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Integration of research results on the regional level in the WAVES Project

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Abstract

The research area of the interdisciplinary WAVES project covers the states of Piauí and Ceará in the north east of Brazil. The focus regions, having an extent of 3000 km^2, are defined as regional level. A GIS based land use development model integrates the research results of different working groups on this level. It calculates yields under different conditions like changes in climate, changes in crop mix and production systems. It balances the yields with regional demand to define gaps in food supply. To prove sustainability of simulated land use ecological standards will be defined.

Key words: model, sustainability, spatial integration, GIS, agriculture and environment

The program "Water Availability and Vulnerability of Ecosystems and Society in the Northeast of Brazil" (WAVES) was initiated following the results of the UN Conference on Environment and Development (UNCED, Rio de Janeiro 1992) to promote preventive strategies for 'sustainable development' under the issue of 'Global Change'. The development of strategies and concepts to provide sustainable life quality is the major goal of the WAVES program.
WAVES is a joint Brazilian-German program with an interdisciplinary research approach. It integrates different disciplines like Climatology, Hydrology, Agronomy, Social and Economic Sciences, Integrated Modelling and Landscape Ecology on both sides respectively. This is of importance, because the interacting between components of physical, economical and social systems are to be integrated.

Methodological Approach

The research area of the WAVES project covers the States of Piauí and Ceará in the north east of Brazil. Both states are located in the "Drought Polygon", an area that is threatened with irregularly recurrent drought periods. With about 470000 square kilometers the extent of the research area is bigger than Germany.

Spatial levels and levels of integration

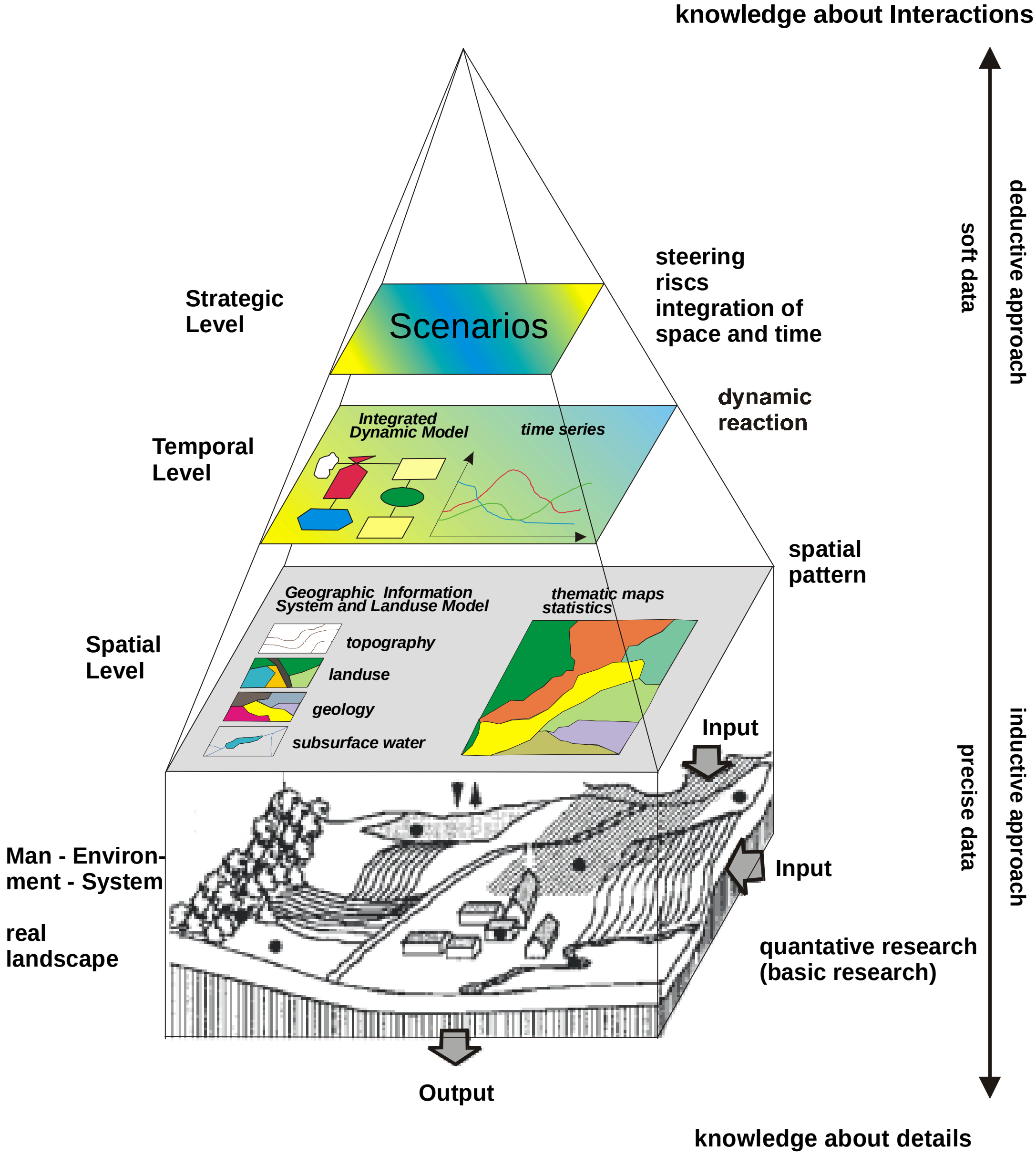
This large area can not be investigated in its totality. The relevant problems are approached on three spatial levels. The macro scale or state level covers both states, the meso scale or regional level with several thousand square kilometers covering some municipios and the micro scale or site level a few square kilometers. Thus interactions between these levels are taken into account by scaling up and down between these levels.
The different disciplines in WAVES work on different scales. The working group for climate analysis for example works on an even larger scale and projects its results down to the macro scale. Investigations of rural economy were carried out on single farms (micro scale). On the meso scale land cover/land use data was obtained through satellite image interpretation. Most

inputs to the meso scale level are based on results of working groups from the micro scale level, which were transferred by up scaling methods.
Beneath the structuring of space into different levels, there are different integration methods applied, to fulfill the interdisciplinary approach of the project WAVES:

- the land use model MOSDEL which integrates results of disciplinary work on the regional level
- the integrated dynamic model SIM - coupling disciplinary models on state level
- integrated scenarios - formulating plausible assumptions of future situations

The relationships between these spatial levels and these levels of integration will be explained based on figure 1.

Fig 1.: Levels of abstraction and integration within the WAVES project (after Haber 1993 modified)



On the real landscape interaction of man and environment takes place. Here quantitative research is carried out by measurement, sampling and field experiments. These results are

transferred to the spatial level by mapping methods based on spatial units. The instrument to deal with these data is the Geographical Information System (GIS). The next level, the temporal level allows the representation of system dynamics. Instruments to do this are dynamic models. The strategic level resumes expert knowledge for risc steering and questions of the system. It's the level where space and time are integrated to strategic scenarios.
Applied to WAVES these levels of integration are represented as follows: Data collected on the 'real landscape' through experiments, questionnaires, runoff measurements, soil sampling, etc. form the basis of the research. These precise data are scaled up to the spatial level, being in this case the regional level of the project. Here the GIS based Model for Sustainable Land Use Development (MOSDEL) integrates the results of disciplinary research from the base level and micro scale, to answer the questions enumerated in the next paragraph. With the integrated dynamic Model SIM the temporal level of the WAVES project is represented. Here disciplinary models or partial models are coupled. The working scale for SIM is the macro scale or state level. The formulation of strategic scenarios of plausible futures represents the strategic level of the pyramid.

Integration on the Regional Level in the Focus Region of Picos

The Focus Region of Picos and Research Goals

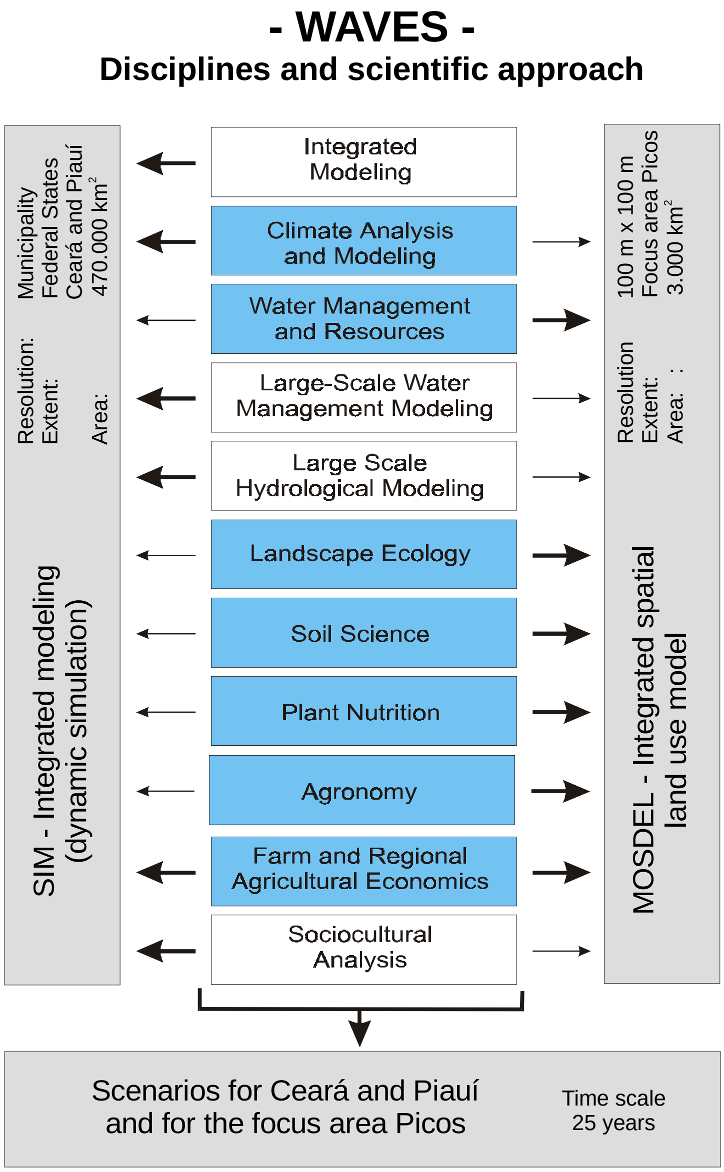
One reference area representing the regional level on meso scale is the Picos Region. The region is formed by four municipios with a total area of ca. 3000 km². It is characterised by a mean annual precipitation of ca. 700mm (concentrated on the main rain period of 3 months) and about 2,500mm potential evapotranspiration.
Topographically and geomorphologically the region is differentiated into two main landscape units: plateau mountains (Chapadas) and dissected valleys.
The regional economic centre, the city of Picos (ca. 50,000 citizens) is situated at a crossing point of important trans- Brazilian traffic roads. To the rural areas, especially to the neighbouring municipalities a significant socio economic gradient can be observed.
Accounting to the main goal, the development of strategies to achieve sustainable life quality, on the regional level the following questions shall be answered:

- What are the agricultural yields?
- What is the regional demand?
- Which environmental restrictions caused by land use will occur?
- How will these output parameters vary if:
- production systems will change
- spatial distribution and area of land use will change
- climatic frame conditions change
- new water management strategies will be implemented
- prices for commercialization change.

The integration of disciplinary results on the regional level

In order to reach the goals of the project the analysis of the complex interactions between natural and social systems require many disciplines working together. Figure 2 shows all eleven working groups involved in the project. The working groups contributing to the research on the regional level are highlighted.

Fig. 2: Contributing Disciplines and scientific approach in the WAVES Project



The following list shows the contributions of the involved working groups as basis for the development of MOSDEL:

Farm Economics:

- economical basis for estimating local consumption
- product prices
- production costs

Soil Science:

- disaggregation of the Piauí soil map for the Picos region to get more detailed information; (supported by Landscape Ecology/GIS)
- deriving soil data for the soil units of the soil map
- soil fertility

Agronomy/Plant Nutrition

- modeling of yields for relevant crops and different production systems dependent on rainfall and site factors

Water Management and Resources

- availability of groundwater and surface water (in cooperation with Landscape Ecol.)
- water quality

Climate Analysis and Modeling

- classification of yearly precipitation
- daily climate data for selected years

Landscape Ecology

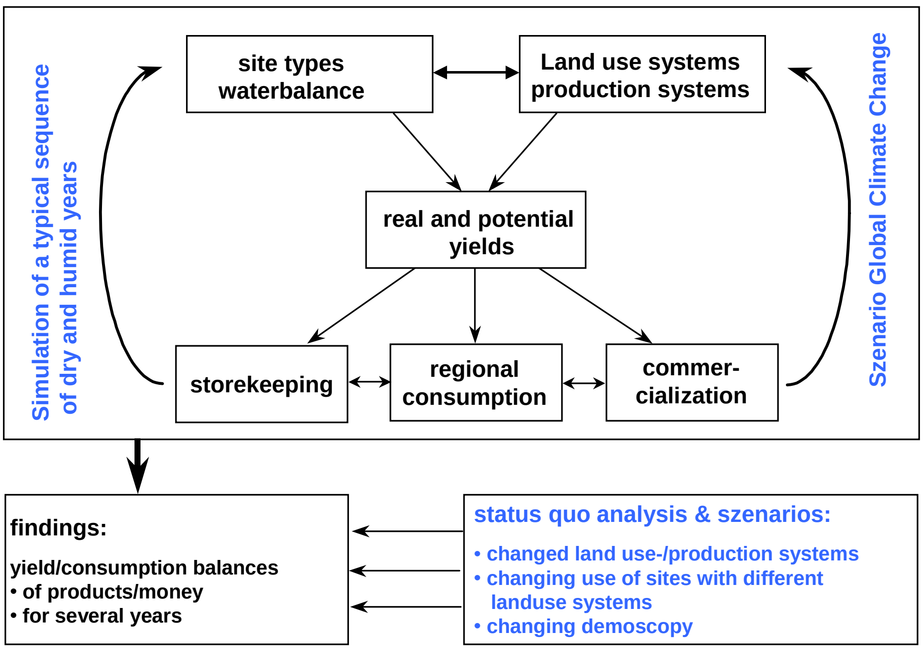
- mapping land use/land cover by remote sensing data and ground check
- spatial allocation of farm types in the region (supported by Farm Agricultural Economics)

These are all components needed for modeling the land use system.

The Integrating Model MOSDEL

The MOdel for Sustainable DEvelopment of Land use MOSDEL is an integration tool on regional level. It is based on a Geographical Information System (GIS). It provides a tool to link different kinds of spatial data with integrated queries. Figure 3 shows the base structure of MOSDEL.
Its object is to approach sustainable development by simulating interactions/relations between natural site factors and land use systems under changing conditions (scenarios). Relating socio- and agroeconomic parameters of land use systems (e.g. production conditions of farm types, income, etc.) with natural site factors (precipitation, soil, etc.) the model balances results of agricultural production with local need/consumption.
By simulating time sequences of dry and humid years with different combinations of land use systems MOSDEL becomes an interactive tool to support land use planning in the model region.

Fig. 3: Base structure of MOSDEL



Natural site types with their characteristic parameters, which are related to corresponding spatial units and the quality of available water are the basis for describing natural system conditions for land use. Land use systems are implemented into the model through spatially distributed farm types. Related to the spatial units for the whole region, yield estimations are derived from models and classification methods.
The spatial data layers for the simulation process are the following:

- Soil types and terrain components:

The official soil map of Piauí (scale 1 : 1Mio) proved to be too coarse to be applied on the regional scale. Therefore, these soil units were overlaid with slope ranges from the digital elevation model (DEM) and a more detailed ‘Terrain Component Map’ (scale 1 : 100,000) was produced. Terrain components are the smallest spatial units of the soil data base SPICE (Soil and Terrain Information system for the states of PIauí and CEará), whose contents can be linked to the GIS-geometries on this scale.
For MOSDEL the Terrain Component Map is evaluated for site suitability for selected crops. It also serves as basis for yield potential calculations.

- Water availability:

The WARIG model (Water Availability in the Rio Guaribas basin) provides MOSDEL with data of water availability and quality. WARIG is built up by modules for surface run off, soil water balance, groundwater and water quality. It provides MOSDEL with spatially related data on water availability for cultivating plants including irrigation water.

- Farm Types

Farm types are an important link to spatially integrate socio economic data. They were allocated to defined landscape units and are the means to distribute land use systems/management in the simulation area. This is the basis to simulate and balance spatial effects of future land use systems on the whole reference area.

- Land cover/Land use

Land cover data was obtained by the interpretation of a digital satellite image. 17 land cover classes were identified out of a Landsat TM5 scene of 1996 and revised by a ground check in April 1999.The interpretation result provides MOSDEL with geometries of available farmland, which can be cultivated during a simulation run.

Environmental standards will be implemented in the future as limits for impacts. The aim is to develop MOSDEL as an instrument for land use planning.

Literature

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