Experience with the use of different model types within an interactive decision support system to climate change adaptation of agriculture

K.-O. Wenkel [1], M. Berg [1], W. Mirschel [1], R. Wieland [1], B. Köstner [2]

[1] Institute of Landscape Systems Analysis of the Leibniz Centre for Agricultural Landscape Research, Muencheberg (Germany)
[2] Technical University Dresden, Institute of Hydrology and Meteorology

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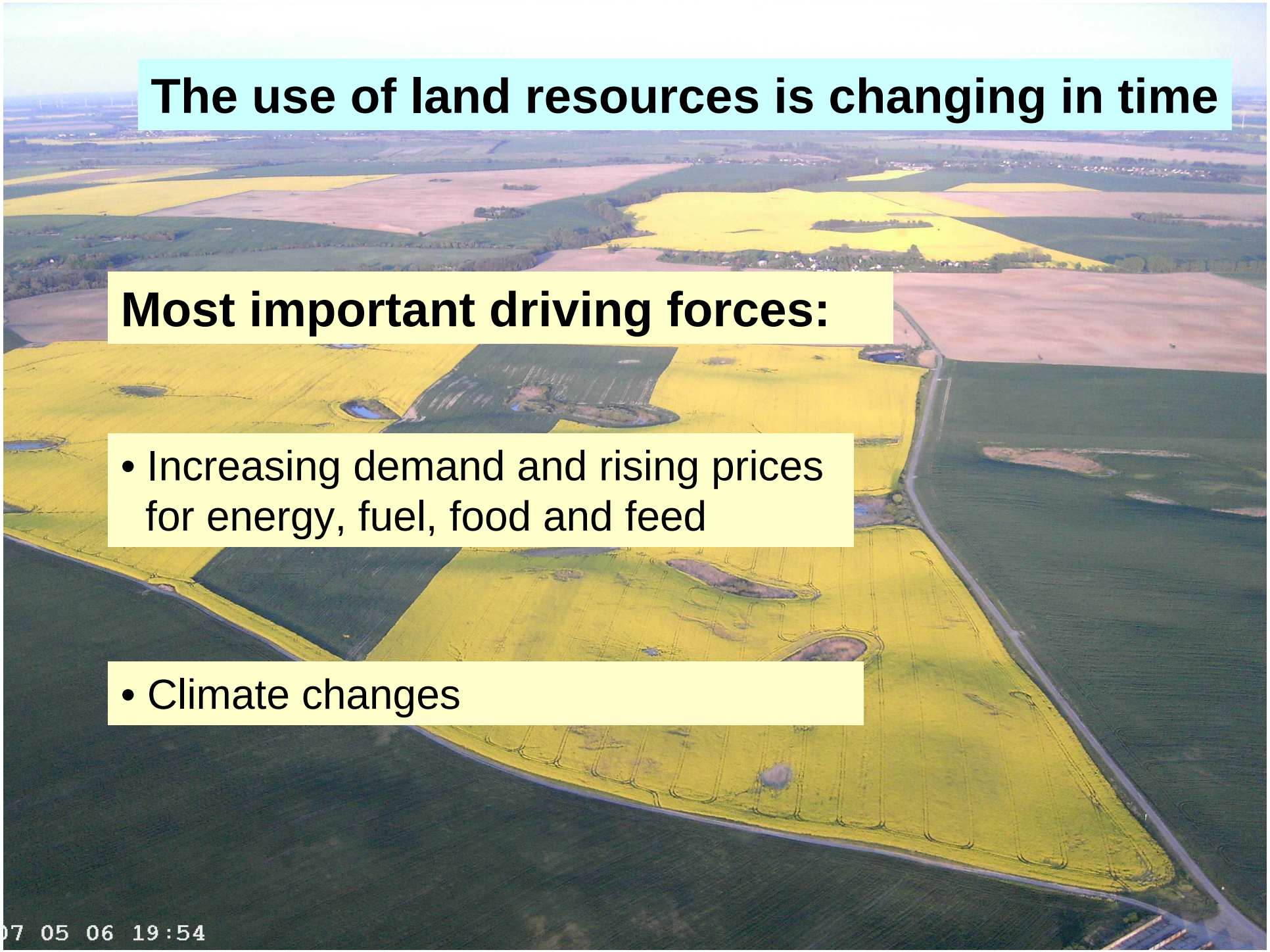
The use of land resources is changing in time



The use of land resources is changing in time

Most important driving forces:

- Increasing demand and rising prices for energy, fuel, food and feed

- Climate changes

What we can observe in the last years?

- **Trend to closer crop rotations**
  (concentration on a few cash and energy crops)
- **Large scale forest conversion**
  (from pure to mixed forest stands)
- **Change of the tillage system in agriculture**
  (from conventional to no-tillage system)
- **Increasing interest to irrigation**

→ **Land Cover changes are rather seldom !**

The central questions for the future:

How we can manage our regional land and water resources in a sustainable way ?

What are the best management practices to converge to this ambitious objective ?

Prerequisites for a sustainable resources management:

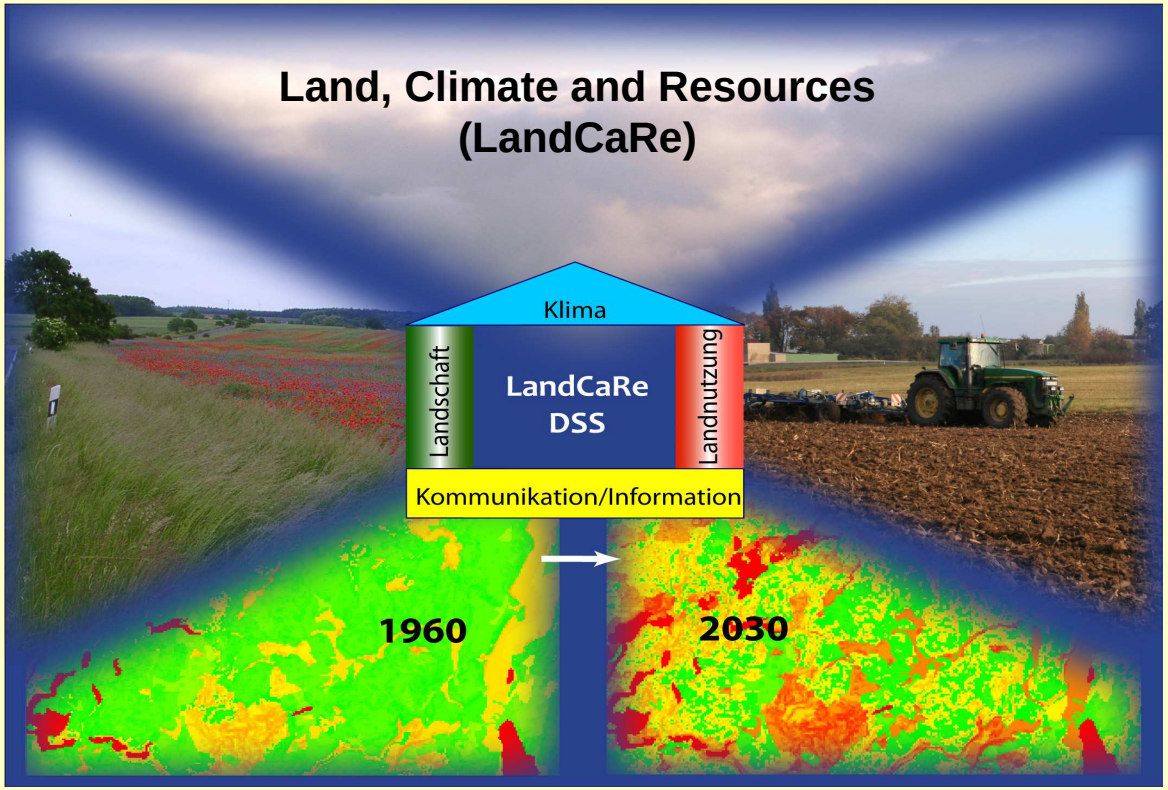
- **Better knowledge on landscape functions**
- **Better skills and tools for the integrated impact assessment of land use and climate changes**
- **New generations of interactive usable decision support systems to support sustainable resources management**

In general we can distinguish two types of DSS:

- DSS which are based on models, which discribe the impacts of changes qualitative (mostly expert or rule based models).
- DSS which are based on process oriented or statistical mathematical models (quantitative models).

LandCaRe-DSS

An interactive usable GIS and model-based knowledge and decision support system for climate change impact assessment and adaptation of agriculture to climate change



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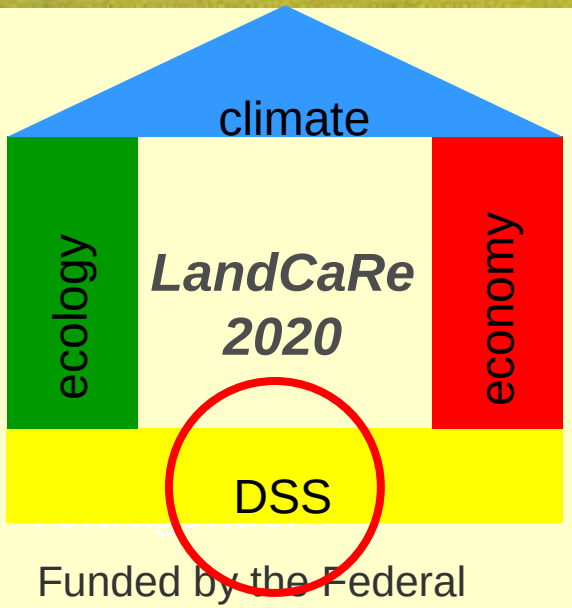
The Project LandCaRe 2020



Funded by the Federal Ministry for Education and Research, Germany

LandCaRe 2020: Land, Climate and Resources – Foresight and Potentials in Rural Areas under Regional Climate Change
(managed by Barbara Koestner, TU Dresden)

Interdisciplinary project conducted by 5 German institutions

including the research fields of

meteorology, ecology, agronomy, socio-economy, modelling and computer science

Duration of Project:

Nov 2006 – March 2010

Some remarks to the concept of the LandCaRe-DSS in general

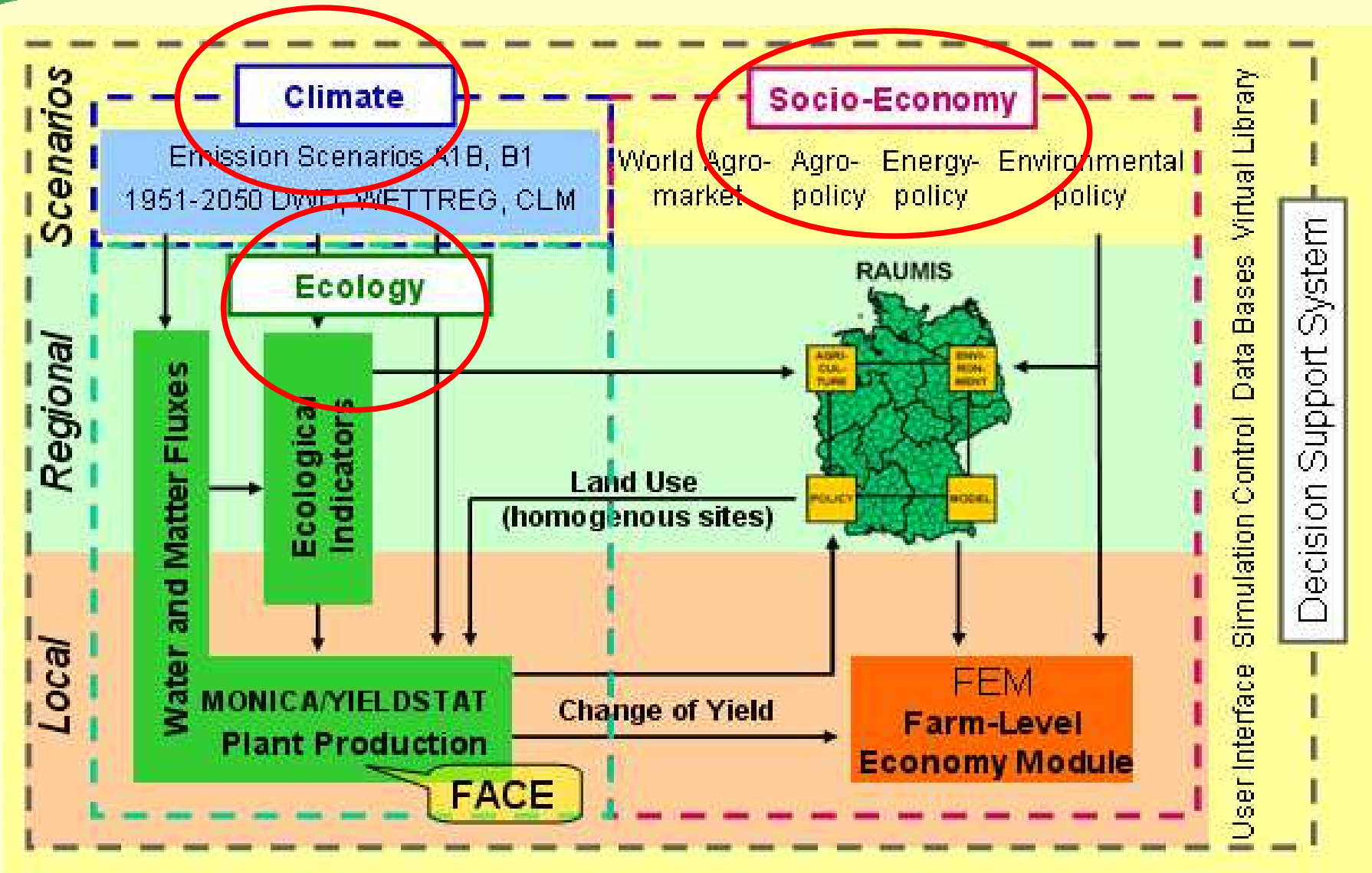
Central Objective of the LandCaRe-DSS

The LandCaRe-DSS is a GIS and model based information and decision support system for strategic planning to support farmers and regional stakeholders to find cost effective solutions to adapt the agriculture on climate change in rural areas

It provide

- **improved knowledge on the past and future climate change in the respective region**
- **assessment of the potential ecological and economical impacts of climate change on farm and regional scale**
- **knowledge on potential agricultural climate adaptation strategies**
- **suitable tools for interactive simulations to compare alternative climate change adaptation strategies for agriculture**

LandCaRe-DSS – overview (oversimplified)



Model - GIS - Coupling

GIS maps

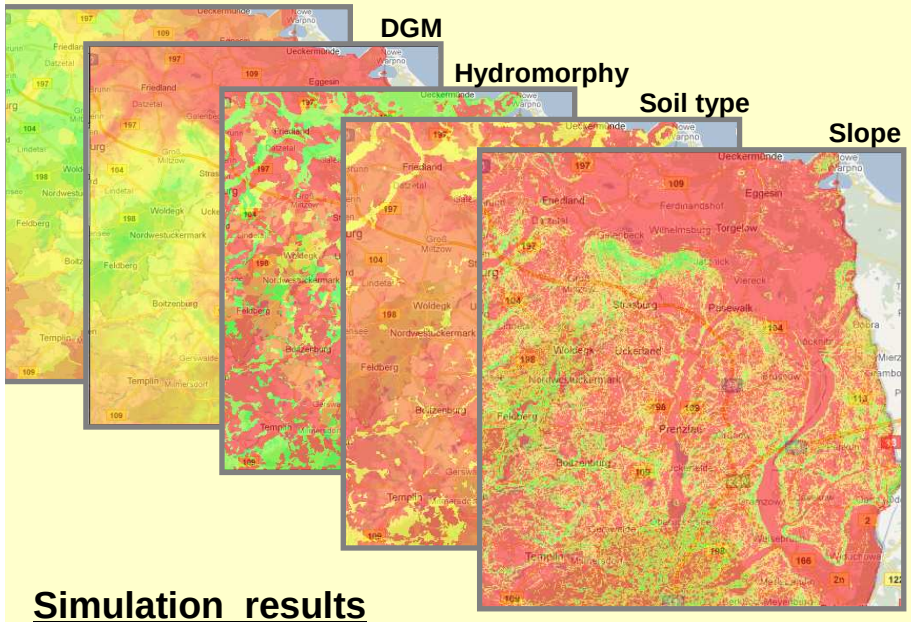
Soil quality index

DGM

Hydromorphy

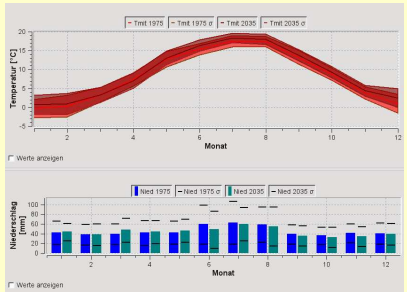
Soil type

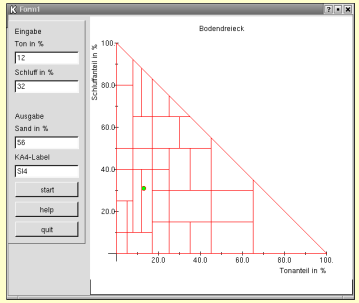
Slope



GIS-Interface

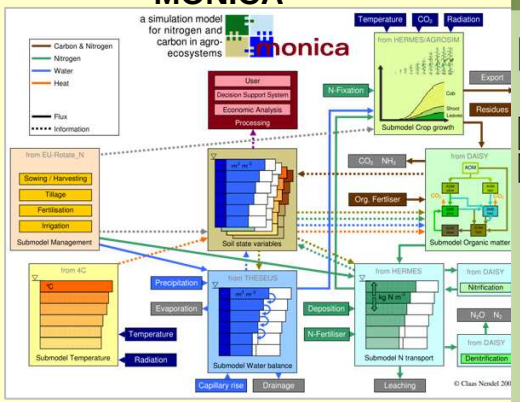
Weather/Climate, Parameter, Management



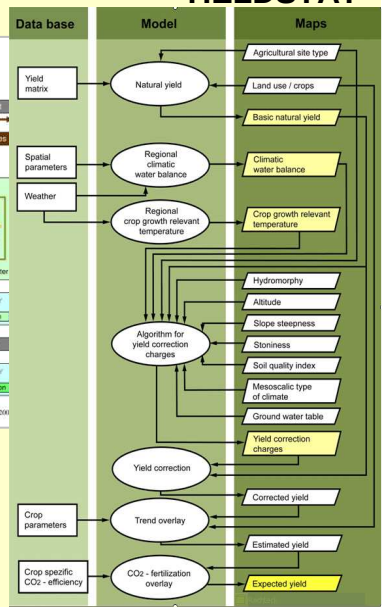


LandCaRe-DSS models

MONICA



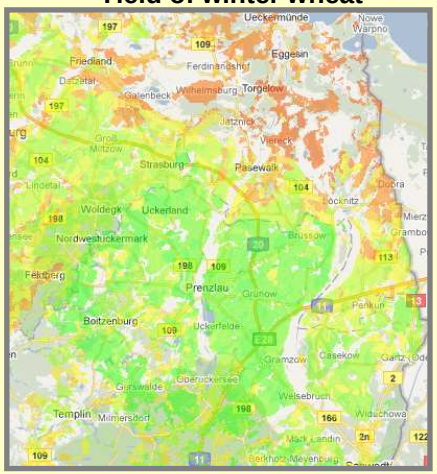
YIELDSTAT



GIS-Interface

Simulation results

Yield of winter wheat



Irrigation water demand

LandCaRe-DSS - main characteristics

- **Interactive** (the user decides which simulations and calculations to execute and runs almost all models by himself)
- **Dynamic** (a large variety of simulations can be run, analysed and compared by the user. The chosen preconditions will affect the simulation result)
- **Spatial-oriented** (the user chooses the desired level of detail by zooming between regional or farm level. Based on this choice different models will be activated for execution)
- **Web-based** (central support, control and update of the entire DSS software and all supporting data)
- **Extendable** (open for further add-ons; frequent update of information, knowledge and data)

LandCare-DSS works with different climate scenarios and different regionalization methods (WETTREG; STAR; CLM)

One of the most important problems in terms of climate impact assessment and decision support:

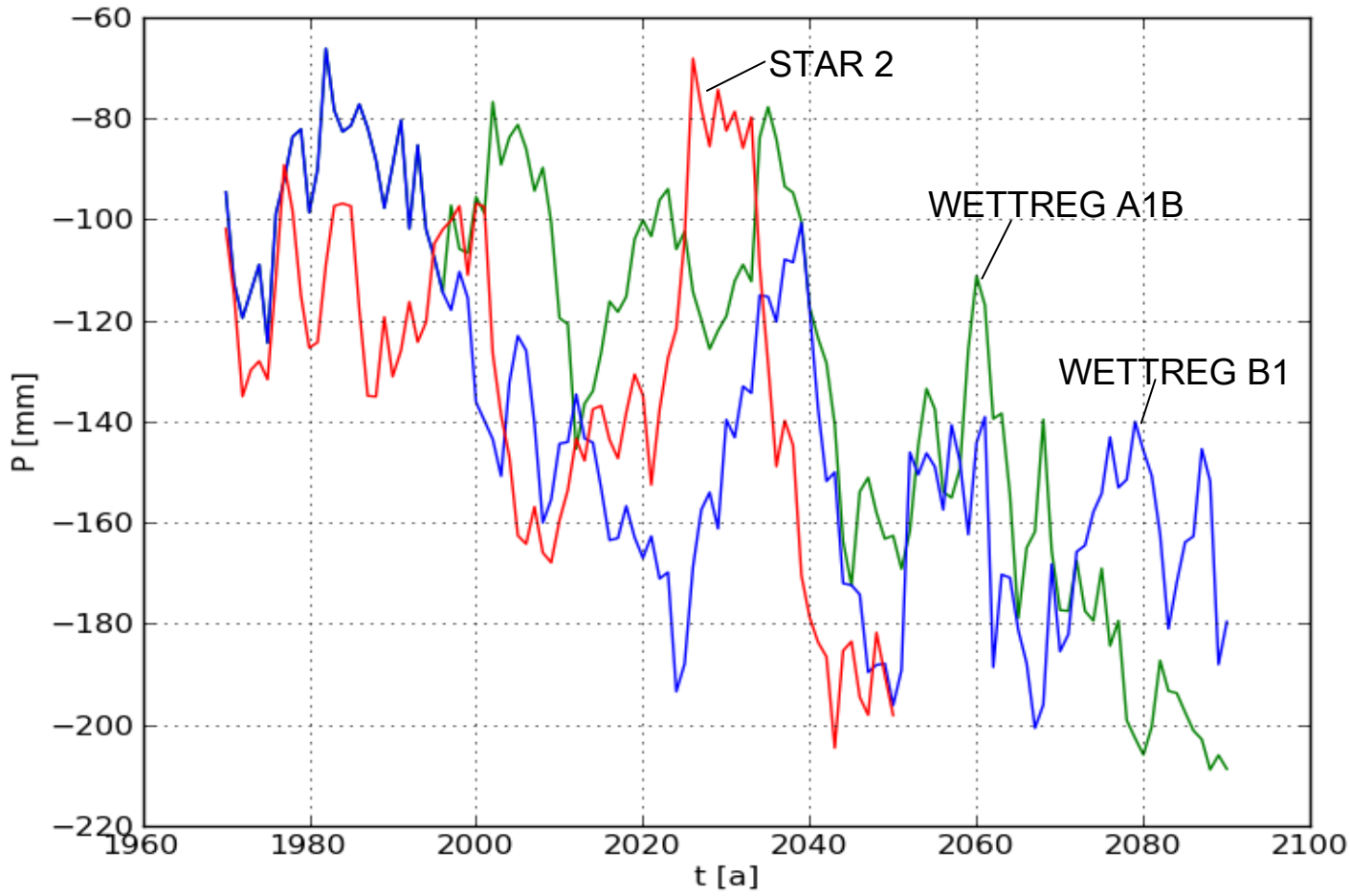
Exposure and dissemination of uncertainties

Solution for this problem:

Multi-Ensemble and Multi-Model Simulations

Projection of the development of climatic water balance by use of different climate regionalization methods and different climate scenarios

Excample: Meteorol. Station Dresden -Klotzsche



Overview of the impact assessment models used in the LandCaRe-DSS

Model	Model type	Spatial resolution	Spatial application level		
			Country	Region	Farm
RAUMIS (yield)	empiric-statistical	municipal	x		
RAUMIS (irrigation water demand)	dynamic	municipal	x		
BAGLUVA (evapotranspiration, recharge)	dynamic-statistical	100x100 m		x	x
EROSION (erosion risk)	empiric-statistical	100x100 m		x	x
ZUWABE (irrigation water demand)	dynamic-statistical	100x100 m		x	x
LANUVER (land use distribution)	stochastic-statistical	100x100 m		x	
ONTO (ontogenesis for arable crops)	statistical	clime	x	x	x
PHAENO (phenology for wild plants)	statistical	clime	x	x	
VEGPER (duration of vegetation period)	dynamic	clime	x	x	x
GL-PROD (grassland yield, quality)	empiric-statistical	100x100 m		x	x
YIELDSTAT (crop yield)	dynamic-statistical	100x100 m		x	x
MONICA (agro-ecosystem as a complexe)	dynamic	100x100 m			x
EÖM (farm economy calculator)	economic calculator	100x100 m			x

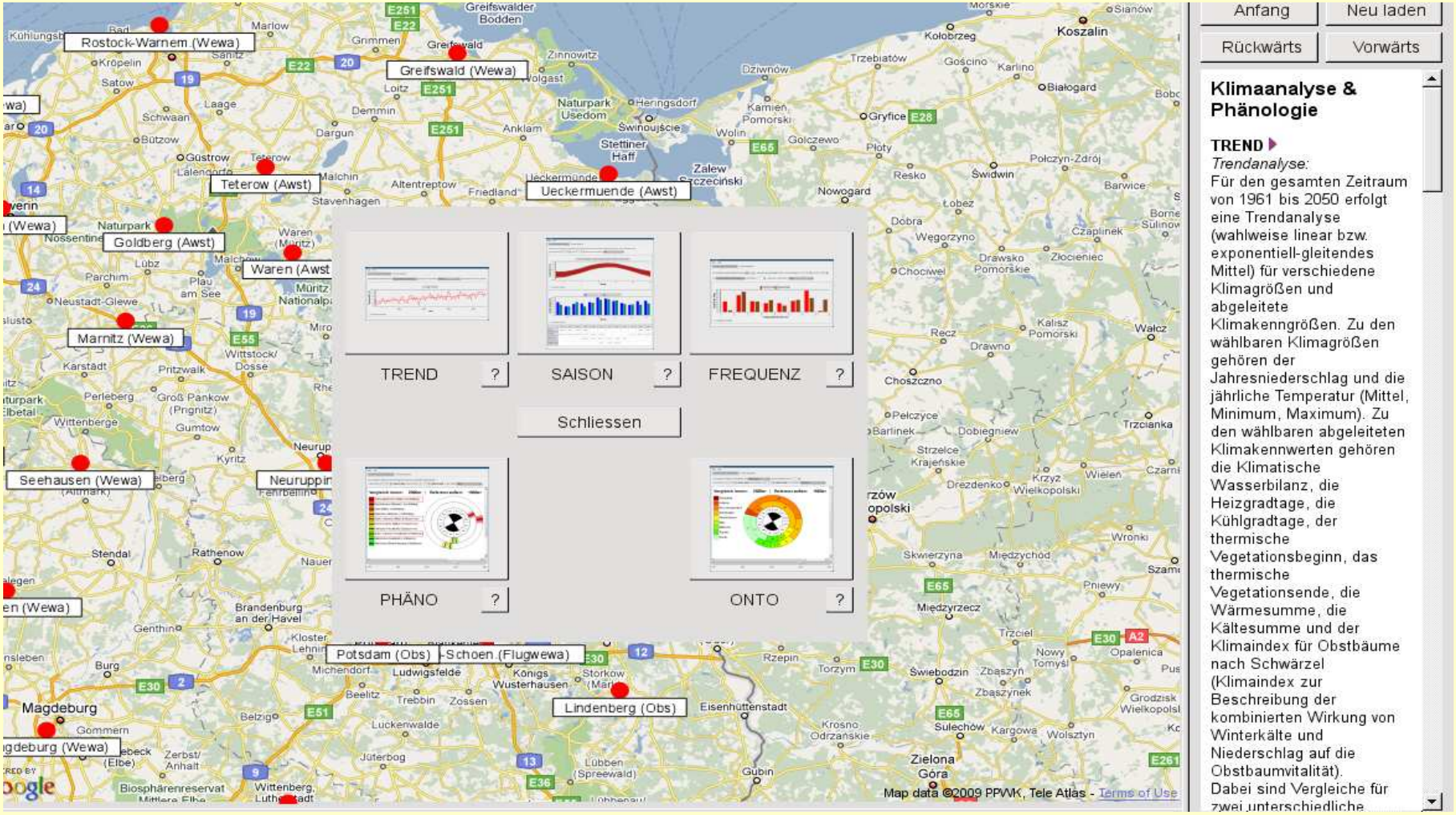
11 models are integrated up to now

Software solution

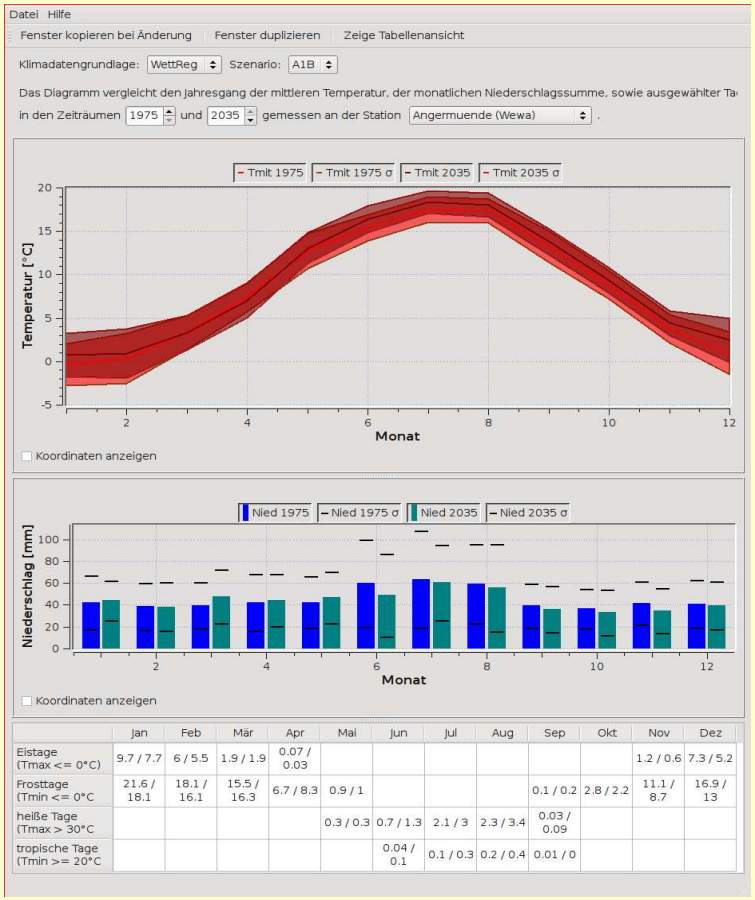
- The DSS is programmed as Open Source in C++ and use Open Source Software (QT, GSL, HDF, ...) so much as possible.
- Besides the traditionally “Windows Icon Menu Pointing Interface” (WIMP) we use a further User Interface, the “Zooming User Interface (ZUI)“.
- The LandCaRe-DSS prototype was developed by the ZALF-research group. The transfer into a Web-based DSS system was realized by the Living-Logic company (Bayreuth).

Some short virtual impressions of the LandCare-DSS

Real-time analysis of climate data (climate projections) and simulated impacts on plant phenology

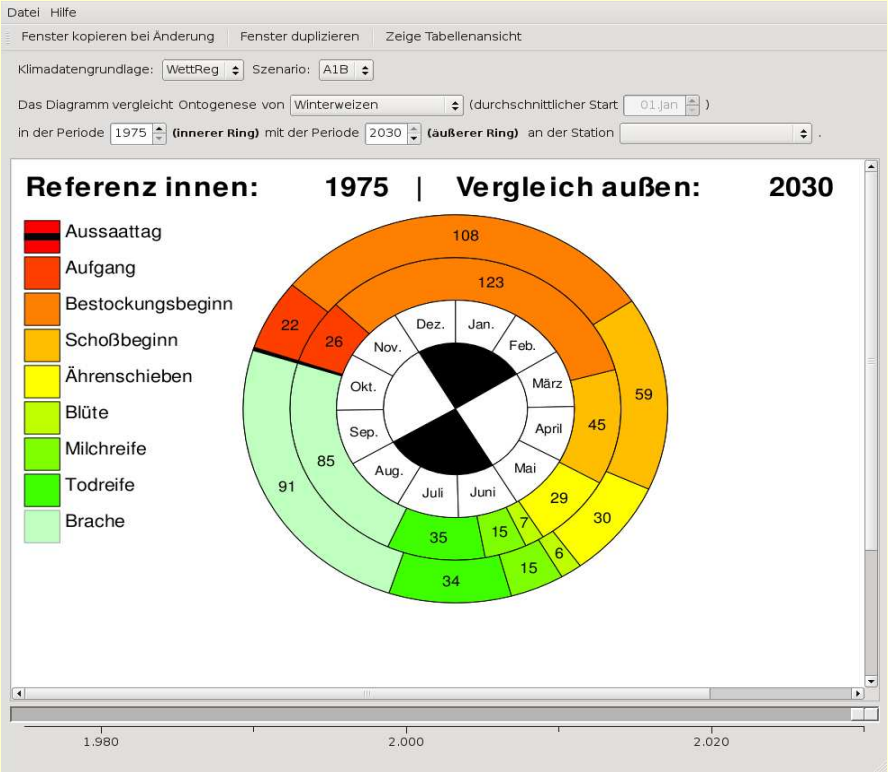


Analysis of regional climate, climate change and impacts on plant phenology (more in detail)



	Jan	Feb	Mär	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
Eistage (Tmax <= 0°C)	9.7 / 7.7	6 / 5.5	1.9 / 1.9	0.07 / 0.03							1.2 / 0.6	7.3 / 5.2
Frosttage (Tmin <= 0°C	21.6 / 18.1	18.1 / 16.1	15.5 / 16.3	6.7 / 8.3	0.9 / 1				0.1 / 0.2	2.8 / 2.2	11.1 / 8.7	16.9 / 13
heiße Tage (Tmax > 30°C					0.3 / 0.3	0.7 / 1.3	2.1 / 3	2.3 / 3.4	0.03 / 0.09			
tropische Tage (Tmin >= 20°C						0.04 / 0.1	0.1 / 0.3	0.2 / 0.4	0.01 / 0			

Change in temperature, precipitation and other climatic parameters during the whole year

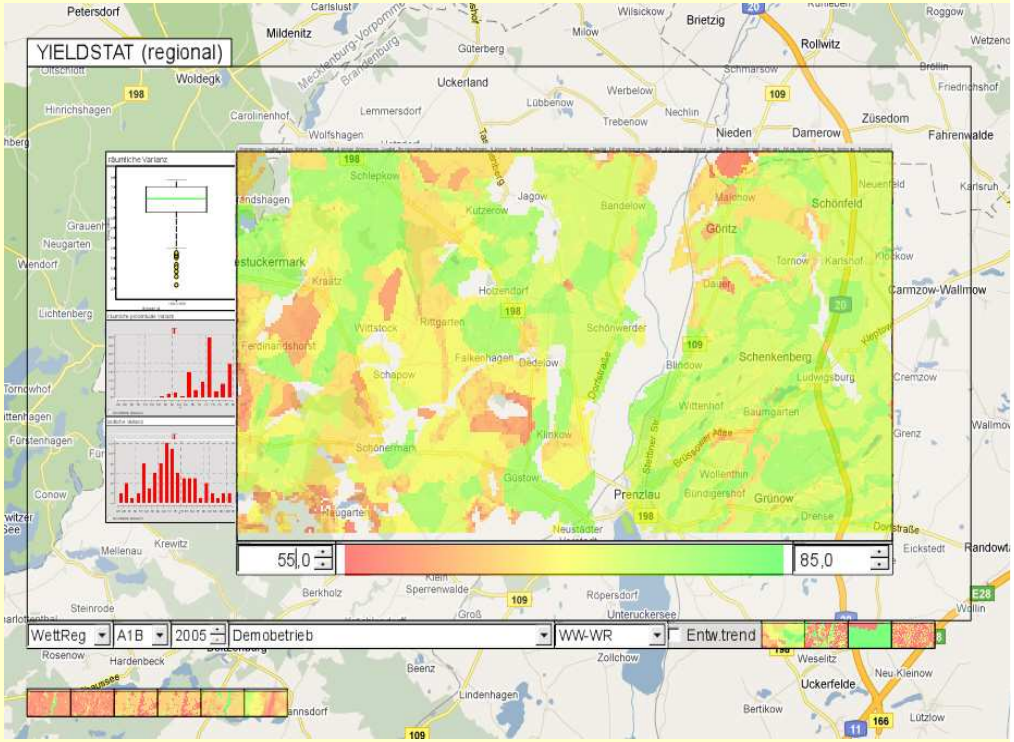


Changes in ontogenesis of winter wheat caused by climate change

LandCaRe-DSS - usage at regional level

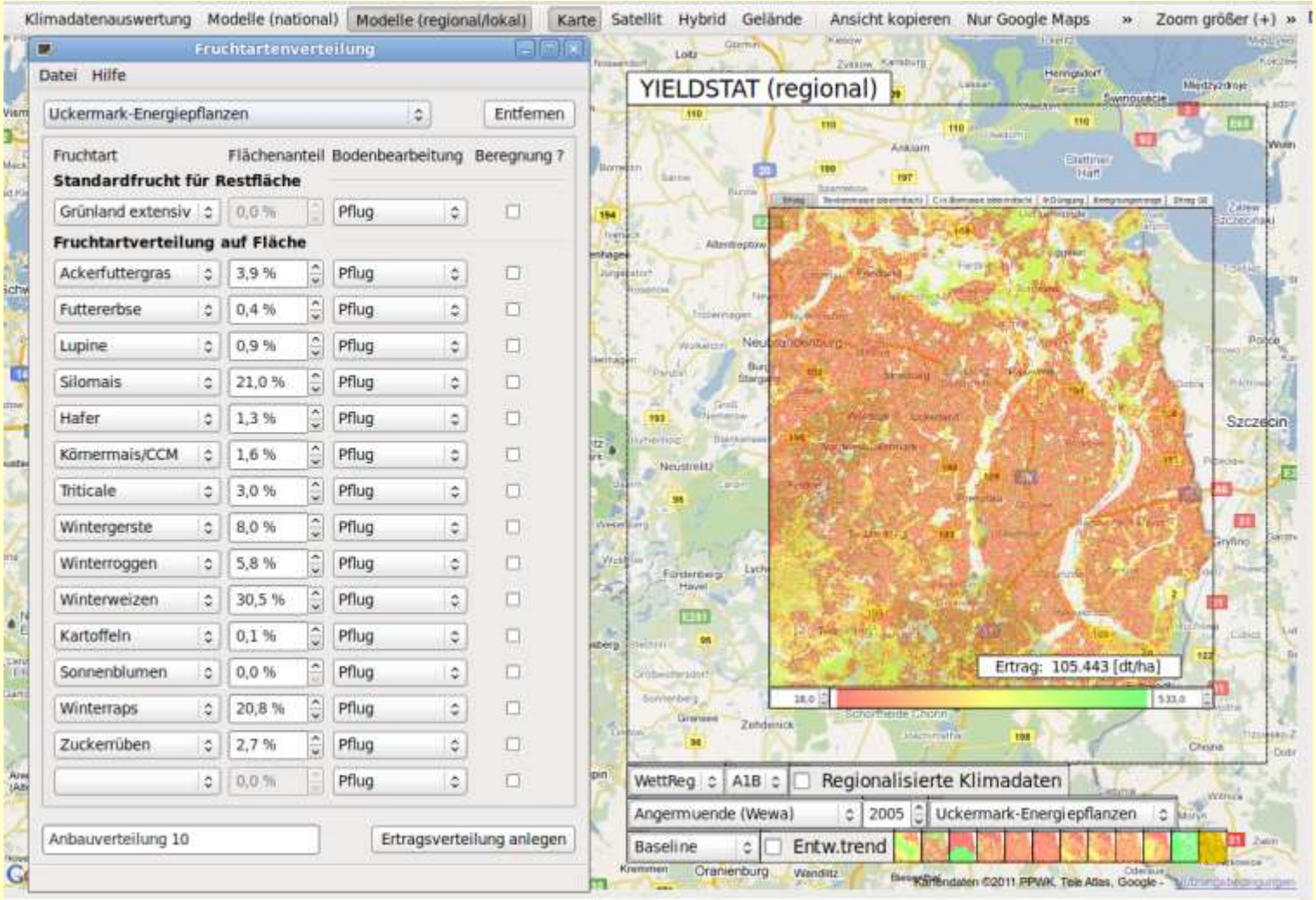
Ecological impact assessment of climate and land use changes on a high spatial resolution (max.250x250m)

- **changes of crop yield on arable land**
- **changes of yields on grassland**
- **changes of potential erosion risk, regional evapotranspiration and ground water recharge**
- **irrigation water demand**



Winter wheat yield calculated for the Prenzlau region, Germany
Regionalisation: WETTREG
Climate scenario: A1B
Climate period: 1991-2020
Crop rotation: winter wheat-winter oilseed rape

Simulation of the probably spatial crop distribution based on a given crop ratio for a selected area



Erosion risk in comparison between conventional and no tillage (WETTREG, scenario A1B)

Year	Uckermark		Weisseritz	
	Conventional tillage	no tillage	conventional tillage	no tillage
	[t/ha]	[t/ha]	[t/ha]	[t/ha]
2005	0,55	0,33	2,42	1,69
2025	0,50	0,32	2,57	1,74
2045	0,45	0,28	2,54	1,68
2075	0,58	0,28	2,91	1,76

Total yield for non-irrigated scenario and irrigated scenario (100% sugar beet and potatoes, 30 % winter wheat and silage maize) and total irrigation water demand for the Weisseritz region taking into account the current cropping ratio

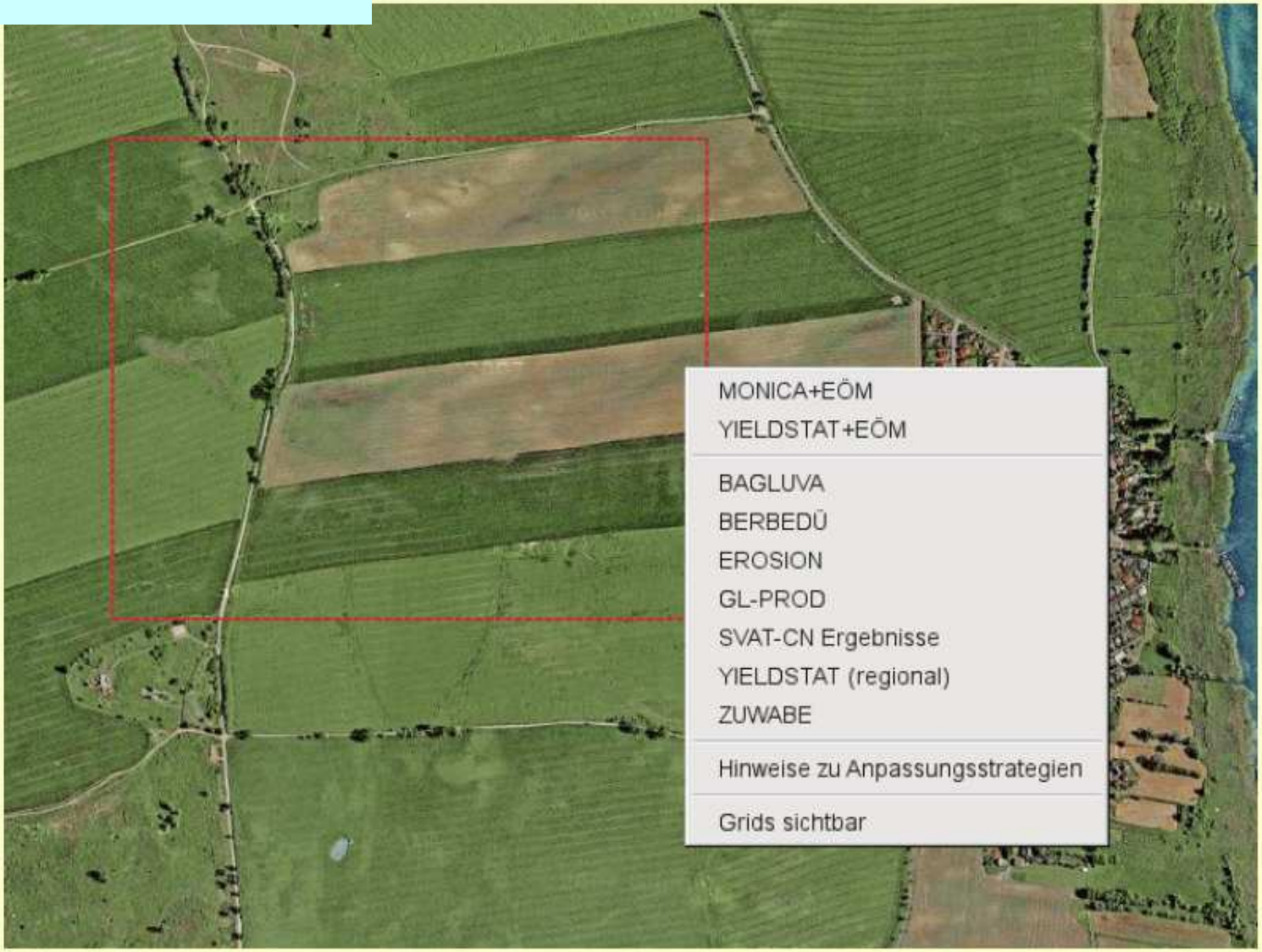
Year	Total yield (non-irrigated) [Mio GEU[1]]	Total yield (irrigated) [Mio GEU[1]]	Yield increase due to irrigation [%]	Mean irrigation water amount on irrigated area [mm/ha]	Total irrigation water demand [Mio m^3]
2005	4,67	4,94	5,7	74	13,77
2025	4,76	5,00	5,1	67	12,44
2045	4,85	5,18	6,9	93	17,17
2075	5,06	5,48	8,4	116	21,53

[1]GEU – grain equal unit

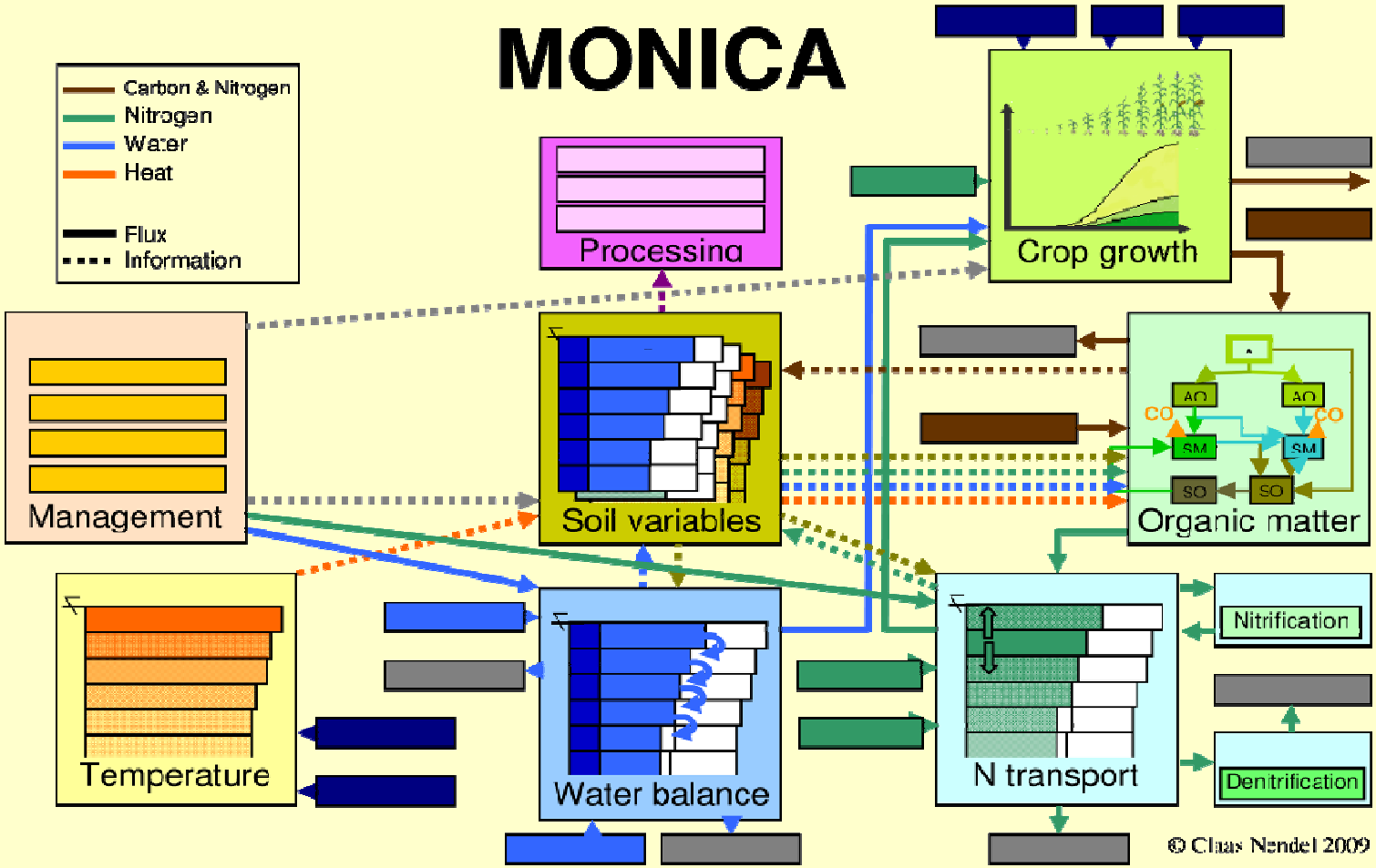
Use of LandCare-DSS on the local or farm scale

- Simulation of the impacts of climate changes
- Interactive simulations to compare alternative climate change adaptation strategies for agriculture under consideration of different price-costs relations for agricultural products and operation funds

Selection of agricultural fields and the model for scenario simulation



MONICA- a new developed process based Agroecosystem model



Results of farm specific scenario simulations for different climate adaptation strategies

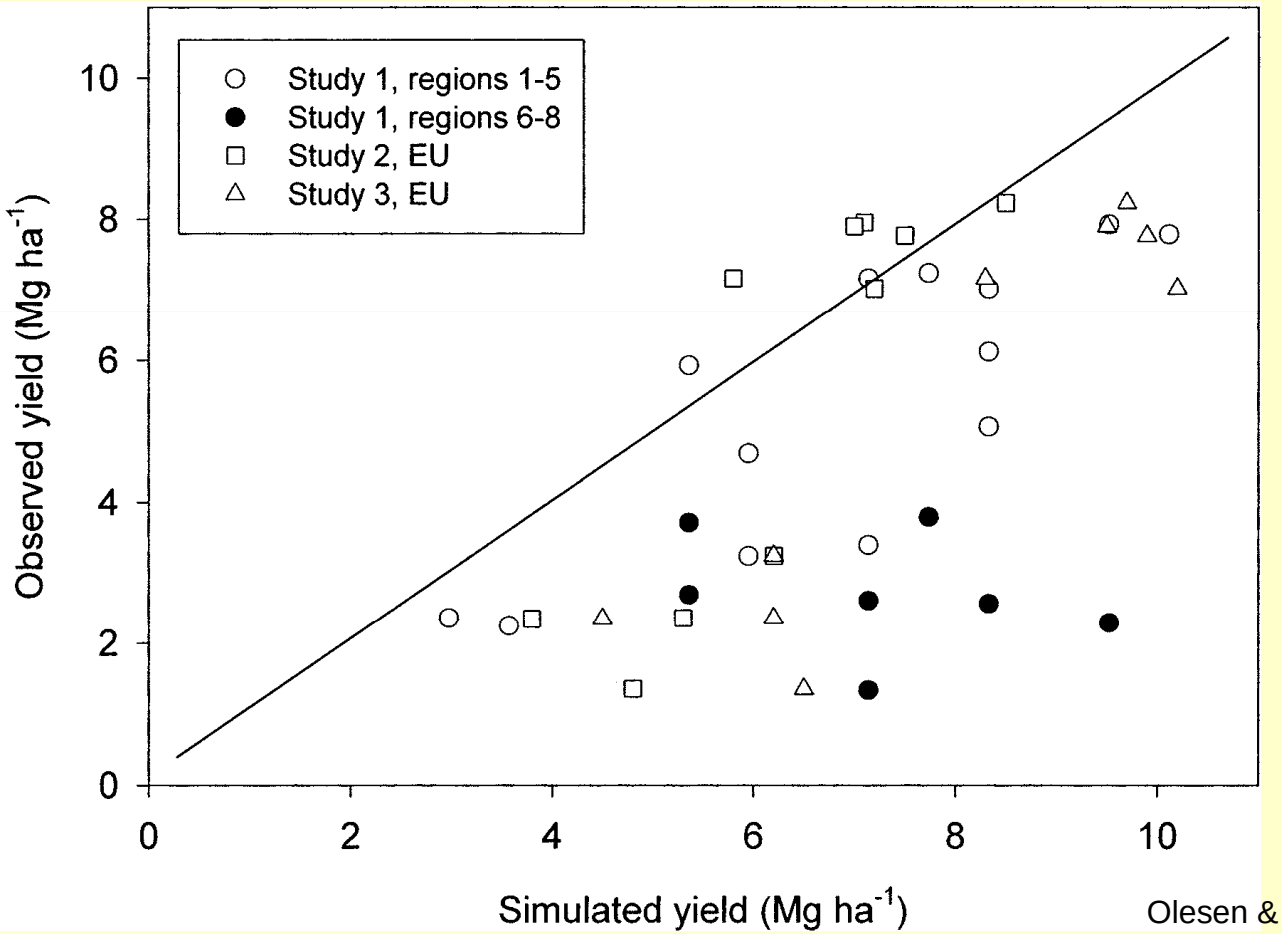
Experience with the use of different model types

Approaches for climate impact assessment on agriculture

- In the majority of the climate change impact asessment studies, crop growth models were employed.
- The used models differ in scope, temporal and spatial scale, complexity or model approach.
- Differences among tested models are often larger than those between single models and observations.

Uncertainties

Observed versus simulated regional wheat grain yield for three studies
(Rabbinge & van Diepen, 2000; van Lanen, et al, 1992; Harrison et al, 2000)



Olesen & Bindi, 2002

Agro-ecosystem Modelling- the parametrization problem

25 Parameters for winter wheat

Table 1. Constants used in GECROS. Descriptions of symbols are given in Appendix L.

Symbol	Equation	Value	Unit	Program code
Constants related to transpiration model				
B_z	(B4)	5.668×10^{-8}	J m^{-2} s^{-1} K^{-4}	BOLTZM
γ	(2)	0.067	kPa °C^{-1}	PSYCH
λ	(2)	2.4×10^{6}	J kg^{-1}	LHVAP
ρc_p	(2)	1200	J m^{-3} °C^{-1}	VHCA
Constants related to leaf photosynthesis model				
ϕ_{2m}	(A3a)	0.85	mol mol^{-1}	PHI2M
O_i	(A1), (A6)	210	mmol mol^{-1}	O2
R	(A4a-c), (A5)	8.314	J K^{-1} mol^{-1}	-
K_{mC25}	(A4b)	404.9 for C_3 650.0 for C_4	µmol mol^{-1}	KMC25
K_{mO25}	(A4c)	278.4 for C_3 450.0 for C_4	mmol mol^{-1}	KMO25
E_{Vcmax}	(A4a)	65,330	J mol^{-1}	EAVCMX
E_{KmC}	(A4b)	79,430	J mol^{-1}	EAKMC
E_{KmO}	(A4c)	36,380	J mol^{-1}	EAKMO
S_J	(A5)	650	J K^{-1} mol^{-1}	SJ
D_J	(A5)	200,000	J mol^{-1}	DEJMAX
h	(A2), (A2a), (A8), (A8a)	3	mol mol^{-1}	HH
f_{pseudo}	(A2a), (A8a)	0	-	FPSEUD
f_Q	(A2), (A2a) (A8), (A8a)	0 for C_3 f_{cyc} for C_4	-	FQ
ϕ	(A8), (A8a)	0.2 (relevant for C_4)	-	ZZ
θ *	(A3)	0.7	-	THETA
Constants related to light scattering and reflection				
σ	(13)	0.2 for PAR 0.8 for NIR	-	SCP
ρ_{cd}	(13)	0.057 for PAR 0.389 for NIR	-	PCD
Constants related to photoperiodism				
M_{op} *	(51)	11 for short-day crop 18 for long-day crop	hour	MOP
α *	(D7)	−2	degrees	INSP
Constants related to setting initial values of crop biomass and nitrogen				
υ_{C0}	-	0.50	g C g^{-1} C	FCRSH
υ_{N0} *	-	0.62	g N g^{-1} N	FNRSH
Others				
w_{Rb}	(45)	0.25	g m^{-2} cm^{-1}	WRB
τ_C	(28)	1	d	TCP
c_{fix}	-	6	g C g^{-1} N	CCFIX

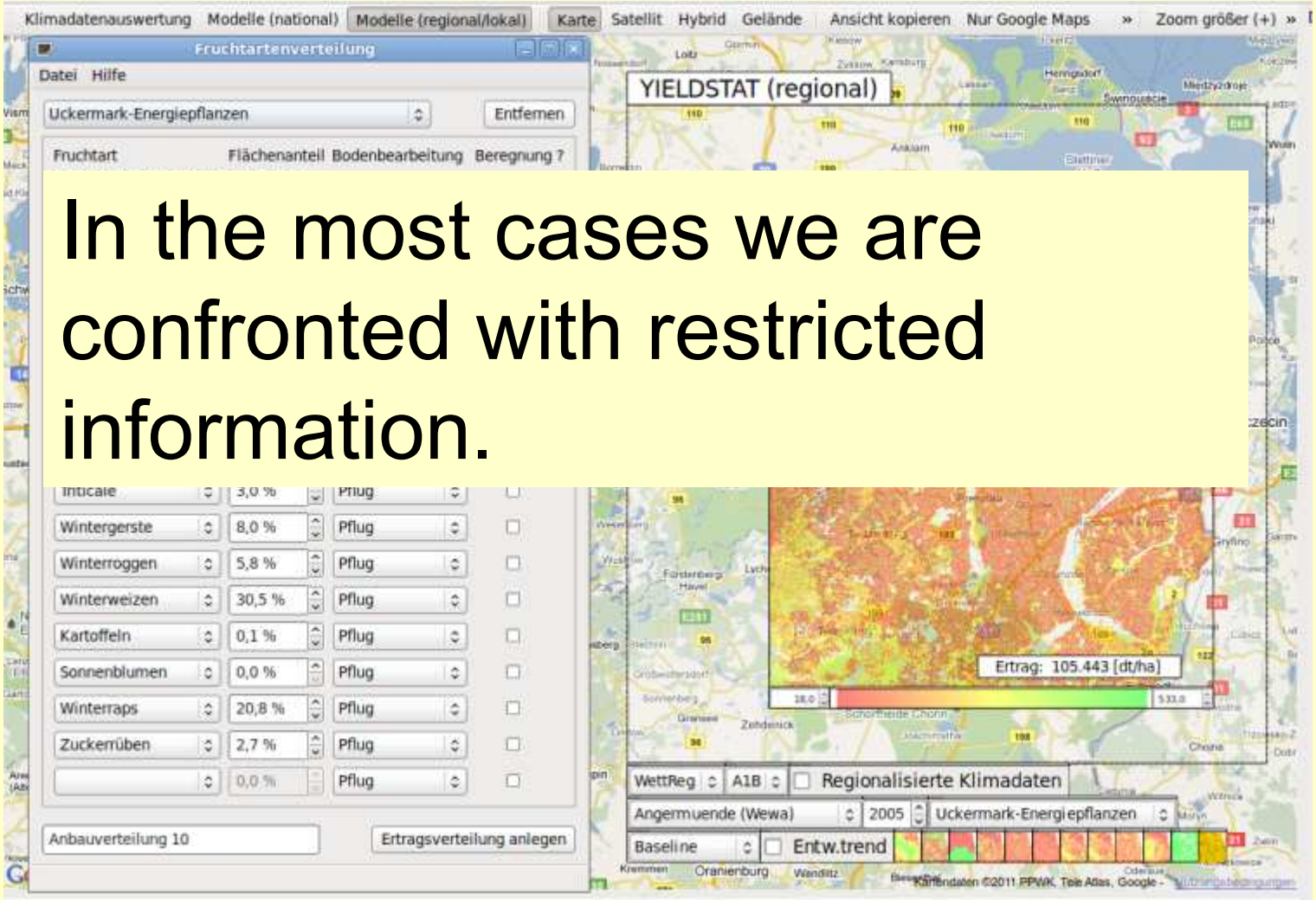
* Values of the marked symbols may slightly vary, depending on crop and experimental conditions.

Example:

Crop Simulation Model GEGROS, Wageningen

(X.Yin, H.H. van Laar, 2005)

Climate or land use change impact assessment on the regional scale



In the most cases we are confronted with restricted information.

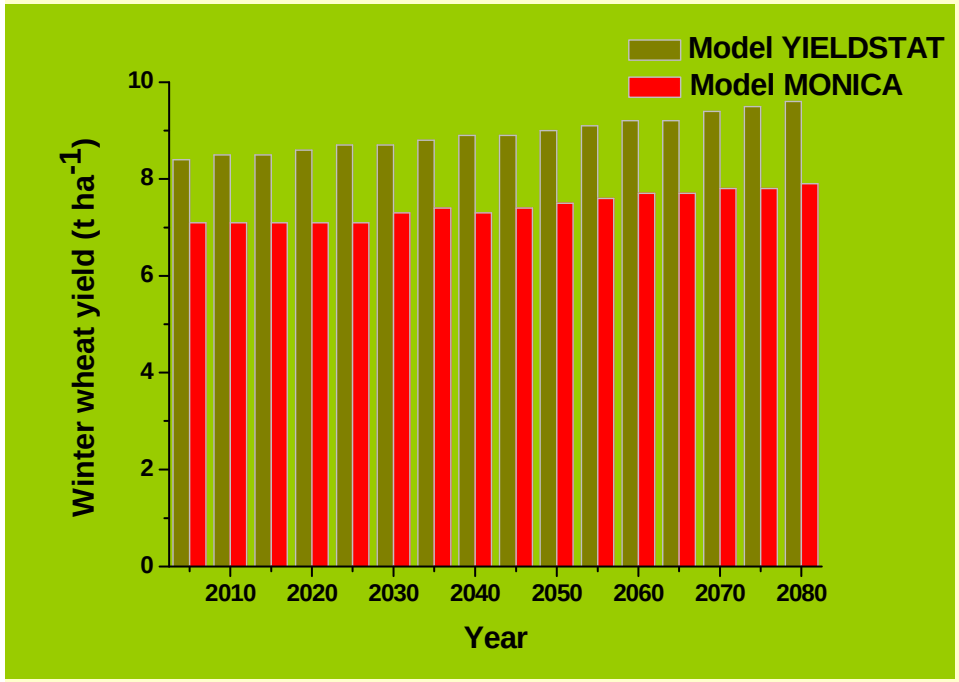
Experience from case studies

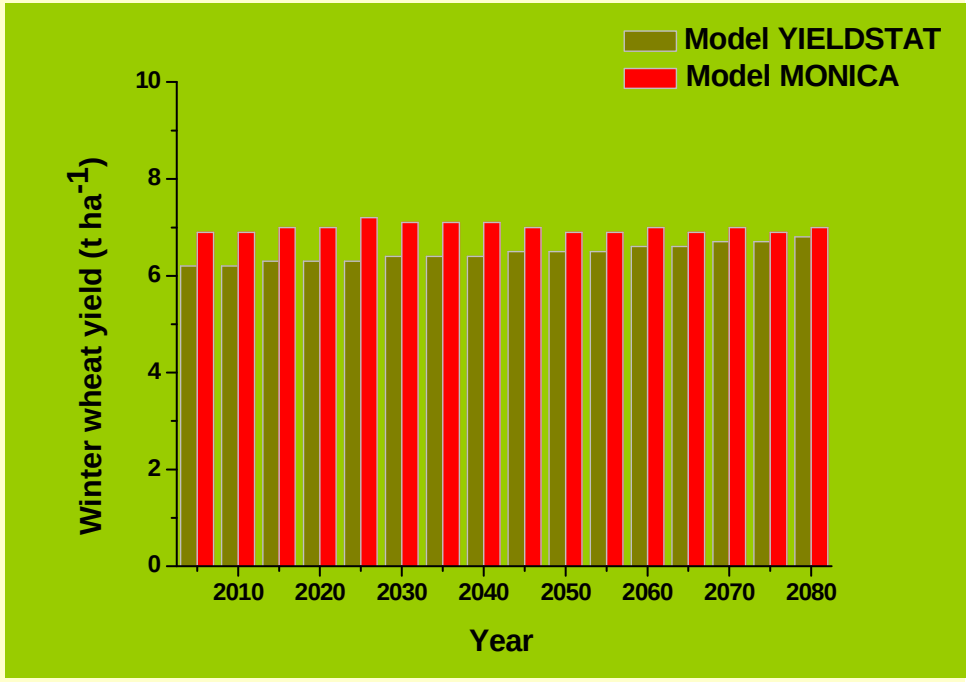
In general, statistical as well as mechanistic process oriented models adequately predict agronomic yield and other ecological values at a given scale.

Different model types need different quantities of input data and parameters

Because at the regional scale we often do not have all the necessary and valid data for the use of complex mechanistic models, the so called REMICs (models of intermediate complexity) have an advantage for regional resources management simulation

Results of predicted climate impacts on yields of winter wheat using different model types YIELDSTAT (statistic-dynamic) MONICA (mechanistic)





Farm within the district Weisseritzkreis
Soil: Lö 4c
Meteorological station: Dresden-Klotzsche

Farm within the district Uckermark
Soil: D4a03
Meteorological station: Angermünde

Conclusions

The development of an interactively useable decision support system for climate change adaption makes high demands on the implementation concept as well as the modules included into the system.

A further important experience is, that the models which are to be included into decision support systems have to be robust, well documented and above all have to be separately verified in space and time before their inclusion into the DSS framework.

DSS supports the possibility of multi-model simulations. This is a prerequisite to assess the uncertainties resulting from different model types, yielding different simulation results with the same inputs.

The first results from the test phase show, that a reasonable use of complex model-based decision support system at the farm as well as the landscape planning level is only possible either involving the model's creators or specially trained people.


Thank You for Your attention !!