CAVES: Complexity, Agents, Volatility, Evidence and Scale

Odra Case Study Final Report

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[1] Made in Vensim software.

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1. Introduction

Activities performed in the Odra Case Study reflect the complexity of the human-environmental system under consideration and the number of tasks to be fulfilled by case study teams. Our primary goals were both to elicit valuable knowledge for the purpose of computer agent-based modeling and to conduct credible scientific research. Furthermore the subject of our studies was meant to be policy relevant.

We started with stakeholders workshops to scope the modeling subject. After additional consultations with experts and the modeling team we have chosen land reclamation (LRS) issues coupled with land use/land cover (LULC) subject for further detailed investigation.

We wanted our work to be interdisciplinary thus decided to take all relevant components of the examined system into consideration, including socio-economic and biophysical subsystems. We have analyzed water law in order to outline the legal framework of LRS related activities. The economic drivers of agricultural production, the base for land use and LRS decisions have been accurately worked out in the form of the economic calculator. Social survey research were conducted to find out farmers' decision rules on farming, the nature of social networks in the study area, perceptions of landscape and land use changes, as well as social, institutional and economic drivers of collective action with regard to LRS maintenance. The main goal of studies on biophysical issues was to provide deeper insight into ecological, hydrological and meteorological processes affecting LULC and LRS in the Odra River Valley. In order to achieve this goal we analyzed time series of meteorological data from the time period 1946-2004. Additionally we have set up a hydro-meteorological monitoring system. LULC changes research was based on archival and contemporary cartographic resources. LRS investigation was performed in the form of field work, including vegetation assessment and mapping. Finally we have designed and performed the role-playing game focused on LRS maintenance as a tool for model validation and a kind of sociological experiment.

In this report we describe all steps undertaken by the Odra Case Study team during three years of the CAVES project and the results of our work.

2. Odra case study complex socio-environmental system

2.1 Study area

The Odra case study consists of 18 communes in the middle course of Odra River. The region is very diverse with respect to landscape structure, land ownership structure and hydrological processes. We decided for the purposive selection of detailed study area, which would be appropriate for the research/modelling problem.

Based on the analysis of relevant maps and statistical data on agriculture as well as on the opinions of key domain experts, the Rogow Legnicki area was chosen for detailed social research, GIS analysis and biophysical model development. Odra river is very important for nature conservation. In the Odra case study region the Natura 2000 Odrzańskie Łęgi are located. Furthermore, Odra river valley is an important international ecological corridor (Fig. 2.1.2). Detailed boundaries of the area were established so as to meet the requirements of hydrological coherence, which is important for biophysical part of the model. A reasonable sub-catchment was separated based on the hydrographical map of the study area[2].

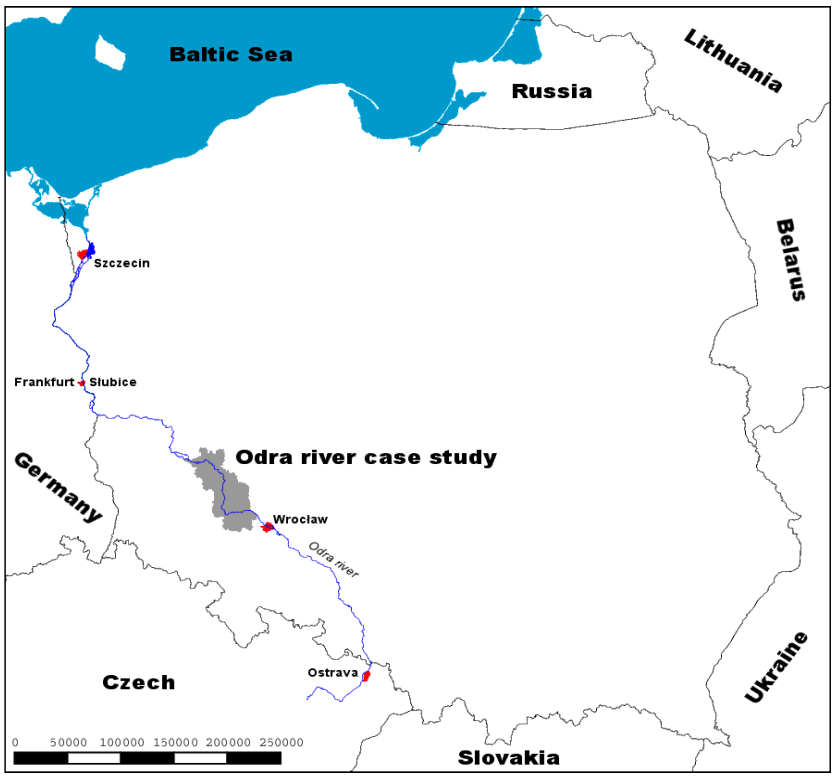

Figure 2.1.1. Odra river case study location

[2] Hydrographic Map of Poland 1:50 000, Regional Center for Geodetic and Cartographic Documentation

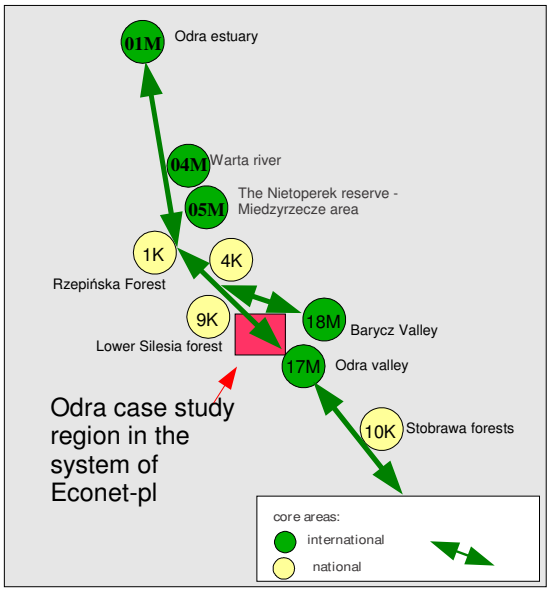

Figure 2.1.2. Odra as an ecological corridor of Econet-PL

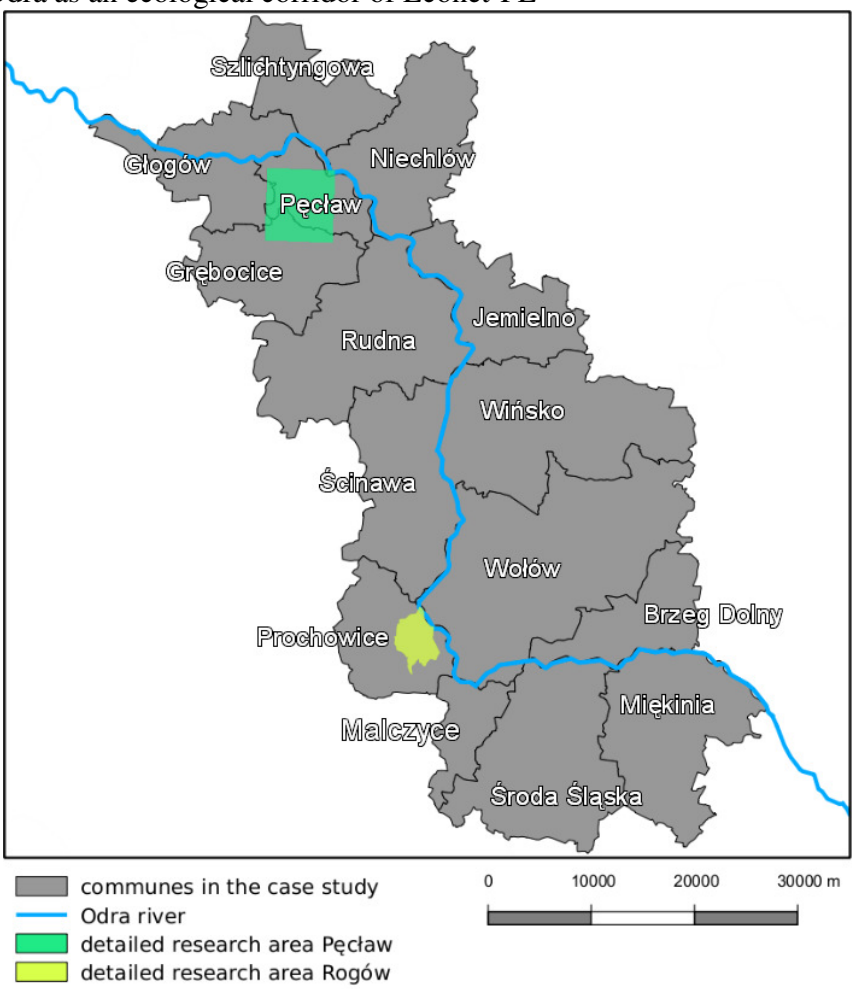

Figure 2.1.3. The communes of the Odra river case study region and location of the detailed research areas

2.2 System structure

The system of the Odra case study consists of two subsystems: socio-economic and biophysical. Socio-economic subsystem consist of the legal, economic and social components. Biophysical subsystem consists of three main subcomponents: land reclamation system, land use/cover and meteorological and hydrogeological constrains. The components of this complex system are described in the following subsections.

Components of the socio-ecological system of Odra case study

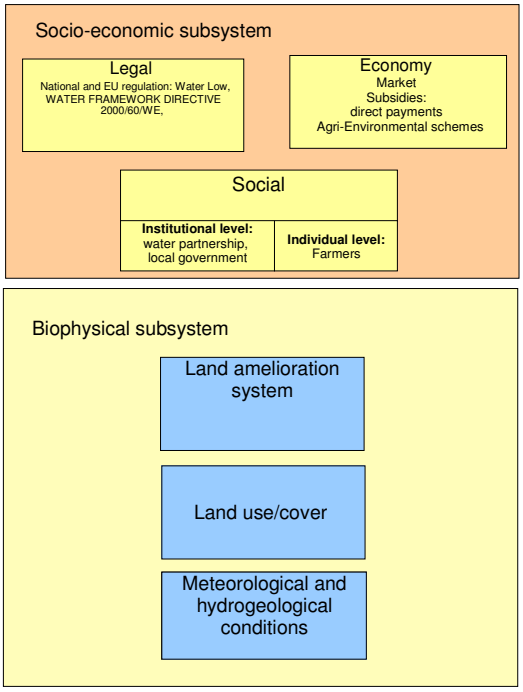

Figure 2.2.1. Conceptual model of the socio-ecological system of the Odra case study

2.2.1 Socio-economic subsystem

2.2.1.1 Components

Present ex-State Owned Farms workers are not able to cultivate land on their own and depend on a very limited social welfare. It is not uncommon for unemployed younger people to live with elders in retirement such that all live off one pension. At present **farmers and State Owned Farms ex-workers** create two different, separated worlds within the same village, so naturally they establish two quite different groups of stakeholders.

Following liquidation of State Owned Farms the land was taken over by central governmental agency responsible for land sale and lease. Both the **State Land Property Agency and also State Forests Agency** become another type of stakeholder as eminent land owners.

System transformation is also connected with local self-government creation. Therefore **different units of local government** from different levels of administration (commune, district, province) must be taken into consideration as stakeholders in our project, especially as they are responsible for spatial planning and management strongly influencing land use possibilities.

The **Middle Odra River Valley Partnership** recently established and lead by an NGO can be treated as a network of stakeholders. It constitutes an interesting case of a local attempt to connect different agents acting for local development and spatial planning. It is a voluntary and open, informal coalition (based on signed declaration of cooperation) of participants, consisting of 39 partners (as of its beginning in December 2004): 16 local governments (rural and urban municipalities), 4 counties governments, 16 NGOs, 2 Forest Inspectorates, and small enterprises. The main aim of the Partnership is to integrate activities of all institutions, organizations, self-governments, entrepreneurships, and other local groups acting for sustainable development and protection of nature and culture heritage in the partnership's territory.

Since our case study region is located in a river valley where flooding occurs, there are some organizations connected with flood control, which should be included as stakeholders. One of them is the **Office of Odra 2006 project** dealing with Odra river valley management. Other organizations are**: Regional Board for Water Management and Dolnoslaski Office for Land Reclamation.**

Next key issue of Odra case study include agriculture and rural areas development, which fall within the authority and jurisdiction of the **Department of Rural Areas Development** and the **Department of Environment and Agriculture** (both operate within the autonomous provincial governments)

The case study area is the object of interest for many **NGOs** activities, both environmental and those connected with agriculture. Their goals include the activation of local communities (developing social capital at the local level), policies to stimulate multifunctional rural development, including tourism and recreation, sustainable development and biodiversity conservation. In this context **NGOs** connected with our study area become the next group of stakeholders.

2.2.1.2 States

Regarding population from Fig. 3 we can see the changing oscillations of population booms and busts. The first boom is evident in the generations born just after World War II (age categories 45-49 and 50-54). The second boom is seen in their children (age categories 15-19, 20-24). Presently we find a very deep drop in birth rate. Two main reasons are: very difficult economic situation for young people, caused by a very high unemployment in the rural region (Fig. 2.2.1.3a) and general trends in most of European populations to have less children. To some extent the outflow of young people from rural areas should be taken in the consideration. However it is still true, that people living in rural areas tend to have bigger families than in cities and towns. The population growth fraction is above 0 for rural communes and below 0 for municipalities (Fig. 2.2.1.2).

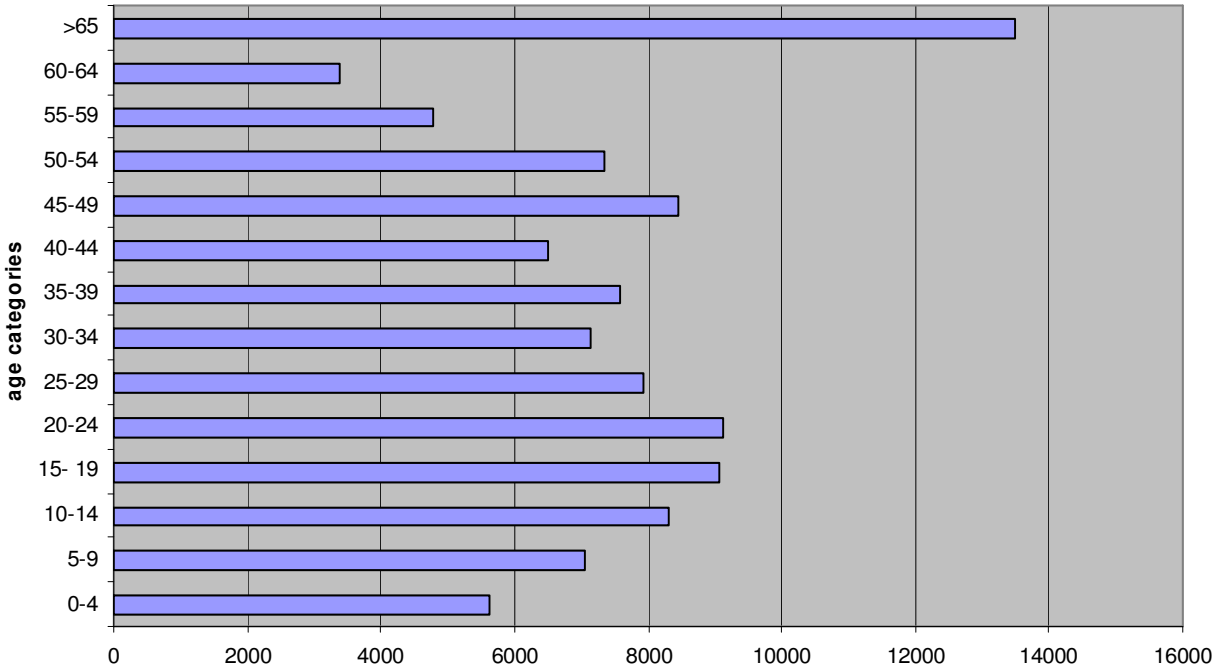

Fig. 2.2.1.1. Age structure in rural communes of Odra case study

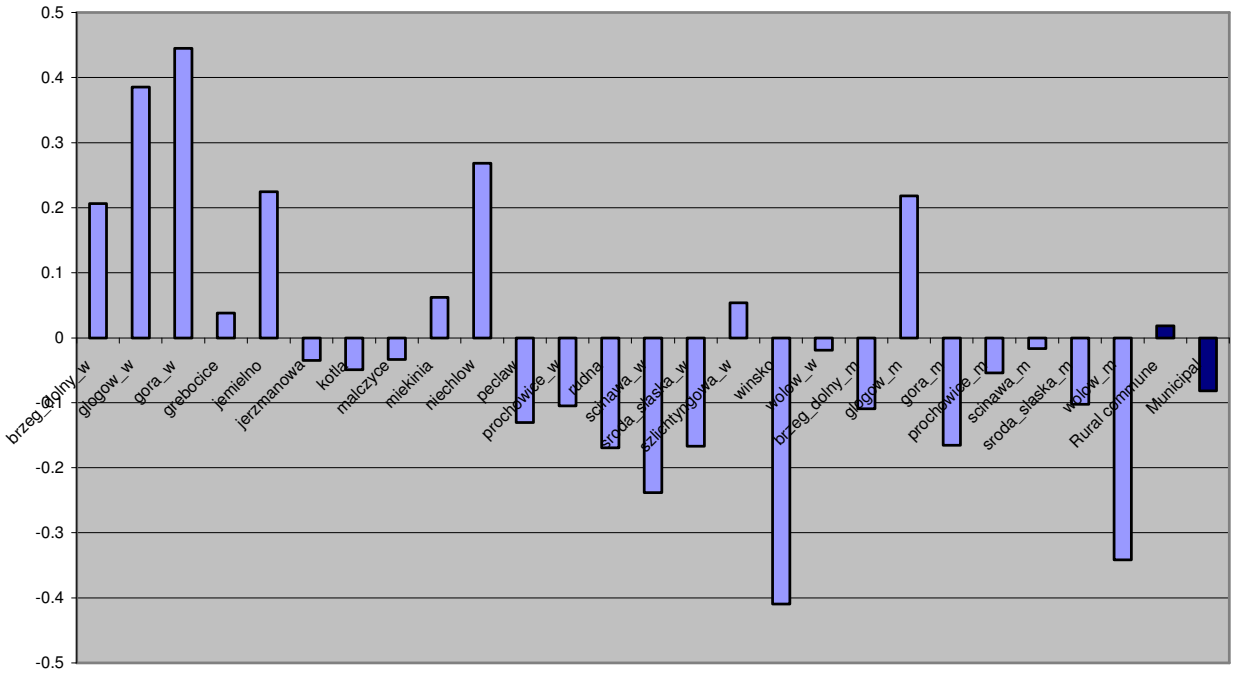

Figure 2.2.1.2. Population growth fraction in 2003 for different communes and municipalities. Blue bars

represent data for exact communes, dark blue are average for rural and municipal communes.

From statistical data we can find out that the percent of fully employed people within the production age range is very low and on average amounts to 15% in rural areas and almost 40% in towns (Fig. 2.2.1.3a). This data strongly contradicts official data on unemployment in Poland (20% in 2005). A significant fraction of people of productive age lives on social welfare or pensions, especially in rural areas. This fact tremendously affects social activity, social networks issues and to some extent land use structure.

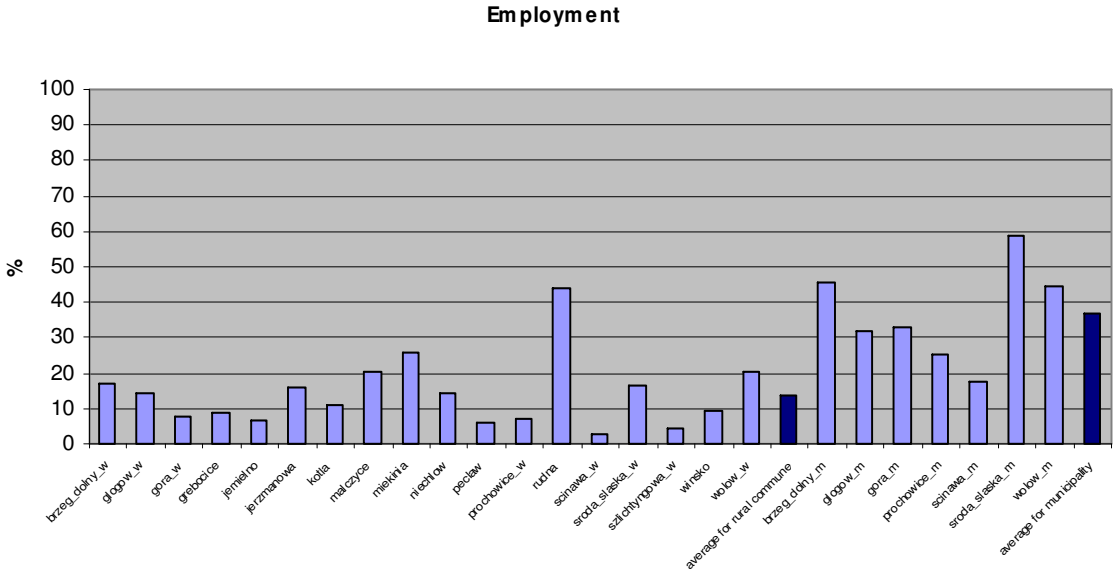

Fig. 2.2.1.3a. Fraction of **employed** people within productivity age range in the area of case study. Blue bars represent data for specific communes, dark blue are average figures for rural and municipal communes

As we can notice from Fig. 2.2.1.3, the unemployment ratio is lowest in towns and Rudna commune (green ones). As regards Rudna, its inhabitants are mostly employed in copper mining industry. Unemployment ratio decreases also in the south-west part of the region, which refers to the vicinity of the big city of Wroclaw.

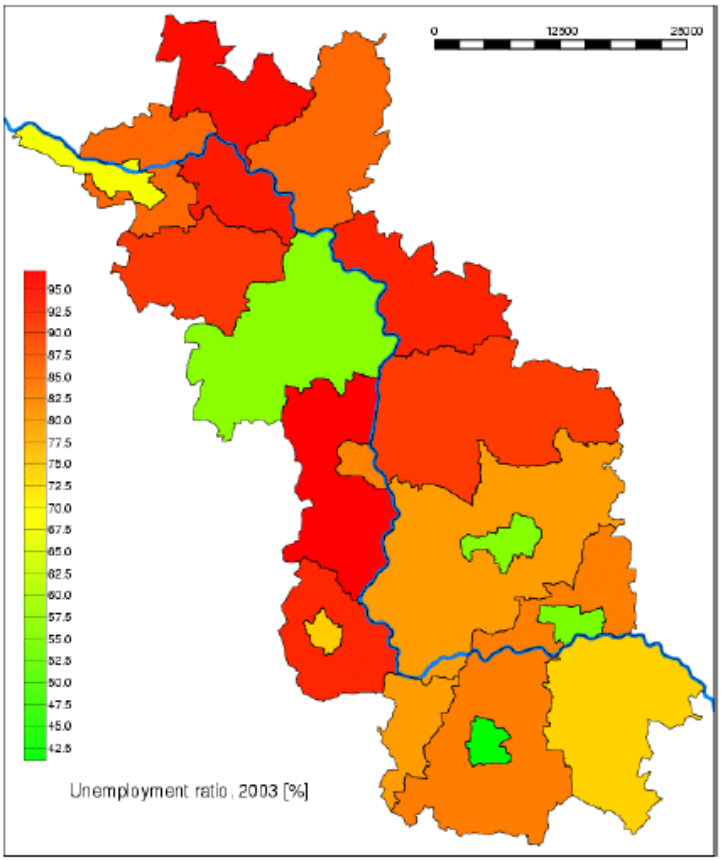

Fig. 2.2.1.3b. Unemployment ratio in Odra case study area in given rural and municipal communes

2.2.1.3 System dynamics

The population of inhabitants of Odra River Valley region changed entirely after the II World War, when the resident German farmers were expelled, and replaced by Poles from what is now Ukraine. Due to socialist system dictate huge areas were taken over by State Owned Farms with their own infrastructure and work system conducive to passive behavior of workers. Before system collapse in 1989 there existed individual farms with private land in every village, but now their number even decreased to 3-4 farms per village.

The way Water Partnerships work also changed. Before 1989 it was obligatory for farmers to participate in a WP and pay fees. WPs were the part of top-down governing system and employed specialists to maintain LRS. At present WPs are voluntary.

2.2.1.4 Interactions

General connections linking all stakeholders are presented in Fig 0. Connections between people (both persons and households) and local self-government as organizations (not single people) are of administrative and formal nature and include relations (links) like voting, meetings with local authorities in order to solve local problems, getting permissions connected with land use, spatial management, development and economic performance, paying taxes etc. The remaining connections mean official channels between organizations.

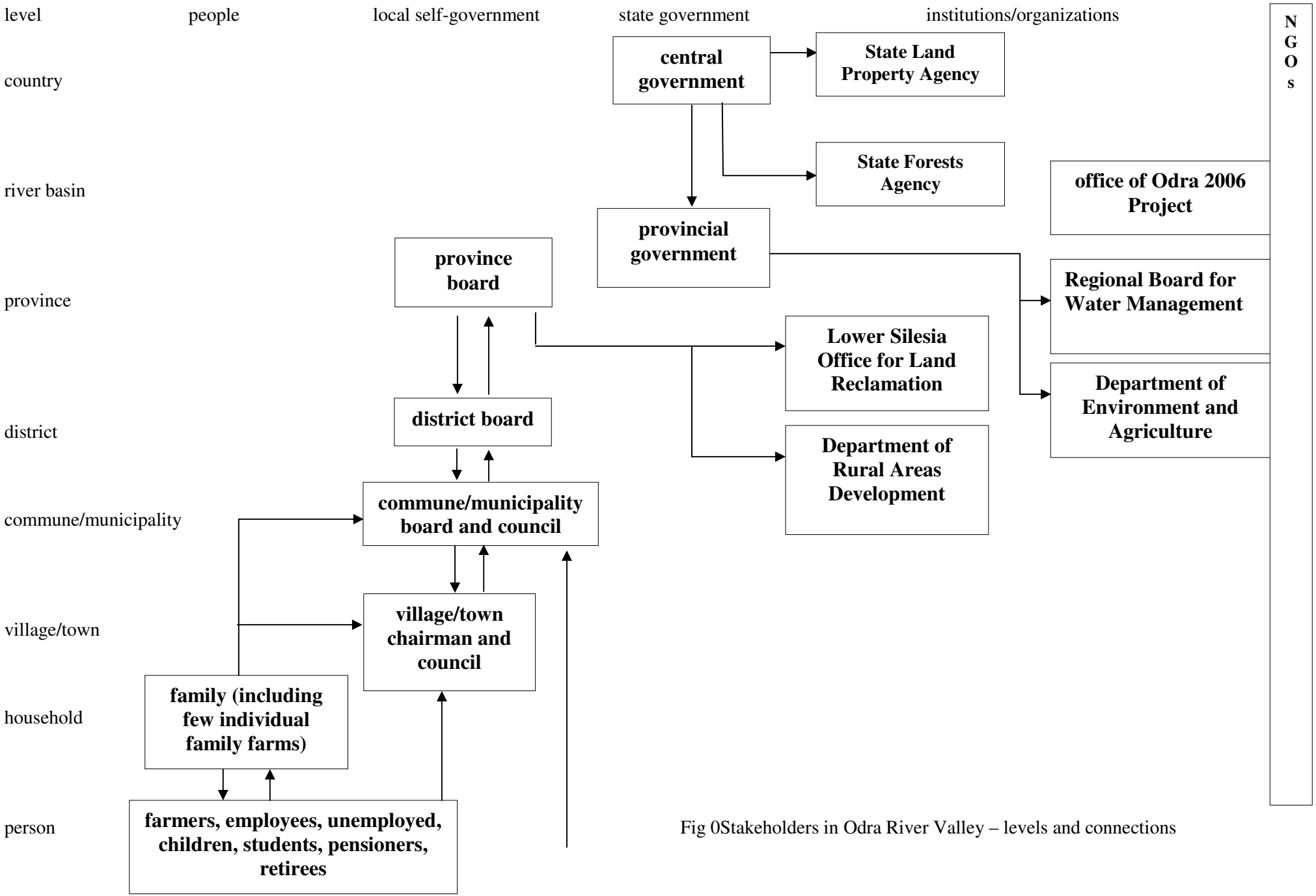

Fig 0Stakeholders in Odra River Valley – levels and connections

2.2.2 Biophysical subsystem

2.2.2.1 Components

Climate and hydrogeology

Climate is an important factor determining the land use. Thermal conditions decide about the set of plants which can be planted, and influences the rate of evapotranspiration. Precipitation is one of the most important elements of the water balance. The amount of water, as well as its distribution during the vegetation period, is one of the most important factors influencing productivity. Extreme events can be destructive. Heavy storms or drought can affect productivity.

The water outflow is one of the major processes affecting the amount of water available for plants. Water is also very an important factor shaping the soil processes. Water availability in a given place depends on many variables, like geomorphological and geological structure of the soil and the level of the ground water.

Land use/cover

Different types of human activity shape the landscape as a mosaic of different land cover types. In the Odra case study region the main land cover types are: arable land, grassland (meadows and
pastures), forest, build-up areas. The historical and actual structure of the land cover is presented on maps (fig. 4.4.3.2; fig 4.4.3.3).

Land reclamation system

The efficiency of the agriculture depends, among the others, on the management of land reclamation system (LRS). The LRS consists of channels and ditches, which drain the soil directly, or through the drainage pipe system. If the LRS is equipped with sluice gates, it can also serve as an irrigation system. In an agricultural landscape, water courses and adjacent vegetation are important due to their impact on water quality, biodiversity, aesthetic values (Baudry and Thenail 2004, Décamps et al. 2004) and their function as ecological corridors (Blomqvist et al. 2003, Jobin et al. 2004). The riparian vegetation is also the most frequent semi-natural habitat in agricultural areas (Manhoud and de Snoo 2003).

2.2.2.2 States

Climate and hydrogeology

Climate is the most dynamic element of a biophysical system. Its dynamics manifest itself in a number of time scales: season, year, decades, millennia. However, it is possible to distinguish the years, which can be a reference for extreme or typical climatic conditions, eg. wet, dry and average year. To describe such states yearly statistics of rainfall, evapotranspiration, temperature and wind are needed.

Hydrogeology

Hydrology is a very dynamic system component as well, however its states do not change as fast as climate conditions do. The most important constant geohydrological features are the

earth surface structure, like density of the river net, and the infiltration rate of soils and rocks. The most important dynamic parameters are the level of the ground water surface, the level of the water in the water receiver etc.

Land use/cover

The state of the landscape structure can be expressed as a simple proportion of different land cover types (fig. ##), but it does not describe all important structural elements of the landscape. The landscape should be considered as a mosaic of patches representing different land use and land cover types. The structural information about this mosaic should also include information about properties of individual patches, like their shapes and pattern of distribution, as well as about the landscape as a whole, eg. like diversity index. Landscape ecology proposes a multitude of statistics, which can be used to describe the landscape pattern and state.

Land reclamation system

For an effective LRS performance, the ditch cleaning should be coordinated. It means that stakeholders who own the parcels along one channel are interdependent. This interdependency is not symmetrical and varies largely in respect to the parcel location along the channel. To determine the reciprocal influence of particular agents working on parcels located along one channel, a number of biophysical parameters should be taken into consideration. It is not possible to determine this interdependency without very detailed information, necessary to predict the water flow dynamics. This requires a sophisticated biophysical model. Every simplification of this complex issue will lead to an unpredictable uncertainty. Nevertheless, simple rules, as close to reality as possible, describing the upward and downward effects of the LRS conservation and operation, are needed for the sociological model of the LRS maintenance. Our simplification of this agents interdependency, based on the knowledge about LRS and hydrology, is not universal and might not turn out to be useful in other set-ups.

2.2.2.3 Processes

Climate

The processes in the climate might lead to a change in the water balance significantly. The rainfall, as well as the rainfall distribution within vegetation season, is crucial for the water balance. Furthermore, an increasing air temperature and/or wind speed can increase evapotranspiration, leeding to a decrease of the water amount in the system. As stochastic climate processe input to the system irregularity.

Hydrogeology

The process of outflow depends on a number of environmental parameters. The most important natural parameters are the infiltration rate which is stable and the water level in the water receiver which is dynamic. The Odra river plays a role of water receiver in this region. The water regime of the Odra river is determined by the high fluctuation of water level, as a consequence of the fluctuation in the rainfall amount in the catchment, which is very variant

during the year. Additionally, the state of the water level in the Odra river is affected by river bed erosion below the weir in Brzeg Dolny. The average water level of Odra in the Malczyce profile, since 1958 decreased by 1,5 m (Głogowski, Parzonka 2007, Olszewska i in. 2004). Such a decrease of water level in the river led to a decrease of the ground water level at the floodplain from 0.3 m up to 0.6 m in the concave forms (Olszewska i in. 2004).

Land use/cover

In the last century, two periods with opposite direction of land cover changes occurred. During the communism era – an increase in the grassland and forest area, and after transition to free market economy – a loss in grassland and gain in the arable land. The changes in the agriculture profitability is the most important driving force in the last mentioned period.

Another LUCC process in the area is afforestation. This is a common tendency for the whole Odra catchment since 18th century, that the amount of forested area increases (Roo et al., 2003, Bielecka and Ciolkosz, 2002).

Land reclamation system (LRS)

The land reclamation system was implemented mainly for drainage purposes. Irrigation always played a minor role. In the last few years, due to significant crop losses caused by drought, the importance of the irrigation increased, but the investment in the LRS is needed to develop the irrigation function. The ecological succession, a spontaneous process in the ditches and channels ongoing if the system is neglected, led to reduce wateroutflow speed. If the system is neglected for over 10 years, a strong, difficult to remove vegetation, might establish. In such situation higher expenditure for vegetation removal is needed.

System dynamics

Land-use-related drivers are usually regular and deterministic in space and time, while soil resources as water and nutrients in interaction with climate variability add a stochastic component to these (land-use-related) drivers. The proportion of deterministic and stochastic components and their autocorrelation in time and space divides purely deterministic from purely stochastic dynamic landscapes (Kleyer M. at all. 2007).

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3. Research problems

3.1 Socio-economic subsystem

The main objective of social research/knowledge elicitation in the CAVES project was to develop the knowledge base for agent based models (ABM). Accordingly the choice of research problems in Odra case study (Odra CS) was guided by the general scope of the CAVES project which includes both land use change and social networks as well as by the requirements of the ABM developed specifically for the relevant area of the Odra River valley. Before research started an iterative process including stakeholders participation and also consultations between case study and modelling teams was performed. The aim of this process was to establish a suitable detailed subject for modelling and consequently research questions for field studies. The process consisted of workshops with local communities and other stakeholders, meetings and

interviews with key domain experts, field trips and discussions between modellers and researchers.

As a result of a.m. activities it became possible:

- to establish both policy relevant and 'CAVES relevant' modelling subject suitable for agent based modelling,
- to formulate research problems for field studies,
- to design a research tool: semi-structured interview questionnaire,
- to choose the representative area for detailed research, GIS inventory and biophysical model development.

The general research problem was formulated as follows: **'What are the rules that guide the decision making of landowners with respect to the land use and the land reclamation system (LRS) maintenance in the Odra CS area?'.**

Final set of detailed research questions is presented below:

1.What are the main land use change processes in the Odra case study region and what are their causes?

2. What kind of decisions do farmers take with respect to land use and what are the reasons of these decisions?

3. What kind of decisions do farmers take with respect to LRS maintenance and what are the reasons of these decisions?

4. What are the social, institutional and economic drivers of collective action related to LRS maintenance?

3.2 Biophysical subsystem

The main research problem of the bio-physical subsystem modelling was to find a proper level of abstraction of physical processes, affecting the land use in the agricultural landscape of the Odra valley. Two levels of abstraction were established: a very abstract, reflecting only basic hydrological processes, but simple to calibrate and control, and more complex, spatially explicit, reflecting the hydrological processes within the landscape more realistically. The second level of abstraction has an advantage for its spatial explicit form, but needs much more data to be set and calibrated.

We tried to answer the following detailed questions:

What is the land cover and its dynamic in the Odra case study?

How to quantify the water balance in the Odra case study modelled area?

How LRS is working and affecting the ground water level?

How ecological succession in the neglected LRS affect its functions?

How riparian vegetation could be used as an indicator of LRS maintanance?

How weather flooctuation impact the LRS effectivness?

What are the main driving forces of land cover changes?

How land cover changes (LUCC) affect the LRS effectiveness, crops losses, and farmers expectation?

4. Knowledge elicitation and research methods

4.1 Stakeholders workshops

4.1.1 Workshops with local communities

Workshops with local communities were performed in Zaborow and Kwiatkowice villages on the 10 and 11th. of May 2005 in order to elicit knowledge on main local problems. Every resident of the village was invited, as well as local authorities. People were asked to write down three main problems of the region, each on a separate sheet of paper. Then sheets were collected and sorted by subject.

Figure 4.1.1 Workshops with local communities

4.1.2 Workshops with experts

Workshops with key domains (land use, water management, social welfare) experts were performed in Wroclaw in order to elicit knowledge on main regional development determinants and to find solutions for problems pointed out by local communities. There were two tasks during workshops.

Task I The problems identified during workshops with local communities were presented to

experts. The task was to work in groups and find solutions for these problems. Experts could choose a thematic problem group they wanted to work in.
Task II The other task was to perform SWOT analysis of regional development issues. Experts worked in groups, writing their comments on paper sheets. Then a public presentation of results and a discussion took place.

Figure 4.1.2. Workshops with key domain experts – SWOT analysis

4.2 Legal and economic analysis

The analysis of Polish Water Law Act was performed in order to find formal rules that form legal framework for individual decisions regarding land reclamation maintenance. The economic balance was calculated for the costs of production and purchase prices in 2005 year. This ear is a first full year for Poland in EU (the accession was in May 2004). The economic data, and economic analysis for 2005 are now available, while for 2006 (second full ear in EU) it is impossible to get some of the data. The calculation was made for the cereals, as an average value of the production costs and purchase prices of seven types of cereals.

4.3 Social survey research

4.3.1 Population of concern and sampling

Population of concern consisted of all landowners living in three villages in the study area. A household was chosen as the sampling unit. Since the population of concern is not too big we decided to make interviews in every relevant household and no real sample was specified. The sampling frame (list of households) was based on credible data on land ownership (including names, addresses and parcels' numbers)[3], what allowed us to reach every land owner in the study area. The interview, if possible, was conducted with a person making decisions about the farm in order to ensure the credibility of elicited information. We suppose that the approved course of action guarantees that studied population is representative for the study area and that elicited knowledge, including decision rules, is believable.

4.3.2 Research tool

The semi structured qualitative interview (Babbie, 2001; Frankfort-Nachmias, Nachmias, 1996) was chosen as a research technique. Interview guidelines and later, more formalized questionnaires, were constructed to find answers for research questions and meet the needs of the modelling team. Many questions focused on reasons and conditions (e.g. IF milk production profitable) of different types of behaviour (e.g. THEN keep meadows) to make it possible to develop rule sets as an important part of the knowledge base.

Interviews concerned the following issues: land use (changes in the past and their causes, decision rules, plans for future), perception of changes in landscape, land reclamation system maintenance (general state, the awareness of legal rules and responsibility, personal care, losses due to droughts/floodings, collective action – Water Partnerships), social issues (perception of social change, social networks, sources of information, cooperation, social activity, decision making mechanisms), economic issues (farming profitability, sources of income, costs of LRS maintenance and investments in farming).

The research was conducted in two stages: the objective of the first one was to get a general insight into land use issues, opinions about LRS and social networks. In the second stage interviews were focused on more detailed (also quantitative) data on farming and economic issues and the specific reasons for the lack of LRS maintenance and collective action. This approach is followed by two versions of the interview questionnaire, from which the first is more in-depth and general, while the second one is more categorised and structured.

The questionnaire was tested and discussed with key domain experts.

4.3.3 Organization of the research process

Interviewees (landowners) in Rogow Legnicki village were identified (names and addresses, phone numbers) according to landownership maps, data form local authorities and other sources of information. The covering letter was prepared and personally distributed among interviewees in order to get permission for interviews. In villages Kawice, Kwiatkowice and Peclaw it was the task of interviewers to identify farmers, since detailed official data was not available.

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[3] Abstract form land ownership registry, District Office in Legnica

All answers were noted in the questionnaires. Moreover some interviews were recorded if the permission from a respondent was obtained.

The first wave of field research was carried out in February 2006, the next one in summer 2006 and the last one in autumn 2007. One interview usually takes about 1.5 hour with a landowner and 2-4 hours with an expert.

4.3.4 Data processing and analysis

The knowledge base for modellers was prepared based on research results as a set of narrative storylines i.e. structured descriptions of farmers' past and future behaviour, reasoning and perceptions regarding land use and land reclamation. Storylines were developed based on interviews' transcripts and present farmers' opinions and perceptions.
The qualitative synthesis of results with respect to the detailed research questions is presented in section 4.

4.4 Biophysical research methods

4.4.1 Hydro-meteorological methods

Climatic conditions

Wrocław–Biskupin (51 deg 07 min N, 17 deg 05 min E, h=116,3 m a.s.l.) meteorological station was chosen as the best suitable for the Odra case study climatic conditions. The basic meteorological data, important for water balance, were analysed from time series 1946-2004. Extremely wet, dry and intermediate years were chosen for simulation of the weather conditions in the Shame model. Full data series are used for the WATCH model and for validation purposes.

4.4.1.1 Set up of a hydro-meteorological ADAS monitoring

During the field work in spring 2007 some potential locations for the ADAS (Automatic Data Acquisition System) station were found, but the final decision was mainly dependent on security of the equipment, so a fenced area within a chosen private property in Rogów was assumed as optimal one. In the beginning of June 2007 the system was launched. A digital SKYE data logger was fixed on a 2 m high mast and the instruments were mounted (Fig. 4.4.1.1).

A complete system consists of an outer part registering meteo parameters and an underground part for analyzing unsaturated zone and groundwater level fluctuations. Similarly to other meteo-stations the measurements of rainfall, air temperature, air humidity, solar radiation and wind speed are conducted in continuous mode using instrumentation which enables proper evapotranspiration calculations. The installed type of monitoring system was equipped with seven sensors which record the data with a minute frequency and average values are stored hourly in memory of the logger. Once a month, the data are downloaded to the computer. Recorded parameters are as follows:

- air temperature – on height of 2 m,
- air humidity – on height of 2 m,

- wind speed – on height of 2 m,
- solar radiation – on height of 2 m,
- precipitation,
- soil temperature – on depth of 5 cm,
- soil moisture– on depth of 50 cm.

Figure 4.4.1.1. Installation of the ADAS monitoring system in Rogów Legnicki, 07.06.2007

The field activity was focused on controlling, re-programming and reading the files which have been put into created database being visualised on linked charts. The monitoring system ADAS was additionally supported by groundwater level measurements using GEALOG logger, which allows to record groundwater fluctuations and temperature with hourly frequency in a well located nearby. Three series of measurements were also done to asses the groundwater level within the whole study area for certain periods of time. This work was supplemented by open channel flow gauging using a current meter in two major streams called Kwiatkowski Creak and Rogowski Creak which drain water from the system.

4.4.2 Materials and methods of LRS investigation

The watercourses were divided into homogenous sections, with respect to vegetation, channel morphology and water regime. The cover of dominant plant species (>5% cover) in vegetation strips along watercourse was assessed. The sum of cover of the aquatic plants was also assessed, with a distinction of the most abundant species. The sections were mapped on orthophoto map, using a mobile GIS set of a PDA computer with ArcPad software and GPS receiver. Adjacent land-use of each section was recorded. All field work was done in June - September 2007.

Further analysis was performed using typology of watercourses vegetation. The typology was based on the classification of riparian vegetation using TWINSPAN, with respect to its applicability in landscape analysis (Szymura et al 2008). The typology is shown on Figure 5.4.4.2.

4.4.3 Materials and methods of LULC research

Landscape changes research was based on archival and contemporary 1:25 000 topographical maps.

Rogow Legnicki area is covered by one 1:25 000 Messtichblatt map sheet from 1944 (sheet number 4764), two sheets of 1:25 000 PPGK map from 1975 (452.23, 452.41) and two sheets of 1:25 000 ZGW map from1993-1994 (M-33-33-B-a,b, M-33-33-B-c,d).

Peclaw area is covered by one 1:25 000 Messtichblatt map sheet from 1933 (4363), two sheets of 1:25 000 PPGK map from 1975 (442.14, 442.32) and fragments of four sheets of 1:25 000 ZGW map, dated 1993-1995 (M-33-21-A-a,b, M-33-21-B-a,b, M-33-9-C-c,d, M-33-9-D-c,d).

Mestichblatt maps are in coordinate system of the 5th zone of Gauss-Krüger system, datum DHDN (known also as datum Rauenberg or Potsdam). ZGW maps are in coordinate system of zone 33N of UTM system. Both coordinate systems are based on transverse Mercator projection. In case of Gauss-Krüger system the reference surface is a local Bessel 1841 ellipsoid, in case of UTM it is a global WGS84 ellipsoid. The PPGK maps are in the coordinate system of zone IV of System 1965, datum Pulkovo 1942(58) with a reference surface Krassovsky 1942 ellipsoid and oblique stereographic projection.

Metstichblatt and ZGW maps were scanned and georectified into their native cordinate systems, using SuperEdit 2.6 software. An optimal number of calibration points and transformation method was chosen for each map series. In case of contemporary, less distorted ZGW maps, 9 points and bilinear transformation gave satisfactory results – maximum root mean square error (RMSE) for sheets that cover Rogow Legnicki and Peclaw areas was 4.8904, minimal 2.3941. In case of archival Mestichblatt maps the maximum available calibration points were used, usually over 200 per sheet, with a bicubic transformation. In case of sheets that cover Rogow Legnicki and Peclaw area this gave RMSE of 3.7751 and 3.6891, respectively. The PPGK maps were obtained already scanned and georectified.

All maps were subsequently transformed into a common coordinate system, UTM 33N, with *gdalwarp* utility from GDAL 1.5.0 software package.

From such background maps the land cover information was digitised on-screen. Following categories were delimited: forest, grassland, arable area, water. Remaining categories , ie. orchards, wastelands, cemeteries were generalised into a common class „other”.

The land cover information, stored in Shapefile format, was imported into database of GRASS GIS 6.3 software. Vector maps were rasterized using cell size of 1m. Raster maps were used as a basis for the calculation of the area occupied by each land cover class in the analyzed years, and to obtain data required for performing a so-called transformation matrix, allowing for more advanced landscape changes analysis (Pontius 2004).

4.5 Role-playing game

AgroGame is a name of a multiplayer computer game designed as a validation tool for an agent based model. Each player of the game plays a role of a farmer, who owns a parcel. There are six such parcels in the game, each owned by a different farmer. The parcels lay on a piece of land of small and homogeneous slope, along a homogeneous channel, that runs through the center of every parcel. This channel is one of the key elements of the game's model. The parcels' area and land use is homogeneous. The game works with a yearly time step. A single game's session consists of 15 time steps. In each time step the game's model calculates yields and a very simple economic balance for every parcel. At the start of the game, each farmer has the same amount of money. During the game farmers spend their money on agricultural production and optionally on maintaining the channel. They earn money by selling agricultural products.

There are two variables that are used for measuring players' performance. One is wealth accumulated during the game and another is reputation. Reputation is measured in special “reputation points”. The more “reputation points” a player has, the higher their reputation. At the end of the game, players are presented with game results, that consist of values of wealth and reputation for all players. The values of wealth and reputation are treated as equally important and it is up to the player to decide which variable is more significant to them.

In every turn a player can undertake certain actions. These actions can be divided into two groups: channel maintenance related actions and social interactions. In the first group there are only two possibilities. A player can decide to either maintain or not maintain their segment of the channel. If a channel's segment is not maintained it cannot remove extra water from adjacent fields. This can lead to local flooding during wet years, which in turn leads to losses of crops. On the other hand, maintaining a channel costs money and during years with average rainfall the flood protection function of the channel is negligible. Even if the channel is not maintained, there will be no flooding. Hence, the player is faced with a dilemma: maintain the channel and have relatively small income, due to high maintenance costs, regardless of weather, or not maintain and have high income during normal years and losses during wet years. The players only have knowledge about the current weather . There are no forecasts available. The effectiveness of the channel in preventing floods on a given field depends not only on its condition along this field, but also along a number of fields below. In other words even if a player maintains their part of the channel, but his neighbours below do not maintain their parts, then the player can still have losses due to flooding. This is the worst possible scenario, as the player pays for channel maintenance and despite of that has poor crops.

The second group of actions consists of social interactions. These are limited to just two, or three possibilities depending on the game's mode. The basic two actions are praising and criticizing. Every player can praise or criticize any other player. When a player is praised, their reputation rises by one point. If they are criticised, they loose one point of reputation. During a single time step a player can criticise or praise another player only once. The game can be run with an additional mechanism of social interaction. It's a complaint. Any player can file a complaint to the municipality office against any other player who is not maintaining their part of

the ditch. The complaint takes effect in the next time step and causes the player against whom such a complaint was filed to be fined a penalty fine. This fine is high and can have a significant effect on the player's wealth. However, the player against whom such a complaint was filed, will be informed about this fact during the same time step and can decide to start maintaining the channel and by so doing, evade the penalty. A player who decides to file a complaint against another player must be aware of the fact, that the other player will be informed about the complaint, will know who filed it and so can undertake some retaliatory actions like criticising.

There were 3 sessions performed in three, each of them consisting of the 15-minutes training game and two main games lasting for about 1 hour. Every player was accompanied by two students, who mad observations of the process and carried out interviews with players during and after the games.

There were 42 players and 7 games.

Figure 4.5.1 Farmer playing computer game with the assistance of students

Figure 4.5.2 Focus – discussion with agro-game players leaded by Barabara Pabjan

5. Results and discussion

5.1 Stakeholders workshops

As a result these workshops identified the main problems in the region as follows:
P ROBLEM I *Risk of floods due to* :

- neglected and damaged dikes
- insufficient river engineering

P ROBLEM II *Maintenance of land reclamation system*
Land reclamation facilities are broken-down and the network of canals and ditches neglected. This causes the following problems:

- seasonal floodings (fields flooded when heavy rains fall in areas where the drainage system does not work)
- lack of irrigation potential (in case of droughts)

P ROBLEM III *Socio-economic issues*
• Insufficient youth support (lack of places to meet and spare time activities)
• Transportation problems (not enough buses, people can't get to work)
• Insufficient road system
P ROBLEM IV *Environmental issues*
• Deforestation and tree stand atrophy
• Low groundwater levels (low buffering of drought)
• Insufficient sewage system

• Reforestation of areas with low production potential is hindered by lack of information about opportunities when management plans are being established and by the high costs of retraining
• Insufficient exploitation of potential for tourism

Solutions to these problems were found during expert workshops as follows:

GROUP I Risk of floods – solutions
• Social activity – cooperation in dike and infrastructure maintenance
• Creation of polders
• Proper spatial planning to avoid to build on floodplains (responsibility of local authorities and legal remedies)
• Individual actions and attitudes (like risk awareness, flood insurance)

GROUP II Maintenance of land reclamation system – solutions
• Agricultural Consulting Centers – education of farmers
• Implement cheap technologies like sluice gates made of wood or sand bags
• Field height markers based on floodplains maps in order to mark out lands susceptible for flooding
• Ditches cleaning together with sluice gates construction
• Aerial photos (in thermal infrared) for visualization of drainage system
• Cooperation with Wroclaw University of Agriculture
• Increase of organic matter in soil (increase of retention)

GROUP III Socio-economic issues - solutions
• Insufficient youth care: it is the responsibility of local authorities
• Transportation problems: adapt timetables to employers' requirements, local authorities should provide workers with transport e.g. small bus, as for private companies it's not profitable
• Insufficient road system: it is the responsibility of local authorities

GROUP IV Environmental issues - solutions
• Forests and tourism: Establishment of Odra River Valley Landscape Park and other protected areas
• Low groundwater level – not true, there is no evidence for this statement
• Tourism: Reclamation of information and organization system, financial and organizational help of partnerships for individuals to develop suitable facilities
• Sewage: Development of sewage treatment works adjoining to the house, but: not enough information and help from Agricultural Consulting Centers, on the other hand farmers do not attend trainings
Reforestation of low class lands: management plan is expounded to the public insight before approval, it is enough to read it and propose motions, but people do not have the habit to read management plans and later complain for included agreements and directions; village chairmen should be familiar both with a plan and farmers, who would wish to retrain their lands and afforest them.

SWOT analysis of regional development issues.

Strengths	**Weaknesses**
Land use and water related issues - Extensive farming - Health foods - Malczyce – water weir and lock - Eligibility for agri-environmental schemes Social issues - Cultural values Institutional and legal issues - Leader + program - Partnership - Existing development strategies and plans (as passed documents) - Lack of protected area status (chance for flood protection and economic growth) - Good work of local authorities Economic issues - Close to Wroclaw and other rich towns - Tourist values - Presence of industry in surrounding municipalities Environmental issues - Satisfactory environmental quality - Natural values: nature reserves, forests, meadows, game - Lack of polluting industry	Land use and water related issues - Insufficient flood control - Insufficient sewage system - Insufficient shipping conditions (low water levels on Odra river) - Seasonal flooding - Land reclamation system neglected - Poor and polluted soils - Lack of dikes - Food processing industry decay - Land ownership issues not clear - Lack of sluice gates on ditches - Not enough water, low rainfall - No reserves of arable lands - Farmers not sufficiently educated Social issues - Poverty, low incomes, unemployment - Young people outflow - Low education and ecological awareness standards Institutional and legal issues - Lack of protected area status (tourism) - Difficulties to get EU funding (complicated procedures, lack of skills) - Spatial planning - Insufficient risk alarm system - Weak cooperation of local governments Economic issues - Insufficient budgets of municipalities Infrastructure issues - Insufficient road system - Transportation problems (not enough buses) - Lack of tourist infrastructure
Opportunities	**Threats**
Land use and water related issues - Agri-environmental schemes - EU accession (funding) - Malczyce – water weir and lock (shipping, ports, employment, power plant) - Ecological or “green” farming - River navigation development Institutional and legal issues - Habitat directive (Natura 2000) Economic issues - Water directive (legal regulations) - Brown coal deposit Legnica - Tourism development - Reforestation - New copper mine (Jerzmanowa-Glogow) - Investments - Housing construction (sites for housing become more expensive)] Infrastructure issues - Ciechanow bridge	Land use and water related issues - Brzeg Dolny water weir and lock (construction disaster, pollution, series of weirs and locks is now needed) - Floods - Malczyce water weir and lock (groundwater level decrease, threat for natural values) - Water directive not executed due to lack of money - Low water levels on Odra river - Pollution (sewage) - Potential disaster in Zelazny most flotation reservoir Social issues - Society getting older Institutional and legal issues - Lack of public participation in decision making and planning Economic issues - Brown coal deposit Legnica

5.2 Legal and economic issues

5.2.1 Legal framework for land reclamation and collective action in water partnerships

Following:
1) Water Law Act from the 18th. Jul. 2001 (Journal of Laws 2001 Nr 115, pt. 1229, Nr 154, pt. 1803, 2002 Nr 113, pt. 984, Nr 130, pt. 1112, Nr 233, pt. 1957, Nr 238, pt. 2022, 2003 Nr 80, pt. 717, Nr 165, pt. 1592, Nr 190, pt. 1865, Nr 228, pt. 2259, 2004 Nr 92, pt. 880, Nr 96, pt. 959, Nr 116, pt. 1206, Nr 273, pt. 2703, 2005 Nr 85, pt. 729, Nr 130, pt. 1087, Nr 163, pt. 1362, Nr 169, pt. 1420, Nr 175, pt. 1462.);
2) Ordinance of the Ministry from the 11th. Feb. 2003 regarding terms and procedures of melioration fees specification and exaction (Journal of Laws 2003 Nr 41, pt. 344, 345).
3) Expert interviews

Abbreviations:
LR – land reclamation
LRS - land reclamation system
BLR – basic land reclamation
DLR – detailed land reclamation
WP- Water Partnership

5.2.1.1 Basic Land Reclamation (BLR)

The facilities of basic land reclamation (BLR) (damming up constructions, water weirs, water reservoirs, canals, regulation and flood control constructions, dumping stations, access roads necessary to maintain BLR facilities) belong to the Treasury and are built at its expense. The BLR facilities may be also built at the expense of other legal or natural persons, as well as co-financed from public community funds. The latter solution is based on the **Marshal's** decision, in agreement with the **Voivod**[4].

Both BLR planning and the supervision of plans' execution, as well as BLR maintenance are the obligation of the voivodeship's **Marshal**[5].

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[4] Poland is administratively divided into 16 voivodeships (regions). In each voivodeship there is one Voivod (Governor) who - as State Territorial Representative - represents Polish Government and central administration, while the Marshal is a representative of the voivodeship's self-government.

[5] Specialist companies are subcontracted to build BLR (following: expert interview EI1).

5.2.1.2 Detailed Land Reclamation (DLR)

Landowners are obliged to build DLR facilities on their lands. DLR includes: ditches, drainage, pumping stations used for pressure irrigation, fish ponds, dikes along irrigated fields, drained/irrigated meadows and pastures.

The maintenance of all kinds of DLR is the obligation of **land owners** or a relevant **Water Partnership**. **IF** this obligation is not performed, **THEN** relevant administration unit, trough official decision determines the scope and deadlines of activities to be done, in proportion to the benefits of given landowners.

5.2.1.3 Detailed Land Reclamation (DLR) built at the expense of the Treasury.

The facilities of detailed land reclamation (DLR) may be built at the expense of:

- the Treasury, with a partial repayment in the form of a **melioration fee**, paid by land owners who benefit from these facilities and who are henceforth called „interested land owners", **IF**:
a) the area is characterized with significant comminution of farms, **OR**
b) DLR facilities are threatened with decapitalization, **OR**
c) agriculture restructuring depends on the regulation of water conditions in the soil.

MY COMMENT: A person becomes an „interested land owner" if he/she benefits from DLR and not if he/she claims to be „interested" through personal decision.

- the Treasury with a share of public community funds, with a partial repayment in the form of the **investment fee**, paid by interested land owners (20% of the costs of DLR facilities construction. The investment fee is an income to the national budget)

The decision to build detailed land reclamation at the expense of the Treasury is made by the **Marshal** in agreement with the **Voivod** after a written request from a **Water Partnership** or **interested land owners** (owing min. 75% of the lands designated for DLR). Foregoing decision has to be announced in accordance with customary practices in the given region and placed on a bulletin board in communal offices, for at least 14 days.

The **Marshal** specifies the melioration/investment fee through official decision, separately for every **interested land owner** and **in proportion** to the area, which is supposed to be affected by given DLR. The land owner, whom this decision concerns, is obliged to provide access to his land and buildings, so that the DLR can be designed and constructed. Melioration/investment fees ought to be paid into the relevant Marshal Office's account.

DLR's (built at the expense of the Treasury) planning and the supervision of plans' execution (BUT NOT MIANTENANCE!!!) are the obligation of the voivodeship's **Marshal**. In case of

damages resulting from DLR's construction, a landowner is entitled to compensation for these damages. A claim for compensation lapses within 3 months from the moment when a landowner discovered the damage. **IF** the construction of DLR is properly organised and conducted with proper technologies, **THEN** the owner of the land, on which this DLR is built, is not entitled to any compensation for either loss of land or damage to the crops.

5.2.1.4 Melioration fees

Regulations connected with melioration fees are established by the Council of the Ministers in the form of an ordinance. The fees depend on:

a type of DLR facilities,
size of the area, which is positively affected by DLR[6],
unit fee rate per 1 hectare of this area,
costs of facilities' construction,
participation of drained/irrigated land users in a Water Partnership,

while:

1) for drainage and irrigation facilities, except pressure irrigation, melioration fee depends on both (product a*b):

a) size of the area positively affected by these facilities
b) unit fee rate that is defined as lump rates quantified in kilos of rye per hectare of drained/irrigated arable lands; maximal rates cannot be higher than 5000 kg/ha; the average purchase price of rye will be taken into account[7],

2) for pressure irrigation, fishponds, reconstruction and modernization of single facilities in LRS the melioration fee will not be lower than 30%, and not higher than 80% of the construction costs[8],
3) melioration fee has to be paid in annual installments[9],
4) members of Water Partnership will have a 15% discount off the land reclamation fee,
5) the fee has to be paid on the account of the relevant Voivodeship Office.

.....

Access to information: The registry of LRS facilities and drained/irrigated lands is managed by the Marshal's Office; access to this information is open and free of charge. .....

[6] In case of ditches it means 50 meters from a ditch, in both sides. In case of drainage it means the area covered with drainage facilities (following: expert interview EI2).

[7] Detailed „rye rates" regarding certain types of LR facilities are presented in Tab.2 at the end of this document.

[8] Detailed percentage of facilities' construction regarding certain types of LR facilities is presented in Tab.2 at the end of this document.

[9] Detailed time periods of paying installments regarding certain types of LR facilities are presented in Tab.2 at the end of this document.

5.2.1.5 Water Partnerships - legal rules of collective action

Water Partnerships establishment and rules

Water Partnerships (WPs) are the organisations, which associate natural or legal persons in order to satisfy their needs regarding water management, including:
1) water supply and processing,
2) protection against pollution and sewage treatment,
3) flood protection,
4) land reclamation system maintenance,
5) fire-fighting waters.

WPs may join together and create WPs' associations.

A Water Partnership is established by virtue of written agreement of **at least three legal or natural persons**.
IF at least 3 natural or/and legal persons come to an agreement on the establishment of the WP **AND** the WP statute is approved by the relevant **Prefect** of a district trough official decision **THEN** the WP acquires legal entity.
IF the statute is not consistent with the law **THEN** the **Prefect** may refuse to approve it.

IF a WP makes profits **THEN** these profits can be allocated only to its statutory purposes.

IF the area designed for LR is not fragmented (forms one complex) **AND** the extent and the technical project of LR were agreed with the **Voivod AND** WP's equity equals at least the amount calculated according to the formerly described methods of estimating melioration/investment fees, **THEN** it is possible to get partial subsidy for LR facilities maintenance and/or construction from the national budget or form the budget of local government.

The member of a WP is obliged to pay dues and complete other performance[10], which are in proportion to the advantage he/she derives from WP activities.

IF the dues and other performance determined by a WP in order to maintain DLR facilities are not sufficient to accomplish statutory objectives set for a given year **THEN** the **Prefect** may apply to WP authorities for increase in these dues and other performance.

IF a WP that maintains facilities built with partial public funding fails to increase those dues and other performance despite the Prefect's request, **THEN** the Prefect himself can decide to increase them. The execution of dues is conducted according to specific legal regulations regarding tax execution.

IF any natural or legal persons as well as **organizational units without legal status**, that do not belong to the WP, derive advantages from WP's facilities or cause pollution of waters being

[10] „to complete a performance" is a legal term, which in this case means „to provide services"

under WP's administration **THEN** they all are obliged to complete a performance in favor of this WP. Degree and type of this performance is determined by the **Prefect** through official decision.

WP authorities

WP authorities are as follows:
1) general meeting,
2) board,
3) audit commission.

General meeting:
1) decides about WP's work plan and its budget,
2) determines the rate of dues and degree of other performance in favour of WP,
3) elects the members of the board and audit commission,
4) examines and approves annual reports,
5) passes resolutions.

General meeting is called by a Board at least once a year.

Resolutions of the general meeting are passed with simple majority of votes, except the ones concerning: changes in the statute, dissolution of partnership, joining other WP, which are passed with two thirds majority of votes and the presence of at least half of WP's members.

IF a resolution concerns changes in the statute or dissolution of the WP or joining other WP or division of the WP **THEN** a WP Member is entitled to one vote

> **ELSE**
> **IF** the statute granted a WP member with number of votes depending on his/her dues and performance
> **THEN** a WP member is entitled to the number of votes that is proportional to his/her performance
> **ELSE** a WP Member is entitled to one vote.

The board of a WP:
1) executes the resolutions of the general meeting,
2) directs WP's activities,
3) administers WP's property,
4) represents a WP.

IF any services and other duties of WP members are not performed within the time schedule **THEN** the board has a right to charge these members with the costs of these services and duties.

Audit commission controls WP's activity, including financial control.

WPs control

The Prefect supervises WPs activity.

The WP board is obliged to tender all resolutions to the Prefect within 7 days from the moment they were passed.
Resolutions conflicting with the law or with the statute are not valid. The Prefect decides on the validity of resolutions and may stop the execution of the resolution for the time of proceedings in a case of its validity.
WP has the right to lodge a complaint about Prefect's decision to the Administration Court.
IF the board breaks the law repetitively **THEN** the **Prefect** may disband the board. The new board has to be chosen within 3 months by the general meeting.

WP dissolution

The general meeting may dissolve the WP through resolution.
The Prefect may dissolve the WP through official decision **IF**:
1) WP's activity breaks the law,
2) 3 months have passed since the board was disbanded and the new bard was not chosen,
3) there are less members than 3.

Tab. 5.2.1.1. Agents and their competence in decision making i.e. the categories of decisions they may take (for example: category „DLR construction includes the following decisions: to construct/not to construct, in which place exactly, what kind of facilities, when to construct, who is going to do it; only the first decision "to construct/not to construct" is a simple binary choice yes/no or 0/1).

Agent	**Decision categories**					
	BLR construction and maintenance	BLR financing	DLR construction	DLR maintenance	DLR financing	Water Partnership establishment
land owner			+	+	+	+
Voivod		+ (if BLR is co-financed from public community funds)			+ (if DLR is co-funded by The Treasury)	
Marshal (which means: LSOfLR on his behalf)	+	+	+ (if DLR is co-funded by The Treasury)		+ (if DLR is co-funded by The Treasury)	+
Water Partnership			+	+	+	
Prefect			+ (it means the control over WP's activities)	+ (it means the control over WP's activities)	+ (it means the control over WP's activities)	+

LSOfLR – Lower Silesia Office for Land Reclamation acts on behalf of the Marshal and performs his legal tasks resulting from The Water Law Act within the scope of water ownership, water management, land reclamation systems and water partnerships.

5.2.1.6 Economic balance of agriculture

The net income (I) is calculated as a sum of the income from production (Ip) and subsidies (S) minus the cost of production, tax and insurance:

$$I = (Ip+S-(TC+Tax))*ha-Ins*Pers;$$

where:
I - income (netto)
Ip - income from production
TC – total production costs
S - subsidies

Tax - tax
Ins - insurance costs
Pers - adult person in the farm

Income from production

The income depends on the productivity and the prices. The productivity is highly variable and depends on many factors, e.g. the weather. To avoid the bias caused by these fluctuations, five years averages are taken. The prices are also variable, but they depend largely on the political and economic situation, which was different before and after the EU accession. Thus, it is pointless to include average prices from the time before and after the EU accession in the calculation. The prices from 2005 are included in the calculation.

Subsidies

The subsidies are of 2 kinds: to the arable land and to the production of certain species of plants (including cereals). Both subsidies are paid per ha. The level of subsidies in new EU countries (EU-10) is 55% of the EU-15 level and will increase to be equal in the 2013.

In 2005 24% of income comes from subsidies.

Total cost

Total costs consist of variable costs and fixed cost.
Variable costs include: seeds, fertilizers, pesticides, subcontracting, own machine work.
Fixed cost include: tax and insurance costs.

Tax

Tax depends on the area and the soil class. It is an equivalent of 2,5 dt of rye (average price from the 3 quarters of the previous year). The soil class is represented as a *comparative fiscal hectare* (tab. 5.2.1.2). If the farmer manages 1 ha of I class soil, he pays the tax calculated for 1,8 ha. If he manages 1 ha of VI class soil he pays only for 0,4 ha.

Table 5.2.1.2. Soil classes as comparative fiscal hectars

Soil class:	***comparative fiscal hectare***
I	1,8
II	1,6
IIIa	1,4
IIIb	1,2
IVa	1
IVb	0,8
V	0,6
VI	0,4

As most of the soils are in the average class, soil class IVa was included in the calculation.

Insurance

The payment consists of two elements: pension insurance and health insurance, which in the 2005 were 672 zl/year and 288 zl/year, respectively.

Relation between the income and the farm size

The result of simulation for farms that differ in size (from 1 to 50 ha) is shown in the tab. 5.2.1.3. Farms larger than the 3 ha achieve positive economic results, but this income is not sufficient to make a living. For comparison the **minimum salary** in 2005 in Poland was 849 zł, which gives 10188 zł a year. This level of income is achieved by farms larger than 17 ha, managed by one person or larger than 33 ha, if the farm is managed by 2 persons.

The influence on the yield

The income depends to some extent on the yield. If the yield achieves the level of 53 dt/ha (average for Germany in years 2000-2005) the income increases and the minimum salary is achieved by farms equal to or larger than 10 ha and 17 ha in farms managed by one or two persons, respectively. If this higher yield is used in equation the relative significance of the subsidies decreases to the level of 18%.

Tab. 5.2.1.3. Income from farms of different size (yield per ha 31,9 dt/ha)

ha	Ip brutto	S	Cp	T	Ins(2)	Pers	I
1	1653	507	1400	94	960	2	-1254
2	3306	1015	2800	188	960	2	-588
3	4959	1522	4200	283	960	2	79
4	6612	2029	5600	377	960	2	745
5	8265	2537	7000	471	960	2	1411
6	9919	3044	8400	565	960	2	2077
7	11572	3551	9800	659	960	2	2744
8	13225	4059	11200	753	960	2	3410
9	14878	4566	12600	848	960	2	4076
10	16531	5073	14000	942	960	2	4742
11	18184	5581	15400	1036	960	2	5409
12	19837	6088	16800	1130	960	2	6075
13	21490	6595	18200	1224	960	2	6741
14	23143	7102	19600	1318	960	2	7407
15	24796	7610	21000	1413	960	2	8073
16	26449	8117	22400	1507	960	2	8740
17	28103	8624	23800	1601	960	2	9406
18	29756	9132	25200	1695	960	2	10072
19	31409	9639	26600	1789	960	2	10738
20	33062	10146	28000	1884	960	2	11405
21	34715	10654	29400	1978	960	2	12071

22	36368	11161	30800	2072	960	2	12737
23	38021	11668	32200	2166	960	2	13403
24	39674	12176	33600	2260	960	2	14070
25	41327	12683	35000	2354	960	2	14736
26	42980	13190	36400	2449	960	2	15402
27	44633	13698	37800	2543	960	2	16068
28	46286	14205	39200	2637	960	2	16735
29	47940	14712	40600	2731	960	2	17401
30	49593	15220	42000	2825	960	2	18067
31	51246	15727	43400	2919	960	2	18733
32	52899	16234	44800	3014	960	2	19399
33	54552	16742	46200	3108	960	2	20066
34	56205	17249	47600	3202	960	2	20732
35	57858	17756	49000	3296	960	2	21398
36	59511	18264	50400	3390	960	2	22064
37	61164	18771	51800	3484	960	2	22731
38	62817	19278	53200	3579	960	2	23397
39	64470	19785	54600	3673	960	2	24063
40	66124	20293	56000	3767	960	2	24729
41	67777	20800	57400	3861	960	2	25396
42	69430	21307	58800	3955	960	2	26062
43	71083	21815	60200	4050	960	2	26728
44	72736	22322	61600	4144	960	2	27394
45	74389	22829	63000	4238	960	2	28060
46	76042	23337	64400	4332	960	2	28727
47	77695	23844	65800	4426	960	2	29393
48	79348	24351	67200	4520	960	2	30059
49	81001	24859	68600	4615	960	2	30725
50	82654	25366	70000	4709	960	2	31392

I – yearly income (net), Ip - income from production, Cp - costs of production, S – subsidies, T – tax, Ins - insurance costs

5.3 Social survey research

5.3.1 Question 1: What are the main land use change processes in the Odra case study region and what are their causes?

One of the CAVES project objectives was to investigate the impact of external shocks on land use and social networks. In the Odra region considered shocks included political transformation in 1989, catastrophic flood in 1997 and EU accession in 2004. In interviews the emphasis was put on capturing changes in land use with relation to these shocks. According to farmers' opinions EU accession seems to be the most influential event of the three. As most important implications they indicate both subsidies and decrease in agricultural production profitability. Often they claim that despite subsidies profitability is lower because production costs increased (e.g. prices of pesticides or fertilizers) and the competition on the market is

tougher. Due to subsidies EU accession encourages two main processes in land use: **afforestation of poor soils** and **turning abandoned lands into arable fields**[11].
Other significant land use change is **turning meadows into arable fields**. This process is caused by the shift from animal towards plant production and especially by the enormous decrease in cattle, which is the result of low milk prices.

The flood in 1997 is perfectly remembered as a huge disaster by almost all of the interviewees, however its longstanding impact on land use is in most cases not noticeable.
Most of the farmers did not observe any changes in their own farming practice directly following the events of 1989, however they are able to indicate processes that occurred generally in the study area and are obviously linked with economic transformation that began in the 1990s. This is for example the bankruptcy or liquidation of purchase centres as well as production yards like sugar refinery, creameries, fodder factories or meet processing plants. Implications for land use include decrease in sugar beetroot and potatoes cultivation in favour of grains and reinforcement in pastures liquidation.

Since economic situation in Polish agriculture seems to be the main land use change driver, it would be unwise not to take it under consideration. Farmers' perceptions of economic regime shift are hardly optimistic. Many farmers perceive changes in agriculture as generally negative and the shift from the socialist towards free market economy (especially the lack of contract agreements and guaranteed prices) is in any way regarded as an improvement. Additionally monetary policy and consequent prices relations and purchasing power influenced farmers' economic viability → "Once I could buy a litre of petrol for a litre of milk." Uncertainties in market and finance hinder farmers' decisions about investment and production.
Certainly there is a social price for transformation. In fact only big farmers, who treat agriculture as business have a chance to make a living on farming and efficiently compete on the market and the time of small family farms seems to be passing away. And although experts claim that farmers are the biggest beneficiaries of EU accession in Poland, only few of the interviewees notice advantages of transformation like increasing number of mechanical equipment on farms, more fertilizers and other chemicals in use and a fact that due to EU requirements good farming practice becomes common.

Interviewees claim that not many real farmers remained in the village: the old ones gave up farming in order to obtain structural pensions, young people moved away and often own land only to get the farmer's type of insurance ("Some even don't know where their abandoned hectares are.") Farmers became aware of the fact that small farms have no chance to compete on the market, but some more optimistic ones admit that with the help from EU there is a development potential for young people who decided to keep on farming and reasonably specialize the production.

5.3.2 Question 2: What kind of decisions do farmers take with respect to land use and what are the reasons of these decisions?

The first decision a farmer must take is whether **to stay in farming business or not**. <u>If farming is perceived as profitable</u> than decisions are made to go on farming and sometimes even increase the farm size and extend production. <u>If farming is perceived as not profitable</u>, then two

[11] In order to get direct payments ploughing fields is required.

decisions are possible: to sell or rent land and skip farming or to maintain status quo – to keep husbandry as is and rely mainly on other than agricultural sources of income. Older farmers usually intend to hand their farms on to successors or the State in order to get structural pensions. It seems that a decision about being a farmer is basically economy driven however only certain significance of family traditions and personal habits can probably explain the behaviour of people who continue current level of farming despite regarding this activity as not profitable.

Regarding **farm size change** two strategies are possible – to decrease or increase it. Since small farms are not economically resilient it is not common to decrease the farm size. The strategy of increasing farm size is more probable, especially in case of young farmers. Some farmers declare that they would like to buy land but suitable parcels are not available in the surrounding area.

Next important decision concerns **production type** and is crucial for economic success. Animal production is not so common now, however there are few farmers who decided for high specialization strategy and maintain battery farms or piggeries. Cattle breeding has almost vanished due to low prices of milk. Most farmers go on with plant production.

Decision on **crops types** is first of all constrained by soil type and quality. Additionally when considering crop types to be cultivated farmers usually make some kind of economic cost-benefit analysis based on crops' market prices and production costs. The production of sugar beetroot is limited by top-down regulations.

Decisions on production type imply certain decisions on **land use**: cattle breeding requires grasslands both for browsing and fodder production; fish require fishponds; plant production naturally results in arable land use type. Environmental constraints may also be important – good quality soils will not be afforestated; some farmers claimed they had not ploughed meadows on the floodplain where crops cultivation is extremely difficult.

Different types of EU subsidies are one of the main external drivers that affect LULCC in Poland currently. Direct payments reinforce ploughing fallow lands as well as turning meadows into arable lands. Subsidies to afforestation initialized big shift towards planting trees on poor lands. However some farmers did not decide for afforestation due to delay in profits and investment requirements on the beginning. Additionally according to farmers afforestation is not profitable if the land acreage is too small. Agri-environmental schemes do not seem to have a big impact now. Farmers are not acquainted with these schemes and if they are they perceive relevant procedures as too complicated and unclear.

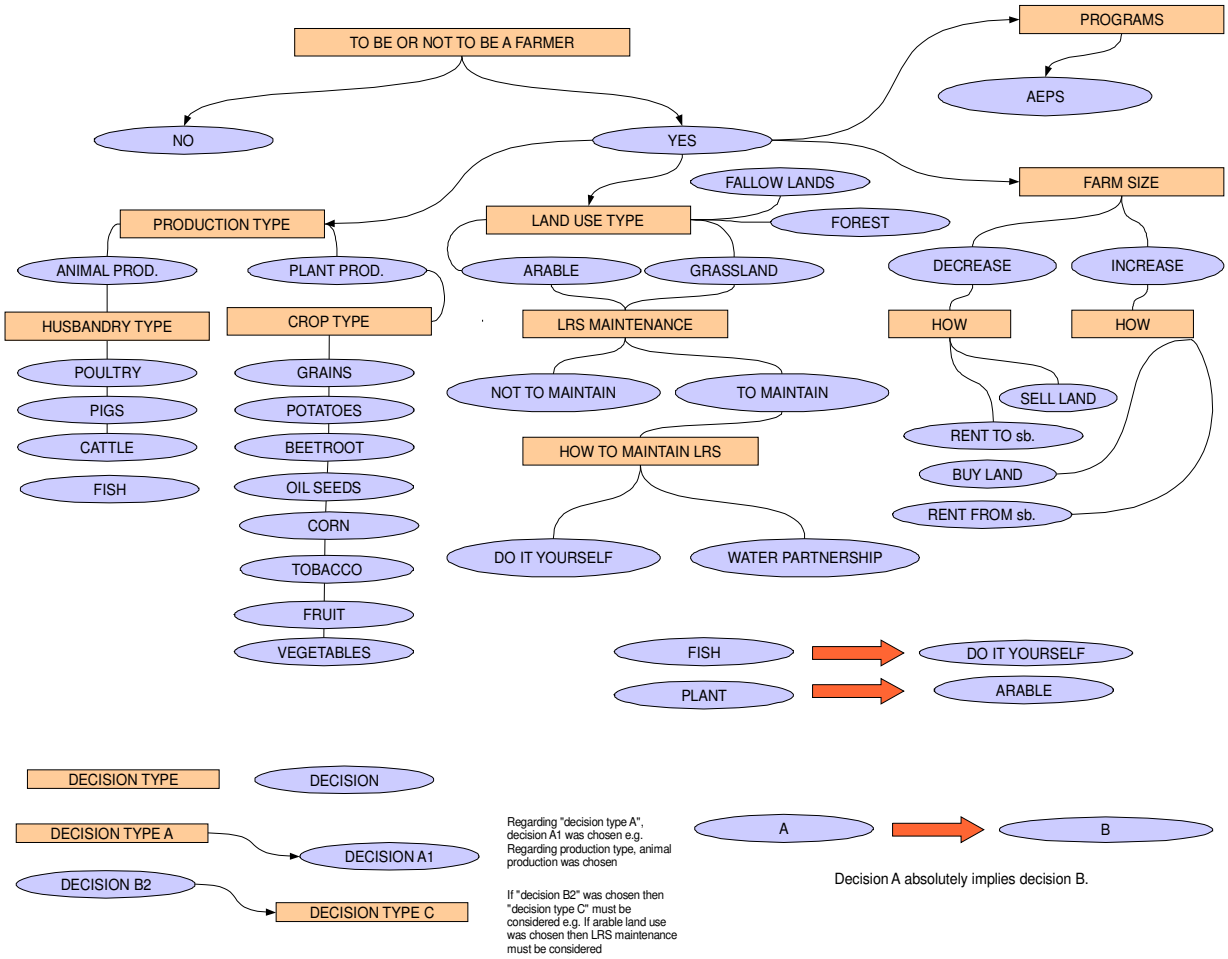


Fig.5.3.2.1. The paths of land use decision making

5.3.3 Question 3: What kind of decisions do farmers take with respect to LRS maintenance and what are the reasons of these decisions?

There are three main facts about LRS in Rogow Legnicki area confirmed by both farmers and experts:

- LRS does not work properly,
- most of the farmers do not maintain LRS (although it is their legal duty),
- Water Partnership is suspended.

Farmers choose different strategies regarding LRS:

- to maintain it properly,
- to maintain it only from time to time in case of troubles,
- not to maintain it.

There is a strong conviction among farmers that the State and/or local authorities hold the **responsibility** for the whole land reclamation system. In few cases this conviction is mentioned as a direct reason for not maintaining LRS ("I pay taxes so it's not my duty"). Other reasons relate

to the **maintaining capacity** in terms of skills, funds, equipment and time, namely the lack of relevant skills and equipment, and the necessity to choose between different time-consuming and money-consuming activities ("Farmers have many other [than LRS maint.] things to do", "Farmers seek for ways to save money.") However there is no agreement among farmers with regard to the assessment of these factors. Three groups of standpoints can be extracted from interviews.

1. LRS maintenance is an extremely difficult task and there is no way that farmers could manage to do it due to lack of skills, equipment, funds and time.
2. Basic LRS is easy enough to be performed by farmers themselves, however from time to time some more advanced work has to be done, which is not possible for farmers.
3. LRS maintenance is so easy that every farmer could do it with basic skills and equipment. Farmers don't do it just because they are lazy and passive.

Farmers are aware of both the general fact that system is interconnected as well as detailed interdependencies along channels and ditches. Thus it is clear for them that only **collective effort** would make the system work. The lack of confidence about this effort is another reason for not maintaining LRS.

There are some **economic drivers** as well. For instance many small farmers do not depend on agricultural production in terms of income so it is not reasonable for them to invest money and time in LRS maintenance. There was a comment that soils and consequently yields in Rogow are so poor that it's not profitable to take care of LRS. Some say that there are generally not enough big farmers in the area to make the system work.

The best reason to maintain LRS is the real dependency on its state resulting from serious agricultural production or having fishponds. If a farmer really needs LRS to be working he/she is even willing to maintain it on other farmers' fields.

Most common desired state of the system is top-down LRS management and/or maintenance by local authorities. In case of management local authorities would be capable to control farmers and coordinate their activities to ensure the collective effort. In case of maintenance local authorities would have financial, technical and human capacity in terms of equipment, skills, time and funds to perform LRS maintenance in the proper way.

That is more or less how situation looks like in the Peclaw area, where farmers just pay dues for the WP and do not have to mow and clean ditches themselves. Most of them expect these things to be done for them since they pay money for that and similarly as in Rogow they are convinced that it is too difficult and first of all time consuming for farmers to deal with LRS maintenance. However some of them claim that they maintain LRS themselves, because they are not satisfied with the efficiency of the WP. It is not clear whether the state of LRS in the Peclaw area was better before 1989 or not, because farmers state contradictory opinions on this issue.

5.3.4 Question 4: What are the social, institutional and economic drivers of collective action related to LRS maintenance?[12]

LRS maintenance requires collective effort to be effective since the system is interconnected. Before 1989 top-down approach was implemented in order to organize farmers in

[12] In this section I will focus on Water Partnerships as the most important manifestation of LRS related collective action in the Odra case study. It is clear that collective action could take some other shapes as well, like non formal agreements among farmers etc. However it does not happen in the study area at the moment.

Water Partnerships (WPs) with obligatory participation. Nowadays there are strong expectations among farmers that local authorities will continue top-down coordination and control of activities regarding LRS maintenance. It happens although the way WPs should be established is currently significantly different than before – according to the Water Law it is expected to be a bottom-up process, with at least three founders at the beginning.

According to farmers in the Rogow Legnicki area the new type WP (after 1989) did not fulfilled its duties properly and was not credible. As a result farmers stopped paying dues. The lack of funding makes things even worse - it looks like the vicious circle with no beginning (Fig. 5.3.4.1). According to farmers' point of view the place to intervene in a system is LRS quality – they declare they would start paying dues if they saw the improving state of LRS. However, it is only declaration and we cannot be sure that people would really behave that way unless we made an experiment.

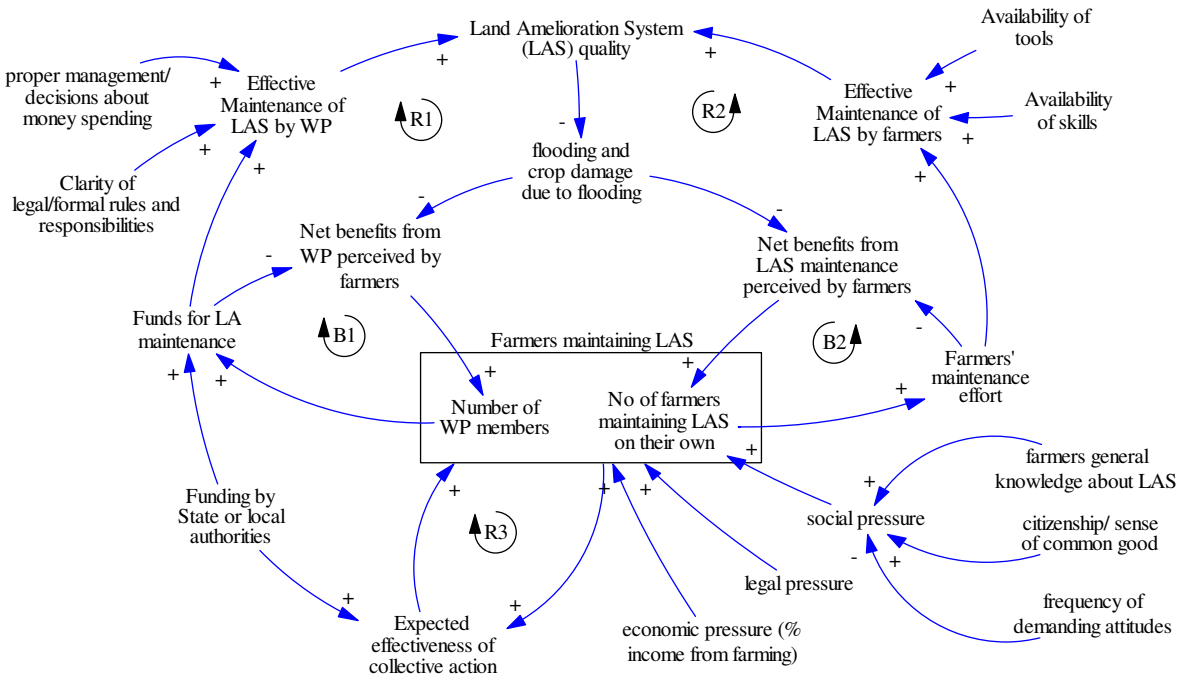


Fig. 5.3.4.1. Causal Loop Diagram of LRS maintenance system (arrows represent causal relations with '+' meaning directly proportional relation and '\\' meaning delay)[13]

It is worth noticing that interviewees mostly remember the old type WP (before 1989) as effective. It is not clear why the new type WP did not manage with LRS maintenance. The hypothesis might be that political transformation including a very serious reform of local government resulted in a legal mess and unclear rules for WPs' activities. They became inefficient and it influenced LR system's quality with a delay of 5-6 years when people stopped paying dues. Moreover the share of the financial input of the State in WPs' funding is now much smaller than it used to be before 1989.

Situation is a bit different in the Peclaw area, where Water Partnereship is active and people generally attend its meetings although they do not seem to be too enthusiastic about that.

[13] Made in Vensim software.

Farmers pay dues and if they don't local authorities send reminders regarding debt. There are people who could not afford paying dues and their debts are now high although according to some interviewees these dues are low. Some farmers perceive WP as efficient and some of them don't – the latter ones are angry about dues, which is similar to the situation in the Rogow area just before WP suspension. Some of the farmers would prefer if local authorities maintained LRS despite active WP in the area. Some of them perceive the system as unjust, because only the landowners having parcels along ditches are obliged to pay and they are not the only ones having benefits from LRS. There were few voices that sometimes basic LRS (owned by the State) does not work and it makes the whole system inefficient.

It seems that there are not too big differences between farmers' perceptions of LRS systems in Rogow and Peclaw. The only difference is that there is still the WP active in Peclaw. But considering critical opinions about its performance it might be possible that the 'Rogow scenario' of WP suspension will occur in Peclaw as well.

5.3.5 LRS issues – discussion

LRS issues might be perceived as a kind of rational choice problem, but not in strictly economic sense. It seems that people just don't do things that cost a lot of effort/time/money and are not substantially necessary. Assuming that our capacity in terms of money/effort/time is not infinite, it is reasonable to make a hierarchy of things and devote effort/time/money to the most important ones. In this way it is a rational choice. LRS maintenance could be important due to benefits from maintaining or costs of not maintaining. Let's assume that both cost and benefits can be social and economic. What are the economic costs of not maintaining LRS? It seems that economic costs for most of the farmers are not high enough. If they are high (in case of big farmers and fishpond owners) they just do maintain. According to key informants economic costs might not be too high considering two reasons:

a) The state of LRS is still not that bad to cause catastrophic losses. Most farmers do not feel forced to do anything - they complain of LR quality, but do not suffer yet enough to organize a WP or maintain LR themselves.

b) Most of the farmers in the study area are small farmers and in terms of income they do not depend on agriculture enough to treat losses as a complete disaster.

What about benefits? The relation between LRS maintenance and benefits is obvious for most of the interviewees but not easy to quantify. It is not clear both for farmers and for experts how much exactly yields depend on LRS and how much on other factors like soil quality or fertilizers. And again – in case of small farmers benefits from agriculture are not that important part of their budget to make them invest in LRS too much.

Social costs/benefits are probably not high as well. It is obvious when we remind ourselves that most of the farmers perceive LRS maintenance as a job of the State or local authorities. In this situation social pressure on LRS maintenance may not be as high as for example on going to church on Sunday.

It seems that for most of the farmers LRS maintenance is to some extent desired, but not absolutely necessary – at least not enough to give own time/money/effort.

However if the reasoning above is correct (and its based mostly on empirical data), it is not clear to me why LRS maintenance was pointed out as one of the most important problems during workshops with farmers on the beginning of the project. That's a kind of contradiction: people say LRS is important but they don't behave as if it was really important although they do

devote their time/effort/money for other agricultural activities requiring skills, equipment and funding like ploughing, harvesting etc.

5.4 Biophysical research

Biophysical component of the socio-ecological system consists of elements playing an important role in the water balance: atmosphere, land cover, soil and vegatation and rivers, which are the water receivers. The conceptual model of the water balance in the landscape is showed (Fig. 4.4.1.). Detailed descriptions of biophysical components are in subsequent chapters.

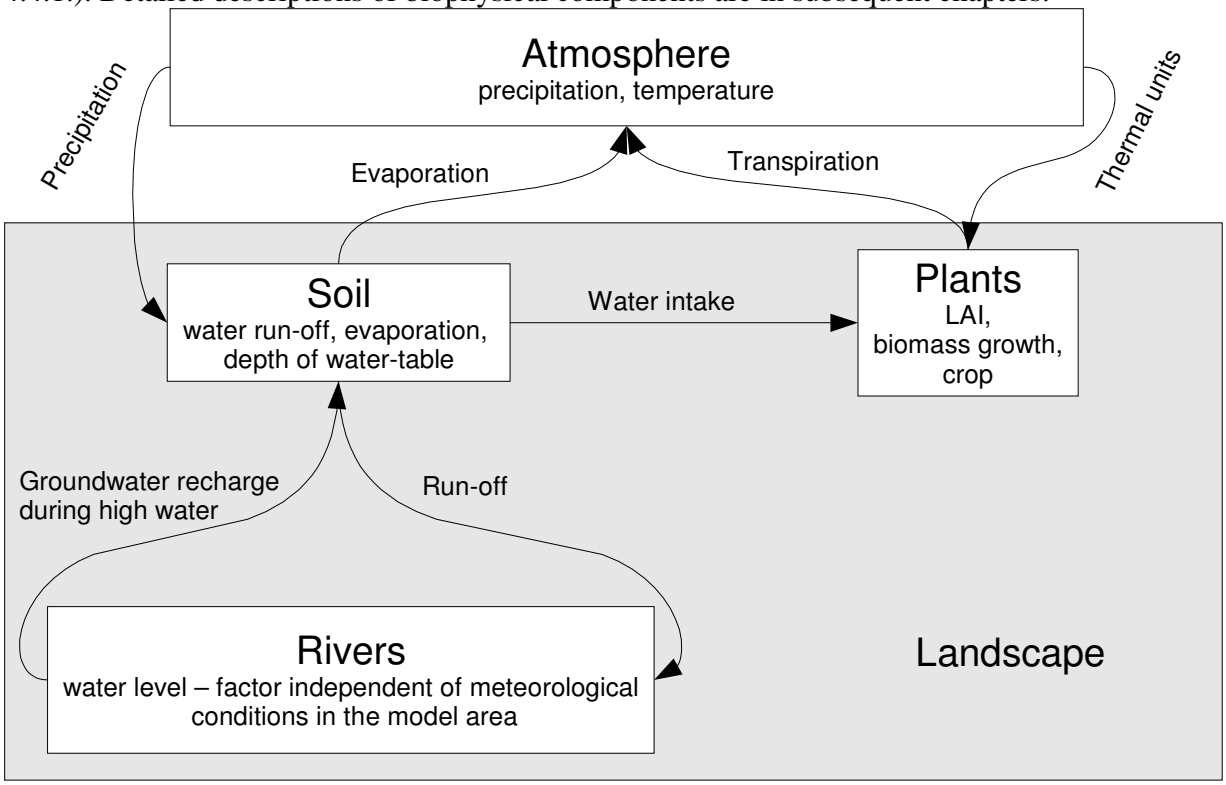


Figure 5.4.1. The conceptual model of the water balance in the landscape

5.4.1 Hydrology and hydrogeology

5.4.1.1 Introduction

In the very first phase of work all cartographical and other archival materials were collected and analysed. As well the topographical maps in scale of 1:10000 and 1:50000 as geological, hydrogeological, hydrographical and environmental maps were used for GIS implementation. Several borehole profiles were withdrawn from the national hydrogeological database which gave an opportunity for a better model conceptualisation considering spatial structure of the groundwater system. Additional fieldwork and measurements were planned to measure seasonal changes of the groundwater level with precipitation. An automatic ADAS

monitoring system of water environment was developed, which was an important step for model verification in environmental aspects.

5.4.1.2 The results of measurements from monitoring ADAS system

So far established monitoring system has been working properly from June 2007 to April 2008 and will be kept for next months to obtain data sets from one hydrological year at least and later 3-year observations are planned. As it is presented in the figures below (Fig. 5.4.1.1, 2, 3, 4), all collected data are used to calculate evapotraspiration, which is one of the main environmental factors influencing groundwater recharge. The soil temperature values recorded on a depth of 5 cm are strongly correlated with air temperature, only the fluctuations are of minor intensity and in winter period the chart-line slowly stabilizes between values 0 ^{0}C and -1^{0}C.

Observations concerning groundwater recharge show a dependence between the rainfall and soil moisture. On Fig. 5.4.1.3 it is clear that the reaction of the moisture sensor is prompt after an intensive rainfall, when the soil moisture achieves maximum and the infiltration coincides. Whereas after dry periods a slower gradual reaction is noticed until the maximum of moisture is reached in particular conditions.

In the mean of energy balance as a force of all environmental processes, the monitoring of radiation becomes the most important component (Fig. 5.4.1.4), which is complementary to wind speed and air humidity in evapotranspiration evaluations. All these data sets were used as calibration parameters in the groundwater flow numerical model including water balance simulations.

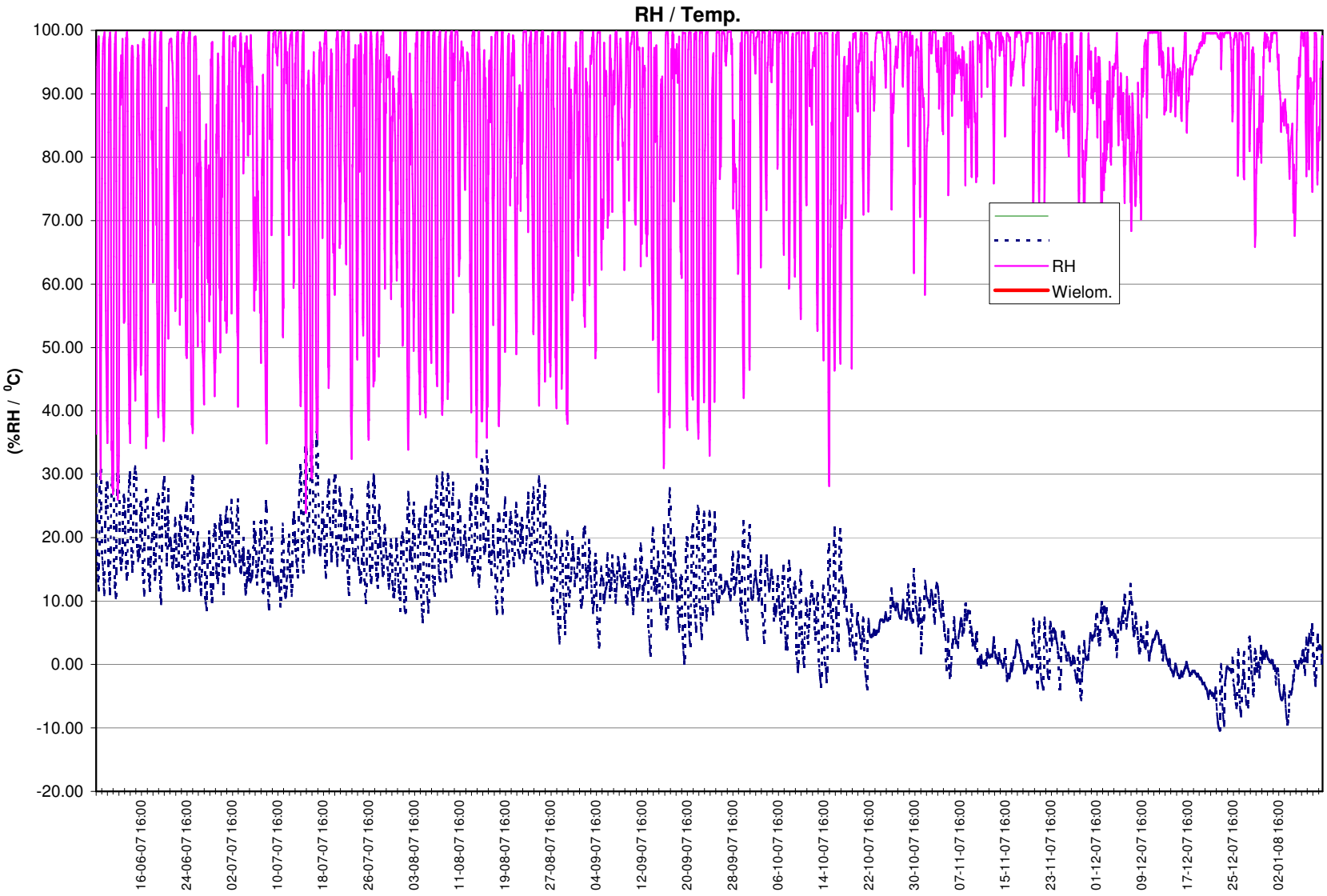


Fig. 4.4.1.1. Air humidity and temperature according to data from ADAS station

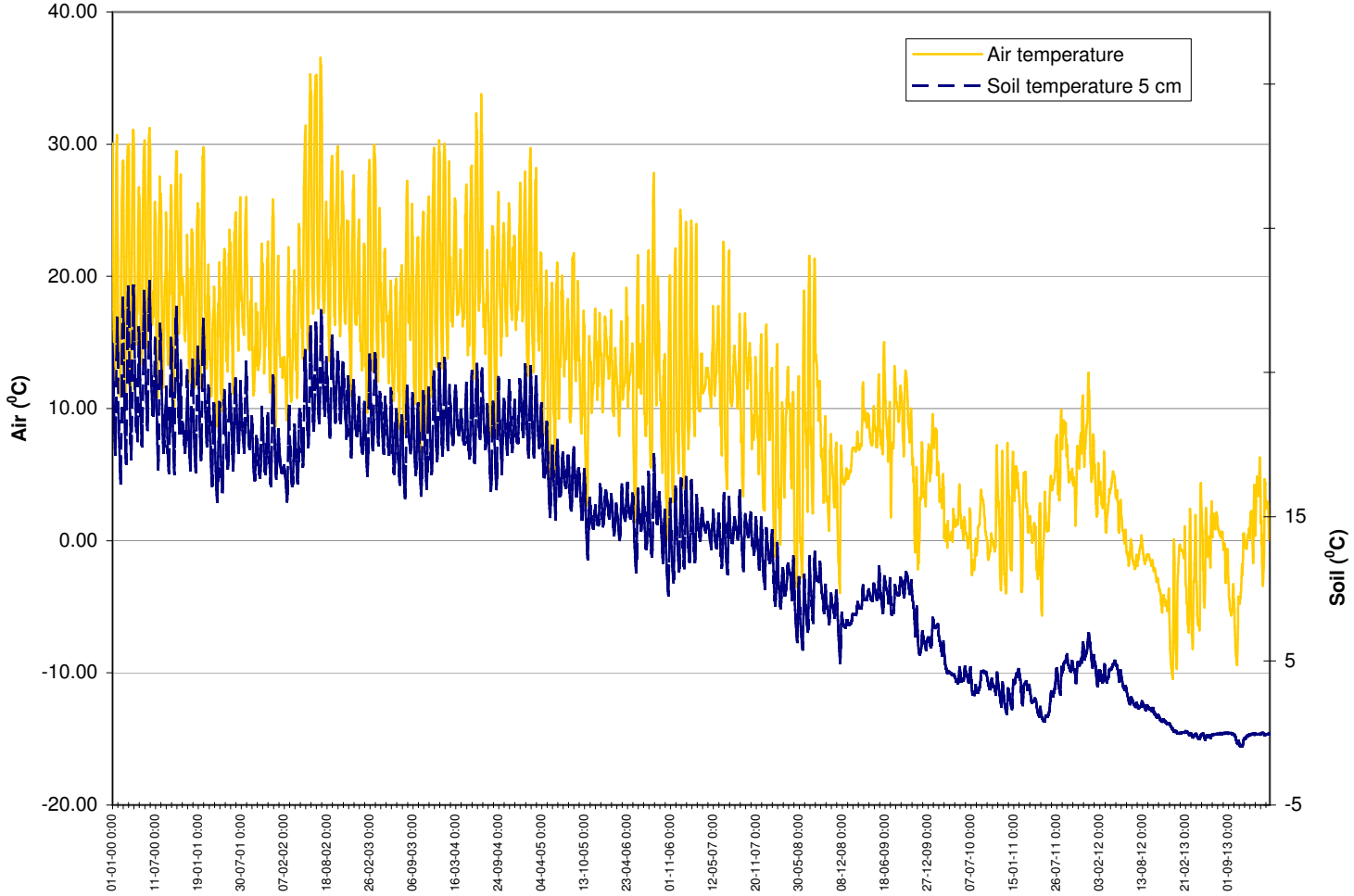


Fig. 5.4.1.2. Comparison of air/soil temperature according to data from ADAS station

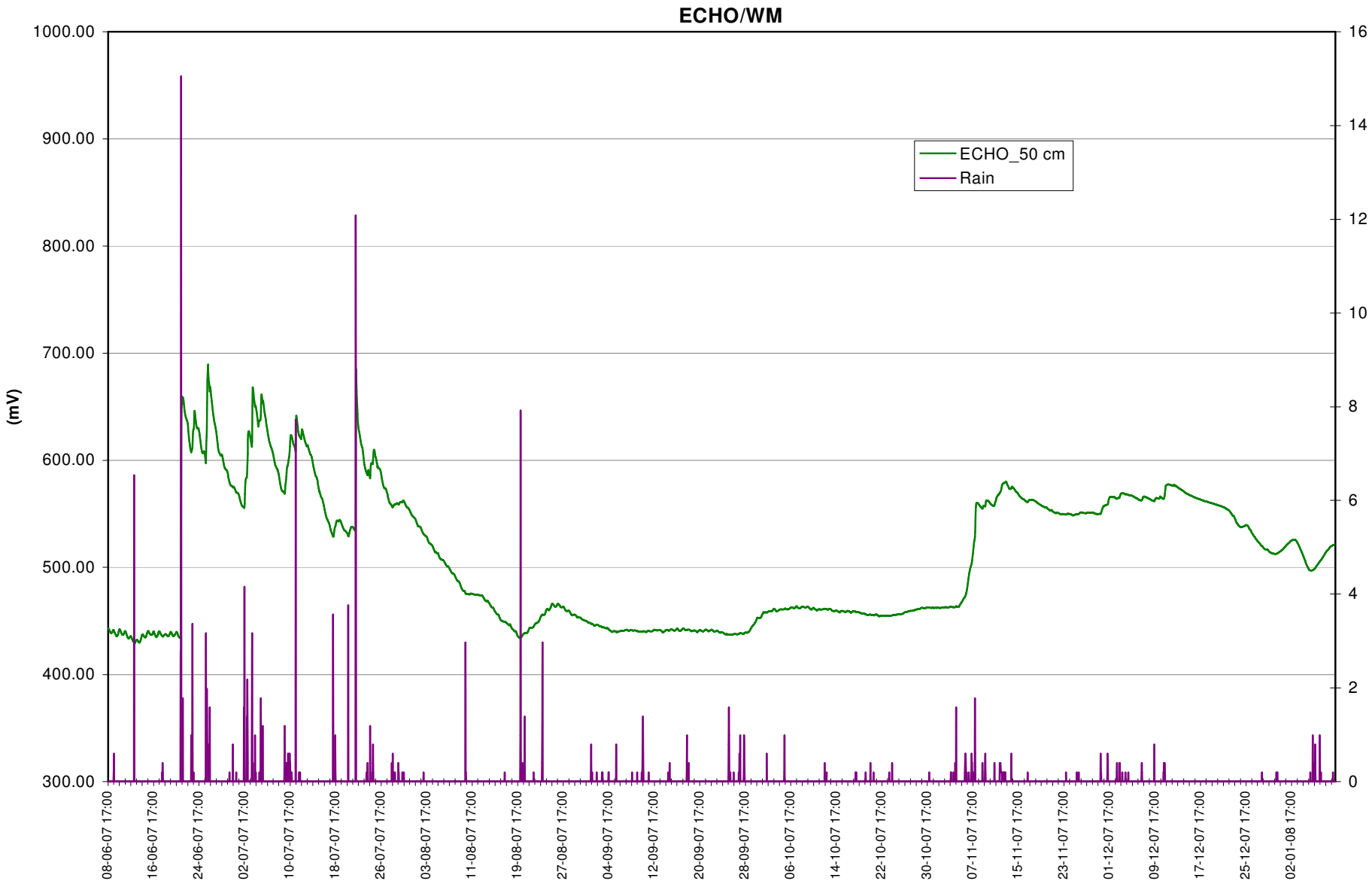


Fig. 5.4.1.3. Relation between the rainfall and soil moisture according to data from ADAS station

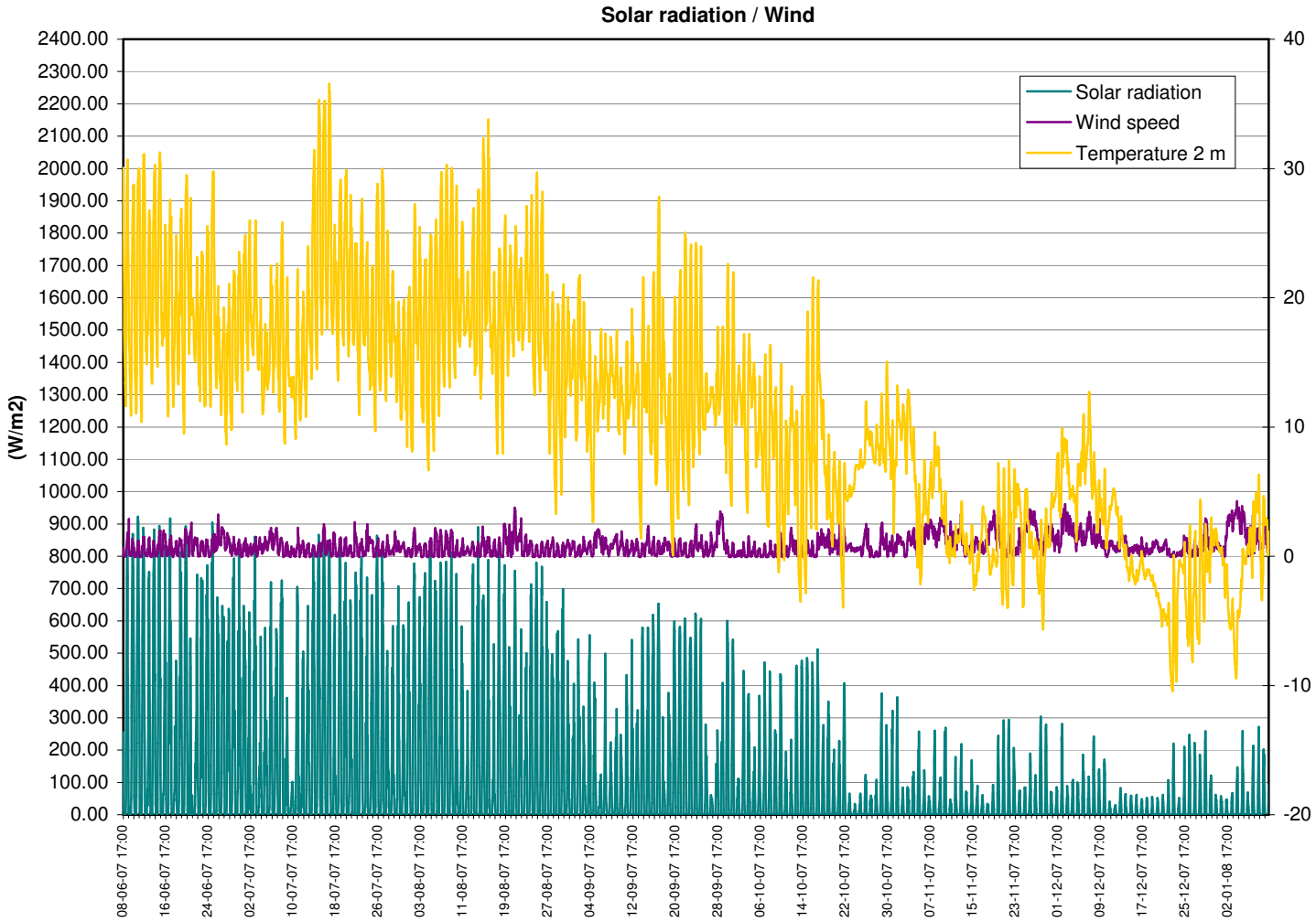


Fig. 5.4.1.4. Relation between the solar radiation, wind speed and temperature according to data from ADAS station

Tab. 5.4.1.1. Measurements of groundwater table in monitoring points

L.p.	Location	Ground surface, (m a.s.l)	Depth of well, (m)	Well case (m)	Depth to g.w. table, (m)			Groundwater surface, (m a.s.l)			Owner
					15/06/2007	19/07/2007	27/10/2007	15/06/2007	19/07/2007	27/10/2007	
1	Rogów Legn. ADAS	99	4.9	0.25		pomiar	ciągły				Siedlicki Dariusz
2	Rogów Legn. (rozwidl.)	98.57	4.08	0.37	2.65	2.58	2.89	95.92	95.99	95.68	
3	Rogów Legn. 28	97.34	3.96	0.17	2.3	2.18	2.46	95.04	95.16	94.88	Drobinoga Jerzy
4	Kwiatkowice 68	99.57	4.45	0.1	4.02	4.12	4.5	95.55	95.45	95.07	Żak Henryk
5	Kwiatkowice 18	97.78	5.07	0.75	2.85	2.95	3.36	94.93	94.83	94.42	Mikus Stanisław
6	Kwiatkowice 34	98	5.47	0.5	3.44	3.46	3.88	94.56	94.54	94.12	Prus Renata

Due to poor condition of the open channels within the area and very low hydraulic gradients, a current flow measurements were conducted only in two major gauging sections. Even in higher water level conditions the streams are motionless or the velocities are strongly limited. The water flow in Kwiatkowski Creak equals 0.0023 m^3/s (8.3 m^3/h) (surface of section F=0.12 m^2) and in Rogowski Creak 0.018 m^3/s (64.8 m^3/h), (F=0.41 m^2).

Figures 5.4.1.5. & 5.4.1.6. Views of monitored open channels in the area 19.07.2007 r.

Figure 5.4.1.7. View of the area close to Rogowski Creak, 19.07.2007 r.

Fig. 5.4.1.8. Trough of the Rogowski Creak in gauging point, 19.07.2007 r.

5.4.1.3 Hydrogeological settings for conceptual model and numerical groundwater flow modelling

Hydrodynamical conditions of the system are determined by the rivers delimiting the area: Kaczawa River to the NW, Cicha Woda to the E and Odra River to the NE. Groundwater recharge is mainly formed by lateral infiltration from precipitation, particularly in the water divide zone in the southern and south-western part, where the infiltration conditions are relatively good due to appearance of near the surface fluvioglacial sands and gravels of good permeability (Fig. 5.4.1.9). On the other hand, in the northern part, close to the Odra valley in its shallowest water table conditions, coinciding with wet land area, the intensity of evapotranspiration can exceed an effective infiltration in the year cycle.

In water flow balance calculations the seepage process from surface waters poses a separate problem, especially in case of the Odra river, which is additionally heavily dependent on the irrigation system.

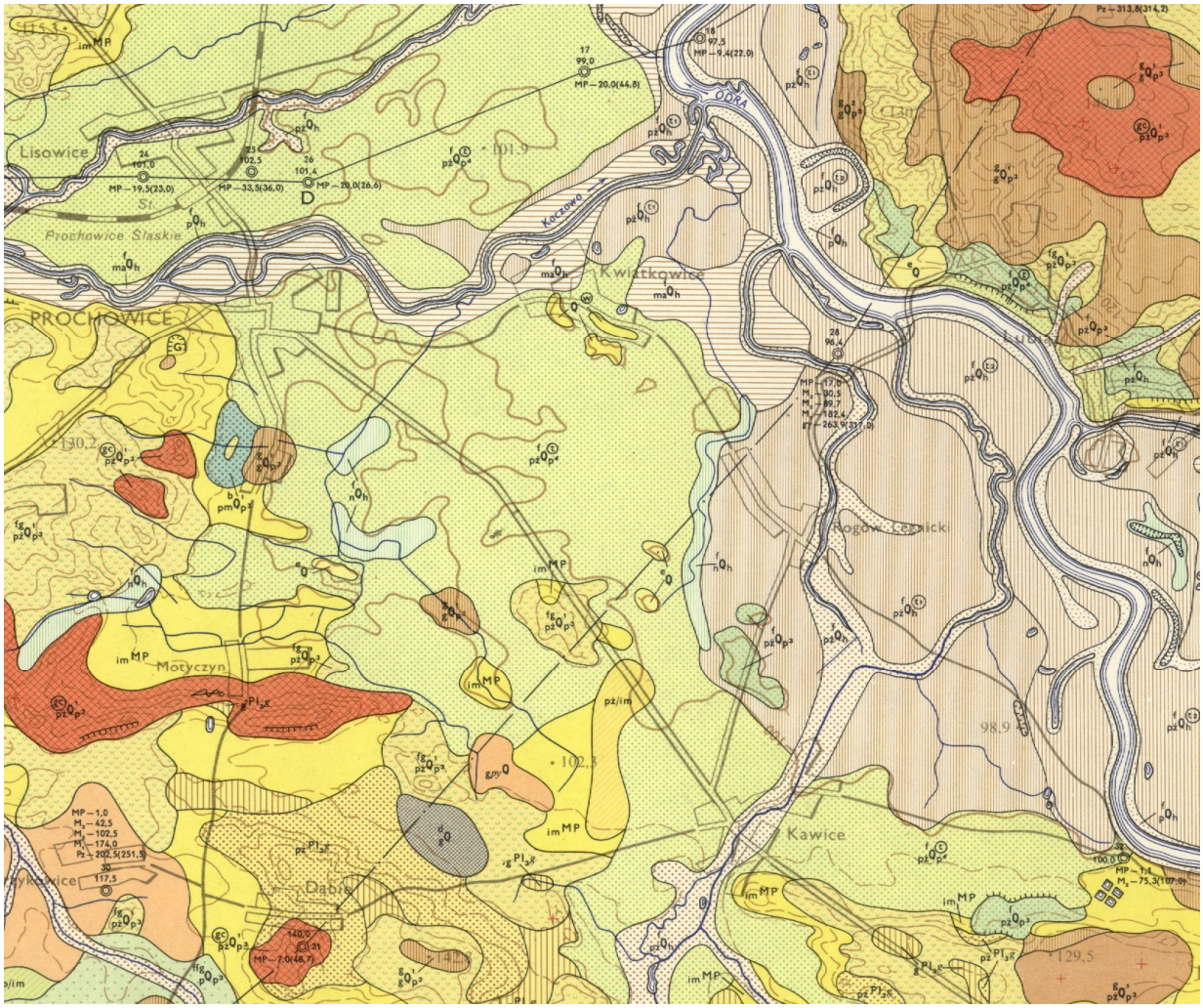


Fig. 5.4.1.9. Geological map (according to Geological Map of Poland 1:50 000)

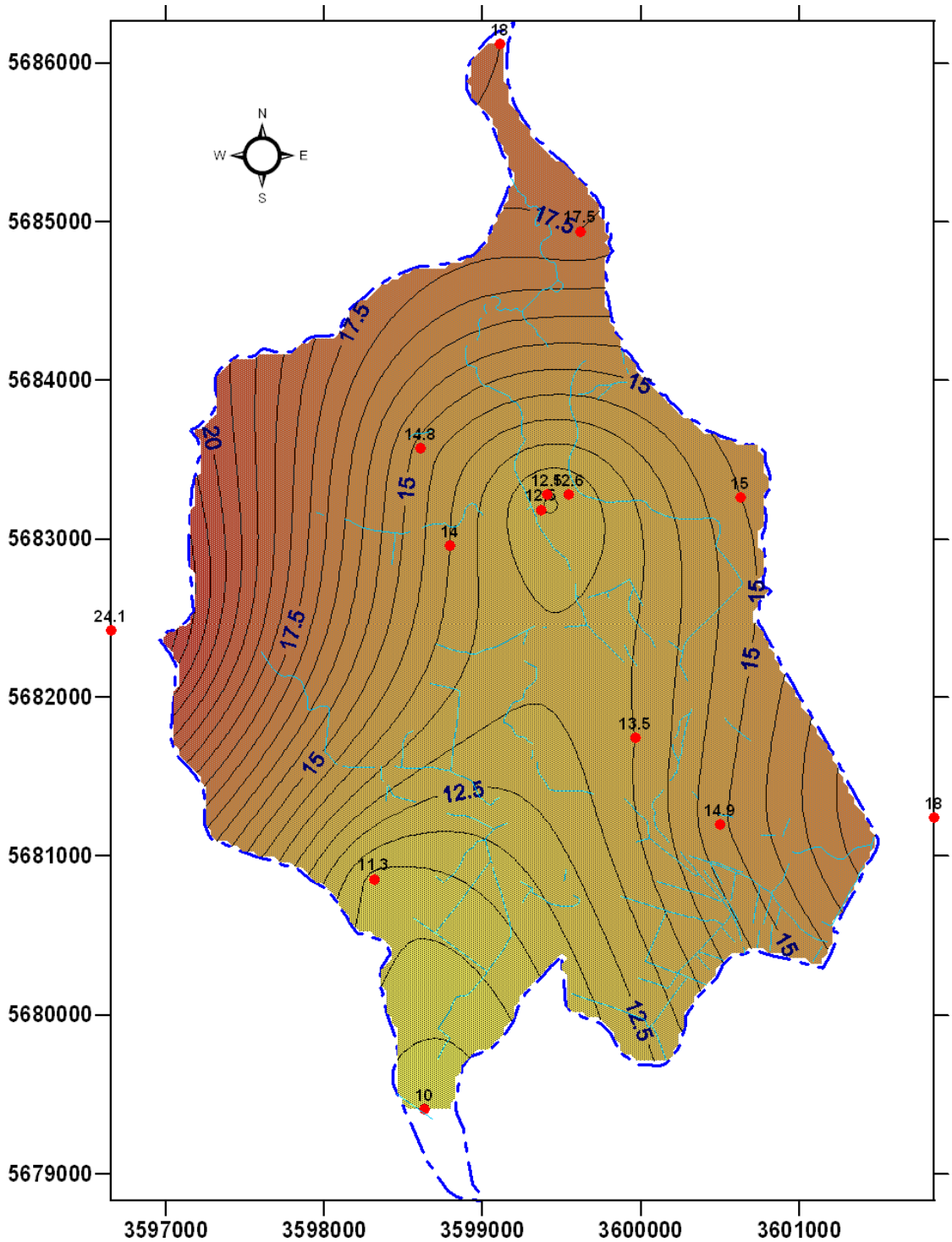


Fig. 5.4.1.10. The depth of aquifer bottom surface

The resultant grid map of the aquifer bottom elevation with coordinates adjusted to the numerical model grid was transferred to the models matrix. According to groundwater level measurements (Tab. 5.4.1.1) the map of head lines was developed (Fig. 5.4.1.11) which

shows that groundwater flow occurs from upland areas on the south and SW towards the Odra river on the northern and NE part. Thus, the main flow direction is S/SW – N/NE. The heads change from 98-102 m a.s.l. in S/SW to 94-95 m a.s.l. in the Odra valley, which gives the hydraulic gradient of $1,8*10^{-3}$. The map was transformed into raster format that was directly applied for model calibration.

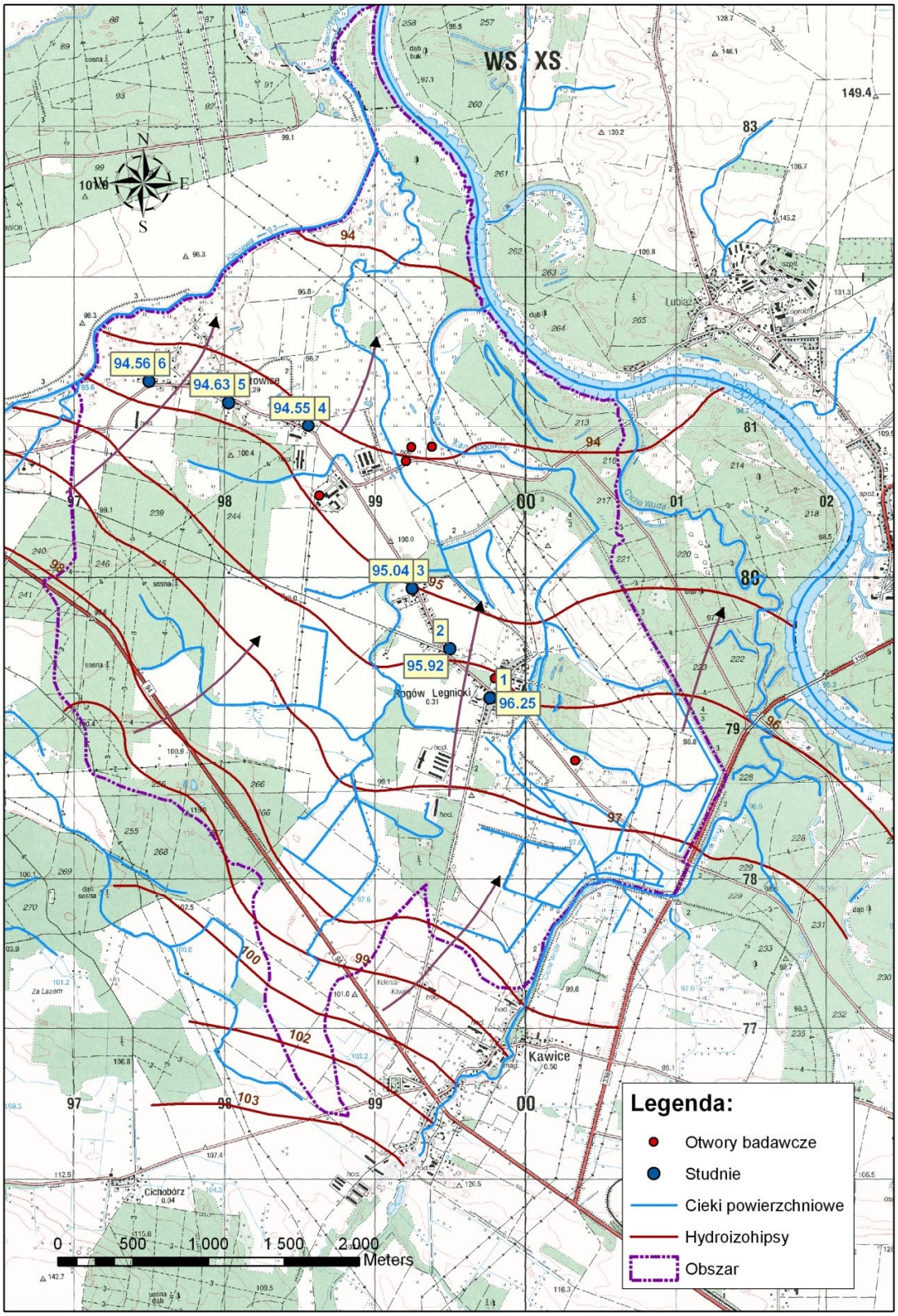


Figure 5.4.1.11. Head contour map with directions of groundwater flow

5.4.2 Climate

The climatic indicator of water balance (CIWB) coefficient (1) was used to select the years representing wet, dry and intermediate conditions.

CIWB = Rd - (Ti*0,136), (1)
where Ti –average 24h tempriture [Co], as the negative value of the tempriture has a minor effect on the evaportation all negative values of the Ti was set to the 0, Rd – 24h rainfall [mm].

Negative values indicate wet years, positive values indicate dry years. The analysis of the time series of CIWB shows high fluctuation with the period 2-3 years. It is also possible to indicate the period of several years representing wet or dry conditions: wet period is 1945-1953, 1972-1977 and 1988-1994. Period 1960-1988 is very variable with normal to dry conditions. Dry condition dominate in period 1995-2002.

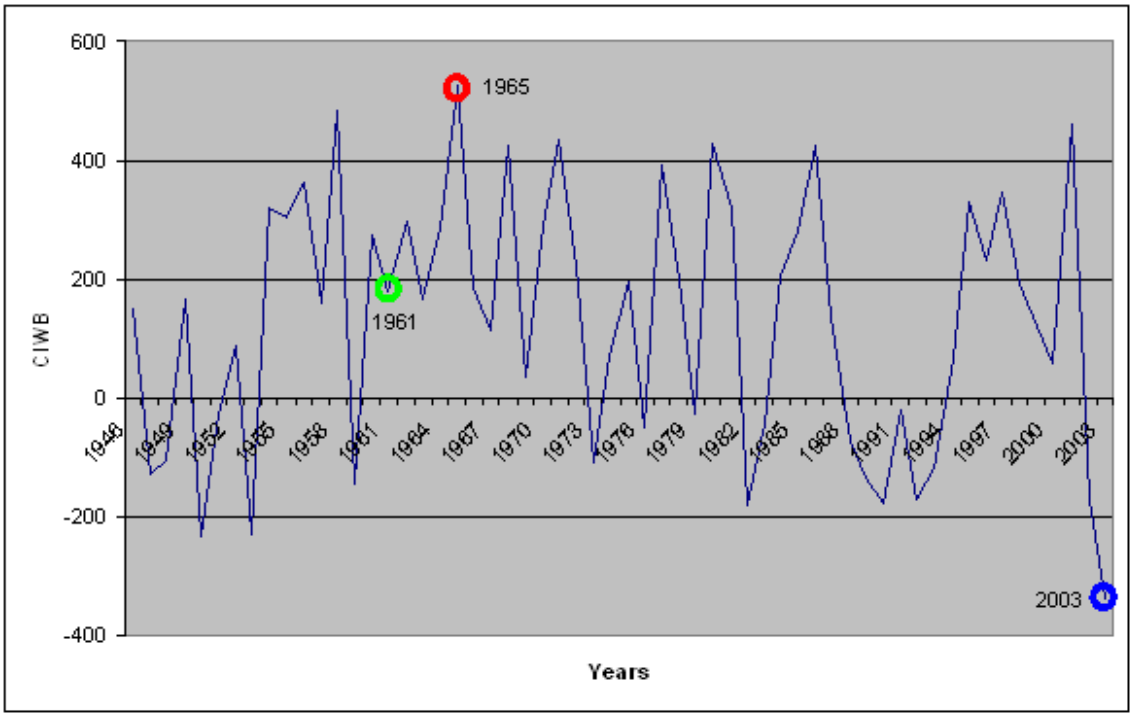


Figure 5.4.2.1. Climatic indicator of the water balance (CIWB) in the period 1946-2003

Years marked with a color ring were chosen as reference years for dry, wet and intermediate conditions – 1965, 2003 and 1961, respectively.

In respect to the impact of climate change on the LULCC it could be assumed that dry years support the transition of grassland into arable land. This transition occurred mainly after

1989, when communism was broken and new free market situation was created. First five year of the 1990's were wet, but the second half of 1990's and the first half of first three years of second millennium have climatic condition of water balance supporting this type of land use transition.

5.4.3 Land use/land cover

The research area and choice of research objects

The project is conducted in the Odra valley, between Brzeg Dolny and Głogów cities. Within the area two exemplary sub-areas for the landscape changes research were chosen. They are Odra valley fragments, of characteristic, relatively wide pra-valley. Both are located on the part of the floodplain that is protected by dikes. Agricultural landuse prevails, with domination of arable grounds. Both areas were flooded in 1997.

The Rogow Legnicki area is located above the Kaczawa river mouth, a quite big left-side Odra tributary. The Peclaw area is drained by numerous small watercourses. It bearies more signs of fluvial activity, manifesting in land relief forms such as former meanders and oxbow lakes.

Both areas can be considered as representative for the agricultural landscape in the middle of Odra valley.

Results

In the Rogow area in early years of XX century, a dominant land cover class was arable land, which contributed for nearly 70% of the total area. The second abundant category was grassland, covering almost 15% . Forest contributed for 10%. Other land cover, including built-up area and water bodies, were about 5% of the total area. In 1970's the share of forests grew to 27%, while the share of arable land dropped to 45%. The amount of grassland increased of about 10%, and was 24%. For the next 20 years major changes occurred in land cover, namely a drop in grassland share to 13% and the rise of arable land share to 56%. The area covered by forests remained on a similar level.

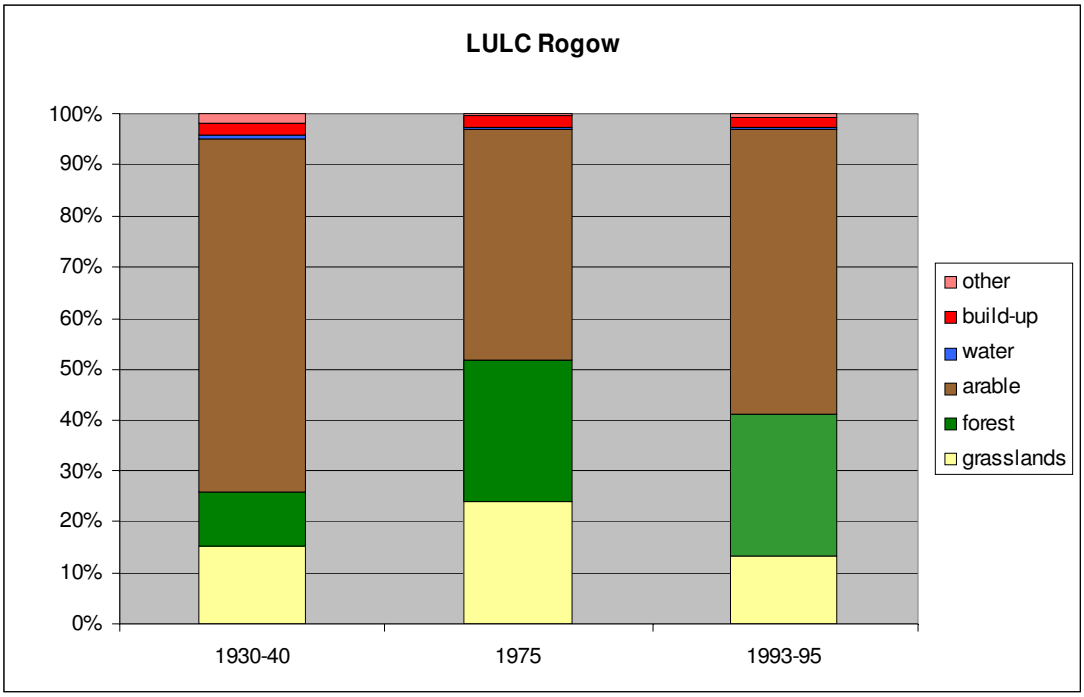


Figure 5.4.3.2. Proportion of land cover types in the Rogów region

In period 1993 – 1975 36% of the analysed area experienced land cover transformation, which means that only 64% remained without change. Arable land was transformed into other on 27% of the area, on 19% new forest emerged and on 12% the grassland. These two types of transitions are a strong signal of systematic changes. In the same time forest was changed into different classes on 2.4% of the area, and grassland on 3%. Changes occurred mainly in the western part of the region, where major afforestation took place and in the northern part, where the arable land between small patches of grassland was replaced by grassland.

During the next period, changes in total occurred on 19.27 % of the area. In general, changes had opposite directions: arable lands gained 13.28% and grasslands lost 12.58% of the total area. Over 45% of grassland was converted into arable land and this transition is bigger than an expected random transformation. Some grassland (4.05%) was converted into forest. Forest in this period was very stable - gain as well as loss was smaller than 3%

Table 5.4.3.1. Major land cover transformation in the Rogow Legnicki area, 1930 – 1970

Transition 1933-1975	Observed minus expected	Difference divided by expected	Transformed proportion of category %	Interpretation of systematic transition
Grassland > Arable	-0.26	-0.14	10.80	When grassland losses arable replaces it, but less than random
Grassland > Forest	0.09	0.08	8.32	When grassland losses forest replaces it
Arable > Grassland	-2.41	-0.20	13.87	When arable losses grassland replaces it, but less than random
Arable > Forest	2.84	0.20	24.26	When arable losses forest replace it

Table 5.4.3.2. Major land cover transformation in the Rogow Legnicki area, 1970 – 1990

Transition 1975-1993	Observed minus expected	Difference divided by expected	Transformed proportion of category %	Interpretation of systematic transition
Grassland > Arable	2.92	0.36	45.90	When grassland losses arable replaces it
Grassland > Forest	-3.05	-0.76	4.05	When grassland losses forest does not replace it
Arable > Grassland	-0.04	-0.05	1.66	When arable losses grassland does not replace it
Arable > Forest	-0.77	-0.31	1.89	When arable losses forest does not replace it

Pęcław

During the first period the total change, including swap, amounts to 21.30%. The most dynamic categories were arable land and grassland – 17.85% and 16.43% of total change, respectively. Loss of arable land was higher than gain, 10.74% and 7.17%, respectively. The grassland gain was slightly higher than loss, 8.88% and 7.55%, respectively. The gain was mainly due to conversion of arable land.

The total change during the second period amounts to 19.27 % . Two main processes occurred there: gain of arable land and losses in the grasslands, 13.28% and 12.58%, respectively. Grasslands was replaced by arable land 11.05% of the landscape, it is higher proportion than expected 8.12% random transition. This transition led to convertion of 45% grassland (tab. 5.4.3.4.)

In Peclaw area, in the beginning of 20th century, the agricultural land together constituted 92%, out of which the arable land was 77% and the grassland was 16%. Other categories

contributed for a minor part of the area – forest for 3%, built-up area for 1.99%, water bodies for 1.15% and other for 0.36%. Such a structure was in general preserved still in 1970's; a minor gain of forest and grassland took place - 6.15% and 17.56%, respectively. Arable land area slightly decreased to 73.31%. In 1990's major decrease of grassland share occurred, to 9.8%, accompanied by a further forest gain of 6.33% and arable land to 81.14%.

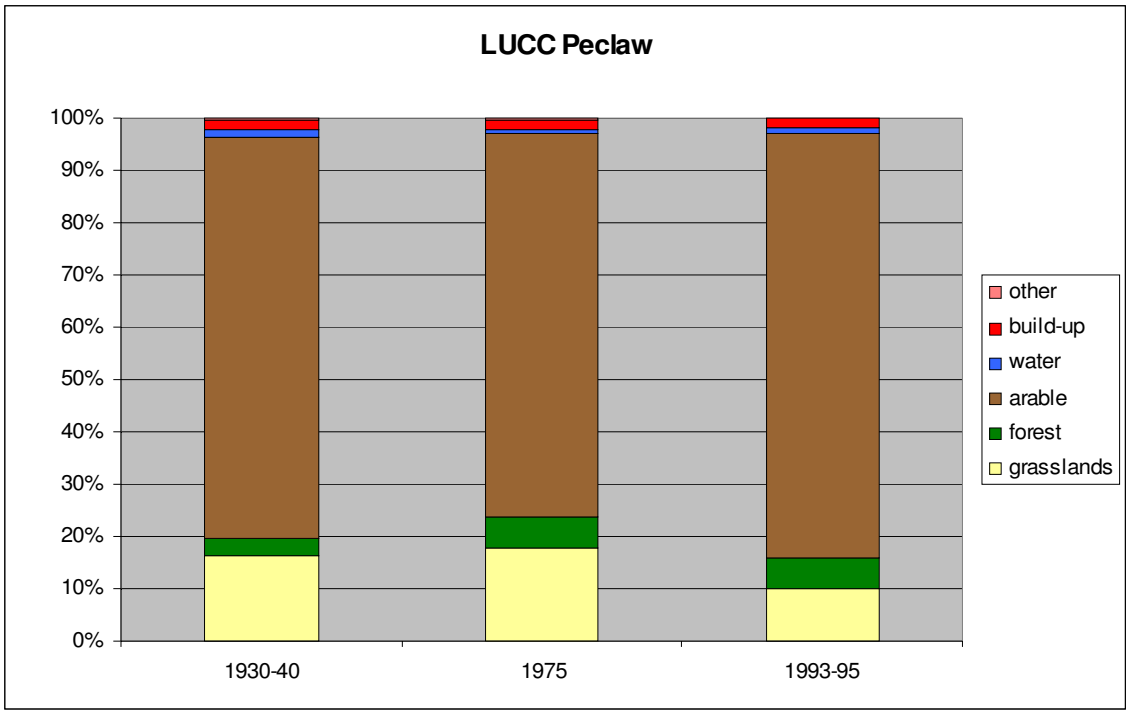


Figure 5.4.3.2. Proportion of land cover types in the Pecław region

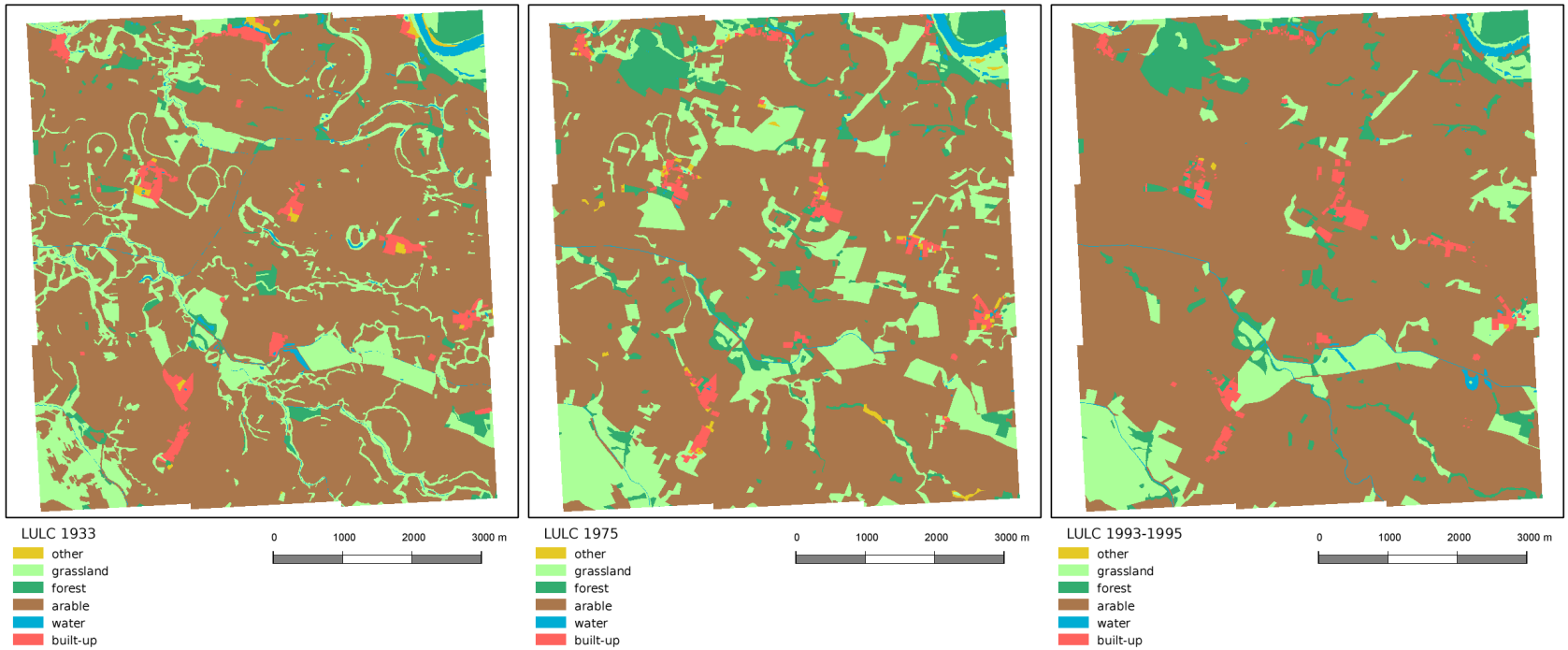


Figure 5.4.3.2. Maps showing the changes of land cover in the Peclaw area

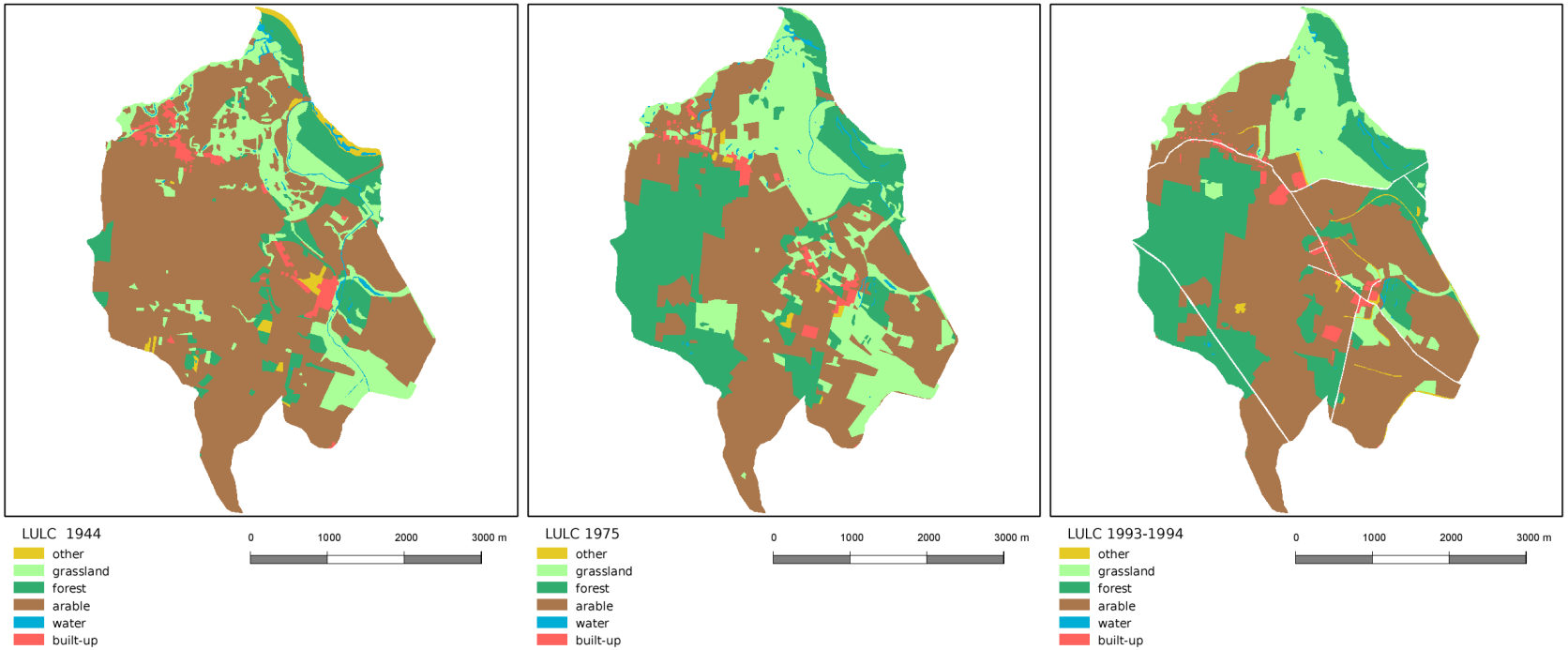


Figure 5.4.3.3. Maps showing the changes of land cover in the Rogów Legnicki area

Table 5.4.3.3. Major land cover transitions in Peclaw area, 1930 - 1970

Transition 1944-1975	Observed minus expected	Difference divided by expected	Transformed proportion of category %	Interpretation of systematic transition
Grassland > Arable	-1.02	-0.15	34.99	When grassland losses arable replaces it, but less than random
Grassland > Forest	0.97	1.73	9.46	When grassland losses forest replaces it
Arable > Grasslands	1.02	0.14	10.53	When arable losses grassland replaces it
Arable > Forest	-0.55	-0.24	2.50	When arable losses forests replaces it, but less than random

Table 5.4.3.4. Major land cover transitions in Peclaw area, 1975 – 1993-95

Transition 1975-1993-95	Observed minus expected	Difference divided by expected	Transformed proportion of category %	Interpretation of systematic transition
Grassland > Arable	2.92	0.36	45.90	When grassland losses arable replaces it
Grassland > Forest	-3.05	-0.76	4.05	Grassland losses, it is replaced by forest, but less than expected by random transition
Arable > Grassland	-0.04	-0.05	1.66	When Arable losses Grassland replaces it, but less than expected by random transition

Summary

In both sub-areas the directions of net changes are similar. In the first transition period the arable land losses, while the forest and grassland gain. In the second period the grassland losses, while the arable land gains. The total change is much higher than the net change, which indicates that the type-swapping changes play an important role in the land cover transitions. The relative swap rate was highest in the grassland category. The most systematic transitions took place during the first period, when grasslands turned into forest in both sub-areas, while in the Rogow Legnicki also arable land transition into forest was systematic. In the second period the most systematic transition was grassland into arable land.

Changes in the first period led to an increase of evapotranspiration. This was a consequence of the afforestation and the decrease of the amelioration system importance, as a result of the grassland area increase. During the second period the forest remained on a similar level. The transition from grassland to arable land led to an increase of the demand for the drainage system.

5.4.3.1 The driving forces of the LULC changes

The main change in the land use in the last two decades are losses in the grassland vegetation and gains in the arable lands. The main force of this change is agro-economy. After 1989 a major decrease of milk production profitability took place.

Livestock and animal husbandry structure

An analysis of the animal husbandry structure in Peclaw commune during the period of our interest revealed two distinct trends. Initially, since late 1970's till late 1990's, a major decrease in the livestock number occurred (cattle including cows, pigs, sheep and horses). This tendency was still present in the following years for sheep and horses, which were least numerous in 2002, during the analysed period. At the same time the number of cattle, including cows, and pigs grew significantly. Pig breeding, with respect to the number of animals in farms, is presently a prevailing direction of animal husbandry in Peclaw commune.

years	stocks of cattle total	incl. cows	pigs	sheep	horses
1976	1578	726	2444	34	276
1981	1080	602	3099	95	163
1987	981	465	1792	123	75
1995	562	219	1652	28	15
2002	562	219	1652	28	15

Table 5.4.3.1. Animal husbandry structure in Peclaw commune
(the number of animals)

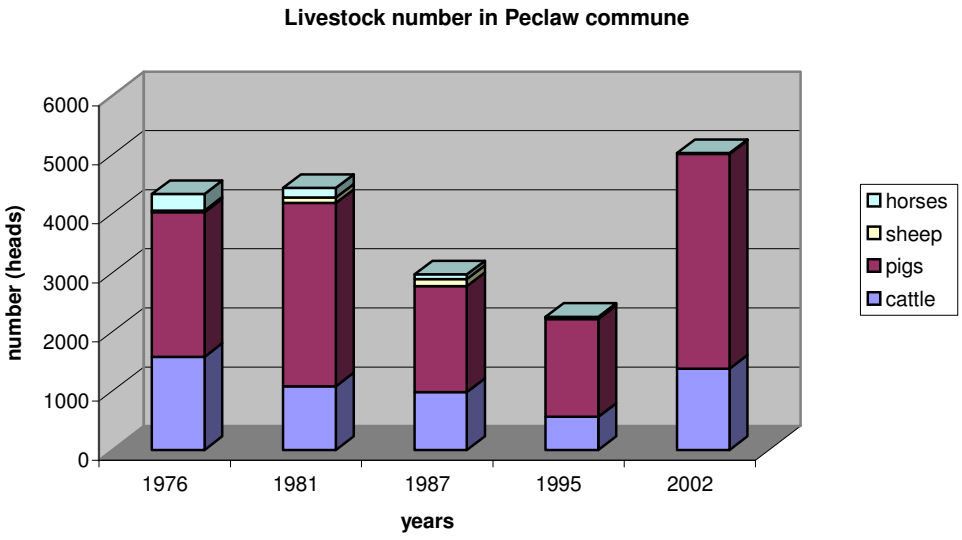


Figure5.4.3.1. Change in the livestock number in Peclaw commune

In Prochowice commune the overall number of livestock significantly dropped during the last two decades, compared to their maximum number in early 1980's. However, for particular animals the trend of change is different. A sudden, big drop in the number of sheep and horses took place. It continued decreasing during the next years from maximum number in 1976, when in the commune there were 514 sheep and 230 horses, until 2002, when their number was 9 and 10, respectively. A clearly visible, systematic drop was also present in cattle stock, including cows. The number of cattle decreased over fivefold, continuously going down from the maximum number in 1976 (2106 items) to the minimum in 2002 (379 items). For cows respectively, the numbers were 954 items in 1976 and 162 in 2002. Some upward tendency was visible in early 1990's only for pigs (in 1995 their number increased by over 1000 items compared with year 1987), yet the number was still lower than the maximum achieved in the beginning of 1980's (4627 animals). According to the most recent data the number of pigs is about 3236 items.

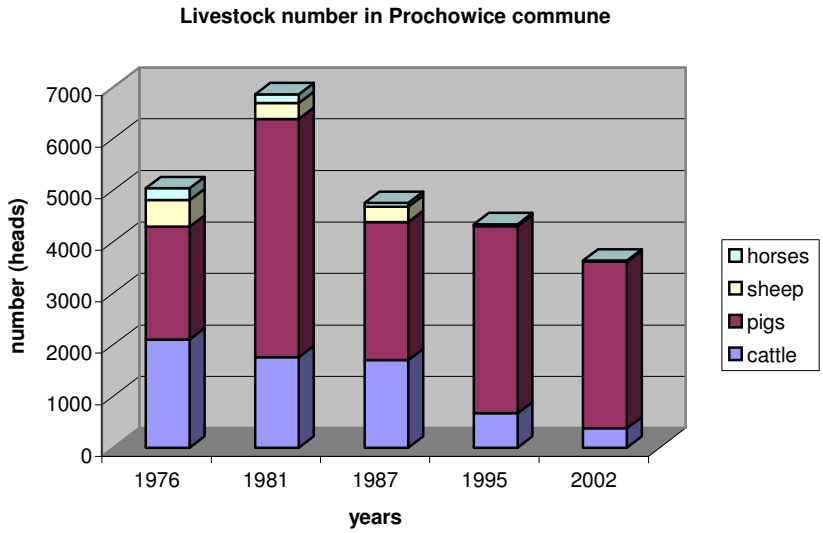


Figure 5.4.3.2. Change in the livestock number in Prochowice commune

years	cattle stock total	incl. cows	pigs	sheep	horses
1976	2106	954	2188	514	230
1981	1756	89	4627	310	167
1987	1703	630	2683	295	71
1995	670	255	3628	14	25
2002	379	162	3236	9	10

Table 5.4.3.2. Animal husbandry structure in Prochowice commune
(the number of animals)

In respect of the number of livestock animals per 100 ha of agricultural land, in both communes same tendencies were present. At the end of 1970's an increase of pigs number was noticeable, whereas in the first half of 1980's a major decrease took place. A downward tendency in cattle number was present until late 1980's.

It is not possible to compare these information with a later period, due to the lack of respective data on the level of a commune in statistical publications. In case of data from the Agricultural Census of 2002 a direct comparison is not possible either, as it uses a different index for livestock animals per 100 ha – namely "big items", which are cattle, pigs, sheep and horses jointly.

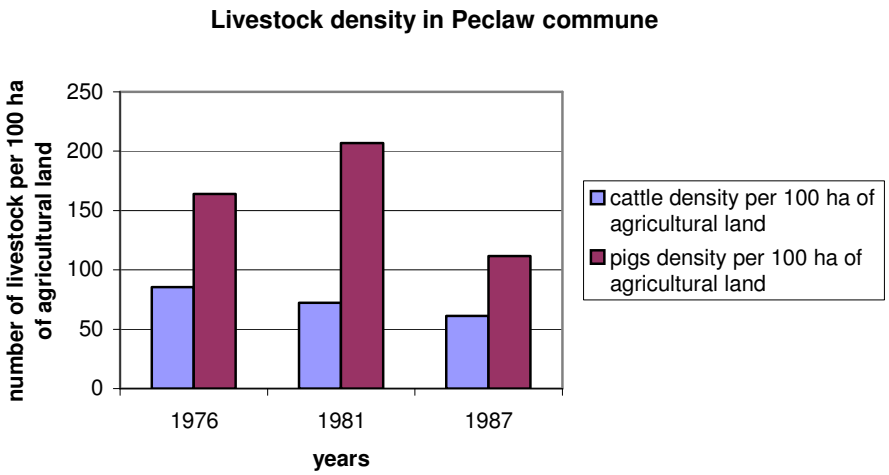


Figure 5.4.3.3. Changes in livestock density in Pęcław commune

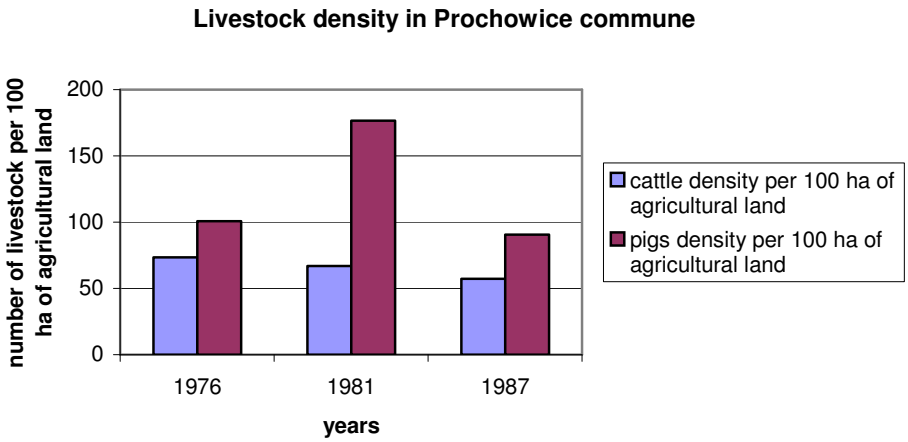


Figure 5.4.3.4. Changes in livestock density in Prochowice commune

5.4.4 Land reclamation system

5.4.4.1 Spatial interdependency of agents along channels of land reclamation system

The efficiency of the agriculture depends, among the other factors, on the management of land reclamation system (LRS). The LRS consists of channels and ditches, which drain the soil directly, or through the drainage pipe system. If the LRS is equipped with sluice gates, it can also serve as an irrigation system. To keep the LRS working, landowners' action is required, e.g. removing the vegetation and sediments from channel and ditches beds. For an effective irrigation, the sluice gates need to be maintained and operated.

Usually, the land surrounding the channel is divided between parcels belonging to different stakeholders (agents). For an effective LRS performance, the ditch cleaning should be coordinated. It means that stakeholders who own the parcels along one channel are interdependent. This interdependency is not symmetrical and varies largely in respect to the parcel location along the channel. To determine reciprocal influence of particular agents working on the parcels located along one channel, a number of biophysical parameters should be taken into consideration. It is not possible to determine this interdependency without very detailed information, necessary to predict the water flow dynamics. This requires a sophisticated biophysical model. Every simplification of this complex issue will lead to an unpredictable uncertainty. Nevertheless, simple rules, as close to reality as possible, describing the upward and downward effects of the LRS conservation and operation, are needed for the sociological model of the LRS maintenance. Our simplification of this agents interdependency, based on the knowledge about LRS and hydrology, is not universal and might not turn out to be useful in other set-ups.

5.4.4.2 Single agent system

To explain how LRS works let us assume that an LRS of a given agent is independent of all others. If an agent maintains the channel, the negative effects of water excess stress could be limited or even eliminated. If the channel is neglected, LRS will not work during water excess stress, leading to crops decline. Furthermore, during the dry period, a neglected channel could even increase the water deficiency stress, as a consequence of high water consumption by plants, growing in the channel bed. In both situations, neglecting the channel will lead to a crops decline. It should be pointed out, that this decline is evident in very wet or very dry years, whereas during the mild years could be not noticeable. LRS equipped with sluice gates will serve as an irrigation system, minimizing the drought effect. The water stored within the channel bed, ditches system and as the ground water, will provide water for the crop production during the dry period. The irrigation role will be fulfilled only when the sluice gate system is operated: opened in early spring, when there is too much water in the soil, and after that closed to store the water in the ditch . If the system is well managed, it has no negative effect on the crops during wet years, and minimises the losses during dry years. In case of a few dry years in a row, the efficiency of the irrigation will decrease.

SINGLE AGENT SITUATION

DITCH MAINTENANCE

	YES	NO
WATER DEFICIENCY	—	▲
WATER EXCESS STRESS	▼	▲

SLUCE GATE OPERATION

	YES	NO
WATER DEFICIENCY	▼	▲
WATER EXCESS STRESS	—	—

▲ - increase
▼ - decrease
— - no effect

5.4.4.3 Interaction

It is trivial to say "water flows down". Similarly, the influence of the upper part of a river on its lower part is intuitively obvious for most people. It is especially true for regulated rivers with water reservoirs controlling the water outflow and affecting the water regime below the dam. However, in a small, lowland watercourse in a flat agricultural area, mainly the upward hydrological effects should be expected. If the water flow in the channel is slowed down, in any of its sections, the upward water level rises. Furthermore, the increase of water level in the watercourse affects the level of ground water and influences the water in the soil.

To build the model of a social aspect of the land reclamation system, very simple rules of the interdependency of agents are needed. Below we describe the interdependency of two agents, owning adjacent parcels. The parcel of agent A is located upward the parcel of agent B (Fig. 5.4.4.1). All possible combinations of their activity in respect to ditch maintenance are shown in Tab. 5.4.4.1, and in respect to sluice gate operation in Tab. 5.4.4.2. Four combinations of their activity connected with channel maintenance are possible: both agents maintain; both neglect; A maintains B neglects, and A neglects B maintains.

In most cases the activity of agent A does not influence the crop of agent B. The only possible downward influence can be expected if agent A neglects the channel, leading to decrease of the amount of water flowing down, as a consequences of intensive water consumption by plants growing within the channel bed. This could affect the crops of agent B during dry periods. Similarly, the sluice gate operation by agent A can negatively affect the crops of agent B (Tab. 5.4.4.2).

All other possible influences are upwards; it means that decisions of the agent below influence the crops of the agent above. The consequences of neglecting the channel by agent B are negative for agent A, as a result of blocking the water flow during the wet period, which leads to water excess stress, even if agent A maintains his section. A situation when water is stored in the channel above the neglected section, being used for plant production during the dry period, is rather unlikely. However, some positive effect of slowing down the water flow by the vegetation within the channel can take place, especially during short dry periods.

Agent A will benefit from the channel being maintained by the agent B in wet weather conditions, because of the higher outflow rate in the ditch. It could work, to some extent, even if agent A does not maintain his own part of the channel (free riding). However, it will work much better when agent A also maintains the ditch, because if his own section of ditch is covered by sediments and vegetation, the drain pipes, that drain the water from his field to the ditch, are closed.

Table 5.4.4.1. TWO-AGENT SITUATION INCLUDING INTERACTION

			AGENT A		
			MAN		**NEG**
AGENT B	**MAN**	**DROUGHT**	AB - BA ▼?	**DROUGHT**	AB ▼? BA ▼
		WET PERIOD	AB - BA ▲	**WET PERIOD**	AB -- BA▲
	NEG	**DROUGHT**	AB - BA – or ▲?	**DROUGHT**	AB ▼? BA - or ▲?
		WET PERIOD	AB - BA ▼	**WET PERIOD**	AB - BA ▼

AB – influence of agent A to agent B
BA – influence of agent B to agent A

MAN – ditch maintained
NEG – ditch neglected
DROUGHT – long period without precipitation
WET PERIOD – period with high precipitation or short very high rainfall

– – no effect
▲ – increase of crops
▼ – decrease of crops
? – the effect is possible theoretically, but its influence on the crop is controversial

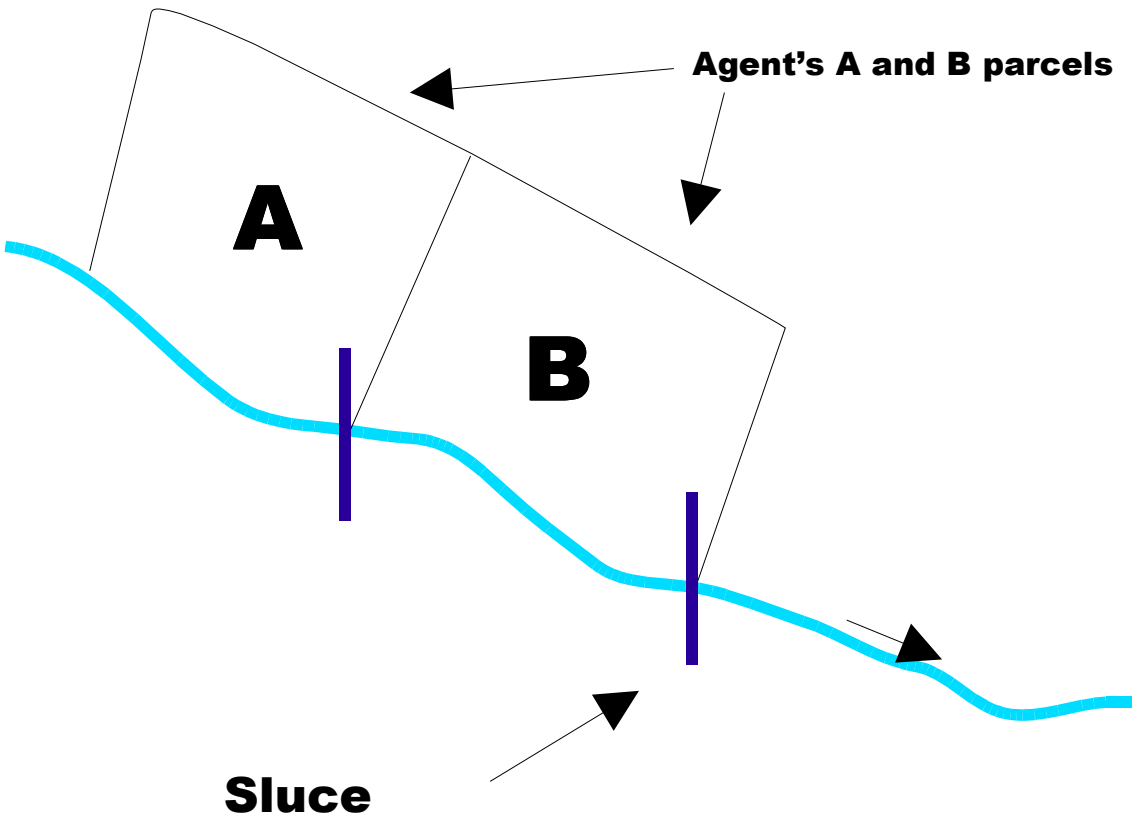


Figure 5.4.4.1. Diagram showing the location of parcels belonging to agents A and B

The sluice gate operation has mainly upward effects. Water storage by the farmer B could be also profitable for agent A, because the result of water table increase has usually long spatial range upwards the sluice gate. In some cases, the downwards negative effect of water storage could be expected. If the water is dammed up, the water loss rate is much higher due to evapotranspiration, and as a consequence less water is flowing down. It leads to a decrease of the ground water table and even can disable the water storage below the sluice gate section of the channel.

Table 5.4.4.2. SLUICE GATE OPERATION – (meaningful only in case of drought)

		Agent A	
Agent		*MAN*	*NEG*
	MAN	AB ▼?	AB -
		B A▲	B A▲

B	N	A B▼?	A B -
	E G	BA -	B A -

Weather and LRS importance

It should be pointed out that maintaining or neglecting the LRS is less important during the years with an average rainfall. During such years, crops much less depend on the LRS . Well maintained LRS can be profitable during wet years, draining the water excess from the soil. Well operated sluice gate system can be profitable during the dry period. However, this positive effect depends largely on the weather conditions in the previous year (or years). If a dry year occurred before the given dry year, the ground water level could be very low, which disables the water storage using sluice gates.

The spatial extent of the LRS maintenance

The spatial extent of the LRS impact on the crops depends on the terrain morphology and the channels inclination. In a plain terrain this effect extent will be greater than in a hilly one.

5.4.4.4 Vegetation as an indicator of LRS system maintenance

The vegetation types growing at riparian zones of the LRS were divided into 9 classes (Fig. 5.4.4.2). These 9 classes are a product of two independent types (series) of ecological succession: first ongoing in wet habitats, the second in drier habitats. Both series driving to the forest vegetation, however the forest stage can be established only if the forest exists in the vicinity of the LRS. If the LRS is maintained, the grassland vegetation dominates the riparian zone. If the LRS is neglected the plant composition changes leading to overgrowing the ditches by shrubs or big grasses like *Phragmites australis* or *Phalaris arundinacea*. Such vegetation blocks the water flow in ditches, causing disturbance of the drainage function of LRS. If the LRS is not maintained, the vegetation blocking water flow can well establish after 7 to 15 years (Figure 5.4.4.3). The classes 5, 6, 7 indicate the LRS maintanance, while remaining are a result of LRS neglecting. Based on the vegetation structure the effectivness of LRS maintanance could be assesed. In the Rogów Legnicki only 34%, while in the Pecław over 70% of the LRS is maintaned (fig. 5.4.4.4.).

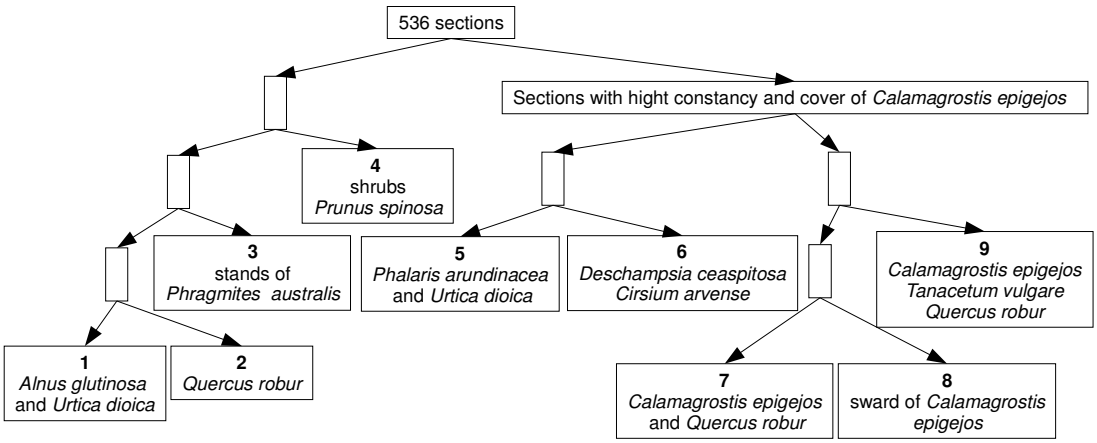


Figure 5.4.4.2. The typology of watercourses vegetation. The species with the highest discriminate value are showed

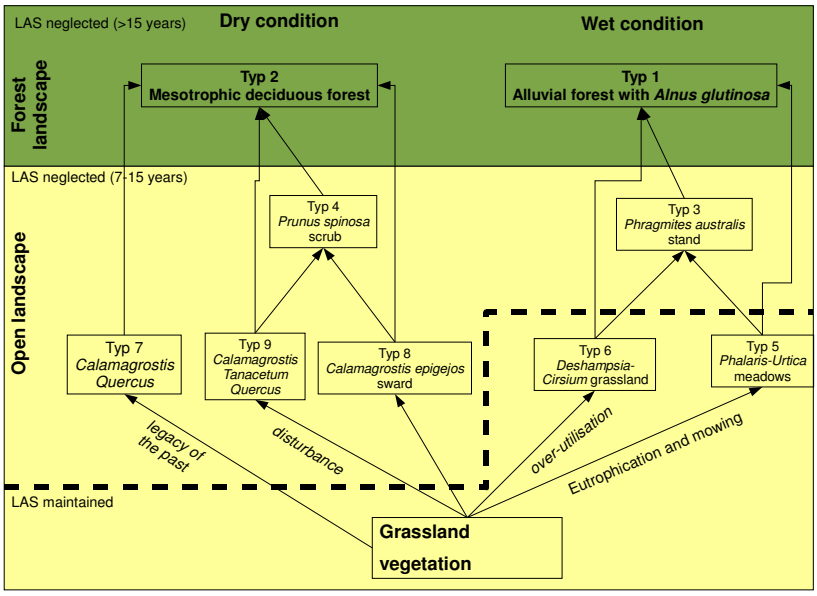


Figure 5.4.4.3. The ecological succession in the riparian zones of the LRS

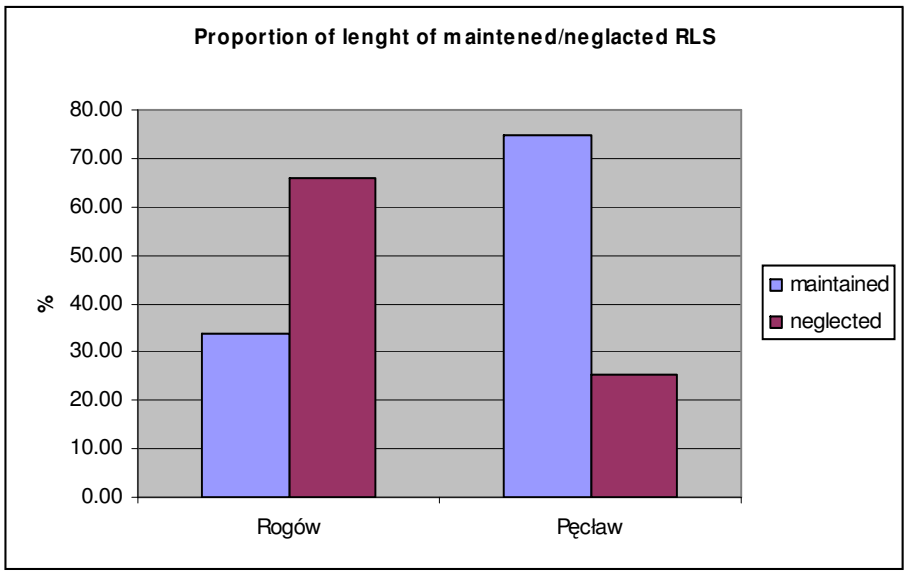


Figure 5.4.4.4 The effectiveness of the LRS maintainance indicated by the riparian vegetation

6. From research to modeling – data transfer

6.1 Agents design

Agents in a model represent households, however not as 1 to 1 mapping but as a generalized agent types. Agent types were designed based on elicited knowledge, basically on the storylines derived from interviews' transcripts and include the following types:

- Unwilling part-time farmer (UPTF),
- Willing part-time farmer (WPTF),
- Big farmer without fish pond (BFNP),
- Fish pond owner (FPO),
- WP initiator (WPI). Water Partnership is an institutional agent.

In Poland farming is still not only a business, but a tradition as well. This means that there are not only big production farms in Polish village but also many small family farms exist, that produce food only for their own needs. Based on this facts we can construct two basic types of farmers: Big Farmer (BF) and Part-Time Farmer (PTF). Following interviews we can say that a BF calls himself a farmer when asked about occupation, mentions farming as a main source of income and produce for sale. Big Farmer is also likely to invest in farming and increase farm's acreage. In our case study he usually owns about 20-40 hectares of land, rarely more. BF is aware of the importance of LRS maintenance because his/her economic success depends exclusively on crop yields, which can be affected by flooding or drought. There are only few big farmers in a village (like 2-5). Most of the households can be described as part time farmers (PTF), which means people who inherited some land from parents and usually produce for own needs only or do not produce anything at all. They do not call themselves farmers and their main source of income is not connected with farming. Some of them treat land and farming tradition with respect and wish to manage even small farms properly - we call them willing part-time farmers (WPTF). They would maintain LRS if sufficient help is provided although they are not able to do it themselves due to lack of time, skills, money, equipment etc. Some of PTFs are not interested in

farming at all and they would rather sell or rent their land – we call them unwilling part time farmers (UPTF). Part time farmers own from 1 to 15 hectares of land generally. They are not interested in LRS maintenance.

From field research we know that some people in the village, usually farmers, have fishponds to produce fish. In our case it is important to characterize this category of actors separately as fish pond owners (FPO), because their behaviour and reasoning regarding land reclamation differ a lot from other actors. In interviews they admit that they clean ditches and operate sluice gates even on other farmers' parcels since it is necessary to ensure certain water level in a fishpond to keep fish production. Additionally their activity considerably affects local hydrological system including flooding other farmers' fields.

From expert interviews we know that the activity of some kinds of WP Initiators was necessary to establish Water Partnerships. Usually they were people from local authorities. But any person, who is socially skilled and rather well known as well as respected in local community can start a WP if he/she finds at least three persons interested. According to farmers' opinions it is necessary to coordinate efforts regarding LRS maintenance, otherwise these efforts are not efficient. They often say something like: "I won't clean my ditches. It makes sense only if others do it. How can I be sure that they do?"

Summarizing, included criteria of household agents' characteristics and distinction refer to land ownership issues, fish farming, activity related to Land Reclamation System maintenance, agricultural knowledge and social network integration. These criteria constitute agents' properties and their values are attributed to agents' types as shown in Tab. 6.1.1.

The set of agents and their properties were validated with one domain expert.

Tab. 6.1.1. Property values of agent types in the model

Agent property	**Property values**	**UPTF**	**BFNP**	**FPO**	**WPI**	**WPTF**
Land ownership	Big farm		+			
	Small farm	+				+
	No farmland	-	-			-
Fish farming	Yes			+		
	No	+	+			+
Activity related to LRS maintenance	Take leadership				+	
	Member of or willing to join WP		+	+	+	+
	Not member of WP but cleaning ditches	-	+	+		-
	Do nothing but willing		-	-		+
	Do nothing and unwilling	+	-	-		
Agricultural knowledge	High		+		+	
	Middle					+
	Low	+				
Social network integration	High				+	
	Low					

6.2 Rules design

The rules were abstracted based on storylines (Tab. 6.1.2). The rules now implemented in a model regard LRS maintenance with respect to social influence and economic factors. The basic reason for maintaining LRS is of economic nature and relates to losses in crops in case of flooding or drought. The majority of farmers is aware of the relation between the state of LRS and yields, although it is not easy to calculate it very precisely. Except economic factors, farmers can be convinced to good practice, including LRS maintenance also by experts. When asked about sources of advice and information in interviews farmers usually mention professional advisors form Advisory Centres. Thus we can assume that socially active experts, including WP Initiators can be a serious source of social influence. If the strategy of a farmer is to maintain ditches, he/she has two options: to do it him/herself or to participate in a Water Partnership. Most of the interviewed farmers admit, they would enter a WP if it existed and worked properly. In case WP does not exist, some farmers maintain LRS on their own, some do not. If economic success depends largely on strategy MAINTAIN, which is true in case of big farmers then the rule " IF myLRSStrategy == MAINTAIN AND noWPExists THEN cleanDitches" is very likely. From interviews we know that most big farmers maintain LRS no matter what.

Tab. 6.1.2. From interviews to decision rules – examples

TEXT IN STORYLINE	RULE
- In case of flooding the losses are up to 40% usually and 80% if ditches are plugged. He cleans ditches himself and has them clear to protect his crops. - He doesn't care about LR since he has no problems with floodings.	IF bigLosses THEN consider myLRSStrategy == MAINTAIN
- He never had something in common with a WP no one has called him up to a WP.	IF askedByWPInitiator THEN consider myLRSStrategy == MAINTAIN
- He manually cleans ditches from branches and he deepens the canal every few years with a mechanical digger. He does it all on his own despite the strong conviction that it should be done by the State.	IF myLRSStrategy == MAINTAIN AND noWPExists THEN cleanDitches
- WP was liquidated 5 years ago. He always participated in WP and its meetings. WP wanted everybody to pay dues so he paid them. But only few farmers in the village think in this way. - He tries to maintain it, as far as he can, but he misses specialist equipment and time. Formerly he belonged to WP because it was a duty, but he would participate even if it wasn't obligatory.	if(exists(WP) AND (myLRSStrategy == MAINTAIN)) then beMemberOfWP
- He would share in a WP if he was sure that local officials and other farmers support him.	if(otherLRSStrategy == myLRSStrategy) then supportOther

The other way to construct rules can look like as follows:

1. Derive main decision drivers from interviews/storylines (e.g. soil class, subsidies, production profitability, present land use)
2. Construct a set of conditions by attributing values to conditions (e.g soli class = I, II, III, IV, V, VI; subsidies = yes, no; profitability = cattle breeding profitable/cattle breeding not profitable; present land use = arable, meadow); values are known from interviews or other sources of information,

3. Construct a set of scenarios – combinations of conditions with different values,
4. Ask expert/stakeholder/landowner about farmers decision under every scenario (e.g. What if he has meadows on III class soils and subsidies for afforestation are available?)
The rule set regarding land use was constructed in this way (Tab. 6.1.3).

Tab. 6.1.3. Farming related rules

IF HAVE MEADOWS

- IF VI or V class meadow AND no afforestation subsidies AND cattle breeding profitable THEN keep meadow
- IF VI or V class meadow AND no afforestation subsidies AND cattle breeding not profitable THEN abandon meadow OR IF direct payments/hectare THEN keep meadow
- IF VI or V class meadow AND afforestation subsidies AND cattle breeding not profitable THEN afforestate
- IF VI or V class meadow AND afforestation subsidies AND cattle breeding profitable THEN afforestate OR IF have big farm and cattle husbandry THEN keep meadow
- IF IV class meadow AND cattle breeding profitable THEN keep meadow
- IF IV class meadow AND cattle breeding not profitable THEN abandon
  OR IF direct payments/hectare OR growing grains very profitable THEN turn into arable

Turning meadows into arable is more likely if 2-3 dry years. When meadow turned into arable THEN yields in 2 years.

IF HAVE ARABLE

- IF I or II or III or IV class arable AND * THEN keep arable
- IF V or VI class arable AND cattle breeding profitable THEN turn into meadow
- IF V or VI class arable AND cattle breeding not profitable THEN abandon OR IF direct payments/hectare THEN keep arable

IF FLOODING

- IF flooded arable for 2-3 years AND *class AND cattle breeding profitable THEN consider turning into meadow (serious decision, yields in 3 years)
- IF flooded arable for 2-3 years AND *class AND cattle breeding not profitable THEN abandon (but first claim for land reclamation restoration wherever possible)

Comments:
- I class is the best, most productive, VI class is the worst, least productive.
- Keep = maintain properly
Abandon = let overgrow, but not change formal land use qualification

6.3 Spatial data for the biophysical model

Following GIS data were created for WATCH, the biophysical model:

Digital elevation model (DEM).

A raster DEM of cell size 10m was created in GRASS GIS by means of natural neighbour interpolation, from TIN (triangulated irregular network) data provided by Lower Silesia WODGiK (Voivodship Department of Geodesy and Cartography).

In order to enable GRASS GIS with natural neighbour interpolation, a script *r.surf.nnbathy* was developed, and published under GPL v2 license, on GRASS GIS AddOns website *http://grass.gdf-hannover.de/wiki/GRASS_AddOns*.

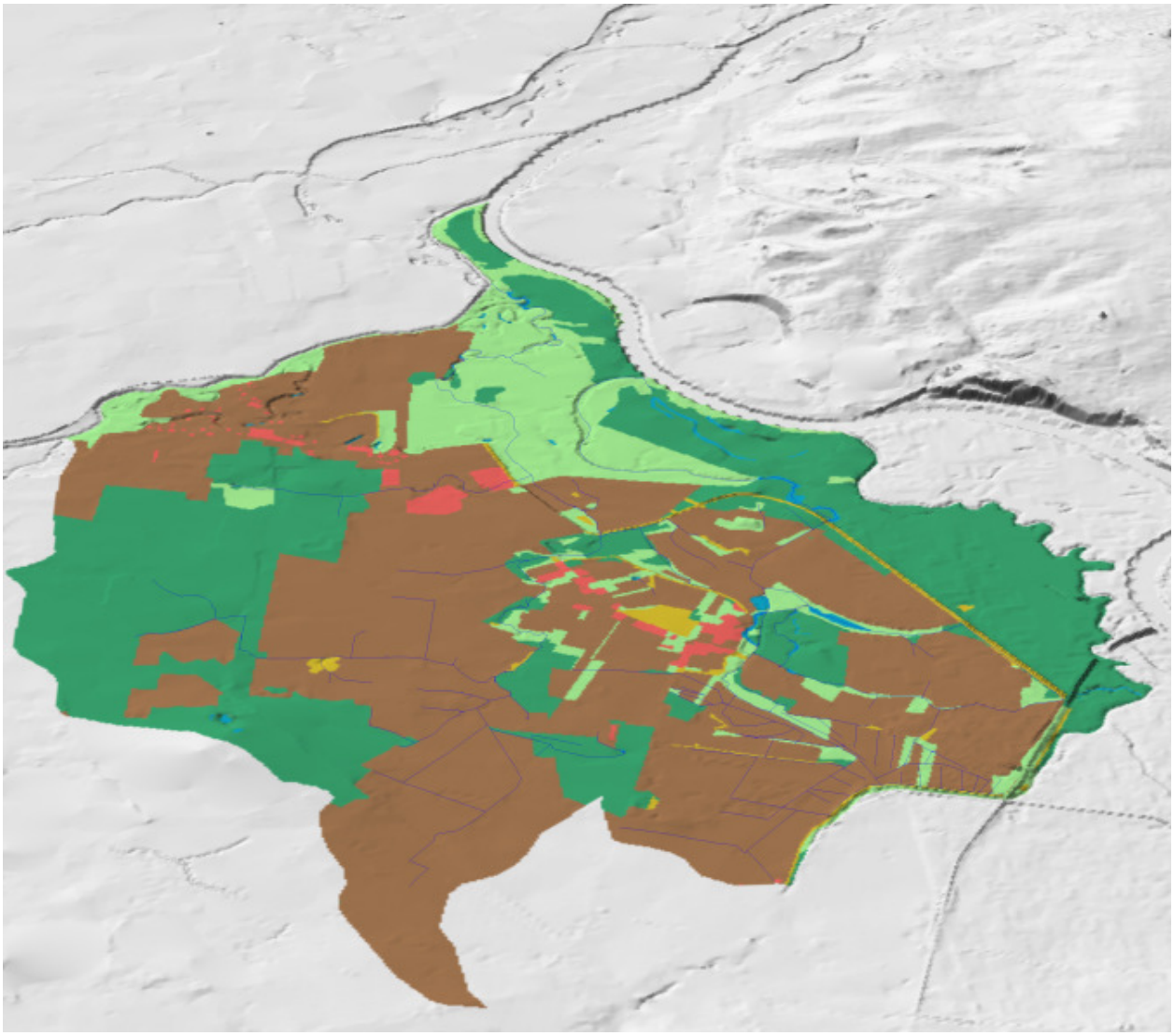
Vertical accuracy of original TIN data varies from 0.27 m to 0.45 m, 0.35 m in average.

2.Land parcels of Rogow Legnicki.

Parcels were digitized from a 1:5000 map into GRASS vector map, and connected with a database of land ownership, land use and soil quality. The data were obtained from Prochowice Commune and Legnica District authorities.

3.Watercourses.

Watercourses were digitised from 1:5000 map within its extent and supplemented with watercourses digitised from 1:10 000 map, to provide a complete coverage for the whole biophysical model area. Each watercourse was divided into segments, one segment per each DEM cell, and a minimum elevation for each segment was calculated, so that a water flow down the watercourse is enforced. This was done in order to improve the hydrological soundness of the model, as it could be hampered by artefact micro-dams in DEM, which are a frequent side effect of limited accuracy of input elevation data used for creating DEM, data pre-processing and interpolation itself. To automate the drainage enforcement, a GRASS GIS script *v.breach* was developed, and published under GPL v2 license, on GRASS GIS AddOns website *http://grass.gdf-hannover.de/wiki/GRASS_AddOns*.



other
grassland
forest
arable
water
built-up
watercourses

Figure 6.3.1. Biophysical model area 3D view. Watercourses and Rogow Legnicki parcels, merged with surrounding land cover data for visualisation purposes, are overlaid on DEM. Elevation is exaggerated 3 times. North is up

7. Conclusions

1. According to the LULCC spatial analysis the conversion of grasslands into arable lands was the main land use related process that took place in the study area in the period 1975-1995. This result corresponds partly with the results of social research: decrease in the grassland area in favor of arable fields is one of the main land use processes perceived by respondents. It can be explained by economic factors – the production of milk and cattle breeding are not profitable anymore. Additionally respondents point out two other land use change processes, mainly driven by EU accession and subsidies: afforestation of poor soils and turning abandoned lands into arable lands. It seems that economy is the main decision driver regarding specific decisions on land use or production type: IF profitable THEN do it! However….

2. Regarding general decisions on staying or not in farming we can observe a kind of devotion of Polish farmers to the tradition of small family farms. They are very likely to go on with agricultural activities even if it is not profitable and the main sources of income are different than agriculture. It was estimated that the income on the level of minimum Polish salary is achieved by farms larger than 17ha if managed by one person and 33ha if managed by two people. Not many farms in the study area are that big.

3. According to farmers and key informants the state of the LRS in the study area is very poor in Rogow Legnicki and varied in Peclaw. Based on the vegetation assessment we can know that only 34% of LRS in the Rogow Legnicki area is maintained properly, while in the Peclaw area it is 70%. In Rogow LRS is not maintained by almost anybody (partly by fishponds owners), in Peclaw it is maintained by the Water Partnership.

4. The pressure for maintaining LRS is evidently not high. Economic pressure is not too high because most of the people do not depend totally on agricultural production. Legal pressure is not too high because article establishing penalty fines for not maintaining LRS is a ‘dead law’. Social pressure is too not high because there is a strong conviction among villagers that it is not a duty of farmers to maintain LRS, but of the State.

5. Both social research and the analysis of spatial interdependencies of agents along channels clearly indicate that LRS maintenance is the matter of collective action. Among other things the problems with LRS result from the lack of collective effort to maintain a common good of LRS. Farmers do not trust institutions, like Water Partnerships, but they also do not trust each other, what is not surprising when we consider that the level of social capital in Poland is one of the lowest in Europe.

6. Water Partnerships do not seem to satisfy their obligations. WP in Rogow is suspended and the one in Peclaw is being criticized. Their performance is perceived as: costly, inefficient, unjust, ineffective, and unclear.

Appendices (attached)

I Interview questionnaire I
II Interview questionnaire II

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