Chapter 7

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Aspects of Use of Innovative Technologies in Supporting Sustainable Development of Marginal Rural Areas

1. Introduction

Marginal rural areas are distinguished by high complexity and dynamic changes of the problems encountered by their inhabitants, the solutions to which seem to be mutually exclusive. A conflict of goals occurs in such areas because both economic development and environmental protection need support, with the latter often perceived as being in opposition to the former. Support for economic development aims at improving the quality of life of people living in such areas, whom marginalisation of rural areas has led to extreme poverty. In this case, quality of life is understood to denote the level of income and availability of services. On the other hand, support for environmental activities aims at preservation of unique biodiversity of such areas which will disappear unless the land is used in an extensive manner, which does not generate high profit. The complexity of problems which occur in rural areas is additionally aggravated by their non-structural character, which manifests itself in the impossibility of defining clear goals, performing quantitative measurement of many factors, finding solutions based on clear laws and applicable theories and expressing components of the decision-making process in algorithms. This lack of possibility of structuring of actions while seeking solutions aimed at sustainable development of marginal rural areas results from the principles of eco-development, which require purposeful building of relations between three components: the environment, the society and the economy. According to the holistic approach, all these phenomena make up entire systems which conform to certain rules, which cannot be deduced from the knowledge of the rules governing each component. A holistic approach requires that the actions, which used to be considered individually, should be considered as a whole. According to the reductionist approach, it was believed that a complex system and its properties can be described by describing and explaining the behaviour of its individual components. In the reductionist approach, it was possible to determine the aims of each action, which facilitated expressing the processes taking place in the components in algorithms. This approach could be expressed as arranged sets of structures, which made up conventional data models. Although the methodology typical of reductionism is much easier to express in a digital environment, it has always been a challenge to describe the natural environment by a range of variables. This is caused by complex processes which occur in ecosystems. The task became still more difficult when the holistic approach was applied in decision-making processes. As a result of applying the holistic approach, a description of the processes occurring in a natural system had to take into account the effect that the socioeconomic system had on it. Includingthe interactions between the natural and socioeconomic subsystems in the decision-making process (the latter of which proved to be even more difficult to describe due to the unpredictability of human actions) has rendered conventional technologies and data models insufficient. Too great a number of exceptions to rules preventedthe formulating of clear laws in structuring the knowledge and a decision.Finding a solution to the problem may be made easier by the development of geo-information technology which can encompass the non-structural nature of the problems which occur in marginal rural areas. Geoinformation technology is a decision-supporting tool, which helps to create approximate descriptions of the function of the natural environment, to create dynamic simulation models, to make assessments of the human impact of the natural environment, to design analyses which are the essence of geo-information programmes and which enable proper preparation of spatial information for decision making (Longley *et al.* 2006). Therefore, using it as a framework for the new technology is justified. However, due to the limitations of the relational model on which it is based, the technology inhibits the decision-making process, which would be suitable for solving complex spatial problems faced by inhabitantsof marginal rural areas.Expanding the capabilities of the georelational model by those provided by artificial intelligence seems to be the most appropriate solution to the problems presented above. Owing to such a solution, the holistic approach could be applied(and become necessary in the sustainable development of rural areas) by providing solutions which take into account all the relations and interactions between human activities, nature, the economy and location.

This article presents a technology which enables solving complex problems occurring in marginal rural areas. This is a technological solution in which the limitations of the georelational model have been removed owing to synergistic use of the geo-information system and artificial intelligence. Synergistic use of the properties of these two technologies has been made possible by embedding an expert system into the georelational system in a manner which enables creating a deductive data model, which can share the objects of the real worldwhich are of key importance to decision making. Owing to such a concept, the holistic approach can be applied in the process of supporting decisions which optimise the development of marginal rural areas. It can also help to solve non-structural problems which dominate in rural areas.

2. Presentation of the problems of marginal rural areas

Optimisation of the development of marginal rural areas is part of a study area of key importance both to the socioeconomic development of the country and to environmental protection. Poland has already solved the basic problems: feeding and industrialisation. At the turn of the 1980s it entered the third stage – that of intensive development and improvement of the standard of living. Unfortunately, the economic and political transformations were accompanied by the formation of marginal areas. Their features include extreme poverty, stagnation, absence of any non-agricultural labour market as well as adverse soil and climatic conditions. Accumulation of unfavourable conditions has made the population of those areas more willing to abandon their farms than transform them to modern agricultural production entities. Abandonment of farms and, in consequence, an increasing share of land on which agricultural activities are no longer carried out may have a negative effect on the biodiversity of the areas, which developed when the land was used agriculturally in an extensive manner and which is inextricably associated with such activities.This is because certain, naturally valuable habitats can only exist in areas extensively used for agricultural production. However, such activities do not generate sufficient profit on poor quality soils. Solving the problem by intensification of agricultural production would causeelements of the agricultural landscape which provide protection and beauty to the landscape to vanish; this would also apply to biodiversity, which makesPoland stand out against other EU countries. A total abandonment of agricultural activities in such areas would result in a similar problem – disappearance of anyaesthetic values of the landscape and biodiversity – by the process of secondary succession. Each unilateral action performed in such areas would have a negative effect on ecosystems with valuable flora or fauna species (investment projects) or on the quality of life of people, by increasing the social and economic stratification of marginal rural areas (if economic development is given up in favour of environment protection). Therefore, the aim of the system presented in this paper is to help to consolidate actions aimed at optimising the development of marginal rural areas in a way which ensures a sufficient level of income and services to their inhabitants and protection of biodiversity.

3. Methodology

Optimisation of the development of marginal rural areas through preservation of biodiversity (Krajowa strategia ochrony i zrównoważonego użytkowania różnorodności biologicznej 2007, Polityka Ekologiczna Państwa na lata 2007-2010 z uwzględnieniem perspektywy na lata 2011-2014) and diversification of economic activities which results in development of marginal rural areas and in creating jobs outside agriculture (Założenia do Krajowego Programu Rozwoju Wsi 2006, Program Rozwoju Obszarów Wiejskich 2007-2013 2007, Cele Strategii Lizbońskiej a Wspólna Polityka Rolna 2008, Strategia na rzecz inteligentnego i zrównoważonego rozwoju sprzyjającego włączeniu społecznemu. Europa 2020 2010), and, consequently, in providing alternative sources of income to rural populations and increasing their level of income, is supported by theSystem of Supporting Decisions Optimising Marginal Rural Areas Development (System Wspomagania Decyzji Optymalizujących Rozwój Marginalnych Obszarów Wiejskich – SWD-ORMOW).

SWD-ORMOW is a computer program which presents a system of managing marginal rural areas as a spatial model based on systems of geographic information. The modelling of the system's marginal rural area management using GIS techniques is based on spatial models of actual objects. Based on the data on location, on object properties and on their interrelations, the effect of specific forms of management on the environment and development of rural areas is analysed. The possibility of linking the phenomena and processes shown on maps with relationships described as predicates is also important in the model. Such a solution allows considering a real system of managing marginal rural areas as an object model and allows artificial intelligence to be applied as a decision-supporting tool. By being designed in this way, the system fulfils the requirements of the holistic approach, which is necessary when solving complex problems. It also makes it possible to implement the idea of sustainable development and provides a chance to prepare strategic plans at a grass-root level. Such plans are necessary to identify the directions of development of marginal rural areas in which ensuring the consistency of various actions and support from the Common Agricultural Policy provides the greatest added value (Leszczyńska 2011).

4. Database

In order to ensure the consistency of data (Komisja Wspólnot Europejskich 2004), which will be created during the process of development of strategies of optimising development of marginal rural areas, the SWD-ORMOW model is fitted out with a subsystem which enables automated utilisation of existing reference data. The subsystem is called GDiZS and is shown in Fig. 4. Making the process automated was important because SWD-ORMOW is intended for beneficiaries who are not GIS experts. Such a solution will also minimise the cost of decision making as extracting data from existing data sets is the cheapest way of obtaining information about the object under study. The VMap L2 database, with a sufficient level of precision and detail which covers 100% of the country area, is regarded as the best set of reference data, and it should be used as the background for analyses associated with making decisions which optimise development of marginal rural areas. Other reference spatial data bases, with a similar level of detail and accuracy and which are available in Poland, are regarded as unsuitable since they do not cover all marginal rural areas. However, the subsystem of the SWD-ORMOW system is flexible enough to be adopted for use with other than proposed reference spatial data bases as sets of input data (further in the paper, the feature is referred to as the system "modularity").

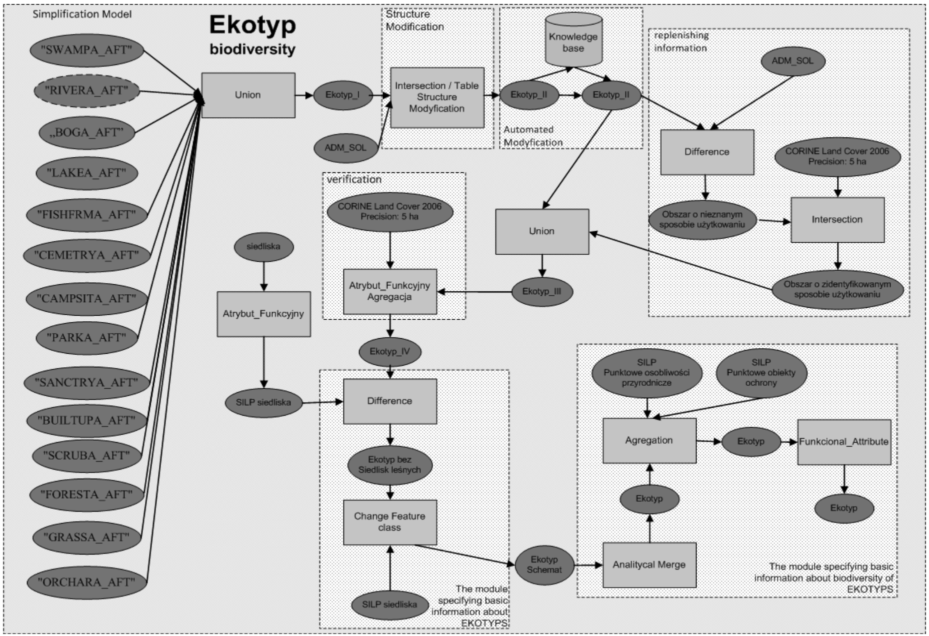

Fig. 1. The simplified model of the acquisition data

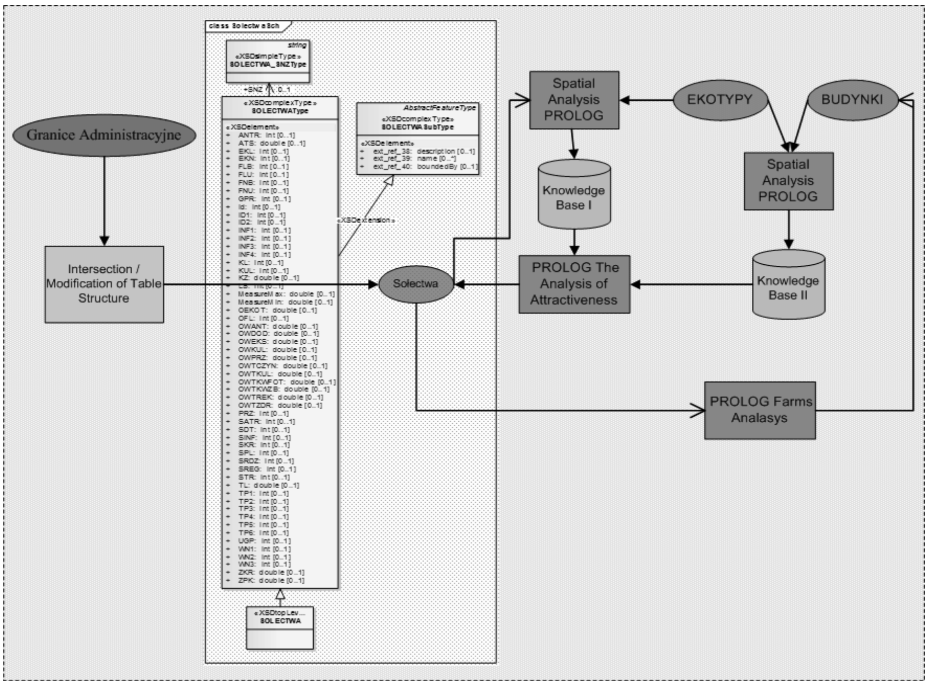

Fig. 2. The model of the real object SOLECTWO

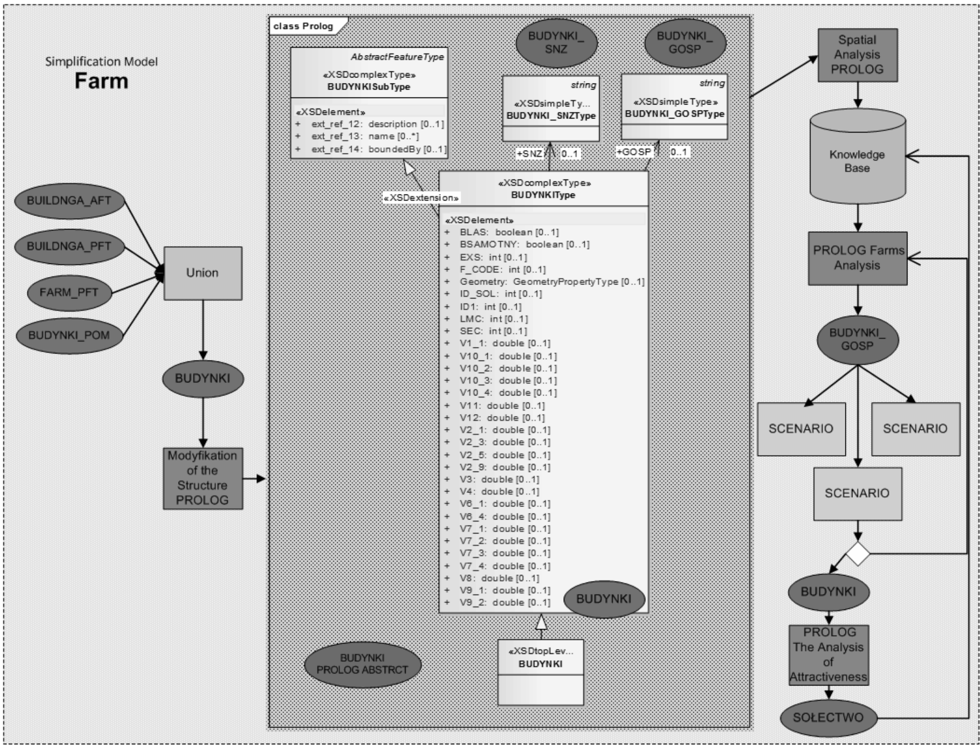

Fig. 3. The model of the real object GOSPODARSTWO

5. Models

The GDiZS subsystem of the SWD-ORMOW system, together with the complementary SZOM subsystem (Fig. 4), enables supplementing missing data with information extracted from sector databases. Missing data are obtained with specially designed spatial models (Fig. 1), which are a component of the SZOM subsystem. The extracted information provides the basis for developing spatial models of real objects – the main subsystems (natural, social, economic) of the real system of marginal rural areas (Fig. 2, 3). Both of these mutually complementary subsystems are an important element which expands the capabilities of the SWD-ORMOW system by the possibility of providing effective support in making space-related decisions to beneficiaries who are not GIS experts.

6. Structure

6.1. SZOM and GDiZS subsystems

According to a classification found in the literature (Malczewski 1999), a subsystem which enables extracting new information is referred to as a Model-Based Management System. Apart from designed models, such as subsystem contains standard programmes to maintain and manage developed models so that they can be run when analyses are being performed. It also has a control system which enables the output of one model to become the input of another. The operation of the Model-Based Management System is supplemented with functions of the Dialogue Generation and System Management Subsystem (Malczewski 1999), which enables searching for data in user-supplied databases, extracting data from multiple sources, automatic data processing to a form suitable for the problem at hand and gathering it in a form suited to the data model of the developed system. The subsystems are integral parts of SWD-ORMOW, making the environment flexible and effective in providing support to decision-makers. Such an environment, together with the expert system embedded in the geo-information system (this part of the system is presented further in the paper) makes it possible to solve even the most complex spatial problems, classified by Malczewski (1999) into group IV problems on a continuum from structural problems (group I) to non-structural problems in all the four elements associated with the problem-solving (group IV).

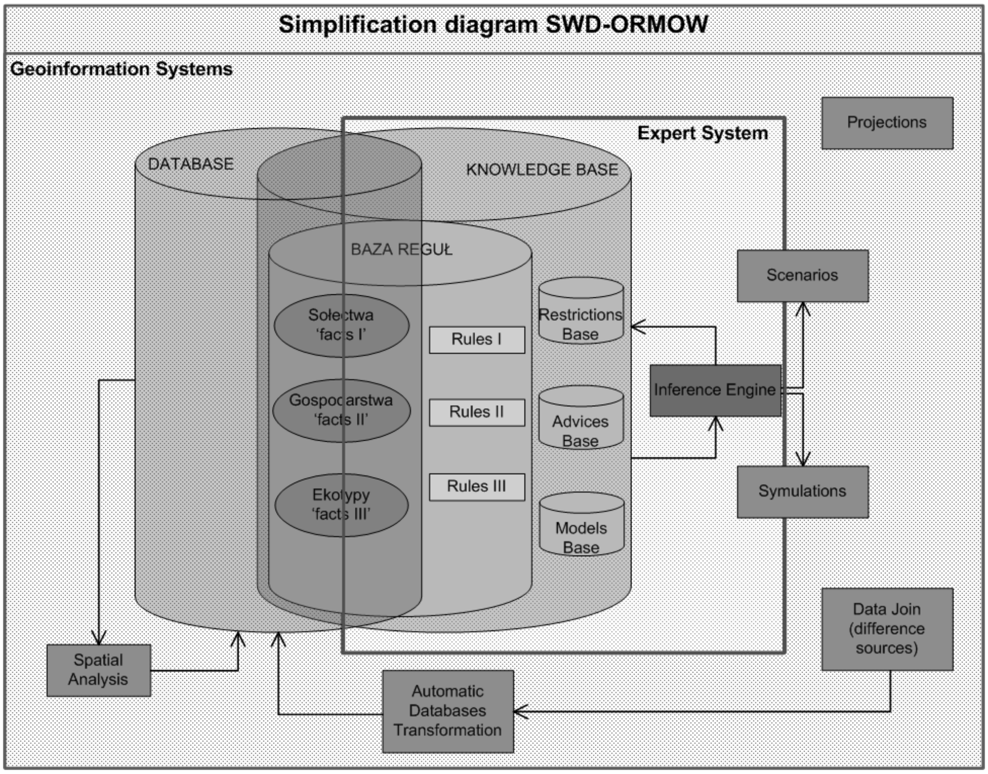

Fig. 4. The Simplified diagram of spatial decision support system for optimization of marginal rural area

Fig. 4 shows a diagram of the model of the SWD-ORMOW system with subsystems: the Model-Based Management System (abbreviated to SZOM

– System Zarządzania Opartym na Modelu) and the Dialogue Generation and System Management (abbreviated to GDiZS – Generowania Dialogu i Zarządzania Systemem) which, when embedded in the geo-information system, together make up a system of spatial decisions support – marked by a green rectangle. Fig. 4 also shows a purple rectangle, which distinguishes another important component of the SWD-ORMOW system. The purple rectangle surrounds the expert system, which – together with the geo-information system – makes up an expert system for a spatial domain (according to the classification: Malczewski 1999, Fischer 2006). Integration of two newly created components based on the geo-information system has allowed developing an intelligent system of supporting decisions optimising the development of marginal rural areas, presented in this paper.

7. A knowledge-based system of supporting spatial decisions

A system which embraces the modules presented in Fig. 4 may be called a knowledge-based system of supporting spatial decisions. Such a system contains two main components: an expert system and a geo-information system, expanded by subsystems which facilitate decision making (SZOM and GDiZS). The main components GIS and SE can be integrated in a variety of ways (from loose to strong integration). Each method of integration provides a different functionality and different capabilities. It is a measure of the merged system whether modules of one system can be controlled by modules of the other and the how data are used. Loose integration enables using the tools which are typical of each of the merged applications without modifying them. Such a solution is possible by applying the mechanism of file exchange, owing to which data are sent or received by applications as files. This makes it possible to use the same data as sources for each application. Therefore, applications cooperate only by exchanging files. Such integration is easier to achieve. However, it does not provide such capabilities as can be provided when one database is used by two applications. Such capabilities are provided by strongly integrated models, where both programmes download and write data to the same file, without using external translators. Such integration enables developing a data model which makes it possible to store complex knowledge, which is necessary to solve non-structural problems. In the SWD-ORMOW system presented in this paper, strong integration is applied, which allows data to be used to a full extent by two integrated systems. Apart from strong integration, a method of combining software has been used which involves embedding an expert system in a geo-information system, which makes it possible to run the processes of the expert system through the graphic interface of the geo-information system.

Embedding an expert system in the geo-information system has enabled expanding the system capabilities through the possibility of imitating the process of expert reasoning in the process of solving complex spatial problems which occur in marginal rural areas. It was very important to provide such a functionality to the system in question because the SWD-ORMOW system was intended to support two groups of beneficiaries: local administration and the population inhabiting marginal rural areas (farmers, service providers), neither of which has the expert knowledge necessary for diverse actions aimed at implementation of principles of sustainable development. Therefore, the knowledge is accumulated in the system owing to special structure which results from a combination of both technologies. Selected elements of the structure are presented below.

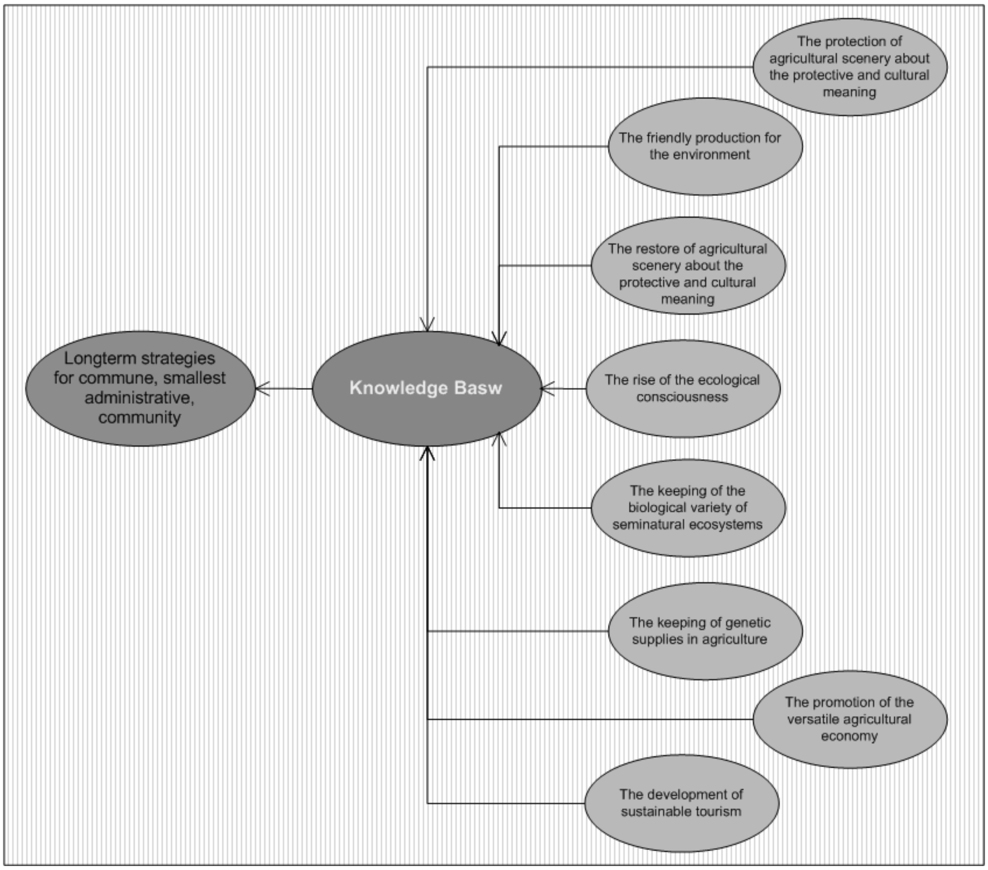

Fig. 5. The simplified scheme of learning the knowledge

7.1. Knowledge base

One of the main elements of the structure of the SWD-ORMOW system is a knowledge base. A knowledge base has been created based on information obtained from experts in selected fields during formal interviews, informal interviews, observation of an expert at work, in the literature and legislation, some of which are shown in Fig. 5.

The knowledge has been encoded in a specially-designed deductive model which synergistically expands the capabilities of the relational system of database management and logical programming. The knowledge base is shown in Fig. 4.

Owing to its properties, it shares the main instances between the expert system and the geo-information system in a way which reflects the complicated relations between the economy, the environment and society in the real world. More information on the issue can be found in the paper "System informacji przestrzennej dla wspomagania decyzji optymalizujących rozwój marginalnych obszarów wiejskich" (Leszczyńska 2010).

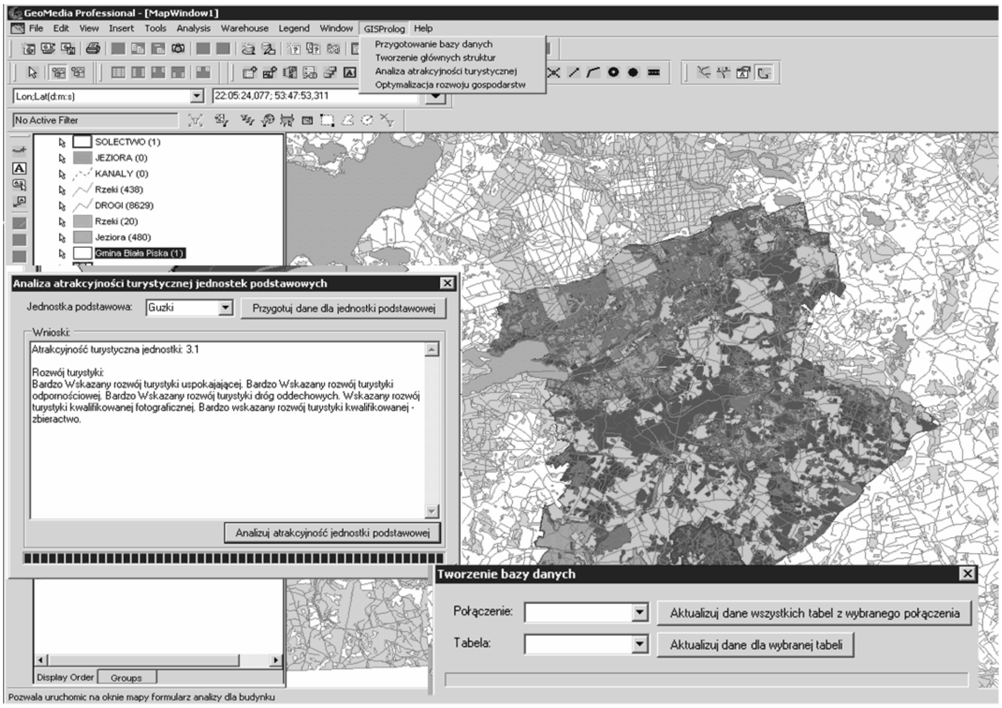

Fig. 6. The elements of the designed interface

7.2. A deductive data model

Apart from sharing the main instances, combination of the capabilities of a relational system of database management with the capabilities of logic programming has enabled developing a deductive model which has become the core element of the SWD-ORMOW system. Such a solution expanded the way in which facts are represented in the relational database. Moreover, it facilitated representation of the complexities of the ties of integrity of utilisation of the modification function and enabled expressing field knowledge in a manner which enables imitation of expert activities (Beynon-Davies 2003).

For the project, the deductive data model has been developed in an evolutionary manner by combining the Prologue with a relational system of database management. Using the logic programming language of the Prologue has enabled the model to express specialist field knowledge as "if-then" rules which represent hidden meanings dependent on a set of conditions. Such an approach presents the real world in the form of logic formulas which make it possible to execute recursive queries andintegrity limitations andto use compound values and deduction and induction in a uniform structure. On the other hand, concurrent use of a deductive database and a geo-information system can express facts not only in a manner typical of logic programming, which consists of a set of "attribute-value" pairs, but also in a way which expands the basic syntax of rules by operations associated with analysis of spatial information, such as: "inside" "farther than" "outside", etc. This has made it possible to expand the process of inferring, which is an important component of deductive databases, by inferring based on facts represented on maps and drawing inferences in the form of maps.

Apart from the deductive model, the SWD-ORMOW system also has a relational model, which allows the properties of each of them to be used synergistically.

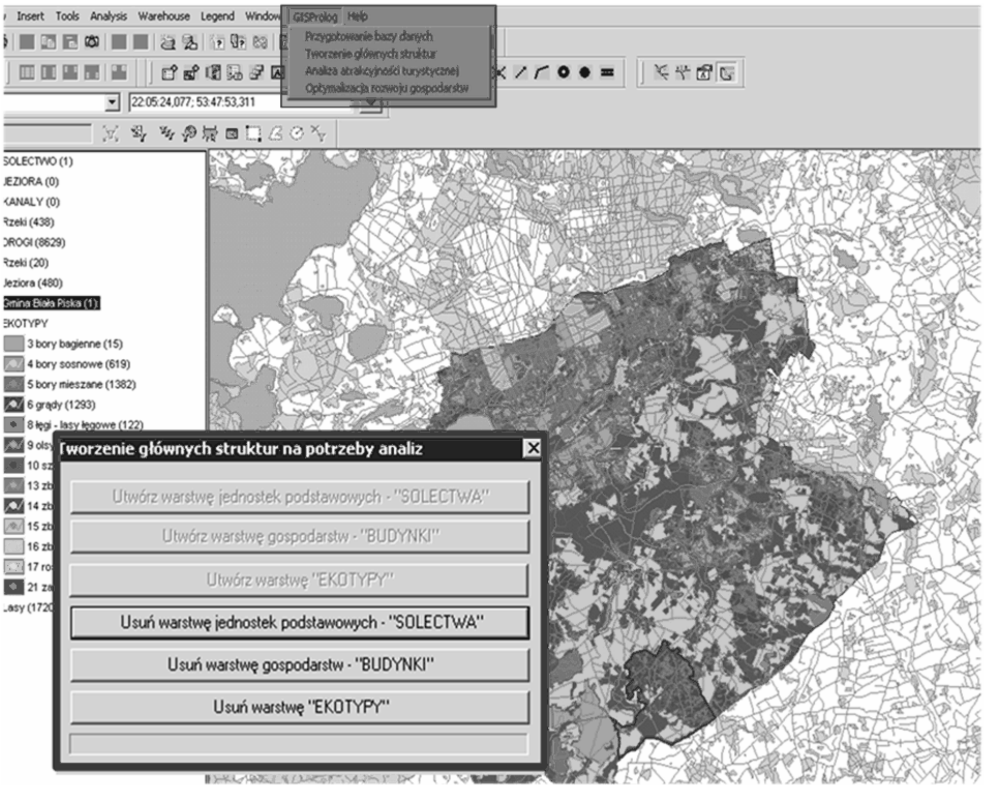

Fig. 7. The elements of the designed interface

7.3. Mechanism of inferring

Inference in the SWD-ORMOW system is carried out in accordance with the resolution and unification principle, and verification of statements performed during the process of concluding is a recursive process. The inference machine, which is a necessary part of an expert system, has been described in the article: "System wspomagania decyzji optymalizujących rozwój marginalnych obszarów wiejskich" (Leszczyńska 2011). Due to the specificity of the logic programming language of the Prologue, notation of facts and rules had the greatest effect on the speed of inferring.

7.4. Interface

The architecture of the SWD-ORMOW system provides its user with a flexible environment for decision taking. One of the elements which allow an environment to be regarded as flexible is the interface. The interface in the SWD-ORMOW system has been designed with those users in mind who are not experts in using geo-information software.

The interface was tested during visits to selected administration units and modified until the functionality required by future beneficiaries had been achieved. The interface created during the evaluation process consists of modules, embedded in the standard interface of the geo-information system, initiated by selection from the main menu. An important element of the interface are the windows which are used for communication with the user. Selected elements of the interface are shown in Fig. 6, 7 and 8. The structure of the interface has been developed based on the SZOM and GDiZS, presented above.

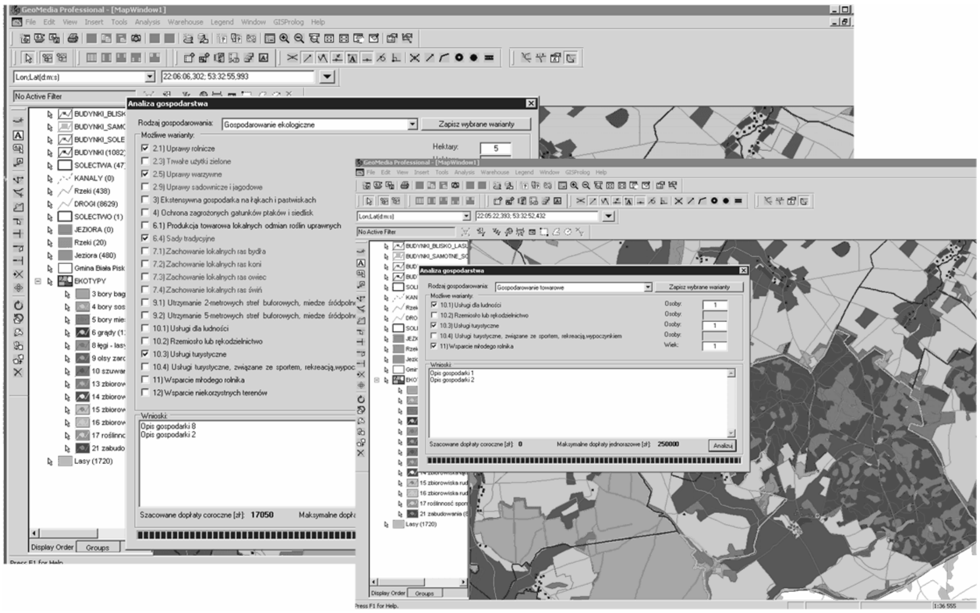

Fig. 8. The elements of the designed interface

8. Summary

The decision support system based on systems of spatial information presented in this paper can be an excellent tool to help in the creation of development strategies for rural areas. A tool which helps to save time and money and, most importantly, which enables implementation of the principles of sustainable development, owing to its ability to carry out long-term simulations of human impact on the environment. It can also be helpful in setting the development directions for rural areas being restructured, in evaluation of the effects of protection programmes, support programmes or programmes which alleviate social and economic problems.

The GIS technology in the system is a natural framework which provides a convenient method of analysing and representing information linked with spatial components. Embedding an expert system in the geo-information system has enabled combining the features of logic programming with a relational database, owing to which the system was fitted out with intelligence specific to deductive databases. In consequence, it acquired the ability to store rules and to apply them in order to impart the decision-making process with an interactive character, becoming an intelligent system supporting the process of taking spatial decisions.

Tangible effects of designing such architecture include creation of a system which enables support forthe process of natural resource management in marginal rural areas, their protection and identifying actions specific to development of the region. Supporting natural resource management and identifying a method of optimisation of marginal rural areas development is possible owing to implementation in the system of strategic and current issues of environment protection and management and strategies of multifunctional development of rural areas. Such a solution makes the system a technology which is useful in the economic sphere, which enables integration of actions aimed at protecting biodiversity with socioeconomic development of marginal rural areas in a manner which provides synergistic support to both actions. The described system was created as a prototype version (it is currently being tested) for the Biała Piska Commune. The character of the Commune is representative for the problems under study. This commune was characterized in the article.

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