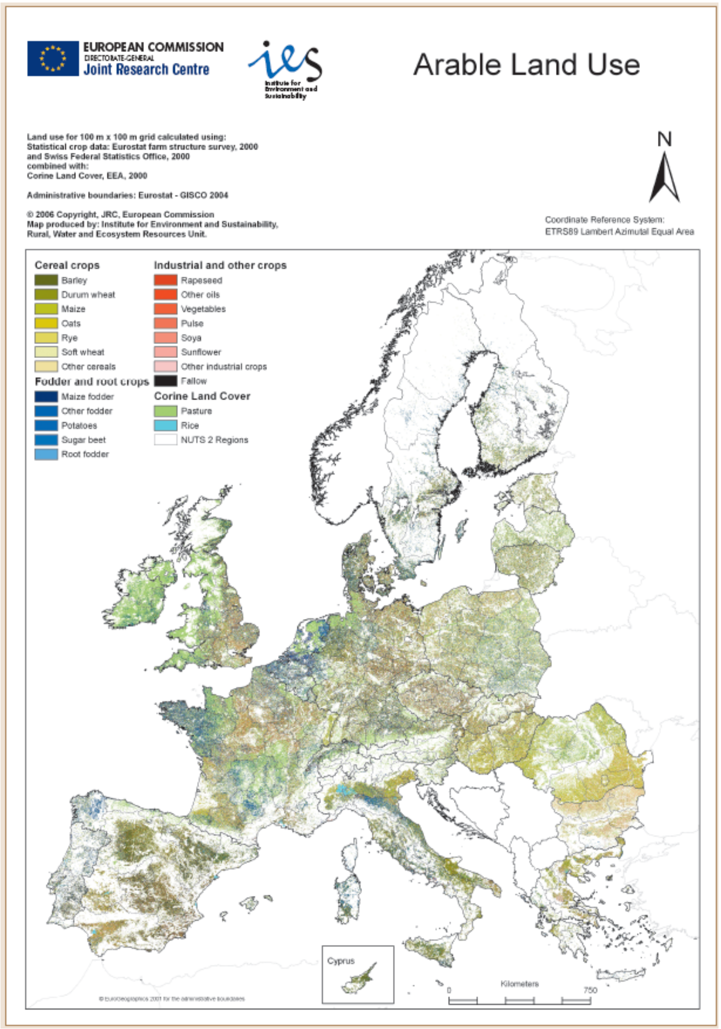


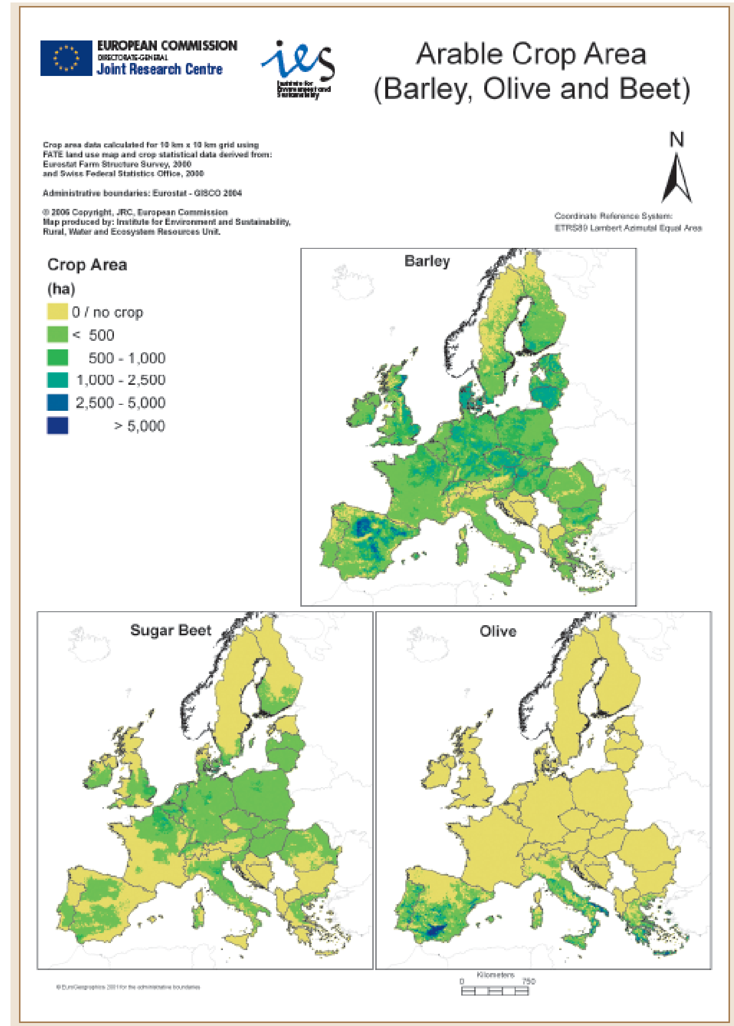
Izauralde, R.C. Simulating Soil Carbon Dynamics, Erosion, and Tillage with EPIC

EPIC -GIS link

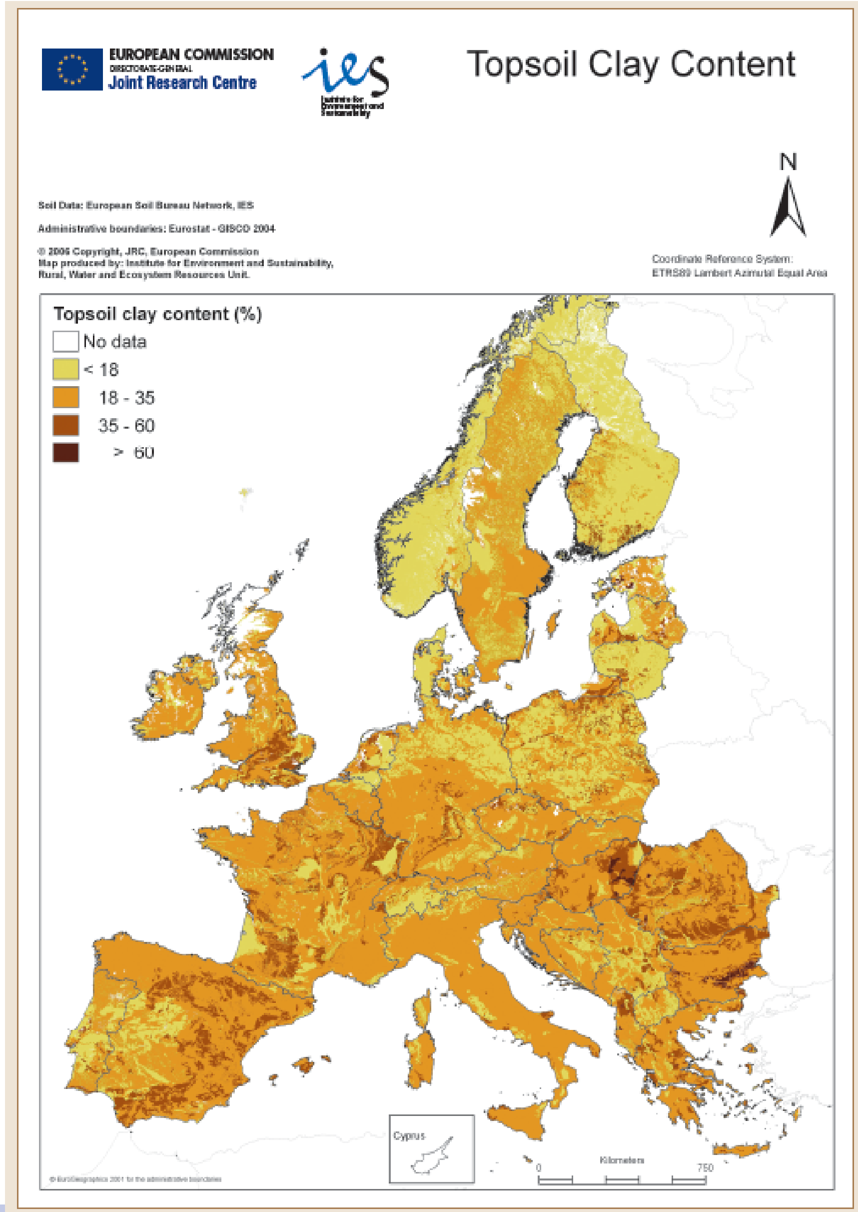


Input data for EPIC





Input data for EPIC



Input data for EPIC

Daily data

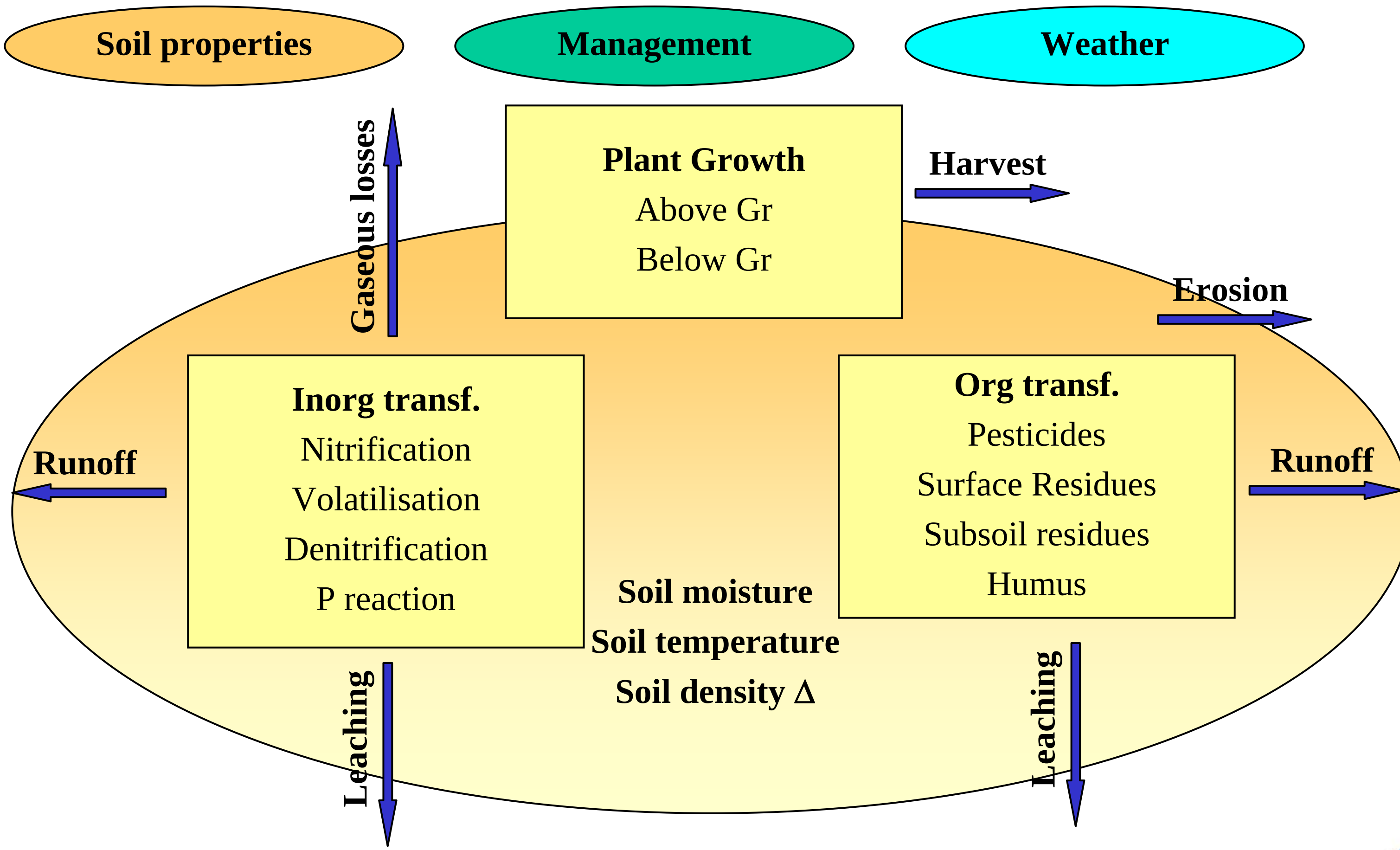
MAXIMUM_TEMPERATURE	Maximum temperature (°C)
MINIMUM_TEMPERATURE	Minimum temperature (°C)
VAPOR PRESSURE	Mean daily vapour pressure (hPa)
WINDSPEED	Mean daily winds peed at 10m (m/s)
RAINFALL	Mean daily rainfall (mm)
E0	Penman pot. evap. from free water surface(mm/day)
ES0	Penman pot evap from a moist bare surface (mm/day)
ET0	Penman pot. transp. from a crop canopy (mm/day)
CALCULATED_RADIATION	Daily global radiation in $KJ/m^2/day$
SNOW_DEPTH	Daily mean snow depth in cm

Monthly data

TMX	Average monthly maximum temperature (°C)
TMN	Average monthly minimum temperature (°C)
SDMX	Monthly av. std. deviation of daily maximum temperature (°C)
SDMN	Monthly av. std. deviation of daily minimum temperature (°C)
PRCP	Average monthly precipitation (mm)
SDRF	Monthly standard deviation of daily precipitation (mm)
SKRF	Monthly skew coefficient for daily precipitation
PW|D	Monthly probability of dry day after wet day
PW|W	Monthly probability of wet day after wet day
DAYP	Average number of days of rain per month
RAD	Average monthly solar radiation (MJ/m2)
RHUM	Monthly average relative humidity (fraction)

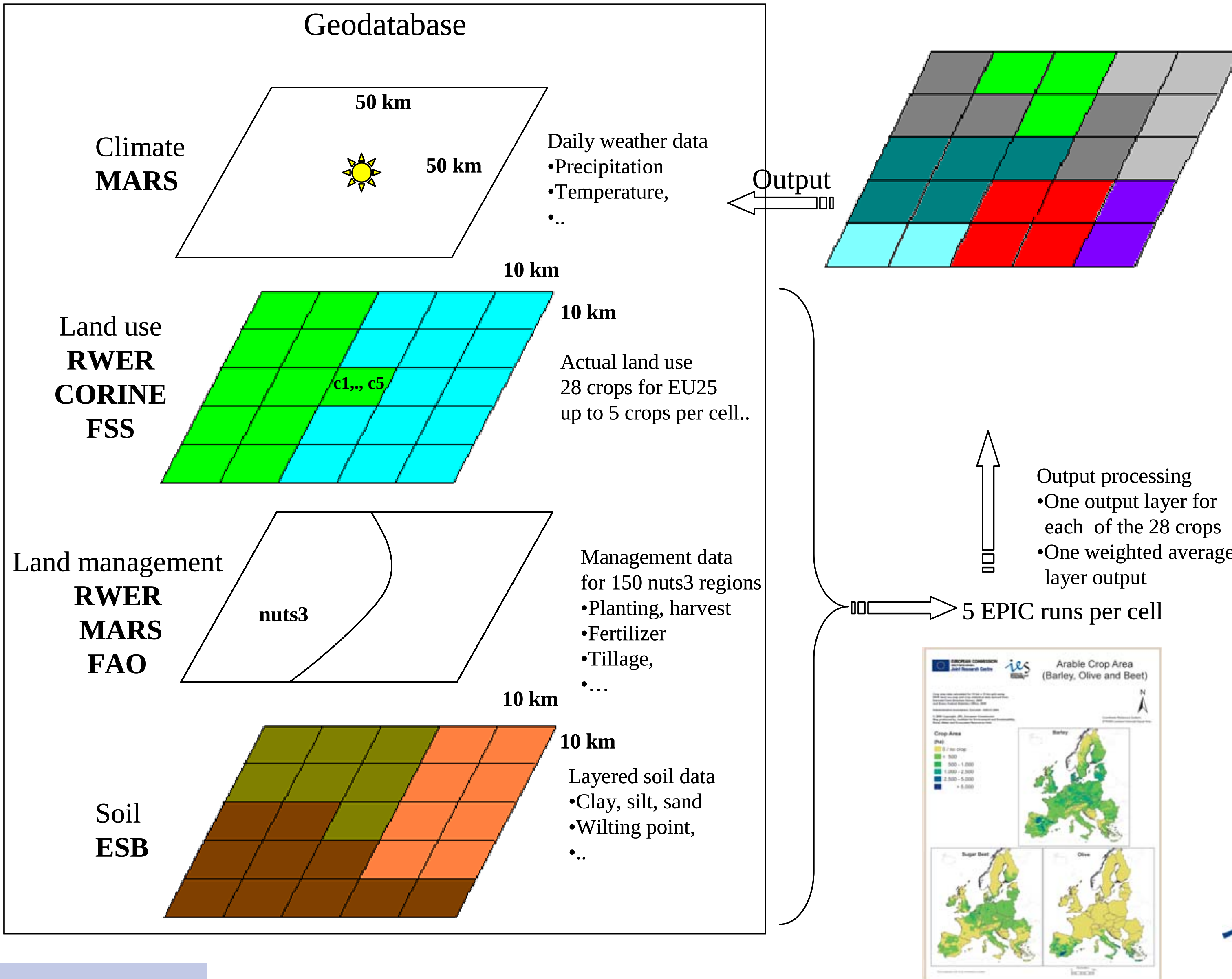
EPIC

A continuous simulation model that can be used to determine the effect of management strategies on agricultural production and soil and water resources



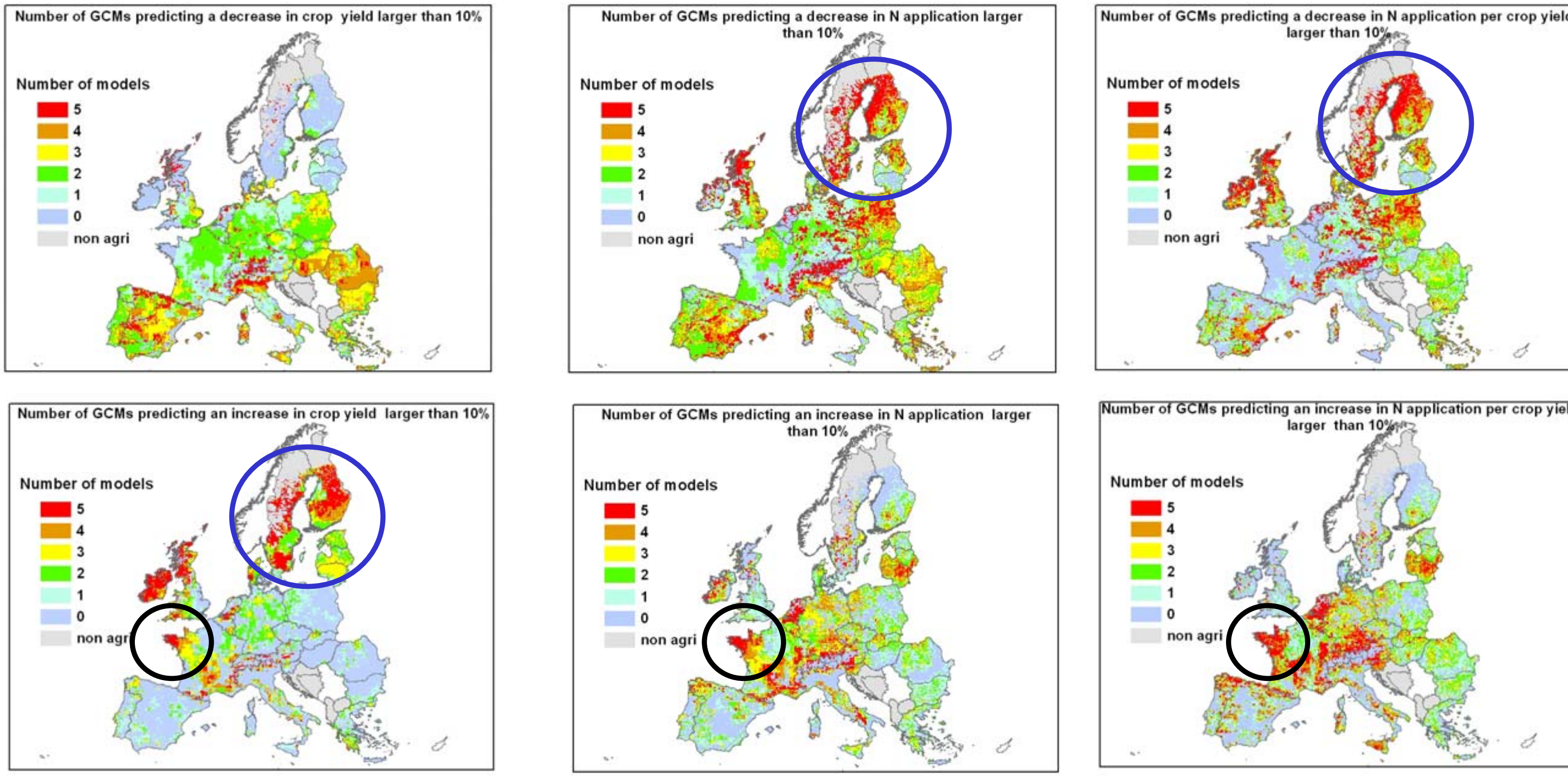
Izauralde, R.C. Simulating Soil Carbon Dynamics, Erosion, and Tillage with EPIC

EPIC-EAGLE: GIS link (Bouraoui & Aloe)



Climate Change results: N use efficiency

A1



Tasks

Three main tasks:

1. Calibrate EPIC-EAGLE for crop yields across Europe to perform reliable crop yield modelling

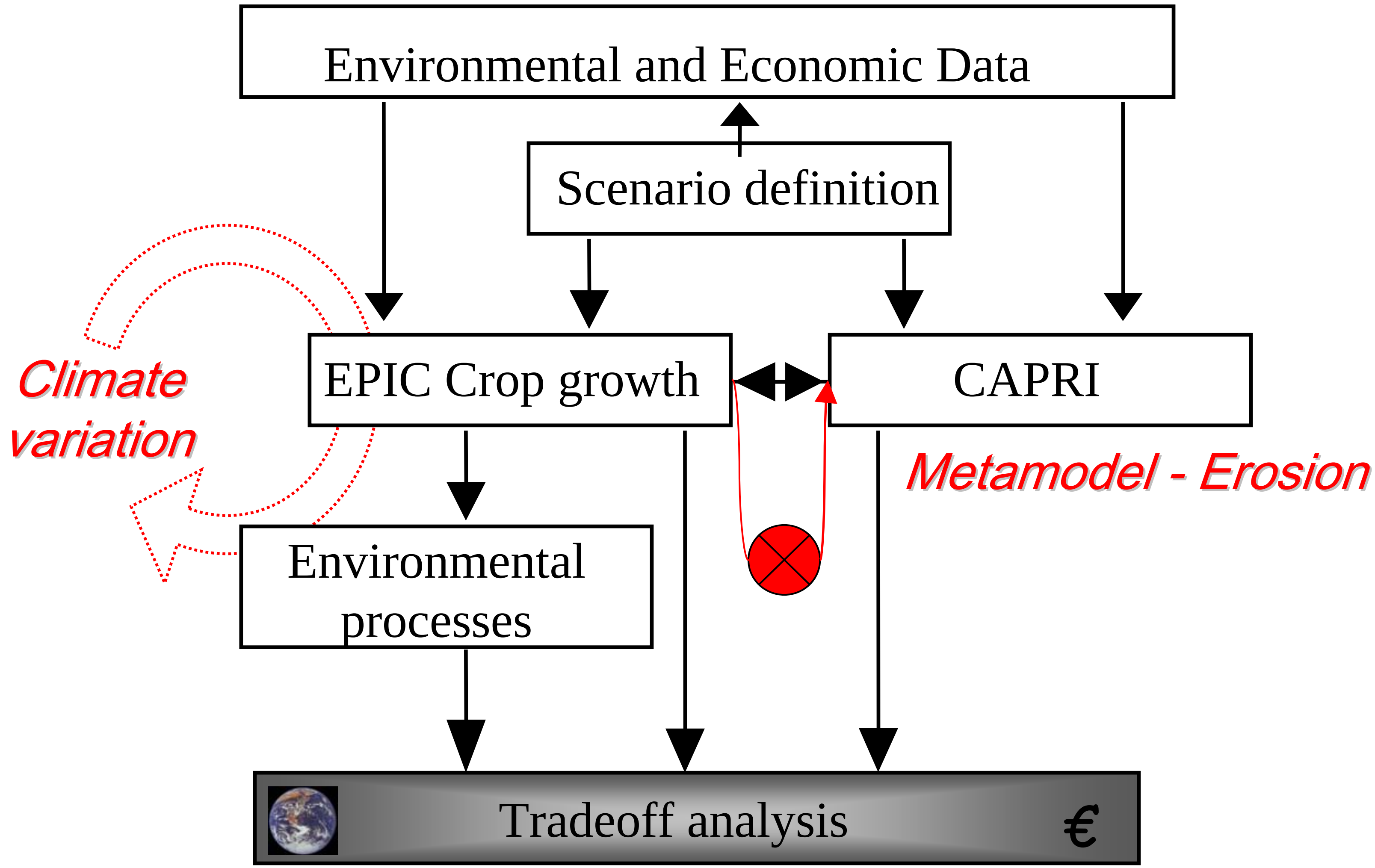
$$\phi(\alpha) = \sum_{i=1}^{N} \left(CY_{i,simulated}^{-1} - CY_{i,observed}^{-1} \right)^2$$

2. Develop EPIC output to create a metamodel for erosion and crop growth and nutrient uptake (CCAT)

$$crop \quad growth = f(x, s, tc; u)$$

3. Which GAEC and SMR's can be implemented.. The erosion model will be a function of (crop rotation,

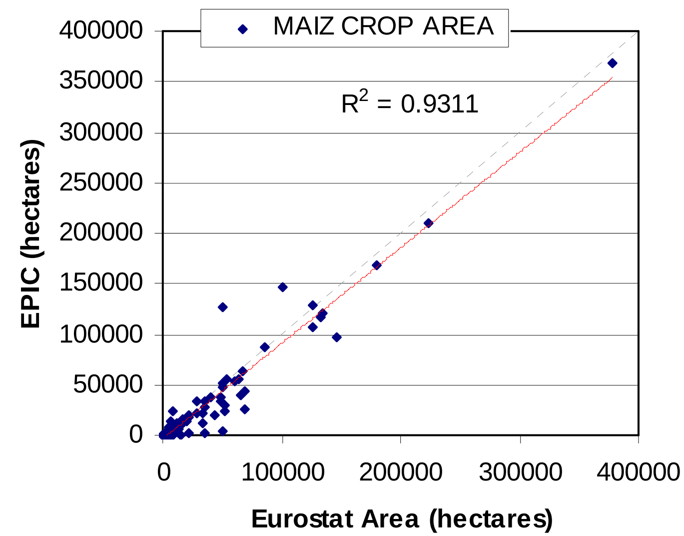
Outline of Approach



EPIC model - EUROSTAT measurements

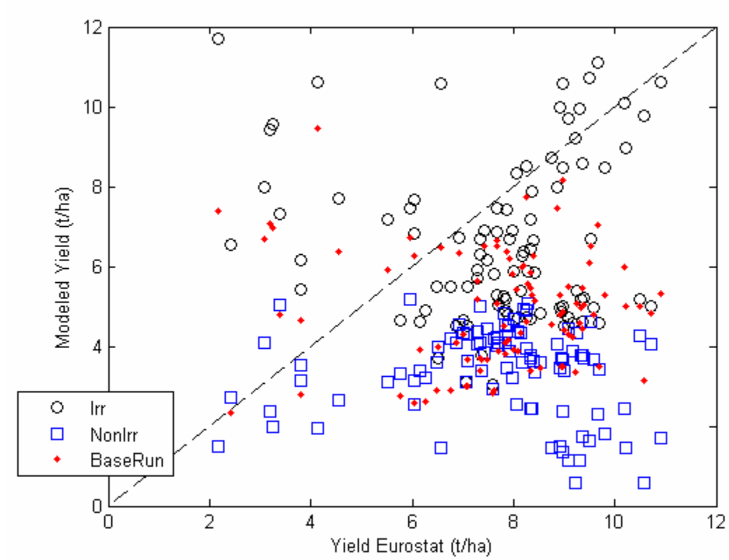
NUTS 2 Level DATA per CROP
(Average of 1990-2004)

- AREA
- PRODUCTION
- YIELD



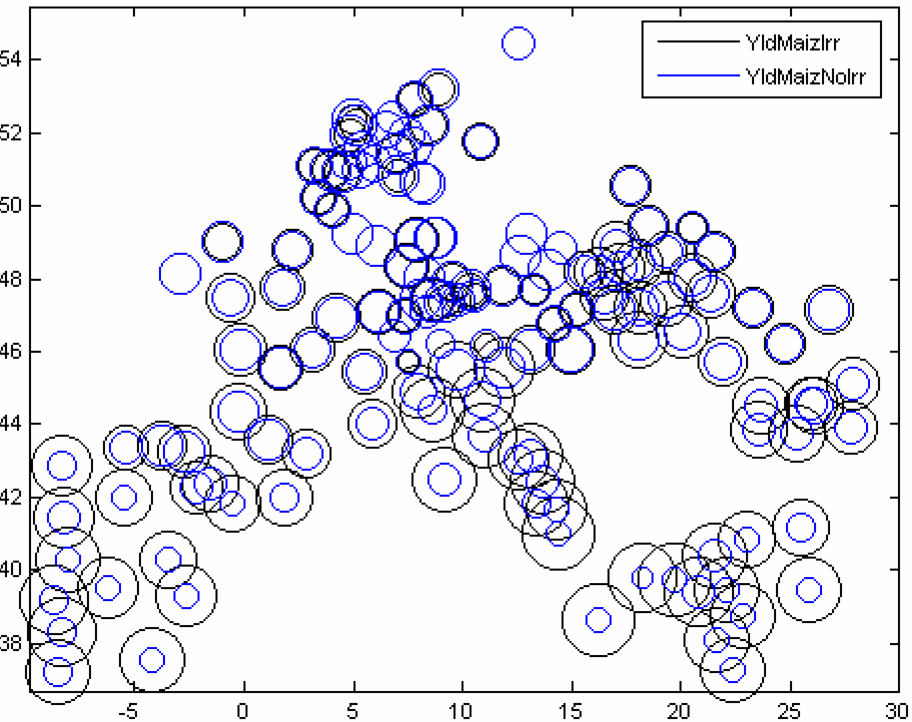
Maize

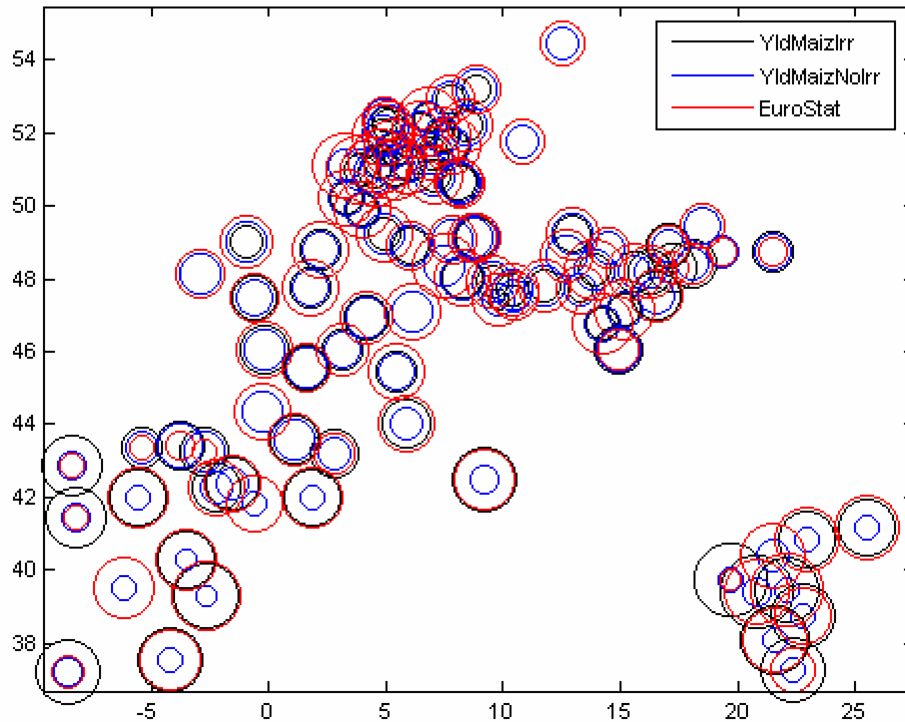
Three Scenarios:
1. No Irrigation
2. No Waterstress
3. 'Base run'



EPIC model – Maize @ NUTS2

EPIC model – Wide Range in Yield and Water Requirement





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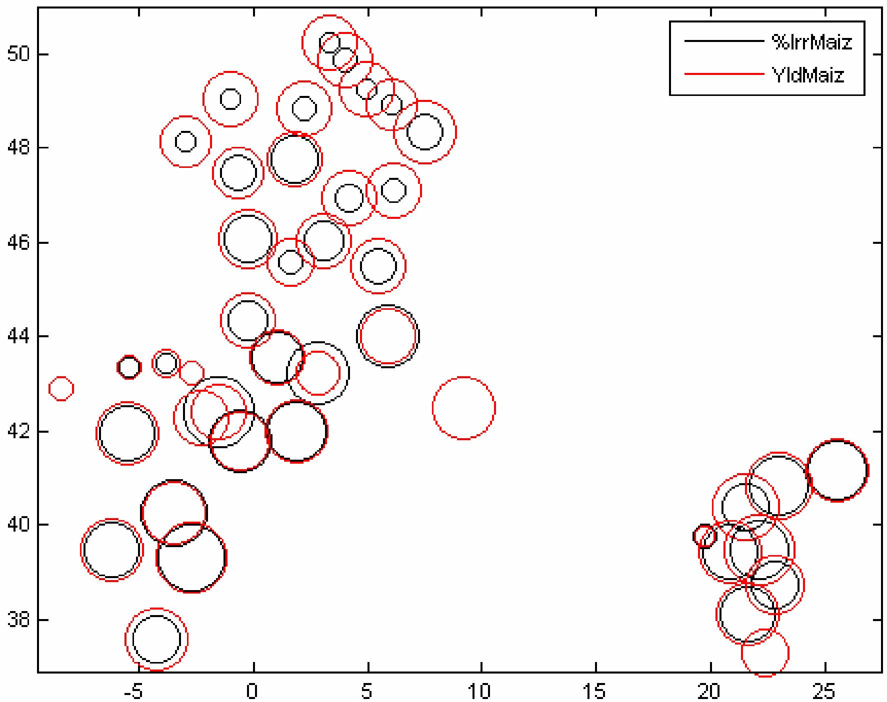
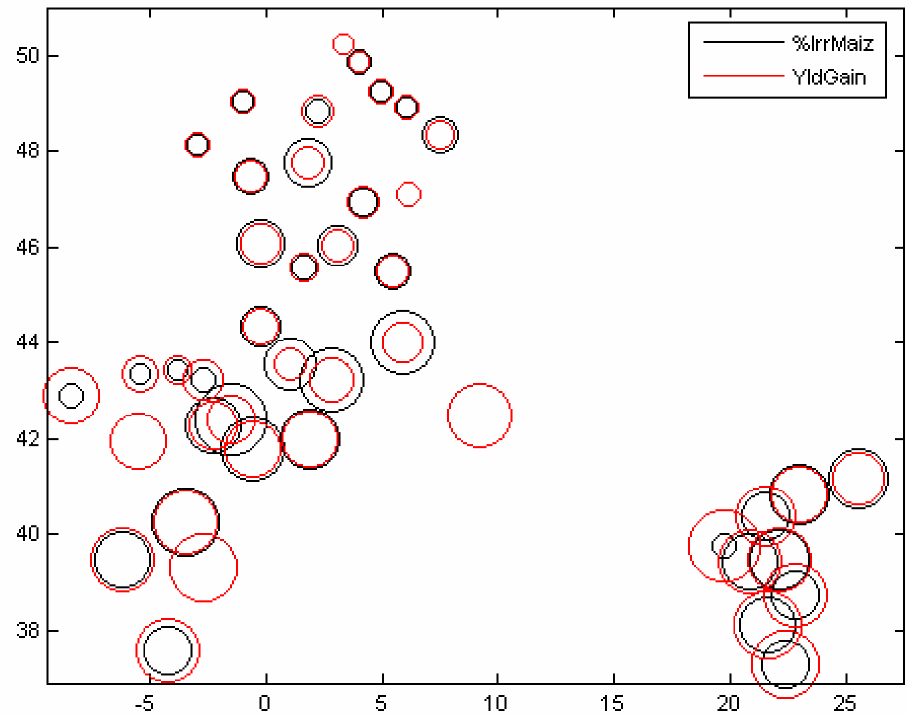
EPIC model – Maize Irrigation NUTS2

IRINA 10



EPIC Yield 'Gain' and Actual Irr



Need for irrigation to be considered spatially…

EPIC metamodels

YIELD as a function of precipitation, NO3 fertiliser, Evapotranspiration

Y=x*AvgOfPRCP+y*AvgOfFNO3+z*AvgOfET;

EROSION as a function of Sand, Silt, Clay, OM, Runoff, Slope
% Simplified EPIC calculation Y = chi(K)(CE)(PE)(LS)(ROKF)

SN1 = (1-AvgOfSLPSAND./100);

K = (0.2+0.3*exp(-0.0256*AvgOfSLPSAND.* (1-AvgOfSLPSILT./100))).*
((AvgOfSLPSILT./(AvgOfSLPSILT+AvgOfSLPCLAY)).^0.3).*...
(1-(0.25*AvgOfOMTOP./(AvgOfOMTOP+exp(3.72-2.95*AvgOfOMTOP)))).* (1-
(0.7*SN1./(SN1+exp(-5.51+22.9*SN1))));

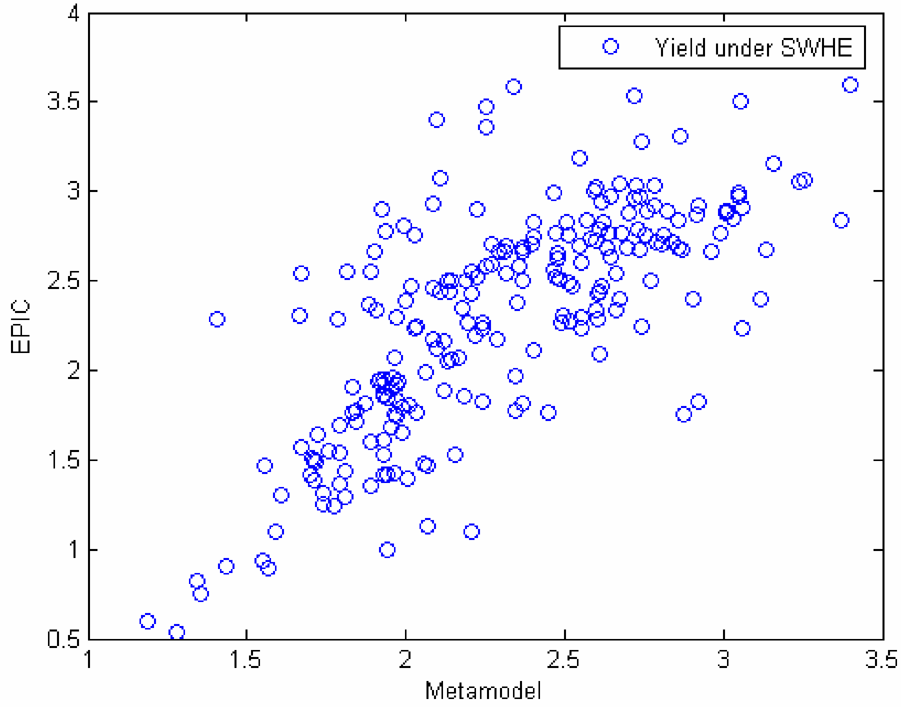
E=(x*AvgOfQ1.^y).*(z*AvgOfSLOPE.^2).*K;

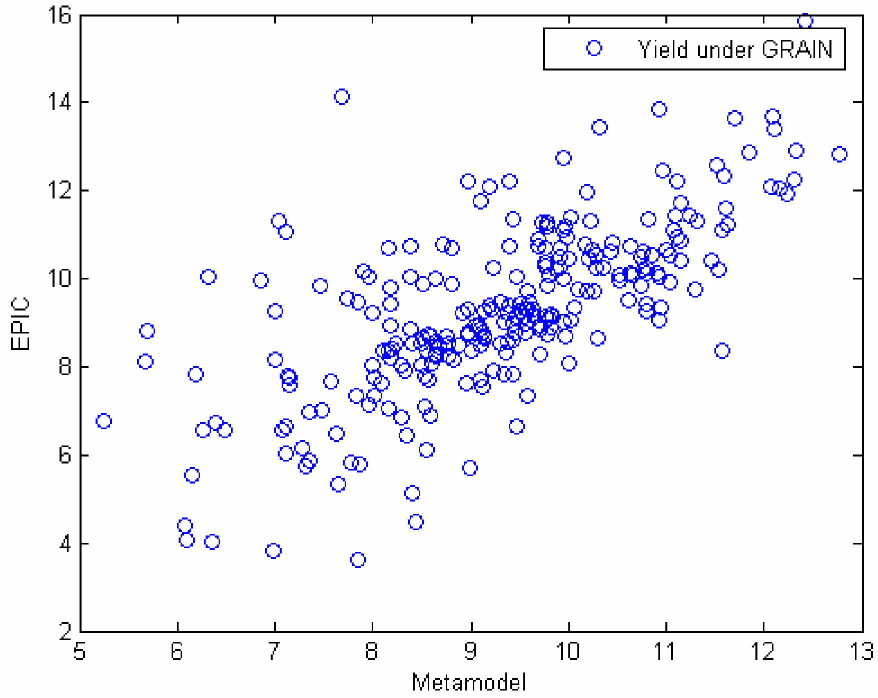
MINIMIZE OBJECTIVE FUNCTION (abs(EUROSTAT_NUTS2_YIELD-EPIC_NUTS2_YIELD)^2;

$$\phi(\alpha) = \sum_{i=1}^{N} \left(CY_{i,simulated}^{-1} - CY_{i,observed}^{-1} \right)^2$$

Using Nelder-Mead simplex algorithm in MatLab

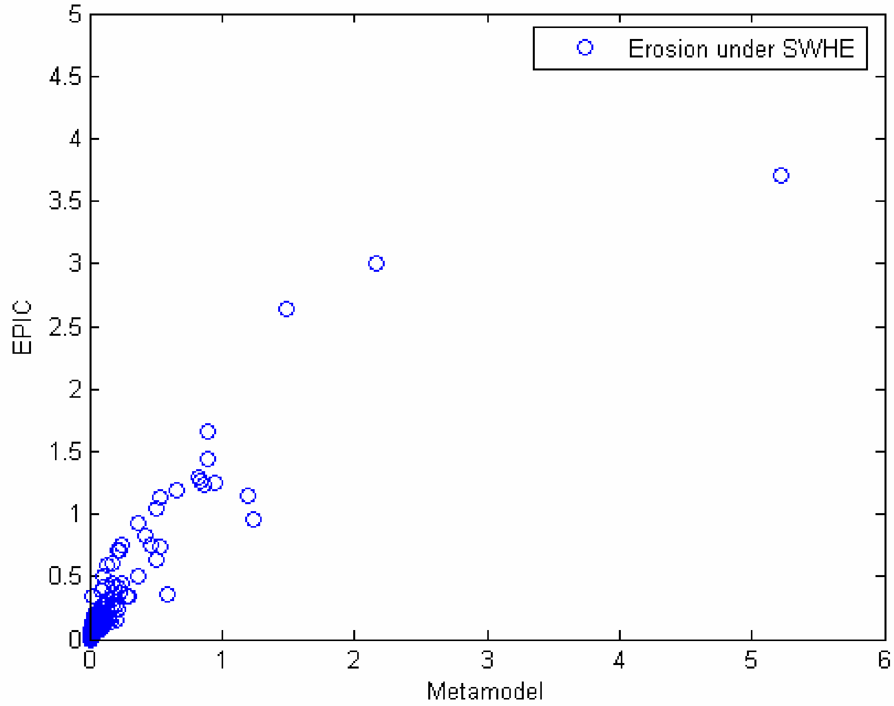
YIELD - NUTS2





- Replication of complex model relatively well presented with three parameters

EROSION – NUTS2



- Once model is calibrated metamodel definition should not be a huge task
- Aggregated on HSMU level if desired
- Use pure statistical method of Wolfgang Britz to derive metamodels

EPIC in CCAT

- Aggregation to HSMU level possible
- Aggregation to yearly time step (MITERRA) possible
- Current calibration and validation status needs improvement
- Yields > nutrient balances
- Erosion > IRINA 25
- Erosion possible problem with yearly time step (event based phenomena)
- No pesticides
- Metals?
- P?

CAPRI and EPIC

- Metamodel for Erosion will be incorporated in CAPRI
- Fertalization uses JRC/CAPRI database

EPIC and SMRs and GAEC

1. SMR

   1. Groundwater (Plant protection - but pesticides questionable)
   2. Nitrate (Application time, to steep slopes, N limits per hectare crop and soil specific, rotation rates, winter coverage, heavy metals)
   3. Sewage Sludge (Application restrictions)

2. GAEC - Subsidiary

   1. Soil erosion (Set aside,)
   2. Soil organic matter (Crop rotations)
   3. Soil structure

Cross compliance issues

- Operation of policy tool clear to all farmers? Compliance rates..
- Choose of non-compliance, penalties not severe enough?
- Definition of GAEC is largely left to MS in the spirit of subsidiarity

Expected outcomes

1. Calibration of EPIC-EAGLE for crop yields across Europe
2. Development of a EPIC nutrient metamodel for CCAT
3. Development of a EPIC erosion metamodel for CCAT

Thank you for your attention!