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Building a Spatial Information System to Support the Development of Agriculture in Poland and Ukraine

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Abstract: The space of rural areas is subject to constant changes in terms of structure and development. The area structure of rural areas, especially in the south and east of Poland, remains unsatisfactory. The weakness of Polish agriculture is the fragmentation of the area structure of its farms; this was due to historical, natural, economic and social factors and, to a large extent, tradition. Therefore, the current status of agricultural land in Poland requires carrying out many arrangement and agricultural operations. In Ukraine, there is also no coherent IT system that would allow for the efficient management of rural space and agriculture. In order to conduct a coherent rural development policy in the region, the self-governments in Poland and in Ukraine are facing the need to expand the existing spatial information infrastructure system. This study is a proposal to expand the spatial information system with elements related only to agricultural surveying. To this end, the concept of building the Agricultural Geodesy Module was created as an element of the region's spatial information system. The Agricultural Land Surveying Module will be an information repository and will enable powering the region's database. Data supplying the repository will be divided into source data, operational data, metadata and final studies, such as analyses or reports. These data will not only be used by the local government of the region, but will also be made available to external users.

Keywords: agricultural economics and policy; sustainable agriculture; Information and communication technology (ICT) in agriculture; rural management; geographic information system in agriculture; prioritisation of land management activities

1. Introduction

In agriculture, we speak about a sustainable development as the balance of three aspects-economic, ecological and social. One of the most important goals of both Polish and Ukrainian science is to define a trend that will ensure the sustainable development of rural areas. The essence of this development will be economic growth, social development and the creation of safe living conditions in rural areas [1]. It is necessary to develop a unified approach to the collection and processing of information on the quality conditions of the agricultural land fund. The whole complex of these data can have an effective influence on a land-user by using the levers of the state control system for the use and protection of lands, securing the fulfilment of the main task of the system of land resource management, i.e., the rational use and protection of lands.

Without systemic solutions in the field of information systems supporting the decision-making processes of authorities at the regional and national levels, correct decision making is impossible. Political decisions will be made appropriately when changes in space are monitored on an ongoing basis. For this purpose, it is necessary to use geospatial data together with information systems. Only such a systemic approach can achieve the intended effect.

The developed database of the Agricultural Land Survey Module (ALSM) has the character of the Decision Support System (DSS) at the regional level. DSS is understood as an organisation simplified in relation to the assumptions made before the decision-making system, which supports the development and programming of decision rules (Figure 1).

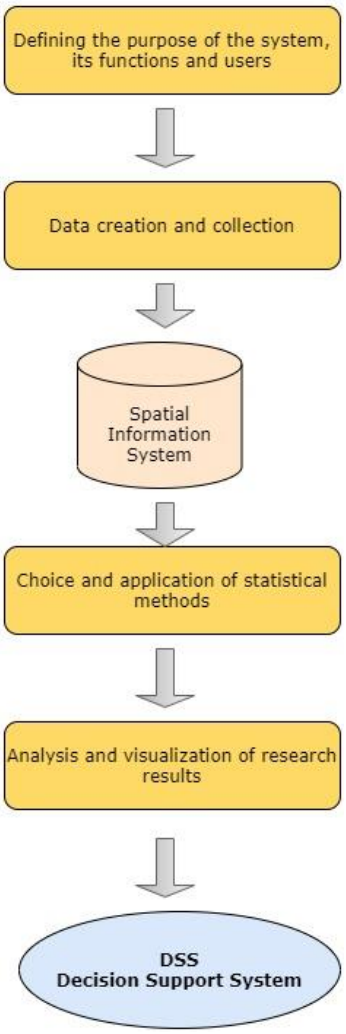

Figure 1. Scheme of system assumptions. Source: own study.

The proposed solutions allow for the assessment of spatial relations between diagnostic features and conducting multivariate analyses. A characteristic feature is the integration of spatial and non-spatial data from various sources. They are stored in database structures and in the visualisation of source and result data [2–4].

The authors have proposed building an IT system—the Agricultural Land Survey Module (ALSM)—in Poland for the implementation of tasks related to the sustainable development of rural areas. This system is also a proposal to be implemented in the rational management of rural areas in Ukraine. In accordance with the provisions of law, regional authorities undertake organisational, administrative, technical and economic activities related to soil and the environment.

They are performed in order to rationally shape the agricultural production space, which is aimed at the effective management of food production and conducting it in accordance with the directives of the European Union [5]. The tasks of the Marshal of the Voivodeship also include the analysis of changes in the agrarian structure of rural areas as well as the programming and coordination of agricultural and land management works (land consolidation and exchange). From legal provisions, it can be clearly seen that in the Polish legal order, the role of the voivodeship self-government under the leadership of the Marshal of the Voivodeship is crucial in the aspect of rural development. Poland is divided into 16 voivodeships (regions). In Poland, many scientific studies have been carried out regarding the analysis of the agrarian structure of rural areas, e.g., [6–9].

In the countries of the European Union, and thus also in Poland, there is an International Association of Classification Societies (IACS) system in which a certain amount of information about land is stored. However, this IACS does not have all the data allowing for the full and correct protection of agricultural and forest land, and thus the rational management of rural space. For example, it lacks information on soil quality (soil classification), which is a fundamental problem of this system. The information on land use flowing from the IACS does not provide the authorities who have the power to decide to change the use or intended purpose of land with knowledge about the natural quality of these soils.

The protection of the most valuable land in a region or country is a global problem in the world. The existing solutions on the scale of the Małopolska region and centrally on the national Polish scale do not solve the problem of the sustainable management of rural space in order to maximise the protection of the most valuable land used for agricultural purposes, which was shown by the authors in [10]. The main purpose of this article was therefore to present a coherently designed system containing full information about agricultural areas, enriched, among others, with data on land classification, which is a key element of the Agricultural Land Survey Module.

The weakness of Polish agriculture, especially in the southern part of the country, is the fragmentation of the area structure of holdings and mountain areas [11–14]. This was associated with historical, natural, economic and social factors and to a large extent, tradition. Due to the huge fragmentation of agricultural holdings, which is characteristic for the areas of the Małopolska (Lesser Poland) Voivodeship when compared to other regions of Poland [15,16], land consolidation is one of the priorities of the Małopolska Voivodeship Development Strategy for 2021–2030.

The problem of the fragmentation of agricultural land is a common problem in various European countries, including the Czech Republic [17], Slovakia [18], Hungary [19], Bulgaria [20], Spain [21], Albania [22] and Turkey [23]. The surveying management of rural areas covers all kinds of activities as well as technical and organisational measures which, taking into account local natural, economic, legal and social conditions, affect the organisation of agricultural production space, i.e., the part of the agricultural areas directly related to agricultural production. Agricultural production space is currently understood as a fragment of the natural landscape, including biological and technical components whose primary function is farming [24–26].

A large problem—both in Poland and Ukraine—is the lack of regional programmes for comprehensive rural area management, and even the lack of an inventory of needs in this area [27–30]. Another example of problems occurring in Poland and Ukraine is the lack of up-to-date and consistent databases containing information about real estate, as presented in [31–33]. Therefore, it is necessary to recognise the spatial structure of the countryside, as it is impossible to conduct a rational policy with regard to rural areas without having a complete picture of the phenomena occurring there. Therefore, in order to conduct a common rural development policy, the regional self-governments of Poland and Ukraine face the need to expand the existing spatial information infrastructure systems.

It should be emphasised that, despite the problems presented above occurring in both countries, at present in Poland there is a much more extensive information system about the area than in Ukraine. In Poland, there is a national geoportal as well as regional and local geoportals, along with a wide range of databases in the field of spatial management. Currently, these IT systems in Poland are expanded

with specialised modules dedicated to solving specific issues. This article is a proposal for such an expansion of the spatial information infrastructure system in the Małopolska region, which lies adjacent to Ukraine. For this purpose, the authors have developed and presented in this article a specialised geoinformation module—referred to as the Agricultural Land Survey Module (ALSM). The ALSM module will soon be implemented in Małopolska, and its task will be to support the management of agricultural land in the region.

It should also be noted that in Ukraine the use of geoinformation systems in managing rural space is much less advanced than in Poland. In many aspects of the implementation of geospatial technology introduced in Ukraine, it is based on the Polish experience. The exchange of experiences between Poland and Ukraine takes place within the framework of joint conferences [34], or joint research projects. Ukraine is in many respects similar to Poland (e.g., geopolitical location, political changes, quality and character of agricultural soils, land ownership structure in historical times). There is a special similarity between the regions of Małopolska and western Ukraine, as represented by the authors of this article. Therefore, if the implementation of the Agricultural Land Survey Module (ALSM) proposed in this article is successful in Małopolska, this system has a good chance of being implemented also in Ukraine and should bring tangible benefits in the management of rural Ukrainian space. The article presents the most important substantive elements of this concept, its functionality and the system requirements that it must meet.

2. Materials and Methods

The research conducted by the authors should be placed in the process of spatial information modelling. The resulting schemas constitute the implementation of the general stage known as the Computation Independent Model (CIM) in the Model Driven Architecture (MDA) creation process—defining a set of methods organising the process of creating computer systems based on the construction of models and their transformation (Figure 2).

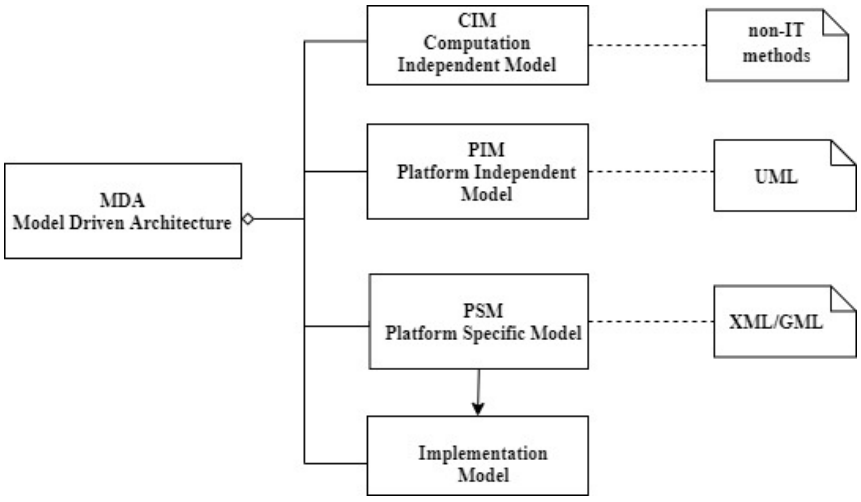

Figure 2. Data modelling. Source: own study.

The Agricultural Land Survey Module will enable the central database of the voivodeship, called the Repository, to be supplied with data. The Repository is kept by the Marshal of the Małopolska Voivodeship. The data supplying the Repository can be divided into source data, operational data, metadata and result data. The Agricultural Land Survey Module Records Repository will be a logically separated space from the Małopolska Spatial Data Infrastructure (MSDI), ensuring the storage of the source data and result data (reports or analyses). This data will be made available to external users.

The source data include:

- Data from the register of land and buildings (descriptive and graphic part) in SWDE, GML formats from the County Geodetic and Cartographic Documentation Centres;
- Data from the State Register of Borders in GML format;
- Thematic maps (including soil–agricultural map, soil erosion map) in SHP format;
- Development areas from the Agency for Restructuring and Modernisation of Agriculture system available in GML format;
- Map scans, also with spatial reference in TIFF, GeoTIFF formats;
- Aerial photographs, orthophotomaps, Digital Terrain Model products;
- Spatial data in SHP, MDB, DXF formats;
- Statistical data in CSV, XLS formats derived from the Central Statistical Office;
- Other statements and reports in XLS, CSV, DOC, DOCX, PDF formats.

The source data captured in the Repository over the years will constitute the operational data. The operational data have a specific structure that allows to perform analyses (including thematic maps), create reports, summaries and monitor changes in the region. The data in the Repository will be organised so as to provide access to current and historical information. They are necessary to implement the statutory tasks of the voivodeship self-government [35,36]. Conceptual solutions using operational data will be presented later in this research paper.

3. Results

This chapter presents the concept of expanding the spatial information system, based on the implementation of the Agricultural Land Survey Module. Figures 3–5 illustrate the individual stages of creating spatial analyses based on the operational data. The first stage of the analyses within the Agricultural Land Survey Module Records Repository will be the analysis of changes in the agrarian structure in the Małopolska Voivodeship (i.e., the analysis of changes in the size of agricultural holdings as well as the number and size of their plots)—Figure 3.

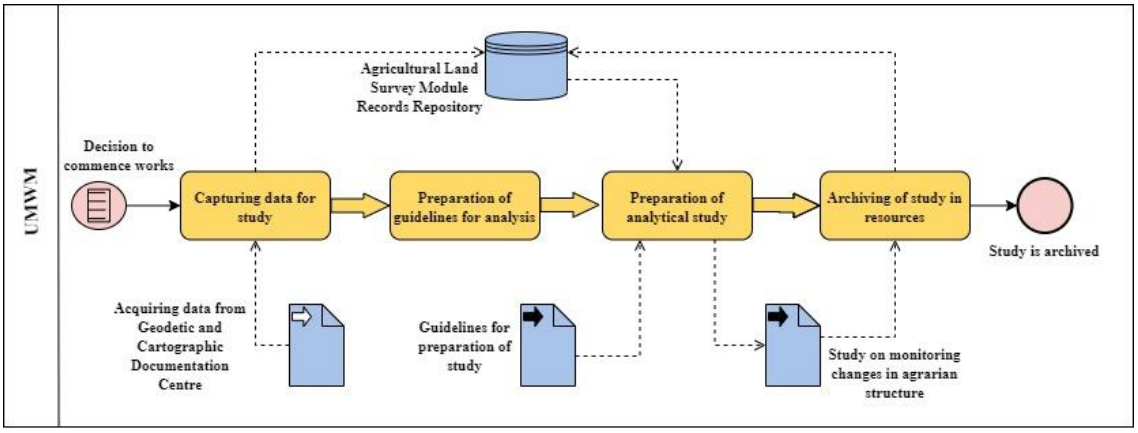

Figure 3. Developing the analysis of changes in the agrarian structure in the Marshal's Office of the Malopolska Voivodeship (UMWM). Source: own study.

The diagram (Figure 3) presents a procedure scheme, from obtaining data from the Geodetic and Cartographic Documentation Centres to archiving the results of the performed analyses, with the possibility of making them available to each system user. The next stage of the analyses will be studies on changes in land use and changes in land quality classes (valuation) in the Małopolska Voivodeship (Figure 4).

The diagram presented in Figure 4 illustrates the administrative procedure from the time the Marshal of the Voivodeship made the decision to proceed to the analysis, through legal and technical activities, until obtaining the results of the analyses and making them available in the proposed system.

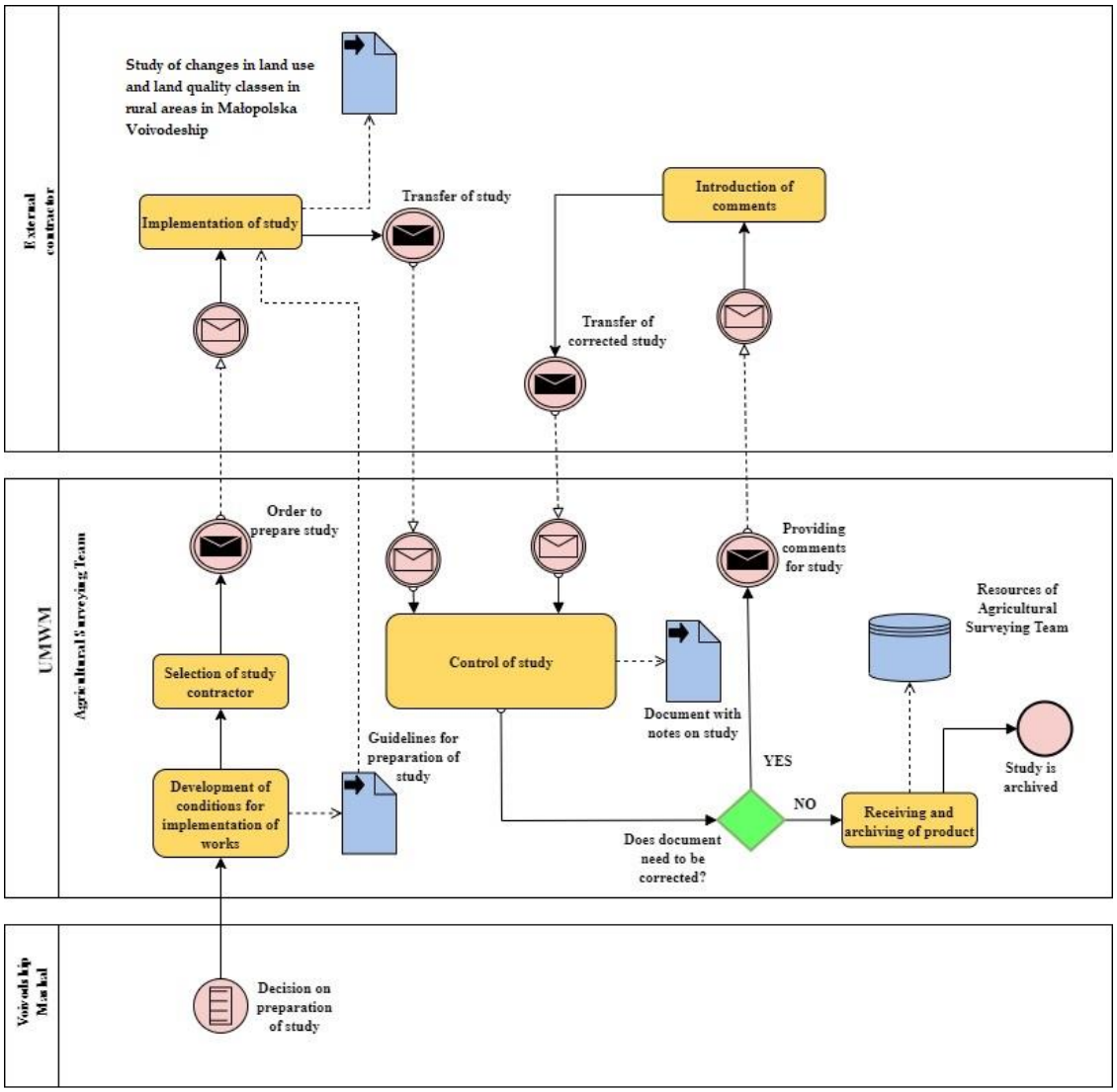

Figure 4. Study on changes in land use and land quality classes. Source: own study.

Due to the very large needs in the region in this respect and very meagre financial resources for land consolidation from the EU and the central government of the country, it is very difficult to decide which areas should be repaired in the first place by consolidation. For example, for the years 2014–2020, approximately EUR 35 million was granted for the Małopolska region under the Rural Development Program, i.e., the maximum level of funding for 1 ha of land is EUR 2800. This allows for land consolidation only for 12,500 ha, i.e., about 1% of the agricultural land area in the entire Małopolska region. Therefore, it is particularly important that the voivodeship self-government decides to identify the areas most in need of consolidation in a thoughtful and prudent manner. Taking such an important decision seems impossible without reliable geospatial data, taking into account the most important features of the land included in the spatial information system. For this reason, a system dedicated to agricultural geodesy is necessary for the rational management of rural space.

The third stage of the analyses includes tasks related to the coordination of agricultural and management works (land consolidation and exchange), taking into account the order of the execution of these works in terms of specific priorities (Figure 5). The necessity to perform such work has been demonstrated in the studies [37–39].

As demonstrated in Figure 5, proceeding to the land consolidation and exchange process is initiated by a joint decision of the voivodeship governor and the Marshal of the Voivodeship. The chart

presents a diagram of the decision-making process from the consolidation decision, through the preparation of the assumptions for the land consolidation project, to the inventory of consolidation works carried out in the voivodeship. This document is defined in [40] and forms the basis for the commencement of land consolidation design works.

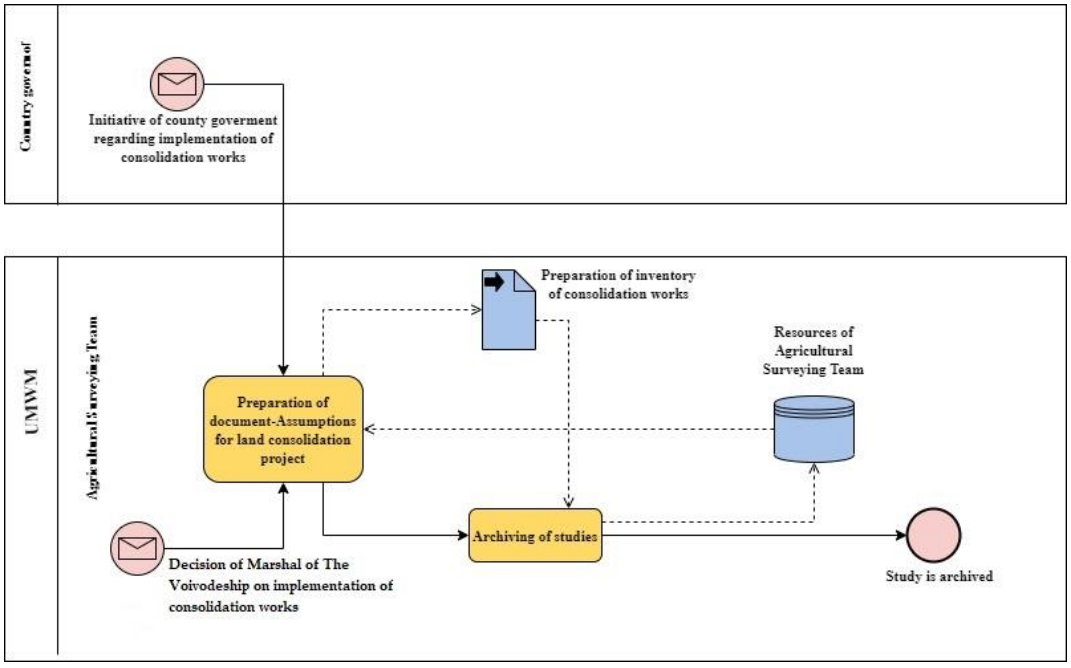

Figure 5. Developing the coordination of management and agricultural works with regard to the priority of these works. Source: own study.

In addition to the aforementioned possibilities of performing analyses based on operational data, the Agricultural Land Survey Module Records Repository should also enable the capture of metadata, i.e., descriptive information for individual studies, including: the date of the study, type and format of the source data for the study, spatial resolution of the source data, description of the preparation methodology for the study and authors of the study. The Agricultural Land Survey Records Repository constructed in this way will ensure the orderly and organised storage of data in specific, developed structures. This will ensure quick access to information of known quality and reliability.

To sum up, the main goal of the project is to expand the existing regional geoinformation system towards increasing the availability and quality of public e-services. The newly created system is to provide open access to public sector spatial information, improve the quality of public records collected in the state geodetic and cartographic documentation centre (mainly topographic objects—BDOT10k), as well as ensure the interoperability of spatial data as part of the national and regional spatial data infrastructures.

The assumed goal will be achieved by creating the Agricultural Land Survey Module (ALSM) presented in this research paper.

The most important functionalities of the Agricultural Land Survey Module include:

- Capturing source data;
- Archiving captured source data together with a description using metadata;
- Managing and browsing the Agricultural Land Survey Module Records Repository;
- Supplying the Agricultural Land Survey Module Records Repository with new data;
- Analysing spatial and descriptive data and creating summaries based on information collected in the Repository, together with the preparation of reports;

- Graphic visualisation of selected information in the form of charts and diagrams;
- Cartographic visualisation of data against the map of the territorial division of the country with an accuracy of a cadastral parcel, using presentation techniques, such as:
    - Cartograms;
    - Carto-diagrams;
    - Thematic maps generated based on unique attribute values;
    - Grouping the locations of spatial objects into point clusters.

The Agricultural Land Survey Module will use various components that are part of the logical architecture of the spatial information system, including:

- Extraction, transformation and loading (ETL) processing environment (ETL-class tools);
- Agricultural Land Survey Module Records Repository;
- Data update services from external records;
- Analytical tools of the Agricultural Land Survey Module Records Repository;
- Map Resources Area with the Analytical Desktop;
- Spatial information system data authentication service.

These components are illustrated in the diagram below (Figure 6).

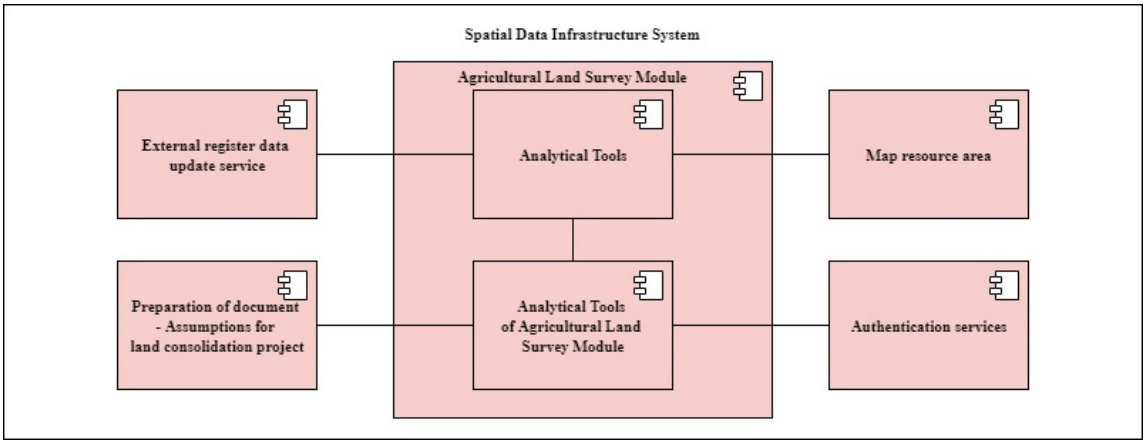

Figure 6. Logical architecture of the Agricultural Land Survey Module. Source: own study.

The logical architecture components of the Agricultural Land Survey Module demonstrated in Figure 6 will be further characterised as follows:

- The ETL processing environment (extraction, transformation and loading) forms the basis for the processes of data import from various sources to the Agricultural Land Survey Module Records Repository; this environment is implemented using the ETL Service. The functionalities of the ETL environment can also be used in data analysis to extract a specific type of data, calculating user-defined indicators in the Agricultural Land Survey Module based on the data available. The ETL processing environment can also support users in exporting data from the Agricultural Land Survey Module Records Repository.
- The Agricultural Land Survey Module Records Repository is a repository of source data, operational data and the results of analyses. The data in the Repository will be described with metadata that allow for quickly assessing the suitability of data for specific analyses.
- The e-services will supply the Repository with spatial and descriptive data from the Geodetic and Cartographic Documentation Centres; this is to maintain continuity in capturing source data and their timeliness. All registers will be updated using the functionality of the spatial information system.

- Analytical tools of the Agricultural Land Survey Module are an analytical component that provides tools for analysing tabular and spatial data and generating results of analyses in the form of summaries, reports, charts, thematic maps (including, for example, carto-diagrams and cartograms). The analytical component provides tools to prepare algorithms for calculating indicators for changes in spatial and statistical data based on data in tabular summaries.
- The Map Resources Area (in particular the Map Application Development Module) is an environment for dedicated map applications, enabling the visualisation and basic analysis of data collected in the Agricultural Land Survey Module Records Repository, followed by data publication.
- The spatial information system authentication service will enable the management of data access in the Agricultural Land Survey Module Records Repository.

4. Discussion

Space management is a process of continuous decision making and creating conditions for the implementation of decisions. This is a conscious action, involving a non-random and non-accidental selection of an alternative that can be implemented. The basic barrier when making decisions in space management at the regional and local levels is the lack of proper and reliable data, as well as the problem of their capturing and integration, e.g., due to different data formats, various scales of maps, or problems with access to the data, managed and created at different administrative levels.

The agrarian structure of Polish farms is very bad, especially in southern Poland. Small farms with very numerous scattered plots lead to extensive rather than intensive farming. Small family farms meet only the needs of the owners of these farms. Land consolidations are intended to improve this disadvantage. The consolidation of land and the enlargement of the areas used for agricultural purposes are the most sensible way to improve farming conditions in Poland. The most difficult situation is in the Lesser Poland region, i.e., the southern part of Poland, for which the authors developed the concept of the Agricultural Geodesy Module system. Only systemic solutions can protect the land from negative human activity and poorly managed agricultural space. In Poland, this problem has become visible to the authorities of the country. Therefore, measures have been taken to create a system aimed at the proper management of land resources. Ukraine, which is struggling with the same problem, wants to take advantage of the solutions proposed in Poland. It can be said that solutions to this problem have arisen in the world in well developed countries. However, many countries still do not know how to tackle the problems of managing rural space or do not have well organised geospatial data to operate effectively.

The purpose of the conceptual work leading to the development of diagrams of the Agricultural Land Survey Module is to automate and streamline the procedure for monitoring changes in land use and identifying problem areas that require consolidation work. These issues have also been discussed in the literature analysing the situation in Europe [41,42]. Comprehensive consolidation and exchange works—inseparably connected with the post-consolidation land development—serve the multifunctional development of rural areas. In addition to creating more favourable farming conditions, they offer residents the chance to improve the quality of their life in the countryside, enable local development adapted to the current needs and expectations of residents and users of this space, while also taking into account the requirement to protect natural and cultural resources. The situation in Małopolska is similar in this respect to other regions of Europe [43–45]. The countryside of Małopolska needs multifunctional sustainable development; this means that the economic, social and environmental functions of the voivodeship should develop harmoniously [46].

The authors of this research paper propose the technology of spatial information systems in planning surveying and management (consolidation) works, which is based on the creation and proper preparation of current geoinformation data. This allows the integration of data related to various spatial units and having a different source.

The creation of a unified geo-informational database on the conditions of agricultural lands, their legal status, number, qualitative characteristics of the soil cover, topography, number of land plots, joined into one field, and the distribution between owners and users is still one of the main tasks of the system of land resource management in Ukraine, which is concentrated in the field of land cadastre. Nowadays, in Ukraine, the system of the state land cadastre partially solves the problem due to the instrument of land registration and the geo-informational program of the Public map, introduced in 2013. The urgent problem is to collect and analyse the information on the conditions of soil cover of agricultural lands and to provide access to the information about landowners of the land plots (lease, sublease, lease with purchase, etc.). Such a system supplies cooperation with the immediate land-users.

It is worth noting that the creation of a database on the quality conditions of cultivated fields does not need to start from the very beginning. There are state and private structures in Ukraine which possess the licence on the performance of the mentioned works and collect information, customised by agricultural enterprises and used by them for the calculation of the norms of fertiliser application to obtain the expected yield.

This work supplies a short description of the database which is formed by agricultural enterprises in Ukraine. In spite of the fact that in the period of active land privatisation in Ukraine, the average size of an agricultural land plot, i.e., so-called land share, is equal to almost 2.5 hectares of arable land, the fields that are cultivated by the agricultural enterprises have tens of hectares, whereas in the eastern regions of Ukraine the fields can have an area of hundreds of hectares. Each enterprise generates a database which includes graphical and table components. The graphical component (Figure 7) is represented as a site plan with the reference to the system of coordinates in the form of a map-scheme of the location of the agricultural fields, with the depiction of contours, number and area of the field. Moreover, there is the graphical manifestation of the share of organic and mineral substances in soils in the form of interactive maps, for example cartograms of the share of humus on the fields of the enterprise. However, all these existing databases are inconsistent with each other, therefore it is necessary to build a uniform IT system for the management of rural space in Ukraine.

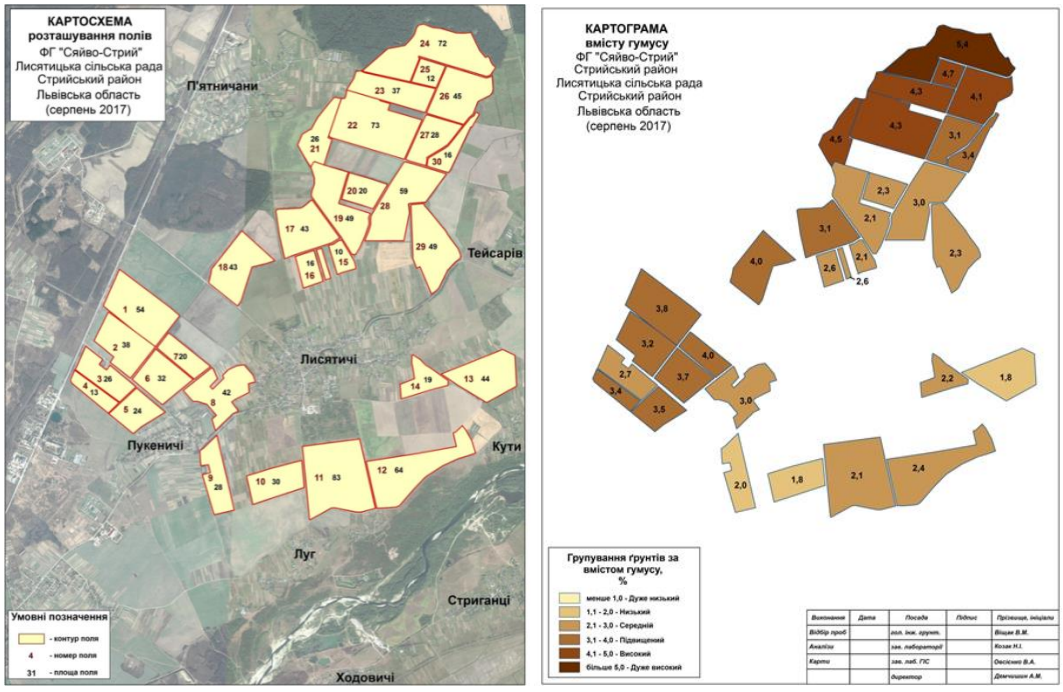

Figure 7. Graphical component of the database on the fields of the "Siaivo-Stryi" farming enterprise. Source: own study.

This type of cooperation using the Polish experience in Ukraine has already been carried out by scientists and the administrations of both countries in the field of land registry [47] and building records in the real estate cadastre [48].

5. Conclusions

The Agricultural Land Survey Module proposed by the authors is an innovative solution for the Małopolska region in the decision-making process regarding the management of rural areas. This module will be an integral part of the spatial information system of the region and will allow for the storage, creation, presentation and analysis of spatially referenced data, as well as the creation of spatial databases. The substantive and thematic scope of the geodetic and cartographic data contained in the Agricultural Land Survey Module Records Repository is necessary to identify surveying and management works in the region. Capturing reliable and current data, the correct diagnosis of the existing state, performing appropriate spatial analyses, using suitable technological solutions and statistical methods forms the basis of correctly made decisions at the regional level in Poland and Ukraine.

Spatial information systems are widely used in many fields, one of which is agronomy. Reliable data on land use, as well as on allocating this land for purposes other than agriculture and forestry, has a significant impact on the protection of agricultural land. Climate change, environmental pollution, destructive human activity and the irreversible effects of the poor monitoring of the changes taking place in the natural environment are a global problem in this world [49,50]. The protection of the soil and natural resources of the Earth becomes a priority within the scope of the appropriate decision-making process in each country. For this purpose, spatial information systems should be created, allowing for the ongoing monitoring of changes taking place in the environment.

This research demonstrates that all information is important for the evaluation of the field conditions. However, nowadays, it is not available for a wide circle of people, particularly leasers, state power authorities, which are authorised to control the conditions of land use, public organisations, administrative and others. Another important drawback of these databases is that they are composed using different programs and formats. This creates obstacles for their fast consolidation into a single integral information field. Hence, it is necessary to develop a unified approach to the collection and processing of the information on the quality conditions of the agricultural land fund.

The whole complex of these data can have an effective influence on the land-user by using the levers of the state control system for the use and protection of lands, securing the fulfilment of the main task of the system of land resource management, i.e., the rational use and protection of lands. The actuality of the tasks is confirmed by the goals and tasks of a set of laws of Ukraine. Among them, the principal ones, focused on the fulfilment of those tasks, include the LU "On Environmental Protection" [51], "On Land Organisation" [52] and "On the State Land Cadaster" [53], as well as the newly adopted law "On the National Infrastructure of Geospatial Data" [54].

The necessity to possess relevant information fuels numerous attempts of creating a base of the geospatial data, which would maximise coverage and consolidate information on the conditions of the land and natural resources of the community.

In conclusion, the implementation of the approach to collecting and processing geospatial information proposed in Poland is also an actual and urgent task in Ukraine. The application in Ukraine has a validation character of the developed system, that is, the tool can be applied to other zones different from where it has been implemented, because the information it integrates can be easily generated.

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