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Modeling and integration of geospatial analytical functions for decision making

Besim Ajvazi

Supervisors:

Prof.Dr. Béla Márkus and Prof.Dr. Kornél Czimber

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MODELING AND INTEGRATION OF GEOSPATIAL ANALYTICAL FUNCTIONS FOR DECISION MAKING

Written by in order to obtain Doctoral (PhD) degree:

BESIM AJVAZI

Prepared in the frame of the GEOINFORMATICS Doctoral Programme
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of the UNIVERSITY OF SOPRON.

Supervisors: Dr. Kornél Czimber, Prof. Dr. Béla Márkus

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Abstract

The spatial decision-making process is considered a quite complex problem, as it must select the best alternative to many possible scenarios to meet a relevant objective. This is a multi-dimensional issue since some features need to be assessed to generate a result that can further support the decision. The same principle is the case of administration and monitoring of agricultural land, where as a spatial phenomenon it is important that the decision-making process dependent on institutional interoperability is supported through the application of geospatial functions.

The responsibilities and rights of central and local institutions to administer and monitor agricultural land are mainly defined in the legislation framework of the respective country. In this research, based on the current legislation of Kosovo, the responsibilities and rights in question are converted into requirements and the need for a sustainable administration and monitoring of agricultural land, including three spatial phenomena, such as: redesignation, erosion and pollution. The solution to the requirements and needs is provided through the application of geospatial functions to collect, store, analyze, distribute and map geospatial data related to these three phenomena.

This research has managed to define the basic and operational spatial data in relation to the above three spatial phenomena. A conceptual data model has been developed, methods of data collection have been defined, data sources, including the creation of maps such as the classification of agricultural land, as well as the map of the current and potential risk of soil erosion, models of presentation, metadata and the quality of spatial data has also been assessed, taking as an example data on land use and coverage. In relation to these data, ie the processes that include them, the basic concepts of geospatial functions are modeled, such as analytical, cartographic, reporting and interoperability. Geospatial data and functions are conceptually modeled as part of a geospatial system for the management and monitoring of agricultural land use in Kosovo. Furthermore, concepts on possible software solutions have been analyzed, including desktop platforms, both open and commercial, as well as Web-GIS based platforms. The importance of classifying the most privileged users is also highlighted.

The new findings of this research clarify how to support the decision-making process through geospatial functions, and as a result provide solutions on how such a way can sustainably manage and monitor the spatial phenomena of redesignation, erosion and pollution. The application of the solution proposed in this paper will greatly affect the increase of efficiency in the process of monitoring and administration of agricultural land, consequently will greatly affect the preservation of agricultural land in Kosovo.

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Acronyms

AI – Administrative Instruction

API – Application Programming Interface

CORINE - Coordination of information on the environment

DCMI – Dublin Core Metadata Initiative

DEM – Digital Elevation Model

DoA – Directorate of Agriculture

DoSP – Directorate of Spatial Planning

DSS – Decision Support System

EGIS – European Conference on Geographic Information System

EU – European Union

FAO – Food and Agriculture Organization

FGDC – Federal Geographic Data Committee

GI – Geographic Information

GIS - Geographic Information System

GNSS – Global Navigation Satellite System

GPS – Global Positioning System

GUI - Graphic User Interface

ICT – Information and Communication Technology

IJGIS – International Journal on Geographic Information System

INSPIRE - Infrastructure for Spatial Information in Europe

ISO - International Organization for Standardization

MoA - Ministry of Agriculture

NSDI - National Spatial Data Infrastructure

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OGC – Open Geospatial Consortium

SDI - Spatial Data Infrastructure

SDSS - Spatial decision support systems

SQL - Structured Query Language

TIN – Triangular Irregulated Network

WCS - Web Coverage Service

WFS – Web Feature Service

WMS – Web Map Service

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Chapter 1

1 Introduction

Agricultural land is among the most important natural resources, which directly affect food production. It is essential to take the right actions in order to preserve and use land rationally. At the national level, it is necessary to draft good policies, prepare strategies and create the needed legislation framework. The next step is the implementation phase, which requires some actions to be taken. Among others, the use of the right technology directly supports the drafted documents to be implemented practically and in a proper manner.

The drafting and implementation of documentation by state organizations must follow the international standards and research groups. A global collaboration of scientists and experts helps improve agricultural land use monitoring by different organizations at the state level. Group on Earth Observation (GEO) is a partnership of more than 100 national governments that coordinates governments' efforts where the decisions and actions are based on Earth observations (https://www.earthobservations.org).

Copernicus is the European Union's Earth observation program coordinated and managed by the European Commission, the European Space Agency (ESA), the EU Member States, and EU Agencies (https://www.copernicus.eu). This program provides data and information to all the interested communities, including government institutions. The information provided is related to agriculture land, climate change and environment, forestry, energy, and natural resources, urban planning, etc.

Earth observation by Global Navigation Satellite Systems (GNSS), remote sensing, aero photogrammetry can significantly assist in implementing actions related to the administration and monitoring of agricultural land use. The Global Positioning System (GPS), as part of GNSS, is one of the techniques for obtaining geospatial data related to land and spatial features on it. Remote sensing enables the acquisition of spatial data without direct contact. The acquisition of spatial data from the air is also enabled through aero photogrammetric surveying.

The obtained data can be further processed and modeled in a certain format. The main goal of obtaining and modeling data is to better understand objects or spatial phenomena and provide a solution to a specific spatial problem, such as administration and monitoring of agricultural land in relation to its use,

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risk of erosion, and pollution. The solution to this spatial problem must be supported further by geospatial analytic functions. As a result, we will obtain information on the state of the object or spatial phenomena. This information can be presented in various forms such as maps, reports, statistical data, etc. Consequently, they will support the decision-making process of public institutions. As such, they will be more efficient and transparent as well. Moreover, the statistical results with maps will be essential to monitor the agricultural land areas and their condition. When authorities compare this information with the product data, they are able to predict national food demands and get a better idea on how to use the land in the future. It is important to use the land in a balanced manner; one approach is meeting the requirements of needed areas for settlements and food production.

1.1 Problem specification

In this research, the main problem which is addressed is that of the administration and monitoring of agricultural land use in Kosovo. The current methods of administration and monitoring of agricultural land use are analyzed in detail from the perspective of responsibilities and authorities of state institutions, both at the central and local levels. Based on the results of the analysis, as well as the needs assessment, sustainable methods based on geospatial solutions have been proposed, which significantly help to monitor and administer agricultural land in Kosovo.

Sustainable management and monitoring of agricultural land help protect existing areas, which can be reduced over time due to the impact of various factors. Among the basic factors that affect the reduction of agricultural land are:

- redesignation of agricultural land into construction land or other purposes,
- soil erosion, and
- soil pollution.

According to an analysis conducted in this research, using data from Copernicus (Corine Land Cover) for 2000 and 2018, it turns out that the area of agricultural land in Kosovo for this period of time has been reduced by about 6.33%. The institutions responsible for monitoring and administering agricultural land use in Kosovo do not apply sustainable and innovative methods for the administration and monitoring of agricultural land, which can provide consistent data regarding agricultural land areas over the years. From the analysis presented in Chapter 4, it appears that agriculture land use administration and monitoring in Kosovo's case is relatively immature. For example, it is found that there is no systematized way through which central and local institutions, use geospatial tools to support the decision-making process during the review of requests for redesignation of agricultural land.

Regarding the monitoring of soil pollution, also the central and local institutions are responsible for conducting continuous monitoring. But, initially it is required to take samples and use interpolation techniques for building maps that will represent the level of pollution in certain areas. As a result, in case the level of pollution is high, the institutions may prohibit or limit the production of the respective agricultural crops in these areas.

Erosion as a partially natural phenomenon may endanger agricultural land as well. Continuous monitoring is necessary, which may start by mapping the actual erosion risk map and the potential erosion risk map. Depending on the map results, the state institutions can take agro-technical measures in order to protect the agricultural land areas from degradation.

The proposed methods for the administration and monitoring of agricultural land use in Kosovo will help the development of agriculture. These methods include the process of identifying the necessary spatial features, their collection methods and integration in the geodatabase, the application of geospatial functions for spatial data management, i.e., the application of systems for the management of geospatial information. Agricultural development is important from two main perspectives: economic and social. Agricultural activity is widespread in Kosovo as a safety net for the majority of the population. In an underdeveloped economy with over 40% unemployment, agriculture remains the primary or secondary source of revenue for many families. The 2011 census shows that about 4.4% of employment is in agriculture, only counting for those formally employed. Adding here the subsistence farming, employment in agriculture is estimated to reach 35% of the labor force (https://www.efse.lu). Beyond economic affordability, reliance on agriculture is also a social issue, where over 60% of the population in Kosovo lives mainly in rural areas. Increasing the development of agriculture, besides improving the population's life in economic terms, will also affect the development of rural areas in general.

1.2 Aim and objectives of the study

The primary goal of this research is the modeling and integration of geospatial analytical functions to support the decision-making process regarding agricultural land use protection from three key factors: redesignation of agricultural land into construction land or other purposes, soil erosion, and soil pollution.

The main objectives are as follows:

- Analysis and assessment of the need for a new approach in the administration and monitoring of agricultural land use in Kosovo.
- Developing a conceptual model for geospatial information systems regarding the needs and requirements on administration and monitoring of agricultural land use in Kosovo.
- Conceptual modeling and application of geospatial analytical functions such as retrieval, reclassification and measurement, topological, neighborhood; and connectivity, to support central and local institutions in decision-making process.
- Conceptual modeling of geospatial data including base maps (satellite images, orthophotos, DEM, state or municipal administrative boundaries and cadastral zones) and operational data (cadastral parcels, land classification, land irrigation network, agricultural land consolidation areas, land use, agricultural land pollution areas, actual erosion risk map, and potential erosion risk map).
- Critical analysis in selecting the most suitable software that makes up the comprehensive spatial system.

1.3 Content organization

The content of this study is organized as follows. The first chapter includes the introduction, aims, and objectives of this research.

The second chapter includes the literature review. This review includes the support for decision-making through geospatial approaches such as the Geographic Information System (GIS). It also includes geospatial functions and their application in the spatial decision-making process. Functions were introduced through classification by Aronoff in 1989. In fact, several other authors have relied on this classification as well, and from a review of the other literature have not identified a proper classification of geospatial analytical functions.

The third chapter includes an analysis of the need to support the spatial decision-making process for public authorities. Several techniques that enable this support have been analyzed, and the spatial decision-making system has been selected by further elaborating its components and possible areas of application. The domain of agricultural land use administration is further elaborated.

The fourth chapter continues to treat more specifically what is discussed in the last section of the third chapter. It includes analysis and needs assessment for a geospatial system related to the administration

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and monitoring of agricultural land in Kosovo. The needs assessment is also based on the legislative framework regarding the protection of agricultural land from its conversion to another destination, pollution, and erosion. The law on agricultural land is analyzed in terms of the legal authorities and competencies that public institutions have in the protection of agricultural land. Competencies have also been converted into user requests from the perspective of using geospatial tools to support the spatial decision-making process. The end of this chapter analyzes the current state of the application of geospatial tools in the respective public institutions.

The fifth chapter includes the conceptual modeling of the geospatial information system. The initial conceptual model of the system has been elaborated, which includes three specific modules: the conversion of agricultural land to another destination, the risk of erosion, and soil pollution. The purpose and primary objectives of this system are defined in this chapter. The spatial analytic functions according to the Aronoff classification are further studied in the second chapter and are presented, where the required functions are selected to solve specific spatial problems related to the three factors in question. Also, a conceptual model of the necessary geospatial data is conducted, including their sources, obtaining techniques, presentation models, and metadata. This chapter concludes with a critical analysis of the selection of open source or proprietary software as an integral part of the overall geospatial system.

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Chapter 2

2 Literature review

2.1 Spatial thinking

Since the world exists in space, we may say that a world without space is inconceivable. We clearly understand that living in this world requires us to think spatially. What does this really mean? Our daily processes are full of spatial content. Thinking spatially can help such processes to be directed properly. Ways of thinking in spatial terms can vary in how they can be expressed. Sometimes we express them through numbers, words, or even visualization (Aber 2017). By thinking spatially, many questions can arise which require a solution. This encourages us to become more creative in dealing with spatial solutions. Being creative helps us to design solutions by converting our thoughts into tools. Consequently, this helps us handle spatial processes at a higher level. How do we express spatial ideas through a) numbers, b) words, and c) visualization? For example, a) The area of agricultural land in Kosovo is 577,000 hectares (NCEI, 2013). The number describes the size of the area of agricultural land in Kosovo. b) The largest areas of agricultural land are located in the south-western part of Kosovo. The word southwest of Kosovo describes the spatial location of the extension of the largest areas of agricultural land in Kosovo. c) The picture shown in figure 2.1 marks out the shape and size of the vineyard areas presented on it.

Figure 2.1 Picture of vineyard areas

The National Research Council of the National Academies (2006) describes spatial thinking as “one form of thinking—is based on a constructive amalgam of three elements: concepts of space, tools of representation, and processes of reasoning”. By understanding the meaning of space, we can use its properties (e.g., dimensionality, continuity, proximity, and separation) for structuring problems properly.

Proper structuring helps us find solutions easier. Solutions sometimes require the analysis of static and dynamic properties of objects and their relationships. Using visual representation (images, graphs, maps) helps us understand the problems better and quickly provide solutions. A clear visualization means a better description and explanation of the objects, their structure, function, and their relationship. To understand these it is important to be educated in the sense of spatial thinking.

In recent days, spatial thinking has become more important than it was before. This can be demonstrated in different ways, but let's present three reasons: 1) the impact of the human being in the natural world, especially in environmental issues is much more complex; therefore, it is necessary to understand it in order to reduce the human's impact on such issues. 2) The high technological developments in recent decades have created powerful opportunities to analyze and understand the world and many processes linked with it. In this perspective, the development of information and communication technology, especially GIS, remote sensing, and photogrammetry, can provide society with powerful tools for handling spatial information. 3) The application of tools related to technological developments provides significant support to the decision-making process. It means that the decision-making process, especially when it involves spatial information, can be taken based on advanced multi-criteria analysis. The process is more efficient and is anticipated to more intelligent solutions. Consequently, such solutions help society improve the quality of life in the world.

2.1.1 Spatial thinking and GIS

Spatial thinking is an inevitable need of human society, and therefore it is related to its very existence. In fact, the main roots of spatial-based computer systems derive from the early days, when handling spatial data had begun, respectively the creation of various registers and maps. This, to a great degree, has to do with the origin of cartography. The first foundations of cartography can be identified with the Egyptians (1292 - 1225 B.C.) and the Greeks (276 - 194 B.C.) (Eldrandaly, 2007b). However, only in the 20th century (1960), when the computer became more widely used, the need for spatial information handling (mainly in infrastructure planning requirements) increased, as well as the use of computer systems based on geographic information was introduced. Until the 1970s, computer processing was enabled through the development of microprocessors when it began with the replacement of manual methods of mapping (Bernhardsen, 2002). In the '80s, powerful workstation computers became the common hardware systems. However, as cost savings and computing capacity increased, during the 1990s, GIS developments began rapidly to increase (Sugumaran and Degroote, 2011). The application of GIS has continued in the 2000s under various technologies such as Web-based GIS developments and mobile GIS. The market for GIS

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software continued to grow, computers continued to fall in price and increase in power, and the software industry has been growing ever since (Eldrandaly, 2007b).

Nowadays, GIS has been transformed into an indispensable and essential tool for solving and answering both scientific and decision-making issues. GIS applications in spatial information management save a great deal of time and cost compared to manual methods.

In the past, real-world modeling was carried out by acquiring data from traditional measurement methods and then presenting them on paper by drawing manually. Currently, mapping is carried out using information and communication technology, namely computer systems that enable the generation of digital maps. The primary difference between these two different time periods has not to do so much in presenting the real world but more in the methodology of analyzing and manipulating the spatial data of this reality. Nowadays, GIS is using data models to represent the information of reality. However, by comparing the past period with the present one, it is obvious that the current problems are much more complex. Potentially, there are more big data than in the past. Satellite measurement techniques produce spatial data for the entire globe. When using the internet, we also have a large number of sources containing spatial data. We have many sources, which are used by professional and non-professional GIS users as well, such as: Google Maps, Google Earth, Bing Maps, OpenStreetMap, Nasa Earth Observations, USGS Earth Explorer, Copernicus, etc. These and other sources use their databases to provide information to individuals and organizations about the navigation, location of several features, such as land use, country borders, cities, businesses, etc. Of course, the existence of more data does not necessarily mean we know the real world better. There is the ability of GIS to integrate all this data and use geographic knowledge to convert them into information. Consequently, it can synthesize into something actionable.

According to Wakabayashi & Ishikawa (2011) at least two aspects of the relationship between spatial thinking and GIS can be distinguished. First, GIS is regarded as a tool of ICT supporting education in spatial thinking. It means that GIS methodologies are very useful in teaching or learning spatial thinking (National Research Council, 2006). Second, spatial thinking has become a conceptual foundation for GIS because it is indispensable for systematizing the body of knowledge of GIScience and GIS use (Wakabayashi and Ishikawa, 2011).

One challenge for GIScience is to embrace spatial concepts and concepts of other reasoning concepts, such as temporal reasoning concepts and to develop traditional HCI (Human Computer Interaction) concepts further (Blaschke and Strobl, 2010).

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2.1.1.1 GISystems

GIS stands for Geographic Information System. Several definitions of GIS have been suggested. Most of them have a primary focus on data, users, software, hardware, and methods. GIS is a system for capturing, modeling, analyzing, and displaying referenced data geographically. Also, GIS can be defined as the information system that processes spatial data (Idrees, Ibrahim and El Seddawy, 2018). Currently, the GIS application in various fields has a great impact – hundreds of thousands of GIS professionals exist around the world. His origin is very much related with the name of Roger Tomlinson, who in 1962 introduced the idea of how computers should be used in map analysis. This idea was introduced within the Canadian Land Inventory (CLI) project. Also, the first GIS term was used by Tomlinson in his 1967 paper "An Introduction to the Geo-Information System of the Canada Land Inventory." In this paper, Tomlinson (1967) presented the requirements, opportunities, and the first GIS system data for CLI. Such GIS systems for land use data management, land suitability analysis, forest management etc., and the interconnections of this information with the census data are among the most important areas of application nowadays as well.

2.1.1.2 GIScience

Science can be defined as a systematic treatment of verifiable knowledge about the elements, structure, and process of reality. GIScience involves systematic treatment of conceptual information about topical (thematic) concerns that are described generally in terms of (geo) spatial, attribute, and temporal aspects of (some portion of) reality, and the interrelationships among those aspects (Nyerges and Jankowski, 2011).

Geographic Information Science is a multidisciplinary science, mainly based on the knowledge gained from geography, cartography, mathematics, and computer science. In the initial definitions, and further, "S" for GIS means the system. However, Goodchild (1992), for the first time, introduced "S" from the perspective of science. He has been highly motivated by some of the scientific papers discussed at conferences such as EGIS and the International Symposia on Spatial Data Handling. In his paper, Goodchild (1992) elaborated "S" for science from the perspective of the science role in GIS. Actually, it has been introduced from two perspectives. The first concerns the extent to which the GIS as an area contains a legitimate set of scientific questions and the level to which these can be expressed. The second applies to the role of GIS in science. So how GIS, as a tool, can help solve specific issues in science, with particular emphasis on issues for which geography plays an essential role in their understanding and elaboration. Also, many years after, Goodchild (2005) wrote another article where he analyses the development of GIScience for the fifteen-year period. According to this article, the concepts of GIScience as introduced by Goodchild in 90s were adopted enthusiastically. Journals (including IJGIS) have been renamed, books have been published, a major consortium of US universities has been established, and specialist programs have been developed in academic institutions. The systems versus science issue have been revisited and reports have been written calling for the establishment of major programs of research funding (Goodchild, 2005). Mark (2003), in his article, mentioned the components of geographic information science, which are as follows: 1) ontology and representation; 2) computation; and 3) applications, institutions, and society. According to the same article, the first component deals with the specifications of the conceptualizations by different groups of users related to the specific domains as well as data modeling and representation are included. The second component deals with qualitative spatial reasoning, computational geometry, efficient indexing, retrieval and searching in geographic databases and spatial statistics. The third component includes the acquisition of geographic data, quality of geographic information, spatial analysis, geographic information, institutions, and society. Obviously, GIScience concepts, as introduced by Goodchild in the 90s until recently, have evolved and, for many reasons, will continue this way in coming years.

2.1.1.3 GIServices

Technologies such as the internet and mobile GIS are in continuous development. Their application now includes many areas. This has also significantly affected the development and application of GIS. Now the Internet enables the distribution of spatial information for all levels of society. This has expanded the application areas since Web-based GIS applications provide simpler use systems. It is possible to use even those who have no access to GIS software, nor the ability to professionally train on the use of such software (Alesheikh, Helali and Behroz, 2002). People can use several GIS services, which may be accessed through Web; Geoportals are one of such examples, where the user can see their property, print a sketch of that property, and even get data as web services. Businesses can share their locations and their business activities. Organizations can use data for statistical analysis.

Technological developments enable the development of Web-based GIS applications that provide specific processing tools. Web GIS has impacted simplifying the technology of GIS application and reducing the cost of spatial data handling. Consequently, the spatial decision-making process has significantly improved.

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2.2 Spatial decision making

Spatial decision-making is one of the most common human activities, both from an individual and an organizational perspective. When choosing a path to follow, when selecting a store location to make purchases, the place to live, we make decisions that require geographic solutions. The management of organizations does not really make any difference in this aspect (Oufella and Hamdadou, 2018). Therefore, in order to make the right decisions, it is essential to consider the spatial relations of objects.

Principally, the spatial decision-making process is considered a quite complex problem, as it must select the best alternative to many possible scenarios to meet a relevant objective. This is a multi-dimensional issue since some features need to be assessed to generate a result that can further support the decision. It requires high knowledge of the relevant field, data collection, which can come from different sources, and often interpretation by a certain number of decision-makers who evaluate them against the interests of the numerous stakeholders involved (Calzada, 2014).

According to Malczewski (1997), the main characteristics of spatial decision problems include:

- a large number of decision alternatives,
- the outcomes or consequences of the decision alternatives are spatially variable,
- each alternative is evaluated based on multiple criteria,
- some of the criteria may be qualitative, while others may be quantitative,
- there is typically more than one decision-maker (or interest group) involved in the decision-making process,
- the decision-makers have different preferences with respect to the relative importance of evaluation criteria and decision consequences,
- the decisions are often surrounded by uncertainty.

Several spatial decision categories exist in the real world. Site selection is one of the most common cases where the spatial decision process involves multi-criteria analysis. For example, a local government wants to find a suitable location for a new park; this involves many factors, such as: accessible location for the children, a minimum size of the selected area, proximity to the residential areas, access to transportation, etc. (Tahmasebi *et al.*, 2014). Land-use allocation is another case of a spatial decision, which aims to select sites in order to properly and optimally use the specific land areas. Actually, this is the opposite of the site selection activities. This could be dependent on the zoning designation of the parcel, the potential surrounding customer base for a business, or physical parameters and limitations of the land for certain kinds of development (Sugumaran and Degroote, 2011).

2.3 Decision making support

As it was presented in the previous section, the decision-making process is quite complex. It may involve many alternatives, and each of them must be analyzed based on specific criteria. Also, this needs to involve data and information from different sources. As such, the decision-making process requires support. One of the approaches is the use of geospatial analytical tools. This could help increase the efficiency of the process and the quality of the final decision.

From a government organization's point of view, they carry rather complex data-related problems, consequently processes that actually require adequate decision-making. Such decision-making should be structured and based on preliminary analysis. For example, a city needs to build e new school. The local government is responsible for finding the right location. In this case, the decision-making process should consider the data analysis based on pre-defined multi-criteria, such as: the distance from industry and commercial areas; proximity to the main road; an area with good air quality; an area with low noise pollution; away from potential natural disasters (stream, flash flood, mud flood, erosion); terrain with not high slope degree (Bukhari, Rodzi and Noordin, 2010). Geospatial functions, i.e. decision support systems, are those that provide various analyses and presentations of information in visual (graphic, figure, and map) and descriptive forms (reports, tables, etc.). Nowadays, it is unimaginable to continue traditional decision-making methods without considering spatial and non-spatial data. With traditional methods, we are mainly considering manual working methods in handling spatial information. These methods are rather difficult to handle in complex situations.

According to Geoffrion (1983), the basic features of decision-support systems are as follows:

1) Decision-support systems are used to tackle ill-structured or semi-structured problems that may occur when the problem and objectives of the decision-maker cannot be coherently specified.
2) Decision-support systems are designed to be easy to use, making sophisticated computer technology accessible through a user-friendly graphic user interface (GUI).
3) Decision-support systems enable users to make full use of the data and models that are available, perhaps by interfacing external routines or database management systems.
4) Users of decision-support systems develop a solution procedure using models as decision aids to generate a series of decision alternatives.

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5) Decision-support systems are designed for flexibility of use and ease of adaptation to the evolving needs of the user.
6) Decision-support systems are developed interactively and recursively to provide a multiple-pass approach.

In principle, every decision-making in managing an organization aims to enable the organization to function efficiently and with no interruptions. Complex situations can vary depending on the interrelated areas. For example, let us consider the work of Matthews, et. al. (1999), which addresses the implementation of a spatial decision support system for agriculture land use planning. The subject matter is complex because it considers marginal lands of particular environmental importance. Decision-making in the management of such land is also complex because productivity must be achieved within environmental, financial, and social constraints. Considering these, the management of such spaces requires extensive information. Therefore, the use of geospatial tools is essential to support such decision-making for efficient land management, as well as for many other purposes.

2.3.1 GIS approach

The potential of GIS enables the generation of results that may be essential for the spatial decision-making process. Moreover, decision-making is a scientific discipline that is actually older than GIS. Computer technology based on GIS methodologies has helped to develop systems that support decision-making.

From the perspective of spatial analysis, decision-making must consider several fundamental issues, such as:

- the potential problem must be clearly formulated and specified;
- specific manuals that help support the decision;
- access to relevant data enabling spatial analysis;
- social issues and environmental constraints.

All of these issues confirm the need for interaction and communication between different institutions, such as ministries, agencies, municipalities, professionals, etc.

GIS enables real-world modeling by simplifying it from some perspectives, such as conceptual, qualitative, and quantitative. The main purpose is to study the various processes in the world, which may also be related to administrative and political issues. GIS functions enable model building, which, through

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further analysis, results in providing important information. As such, they help in improving the relationship between data from several sources. For example, a company wants to establish a new coffee house in a city (Ringo, 2009). The main aim of the company is to find the most profitable location. Using GIS approach, a data collection process is one of the first steps. Since several sources need to be used, the data potentially could be in different formats. For example, demographic and socioeconomic data from the census institution as tabular data; the locations of the existing stores from any website as spatial data format, i.e. shape file; the planned land use from the relevant institution website as raster data format. Roads are important as well and their data may come in shape file. After the data preparation process, they could all be integrated into a unified database for further specific analysis. Finally, the results of a new location will be presented on the map.

The two main GIS capabilities, such as spatial analysis and information management, can support the spatial decision-making process. The first one includes geospatial functions as well as data modeling, topological modeling, network analysis, geostatistics, geocoding, etc. The second one involves numerous GIS functions, such as capturing, storing, retrieval, manipulation, basic analysis, data displaying, etc. (Demetriou, 2013).

It is essential that for solving a certain problem, the decision-making process relies on effective communication through exchanging the information and ideas. Applying GIS methodologies can significantly improve the problem-solving process. It can result in significant information if the spatial data is handled properly. This could be achieved as an ongoing process ranging from data processing, information, decision making to problem solving (Heywood, Cornelius and Carver, 2006).

According to Markus (1997), GIS is an ideal tool to use to analyze and solve multiple criteria problems:

- GIS databases combine spatial and non-spatial information.
- a GIS generally has ideal data viewing capabilities - it allows for efficient and effective visual examinations of solutions.
- a GIS generally allows users to interactively modify solutions to perform sensitivity analysis.
- a GIS, by definition, should also contain a spatial query and analytical capabilities such as measurement of area, distance measurement, overlay capability, corridor analysis.
- GIS has the potential to become a very powerful tool to assist in multiple criteria spatial decision making and conflict resolution.
- some GIS have already integrated multiple criteria methods.

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GIS models can help us understand and simulate different decision-making processes. In cases where we have simple databases on which to design relevant questionnaires, a decision-maker may face insufficient information to make the final decision. However, in a complex decision-making system, it is important to have the necessary information which can be modeled within a certain environment. As such, they could be analyzed in an attempt to achieve possible alternatives to problem-solving. Consequently, decision making would be more efficient and with a lower probability of risk (Tamás, 2011).

The article "A Decision Support System for Business Location Based on Open GIS Technology and Data" (2014) offers a new perspective on the strategic decision of business location by taking advantage of the power of GIS technology, which has been rapidly developing in recent years. What is more important in this article is that the author has chosen a simple manner in terms of computer technology - using open-source software for solving a particular problem. The use of open-source technology in solving problems through GIS will be one of the tasks of this thesis. This is because open-source software is developed and offers sophisticated functions in analyzing and presenting spatial data. In another article, "A GIS-based decision support system for measuring the territorial impact of transport infrastructures" (2014), the authors presented a Decision Support System to assess the territorial effects of new linear transport infrastructures based on the use of GIS. The TITIM – Transport Infrastructure Territorial Impact Measurement – GIS tool allows these effects to be calculated by evaluating the improvement in accessibility, loss of landscape connectivity, and the impact on other local territorial variables such as landscape quality, biodiversity, and land-use quality. This research supplies a unique DSS to correct the lack of modeling tools that integrate both accessibility and territorial environmental impacts in transportation planning.

2.4 Geospatial analytic functions for decision making support

Registration of data in the geodatabase is not among the only issues for which Geographic Information Systems are aimed. One of the key capabilities of GIS is spatial analysis - which aims to identify spatial relationships once the spatial data are obtained through various geospatial techniques. In fact, this is one of the most important advantages of GIS compared to other information management systems. The basic geospatial functions are used in a logical sequence to solve complex spatial problems using integrated analysis of multiple geographically distributed factors by a logical sequence with GIS modelling functions (Brozova, Klimešová 2010). The taxonomy of GIS analytic functions is the subject of multiple authors (Aronoff 1989; Burrough 1992; Goodchild 1992). Albrecht (1995) provides a comprehensive list of 144 functions. The list consists of all functions the author found in other literature - some of them

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mentioned above. Also, in his research, Albrecht (1995b) has created a list of universal GIS operations with essentially 20 operations, classified into seven categories: interpolation, search, location analysis, terrain analysis, distribution and neighboring, spatial analysis, measurements. This list is mostly similar to the Aronoff (1989) classification. Also, some other authors (Buckley, 1998) are based on the Aronoff taxonomy of GIS analytical functions. He identifies four categories of GIS analysis functions:

- Retrieval, reclassification, and measurement;
- Topological overlay;
- Neighborhood operations; and
- Connectivity functions.

2.4.1 Retrieval, reclassification, and measurement

Retrieval functions involve the selective search, manipulation, and output of data without modifying the spatial location of the feature, its attributes, or creating new spatial entities (Aronoff, 1989). They can be used on both spatial and attribute data. Retrieval will provide output data without modifying the input one. The data will be selected and viewed graphically.

Reclassification is a process where we produce an output data set as a result of removing some of the characteristics from an input data set. Consequently, the number of output values will be smaller than the input one. The input spatial features can be in the raster cells or vector format. Reclassification is an attribute generalization technique. It involves selecting data based on a specific attribute and classifying it based on that attribute values. In raster data analysis, numerical values are often used to indicate classes.

Dissolve is one of the functions which can be used for reclassification data analysis on vector format. It will create an output data reclassified based on the selected attribute value. This is a common function in most of the GIS-based software. In some software, the new reclassified layer will be created, while in some others, the boundaries of the input layer will be simply dissolved. The way of displaying the results provided by *dissolve* analysis depends on the specific software.

2.4.2 Topological overlay

Overlays are the most frequently used functions in geospatial analysis. They allow the combination of two (or more) spatial data layers, comparing them by position and treating areas of overlap and non-overlap in distinct ways (Huisman and By, 2001). Overlay functions can be applied in both vector and raster data. The main principle of such functions is to analyze and compare geographical features of the same location

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in both spatial layers, considering that both layers refer to the same location and same geo-referenced data.

Raster data is in standard geographical form, where the location is presented through cells of equal size and in identical form distributed in rows and columns. Each cell can contain its value, and depending on the value it represents, it can be integer or floating. In case the value for the cell is missing, it is presented as no data. This regular structure of the raster model allows the spatial relationships between them to be formulated and analyzed more efficiently. Therefore, overlay analysis on the raster model has several advantages over the vector one (Raju, 2010):

- More efficient processing because the regular data structure makes the analysis functions process more efficient.
- Larger data sources, e.g. satellite imagery, aerial photographs, and digital altitude models that can be found in sources that can be easily integrated into GIS systems.
- Different types of features are organized in a layer, e.g. the same grid may consist of points, lines, or polygons, as long as different features are assigned different values.

Analysis of raster data can be performed on a single layer or several raster layers (Herbei, Ular and Dragomir, 2011). There are different types of functions from Map Algebra that can be used to analyze raster data. They are mainly based on location information and are classified into four main types: local, focal, zonal, and global. Local operators take into account the analyses in each cell. Some of them are arithmetic (add, subtract, multiply, divide), statistical (minimum, maximum, mean, median), relational (greater than, less than, equal to), Boolean (not, and, or), trigonometric (sine, cosine, tangent, arcsine), as well as exponential and logarithmic (exponents and logs) (https://learngis.org/textbook/). Focal operations that analyze the data of each cell based on the information of a neighboring cell; zonal where calculations are made in each group of cells with the same values and global where the values of one cell in a raster are analyzed to all cells in the other raster.

Several topological overlay processes are available in the vector data model, such as point in polygon, polygon on point, line on line, line in polygon, polygon on line, and polygon on polygon. It means that one of the features must always be a line or polygon, and the second may be point, line, or polygon. Some GIS software requires that overlay occur on only two data features at a time and create the third feature. In cases where more than two data features are involved, this approach requires using overlay functions many times to generate the final overlay result. In some other software, the overlay function can be used to analyze multiple data layers at the same time.

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2.4.3 Neighborhood operations

As mentioned above, the main principle of the local type overlay analysis is the comparison of raster layers cell by cell, and this results in a new raster. However, in the zonal type operators, each of the cells' neighborhood data was considered for analysis. The same principle applies to neighborhood functions, where the values are analyzed near the respective location, not only in the exact location.

The most common neighborhood operations are search functions, topographic, and interpolation. The objective of interpolation is to create continuous surfaces based on point samples (Sylka *et al.*, 2018). The search functions operate with two types of data, such as numerical and thematical. Numerical functions are the total, average, maximum, minimum, and diversity, and thematic functions are the majority, maximum, minimum, diversity (Aronoff, 1989). Functions that provide topographic representation are categorized as neighborhood operations. The topography of the land surface can be modeled by elevation data set, which consists of sample points. These sample points can be regularly and irregularly distributed throughout the location which they are being represented. Where they are regularly, it means that the surface is represented in a raster model (Digital Elevation Model). In case of irregular, Triangulated Irregular Network (TIN) as an alternative form is the representing model. Such models help to provide the user with elevation data at specific location. In addition, some other functions provide with elevation analysis, such as slope which may be measured in degree or percentage and aspect represented by angle from 0 to 360 degree at maximum. In addition to elevation analysis, such functions are very useful while analysing with other data in specific cases, for example soil mapping, soil erosion risk, suitable location analysis, etc.

Other interpolation methods are part of the neighborhood functions. Interpolation is the procedure of predicting unknown values using the known point values, which may be regularly or irregularly distributed. Inverse Distance Weighting, Kriging, Natural Neighbour and Spline are among the commonly used spatial interpolation methods (Ajvazi and Czimber, 2019). The Inverse Distance Weighting approach is a local deterministic interpolation technique that calculates the value as a distance-weighted average of sampled points in a defined neighborhood (Burrough and McDonnell, 1998: Burrough, P.A. and McDonnell, R.A. (1998) Principles of Geographical Information Systems. Oxford University Press, Oxford). Kriging uses a statistical model, which includes autocorrelation. This relationship between the values of data points and the distance between them is known as spatial autocorrelation. Based on the natural neighbor coordinates, Robin Sibson developed a weighted average interpolation technique that he named natural neighbor interpolation (Ledoux, Gold and Fisher, 2005). Spline is a deterministic interpolation method where the predicted values are estimated using a function minimizing the total curvature of the surface.

Buffering is another common neighborhood function, which provides a buffer within a set distance around selected features (point, lines, or polygon). Since they represent an area around a specific feature, the generated buffers will be polygons. Buffering is also referred to as *corridor* or *zone generation* with the raster data model. Usually, the output buffering feature will be utilized in the next topological overlay analysis with another feature.

2.4.4 Connectivity analysis

Connectivity functions include *proximity analysis*, *network analysis*, *spread functions*, as well as 3D surface analyses such as *visibility* and *perspective viewing*. The latest is developed mostly in commercial GIS software. Raster-based systems often provide more sophisticated surface analysis capabilities, while vector-based systems tend to focus on linear network analysis capabilities. However, this appears to be changing as GIS software becomes more sophisticated, and multi-disciplinary applications require a more comprehensive and integrated functionality. Some GIS software provide both vector and raster analysis capabilities within this function category.

2.5 Spatial decision support systems

As presented in section 2.2, spatial decision-making is a multi-dimensional problem. Many attributes need to be evaluated in order to achieve the result of decision support. It also requires an in-depth knowledge of the relevant field as well as the acquisition of data from various sources. As such, they must be interpreted and evaluated by a considerable number of decision-makers, taking into account the requirements of the various stakeholders. Therefore, decision-making is rather complex because it is a multi-disciplinary process. That is why it is crucial to build a well-supported decision-making process. This process will enable analyzing the problem and generating possible solutions. Spatial decision support systems (SDSS) are complex systems because they are characterized by a wide variety of approaches, application areas and development technologies. Such systems make available integrated and flexible tools that will aid decision-making regarding spatial issues. In addition, these systems can help describe the evolution of the issue or system, provide knowledge-based formulation of possible actions, simulate consequences or actions of decision possibilities, and assist in the formulation of implementation strategies (Sugumaran and Degroote, 2011). SDSS provide decision-makers with a decision-making

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environment that incorporates different tools such as spatial database management, spatial modeling, analytical models, graphical display, and tabular reporting (Zhu, 1995).

Applications of SDSS aim to improve the effectiveness of the decision making process by incorporating the evaluations of decision-makers and computer-based software within the decision-making process (Malczewski, 1999). However, the SDSS cannot replace assessments deriving from the knowledge of decision-makers; instead, they improve the decision-making process, mainly the structured part, and consequently automate the decision-making process.

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Chapter 3

3 Spatial decision support for government organizations

Nearly 80% of government organizations have some type of location data, even if it's addresses or zip codes and addresses (Ralphs, 2003). By using geospatial tools, they can gather spatial data and display them on a map. Government organizations that possess a lot of spatial data benefit from geospatial analytics by knowing accurately where the spatial features are located, their attributes, their complex relationships, etc. The solution is based on geographical models, including maps, graphs, statistical analysis etc., that help such relationships be more understandable. By applying geospatial tools, organizations are able to resolve issues involving spatial information; consequently, they can answer many questions with location content. For example, "where are the urban areas in the country?"; "where did the changes in land use mostly occured?"; "where is the soil more suitable for a certain crop cultivation in agriculture?".

Many government organizations are dealing with spatial information; for example, the state authorities of geodesy, cadastre, and cartography, other organizations at the local level, among their basic tasks have the management of spatial data, including their dissemination. From this perspective, each organization has specific tasks, for example dealing with the design of cadastral maps, the production of products from the air such as ortho-images, the maintenance of cadastral records, the execution of geodetic works, etc. Also, other authorities are engaged with sectors that need spatial data management, for example, agriculture institutions, environment, infrastructure, etc. Consequently, all of these have some tasks in common, ranging from data collection, quality control, analyzing, mapping, to publishing or disseminating information.

3.1 Spatial problems and decision-making process

Dealing with situations where spatial decision-making is important presents almost the very common daily cases that people are concerned about. As part of their activities, people make decisions that are actually influenced by geographical locations, e.g., identifying the shortest route from point A to point B, identifying stores, etc. In this perspective, the same happens with government organizations. They have to make decisions related to spatial matters, e.g., strategies on land use planning, environmental management, other infrastructure-related activities, agriculture, etc.

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By nature, spatial problems can be:

- unstructured,
- structured, and
- semi-structured.

Unstructured spatial problems are called such because of the variety of stakeholders or parties concerned, the uncertainties that arise as a result of several possible decision-making alternatives, and the appropriate estimates for different locations (Malczewski, 1999). For example, defining suitable locations for public facilities (hospitals, schools, highways) is difficult to be specified strictly through some rules and be formalized through programming languages. Besides other reasons, such examples may result in more than one alternative. In comparison, structured problems refer to cases where their solution is possible in a structured way. In such cases, the persons involved in this process can identify all the possibilities that lead to the final solution without a variety of alternatives being possible. Cases like these are mostly recurring issues and can be formulated through a programming language and therefore independently solved by software without human involvement in decision-making. However, decision-making is concerned with the spatial issues that are generally found between the two categories discussed above. Such problems are called semi-structured because they are possible to be solved through an interaction of decision-makers and computer systems. The structured part of the problem is solved automatically with the help of software, while the unstructured part is solved through the involvement of decision-makers. Semi-structured problems are often multi-dimensional, where the purpose and objectives are more difficult to define. In this regard, various alternatives to solutions may also be presented. Given that they may involve different stakeholders, the decision-making process can also be characterized by a variety of ideas. Therefore, in the context of using or developing spatial information management systems, an important aspect to be considered is the reflection of the problem structure (Sprague and Watson 1996).

3.1.1 Spatial decision-making process

Decision-making is a sequence of activities starting with problem identification and goal-setting, generating alternative solutions, evaluating alternatives, and selecting a final solution (Drobne and Lisec, 2009; Sugumaran and Degroote, 2011). Therefore, the way of organizing and listing the activities needed in the decision-making process is essential (figure 3.1). Proper listings affect the quality of decision-making.

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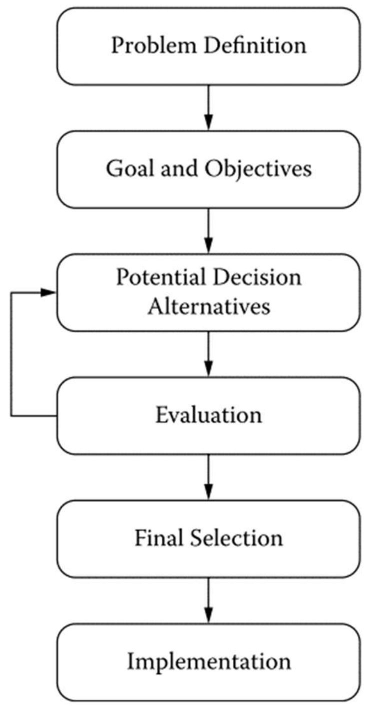

Figure 3.1 Spatial decision-making process (source: Sugumaran and Degroote 2011)

In terms of the decision-making process, there is a new way that is a model of group decision-making since such a process may involve different groups who are invited to propose potential spatial solutions. This model can be used irrespective of whether the process refers to decisions within an institution or other parties. The main reason why such models are needed in the decision-making process is that many spatial problems are semi-structured for which solutions cannot be rendered easily. Therefore, such complex problems require the participation and input of persons who can represent diversity in competencies. This approach can generate solutions to various spatial problems. There are many such cases, such as the land use designation, the development of municipal development plans, the selection of potential areas for different purposes, etc. Participatory land-use planning is another example that involves many people in the decision-making process. This is a holistic assessment of physical, social and economic factors in such a way as to encourage and assist land users in selecting options that increase their productivity and at the same time are sustainable and meet the needs of the society (FAO, 1993). The involvement of the people into the land use planning process has become inevitable not only because of the ability that people nowadays to understand and express their needs but also their facility to be involved into the mapping process by using GIS methodologies (Chambers, 2006).

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3.2 An overview of government services related to land use

Institutions dealing with agriculture and rural development in Kosovo are responsible for several issues, for example, proper utilization of agricultural land, namely its protection against eventual degradation, management of data related to different crops, management of the subsidy process for farmers, etc. In this perspective, it is important that spatial and non-spatial information related to specific issues is properly managed and easily disseminated to stakeholders. Although there may be multiple stakeholders, they can be classified as ministries, local governments, businesses, and citizens.

Central institutions. Many state institutions are in charge of leading and managing specific sectors. Agricultural land administration in Kosovo is under the jurisdiction of the MoA. In this case, administration refers to issues of agricultural land use, designation of its classes, consolidation, protection against eventual degradation, regulation, and protection from erosion. It is not about ownership and valuation, even though these two are often part of a general land administration concept. Kosovo Cadastral Agency is the responsible institution for ownership data, while the Ministry of Finance is for the valuation data.

Local governments. The second level of governance in Kosovo is that of local or municipal governance. Administratively, the municipality means a territory that includes one city and several villages. From the perspective of governance, their rights and obligations are defined by the law on local self-government (https://gzk.rks-gov.net). Based on this, municipalities have the right to own and manage movable and immovable property, to sell and lease movable and immovable property. They also maintain and manage a register of movable and immovable property in use and possession. In addition to their properties, the municipalities are also responsible for managing the process of land use. Citizens can, according to their requests, plan to use the land. On the other hand, the Municipal Government is obliged to provide the appropriate services in order to respond to their requests. The agricultural land use and its conversion to other destinations could be done based on the criteria as specified in the Law on Agriculture Land. According to the law, the land intended for agriculture can be changed to be used for other purposes (https://gzk.rks-gov.net). As a country in transition, the demands for changing the designation of land use from agricultural to other purposes are very high. The main purpose is for the construction of facilities, in particular that of private and collective housing. It is predicted that the real agricultural land size in the country does not comply with current agricultural land registers in Kosovo. Therefore, it is essential that services related to this process are made transparent and controlled by the local government and the Ministry as well.

Businesses. From the perspective of using spatial information as well as their production, businesses are among the main stakeholders. As users, they are often dependent on services provided by state institutions. For example, an investor interested in construction or industrial investment in a specific site should be provided with all the information regarding land ownership, land use plan, destination, etc., in an expedient and transparent way. Such information should be easily accessible to businesses. At the same time, the shared information should be accurate because eventual inaccuracies can economically damage the potential investor.

Citizens. Generally, governments must provide citizens various services, such as education, health, emergency services, infrastructure, environment, land administration, spatial planning, etc. From the perspective of land use, citizens, as part of social expansion and development, can plan to use their land as per their interests. However, there are cases when individual interests may not be in line with the general public interest. For example, let's consider the case of a parcel where the owner wants to change its current designation to a residential area; but, according to the law, that is impossible since the criteria are not met. There are other similar cases, that is why it is imperative to use the information and communication technology capabilities to manage such processes properly. For example, sharing such information through the Internet helps citizens better plan their land use in the future. Also, citizen participation can be very important in cases where there is an on-going process of developing plans for land use.

From the above, many institutions are involved in the land administration process. This affects the communication and decision-making process to be a bit more complex. Therefore, it is essential to build sustainable communication internally in a particular institution, i.e., MoA. In addition, good cooperation with other institutions, i.e. MoA with municipalities, is necessary. Also, proper communication by sharing information with the citizens is very important.

3.3 Analytical tools need assessments

Needs assessment is a systematic set of procedures used to determine needs, examine the nature and causes, and prioritize future actions. Gap analysis, needs analysis, and performance analysis are occasionally used as synonyms for needs assessment, yet they are more frequently defined as needs assessment tools (Watkins, Meiers and Visser, 2012). Needs assessment is essential for proposing solutions. When dealing with specific cases in analyzing the state of the analytical tools and applying

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them in the governance, we first define the spaces (or the deficiencies) in process management, and then we propose a solution.

Spatial decisions made by individuals without a preliminary or even formal analysis, can provide inadequate solutions and can therefore be costly and time-consuming. But, in contrast, wrong decisions by government organizations can have far-reaching consequences.

Often the leadership of an institution has to make decisions where not all aspects of a procedure are known. Such cases are mainly concerned with semi-structured problems. Therefore, in these cases, it is necessary to use information systems, which through models, functions for data manipulation and output generation enable decision-makers to carry out their evaluation. Therefore, many organizations already use such systems in order to improve the decision-making process, and in particular when dealing with critical activities that require rapid and complex decision-making (Averweg, 2012).

By comparing operational and strategic decisions, particularly the key steps of the decision-making process such as intelligence, design, solution, and review, differences can only emerge. Operational decisions must be made in a limited timeframe because rapid responses are needed. Other steps such as intelligence, design, solution, and review are reduced to simple rules which can be implemented through standard spatial functions. In the context of strategic decision-making, the basic decision-making steps outlined above are much more carefully considered. Intelligence may include some persons or field experts; design considers several criteria and seeks more alternatives, and it may include various spatial data, multiple analysis, and presentation tools; the solution requires evaluation of all alternatives, and equally the review may re-analyze the steps followed.

From an organizational perspective, analytical tools have more to do with the decision-making process and the stakeholders who deal with it. In the absence of such systems, decision-making can be considered more of an individual matter. However, in a state institution, decisions have to result from analysis based on data and tools. In this case, decision-making may not be individualized, but it necessarily involves a data analyst. Through spatial information management systems, they provide decision-makers with the information presented in various forms, such as reports, statistical data, maps, etc. Consequently, they will be able to provide the recommended solutions.

From a functional perspective, the organization's benefit may derive from operational issues that are more related to common problems. For example, in the field of environment, identifying the location of potential pollutants; in agriculture, identifying parcels with specific agricultural culture for subsidy issues,

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etc. This is a very important aspect for the organization to function properly. However, reliance on long-term strategic planning processes is crucial. Such planning, unlike operational planning, has greater demands on problem analysis and structure (Jankowski and Nyerges, 2011). Plans by the municipal government regarding planning on land use for a period of ten years within its administrative boundaries may be considered a strategic plan. Consequently, such issues potentially involve many requirements for different data and analyses.

3.4 Techniques for spatial decision support

Technological developments in the last two decades (Drobne and Lisec, 2009) have influenced the application of computer systems to solve spatial problems. However, in order to reach alternative solutions to the decision-making process, it is essential that the activities are carried out within a well-organized structure (figure 3.2). For example, by comparing traditional and GIS application methods, we say that traditional methods are initially focused on discussing the alternatives selected and then analyzing them based upon necessary criteria. The GIS method first considers the minimum criteria or requirements to be met, then generates alternatives through various forms such as reports, statistics, graphs or maps (Drobne and Lisec, 2009).

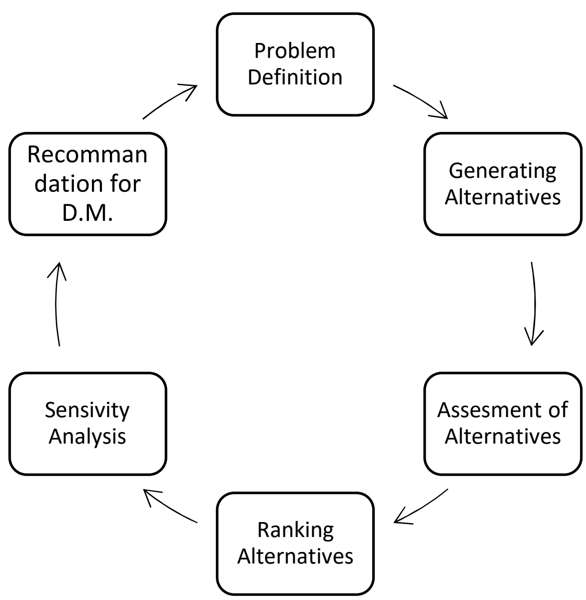

Figure 3.2 General approach in Spatial Decision Making

From the perspective of computer systems application to support decision making, besides GIS methods, other systems such as expert systems and spatial decision support systems are also known. It is often

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necessary for such systems to be modeled on a single basis, but in this case, let's firstly present their characteristics in particular.

GIS is a geographic information system that can provide opportunities for obtaining, storing, analyzing, and presenting spatial information. Such opportunities can, in certain cases, be easily utilized to support a decision-making process that may, in fact, be related to different areas of application. However, GIS does not fulfill all the requirements of an SDSS because it is not a dedicated system. However, GIS offers a wide range of possibilities, each of which can be valuable and used for other cases that do not necessarily involve a decision-making process.

Expert systems are computer application that solves complicated problems that would otherwise require extensive human expertise (Wai, Abd. Latif B. Abdul Rahman and Aziz, 2005). These differ from traditional computer systems, in particular in the way of knowledge treatment where traditional systems treat knowledge primarily about data and software, while expert systems generally treat knowledge as facts, rules and conclusions (Robinson and Frank, 1987). In fact, such systems are also called knowledge-based systems (Zhu, Healey and Aspinall, 1998). The facts and rules provide modeling for spatial problem solving, while conclusions show how problem-solving knowledge is utilized.

SDSS facilitates the decision-making process in various geospatial areas. They are systems designed to support users or groups of users in enhancing decision-making efficiency when solving semi-structured spatial problems (Malczewski, 1999). GIS capabilities in integrating, analyzing, and presenting spatial data are essential in building such systems. The integration enables more complex involvement as can data from different sources and formats. Functions of spatial analysis assist in the necessary manipulation of spatial data, which are based on predefined rules. Such a process achieves the critical generation of information, which further visualizes the decision-making process significantly (Rinner 2018).

3.5 Spatial decision support systems

Information technology developments have not only enabled the development of data handling systems, but they have also been developed to enable spatial decision-making support. The use of spatial information improves the decision-making process by addressing problems systematically, analytically, and visually. From the perspective of managing different domains, some organizations often make decisions that involve spatial data. Nevertheless, in many cases, they lack the use of information systems that provide support in spatial-related decision-making. As a result, they fail to effectively manage the problems they face. Consequently, the relevant areas cannot be properly managed. From a spatial

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information management perspective, the proper way implies efficient handling of information, preserving, analyzing, and presenting it through systems based on GIS methodologies. Simultaneously, such methodologies have made a major contribution to the treatment of spatial and non-spatial data. Reliance on decision-making is now highly effective and is characterized by the application of specialized models geared towards a specific area of decision-making (Pick, 2005). Also, developments in data collection systems, GIS technologies, geographic information science and computers have made the decision-making process easier and more attractive. Such developments have allowed decision-makers to have a clearer view of the phenomena or problems.

Spatial decision support systems enable spatial decision-making processes to include decision makers' evaluations by converting them into criteria, then into data, and ultimately into results. They offer a user-centered approach to deal with unstructured decision problems by integrating predictive and prescriptive models with evaluation functions to assess the quality of the options being considered and "what-if" capabilities to test alternative combinations of procedure and data (Jankowski and Nyerges, 2011). SDSS aims to improve the effectiveness of the decision-making process by incorporating the evaluations of decision-makers and computer-based software within the decision-making process (Malczewski, 1999).

However, SDSS cannot replace assessments through the knowledge of decision-makers. Rather it improves the decision-making process, particularly the structured part, and subsequently the automated decision-making process.

Such systems should be developed on the basis of basic principles, such as:

- ✓ To enable structured data storage in a geodatabase.
- ✓ To provide answers through data analysis to spatial questions that can arise.
- ✓ To offer the opportunity to present data in various formats such as graphs, tables, reports, etc.
- ✓ To be easy to handle.

3.5.1 Historical background and trends of SDSS

The concepts of DSS are based on the seminal work by Simon during the 1950s and 1960s (Simon 1960). DSS evolved as a field of research, development, and practice during the 1970s and 1980s (Sprague and Watson 1996). In the 1970s, the concept of DSS began to develop as an Information System, notably with the work undertaken at the Massachusetts Institute of Technology (Keenan, 2003). DSS usually dealt with a relatively small volume of data, mainly focused on the financial and operating data for business use. Spatial data were not involved. The evolution of SDSS is closely linked with GIS

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and DSS (Calzada 2014; Sugumaran and DeGroote, 2011; Keenan, 2006;). SDSS were mainly related to the need for expanding the GIS capabilities since the basic concept of GIS was introduced during the 1960s. The goal was to solve complex, ill-defined, and spatial decision problems. Also, SDSS requires the use of spatial and large volumes of data. In order to have them processed, the computers need to be more powerful. Starting in the mid-1970s, SDSS evolved and became recognized in the GIS and GI Science fields. In the 1980s and 1990s, some improvements have been incorporated into GIS, mainly from mapping and visualization perspective. Also, SDSS was included as a research and curricular component in the first U.S. Centre for Geographic Information and Analysis, founded at the University of California Santa Barbara in 1990 (Pick, 2008). By the mid-1990s and over the last decade, significant advances were made to GIS. GIS technological advances have had a great impact on the development of SDSS. Using GIS-based applications through the internet has expanded the areas of applications as well. These systems have become available in mobile devices as well.

3.5.2 The components of SDSS

As some authors of the SDSS literature discuss SDSS main components from different perspectives, it is not easy to identify them. Considering SDSS at a basic level, the main components are spatial database management, model base, and dialog management (Malczewski, 1999). Demetriou (2013), in his thesis, mentioned that a typical SDSS should comprise three main components: a database management system (DBMS) containing data and data processing procedures; a model base management system (MBMS) containing the functions to manage the model base; and a dialog generation and management system (DGMS) which is the user interface and the reports/display generator. According to Forgionne et al. (2005), a typical SDSS has four components, such as spatial database, analytical tools, decision models, and user interface providing easy access to decision models, database, analytical tools as well as an attractive display of the output.

SDSS should be designed for ease of use, to provide solutions through the presentation of a series of alternatives, flexibility in use, ease to adapt, as well as to support analytical methods (Sugumaran and Degroote, 2011). This definition helps us in defining the components as well. According to Sugumaran and Degroote, the four core components of SDSS are: the database management component, model management component, dialog management component, and the stakeholder component (figure 3.3). The knowledge component is another optional component that is not included in the traditional SDSS.

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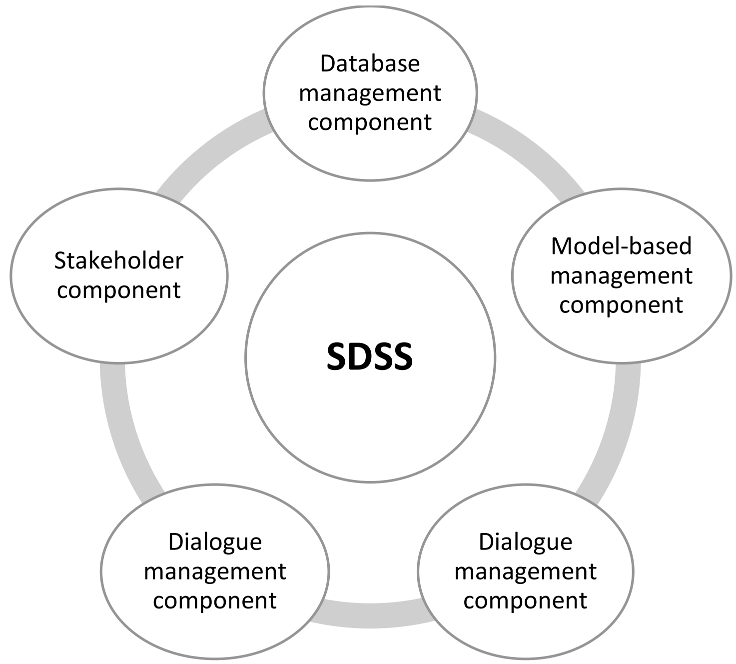

Figure 3.3 The main components of SDSS

As introduced above, all components will be considered in this research thesis. Below is given a short introduction to each component.

Database management component. From the perspective of Sugumaran and Degroote (2011) GIS is considered as a database management system component. Indeed, GIS capacity exceeds the ability of a spatial database management system. This component is mostly related to all data management tasks, such as: storing, maintaining, retrieving, extracting, etc. It makes it possible to get all necessary data in the form appropriate for a specific decision-making problem.

Model-based management component. It provides the ability to manage, execute and integrate different models, which help the SDSS to examine the locations, attributes and spatial relationships through various analytical methods. GIS technology provides such analytical functions, but some of the GIS programs lack the possibility of advanced analytical modeling (Chakhar and Martel, 2004). Recently, some of the GIS software programs have improved the capabilities on modeling frameworks. Most of such software programs, especially the proprietary ones, rely on existing functions, which means that they do not provide the users with the necessary capabilities for more complex spatial decision-making processes.

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Dialogue management component. As discussed in the sections above, the spatial decision-making process involves interactive participation of the end-user and SDSS. A final result through the application of an SDSS is largely dependent on end-user interaction with the system. Advanced opportunities for effective communication significantly contribute to the successful implementation of the SDSS. Indeed, this represents one of the core components of the SDSS. The dialogue management component is about communication between the user and all functions or components of the SDSS. In such cases, the graphical user interface (GUI) is essential. Therefore, during the development of the SDSS, special focus is required so that the system can be easily utilized. In this regard, referring to Malczewski (1999), to meet the conditions of being well-developed SDSS from a GUI perspective, there are at least four principal issues that need to be considered: accessible, flexible, great interactive layout, and various functionalities.

Stakeholder component. This is not discussed as one of the main components of SDSS in most of the literature reviewed (Densham 1993; Finlay 1990; Keenan 1996, 2003; Keenan and Jankowski 2019; Malczewski 1999; Matthews et al. 1999). In their article, Rodela et al. (2017) discussed many times for the stakeholders in SDSS, but not specifically as a component. Their perspective was more on how SDSS contributes to improving the decision-making process for different stakeholders. However, Suguraman and Degroote (2011) have described the stakeholder as a central component of SDSS. They present the importance of various stakeholders in a successful application of an SDSS in a specific spatial problem. According to this book, the stakeholders include the decision-maker or end-user, developer, expert, and analyst (figure 3.4).

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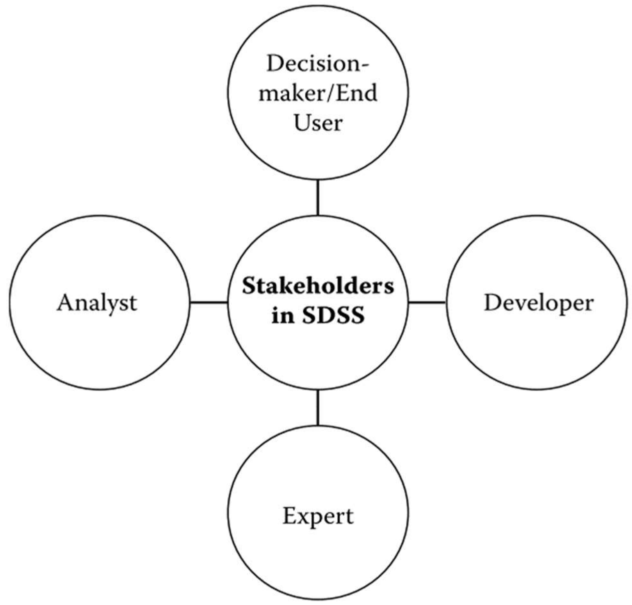

Figure 3.4 Stakeholders involved in SDSS (source: Suguraman and Degroote, 2011)

The expert has knowledge of available software techniques, as well as knowledge in crucial problems when a spatial decision is involved. The developer has a role in collecting end-user requests, system architects, and interface developers in order to program the system operation. The analyst is mainly concerned with analyzing data, generating results, and interpreting them. Decision-makers are among the stakeholders who are informed about the results acquired from the system that may represent different scenarios related to the spatial problem.

Knowledge component. Traditionally built SDSSs do not include the component of knowledge that are often needed to solve spatial problems. However, spatial decision support requires involvement through the integration and interpretation of knowledge by experts. Such knowledge enables support for users within the decision-making process. An SDSS should be able to "use substantial knowledge about the problem domain, and should guide the user in systematically examining various potential scenarios before arriving at a decision." (Armstrong *et al.*, 1990) In cases when a knowledge component is included within an SDSS, then the entire decision-making process involves stages such as problem model formulation, model evaluation, and generation of a solution. (Zhu, Healey and Aspinall, 1998) Thus, the knowledge component is used to successfully accomplish the milestones in question, to guide the communication between the user and the system, and to facilitate the process through delivering messages to the user.

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3.5.3 Application domains

Since SDSS involves the analysis and visualization of spatial and non-spatial data, it means that several domains can apply solutions such as natural resources management, environment, urban planning, agriculture, and many others (figure 3.5).

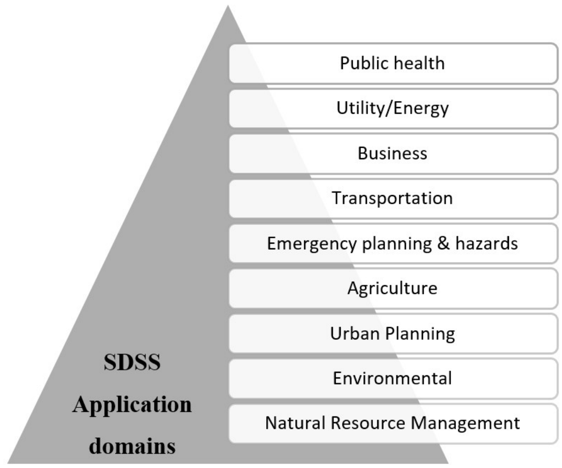

Figure 3.5 Categorical view of various SDSS application Domains

Regarding environmental issues, the most common cases are concerned with themes such as waste management, pollution, and natural hazards. (Keenan and Jankowski, 2019) Many cases exist for agriculture purposes. The author, Ajvazi, in his article (2015), introduces the national farmer register system in supporting the agricultural subsidy process in Kosovo. This is among the common examples of SDSS applications in agriculture. This kind of system serves as the main tool for State Governments to manage the process of farmer's subsidies. They help a lot the organizations from an operational point of view. Also, the other article of Ajvazi (2017) presents another level of SDSS example for agricultural land use planning. This is a more problem-specific example of SDSS. It can be used by local or state institutions and private organizations. Similar research has been done by Trendafilov et. al. (2010), but this article is in the field of forestry and deals with suitable sites for afforestation. Many other case studies exist on the topic of water resource management. The authors Rao and Kumar (2004) have presented a model of SDSS for watershed management in the western part of Doon valley, India. They have built a prototype SDSS for watershed management, analyzing various spatial datasets such as land use/land cover, hydrological layers, land capability classis, soil texture, rain fall. The land use planning is one of the most common cases of building information systems for supporting the decision-making process. The Canada Land Inventory presents one of the first cases (Pratt, 1965; Tomlinson, 1967). Indeed, several authors have promoted the application of decision support systems for land use planning (Cruz, 2006; De

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Meyer et al., 2013; Matthews et al., 1999; Van Der Kwast et al., 2011; Zhu, Aspinall, & Healey, 1996; Zubi, 2018). In their article, Zhu et al. (1996) discussed the design and implementation of a knowledge-based spatial decision support system, including analytical, rule-based, and spatial modeling capabilities for land use planning in rural areas. The primary purpose of this knowledge-based SDSS was strategic land use planning in rural areas. It presents an approach that gives an advantage to knowledge-based techniques while mentioning some of the shortcomings of GIS in supporting the decision-making process. GIS is classified as user-unfriendly, non-interactive, and inflexible. It might be accepted since the article refers to 1996; otherwise, it contradicts today's capabilities of GIS technology. Recent technological progress, including GIS and the Internet, has provided opportunities to overcome many limitations of previous basic GIS systems by developing further systems to help the decision-making process. Web-based GIS applications are good examples (Wu et al., 2008), and the possibilities for further developments among the open-source GIS systems are another one (Kropla, 2006; Steiniger and Hunter, 2013; Mohammed, 2014). Therefore, an existing GIS system could be further improved for the specific needs of the end-user. This is a kind of customization, which can be done by adding plug-ins or extensions. In such cases, developers usually utilize an Application Programming Interface, API (Steiniger and Hunter, 2013). Several GIS desktop systems provide such options.

3.5.3.1 Agriculture land use planning

Agriculture is a sector which suited for the application of GI systems because it is natural resource-based, requires the management of large quantities of products and services, and requires to record all the operations starting from the preliminary phase of land planning and allocation to the marketplace (Pierce and Clay, 2007). The main phases of agricultural development are pre-cultivation, cultivation (including harvesting), and post-cultivation (figure 3.6). The application of information management systems is possible throughout all these stages (Ajvazi, Loshi and Márkus, 2016). The pre-cultivation phase includes the proper use of agricultural land, namely the selection of land most appropriate to a certain crop. The application of SDSS, GIS, remote sensing, and knowledge management system at this stage is crucial. However, in other phases, both in cultivation and post-cultivation, the application of systems that support spatial decision-making is very important.

At the user level, the use of the SDSS may serve at an individual level, namely in the management of farms and agricultural holdings, then at the level of a municipal or regional government, for the administration of specific agricultural crops, and lastly, at the level of state government, for the purposes of strategic planning in this field. Common examples for management of agricultural cultures, especially at the stage of cultivation, deal with the evaluation of the condition of agricultural cultures, the spraying process, irrigation, etc.

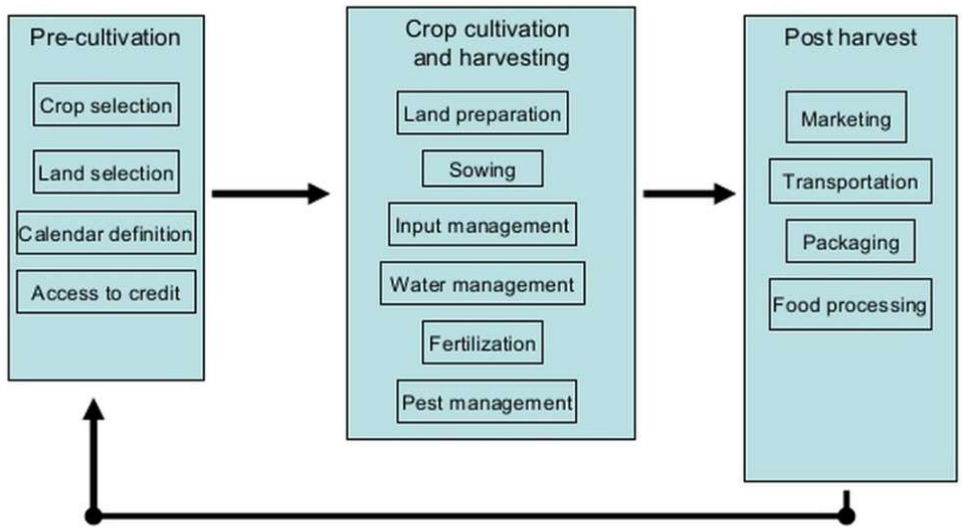

Figure 3.6 Main phases in the agriculture sector (source: Wagenineen, 2009)

Kaparthi and Sugumaran (2009) discussed the construction of a Web-Based SDSS, which produces real-time data on the state of crops and their yields.

As stated in the introduction to this section, the application of the SDSS in agricultural land use planning is essential. Matthews et al. (1999) have presented how a spatial system can support rural land management decision-making in terms of agricultural land use opportunities and the impact of the land use redesignation. In their study case, the authors have included the knowledge-based component and GIS components as part of the proposed spatial decision support system. It must be noted that many authors have discussed the SDSS application related to agricultural land use (Aspinall, Miller and Birnie, 1993; Sengupta *et al.*, 2005; Röhriga and Laudienb, 2009; Oliveira *et al.*, 2014).

The development of the systems should be made according to the user requirements. They should be equipped with features that will be required from the end-user. User-friendly features, as well as easy and inexpensive maintenance, are equally important. Also, it is crucial that the generated information is reliable. Satisfying such requirements will influence the application of the spatial supporting systems in rural land use planning. Such approaches will have more credibility. Consequently, the use of SDSS in rural land use planning will increasingly grow.

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3.6 Empower the institutions with a system of supporting the spatial decision

Supporting the spatial decision process starts with including the location information in decision-making. Within institutions or organizations, we have different departments that operate at the operational level, planning level, and finally, a few at the management level who can make the decisions. For proper functionality, it is important to share the information and facilitate collaboration between different levels in the organization (https://www.esri.com/about/newsroom/insider/empowering-gis-professionals-and-transforming-organizations/).

What do such systems need to provide? Let us explain through the following steps:

- Create a unique platform for easy access of data by authorized users. This means that data becomes accessible regardless of location and utilizing different technological devices. It is not the size and complexity of the data that matters, but access by all users anytime from anywhere.
- The data must meet the requirements of the users and the purpose of the system. Therefore, it is necessary to analyze and understand in advance the workflow of all users within the institution. Through this, we understand the institution's organizational and administrative work processes and convert them into necessary data and make them accessible to all appropriate users.
- It must be a system within a sustainable technological environment but also at the same time enable continuous innovative development. This should be an ongoing process with the main goal of increasing the efficiency and performance of the institution.
- It should offer the possibility of integrating existing data through web services. Through this, we achieve new use of data that may already be part of other applications or systems.

Figure 3.7 Web GIS transforming organizations (Source: https://www.esri.com/about/newsroom/insider/empowering-gis-professionals-and-transforming-organizations/)

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When most of the work processes up to decision making are supported through systems with some of the capabilities they have to offer (as above), and which provide full integration of all the necessary employees within the institution, then an institution provides a work environment where innovation as an ongoing process becomes the key tool for sustainable decision making. As a result, it makes the whole institution better manageable, transparent, and powerful (figure 3.7).

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Chapter 4

4 Analysis and needs assessments of geospatial information system for agricultural land use administration and monitoring in Kosovo

4.1 Introduction

Land is a fundamental component of the ecosystem. It is essential that the states carefully tackle human relations towards the land. Such a relationship contains many challenges that need to be specifically addressed. The main purpose of this is to achieve a rational use of the land and its resources. Proper management of these processes would enable sustainable development, both economically, environmentally, and socially as well (FIG, 2001). In fact, the role of land in the economy is crucial, although it may not often seem so. For example, sustainable economic development depends on the registers of property rights.

Many states face the problem of proper land use. There are several reasons for this, including the factor of expansion and growth of the population. This greatly affects the expansion of urban areas. On the other hand, as the population grows, so does the need for food. This shows that one of the fundamental challenges of proper land management is the growing need for larger areas of agricultural land and, on the other hand, the need to expand urban areas. Such a challenge does not only refer to the current demands but also long-term planning for future generations. For this to be resolved, proper land management is required. Land management refers to the activities that are associated with its management as a common resource of the environment and the economy towards sustainable development. Land administration and its management are two interdisciplinary activities. Land management refers to the processes of defining, collecting, and disseminating information on its ownership, value, and use in the implementation of land management policies (Sevatdal, 2002). Land management activities are more of an operational nature rather than a strategic one. Proper and effective land management contributes to better management of the land, consequently to a sustainable economic development of the country. Although the ownership, value, and use of land are independent in concept, they are not in practice. Each attribute of land needs to be carefully managed and to achieve this, there must be good land records: of ownership to ensure security of tenure; of value to ensure fairness in land and property taxation and equity in the compulsory

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acquisition of land for State purposes; and of the use of land to ensure efficient resource management (United Nations Economic Commission for Europe, 1996).

The Republic of Kosovo is one of the newest countries in the world, declaring its independence on 17 February 2008. Being a country that emerged from the last war of 1999, the challenges of building infrastructure and land administration continue even to this day. In particular, land use management is quite fragile. Numerous projects have been developed over the years, but data on designation changes and land regulation have been retained only within the responsible cadastral institutions. Municipal cadastral offices comprise local institutions responsible for such matters, while the Kosovo Cadastral Agency is the central authority for the maintenance of cadastral databases, maintenance of property registries, mapping and GIS. It is also the central authority for geospatial data infrastructure (http://www.kca-ks.org/akk). Data on agricultural land use and agricultural land use conversion, soil classes, land consolidation are only saved on cadastral registers. In case of requirements, some statistical data could be compiled by cadastral authority and sent to other related authorities to support the strategic planning. But this is not sufficient. In fact, the local and central institutions in charge should be able to use information management systems for operational and strategic purposes as well. In this perspective, the Ministry of Agriculture is the responsible institution that should monitor the use of agricultural land, i.e. protect it from eventual degradation. Also, the municipalities are in charge on the local level.

4.2 Agricultural land administration

One of the first to use the term Land Administration was the United Nations Economic Commission for Europe in 1993 in the context of their land administration guidance document. The precise definition of this term, referring to this guide, is as follows:

"the process of determining, recording and disseminating information about ownership, value and use of land and its associated resources. These processes include the determination (sometimes called ′adjudication′) of land rights and other attributes, surveying and describing these, their detailed documentation, and the provision of relevant information for supporting land markets".

Also, some other definitions from "Draft Glossary for UN-FIG Declaration":

"Land administration: the processes of determining, recording and disseminating information about the ownership, value and use of land when implementing land management policies."

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4.2.1 The need for agricultural land use planning and monitoring

In order to achieve a rational land use, it is important to make a proper distribution for different uses by meeting the requirements from different perspectives (Wrachien, 2003). Planning for agricultural land use is essential in providing the necessary food products. In principle, this is achieved through strategic planning for the proper administration of all its processes. Several activities are required to carry out phases such as the definition of soil characteristics, definition of specific areas for agricultural development, land consolidation, protection of agricultural land from eventual degradation, weather erosion, pollution, or uncontrolled expansion of urban or industrial areas.

Kosovo's territory constitutes a relatively small area of 10906 km^2, and referring to the official reports of state institutions (NCEI, 2013), about 577,000 hectares are agricultural land. So, about 53% of the country's area is agricultural land. From an economic development perspective, agriculture consists of around 14.1% of Kosovo's GDP. A good planning and practical development will have a good impact on increasing the economic development of the country. Also, over 60% of the population in Kosovo lives mainly in rural areas, so increasing the development of agriculture, besides improving the life of the population in economic terms, will also affect the development of rural areas in general. Even if we take as a base the total number of population, which according to the 2011 census is 1.8 million, the surface of the agricultural land per capita will be about 0.32 hectares. This is above the average of EU countries, which is 0.24 hectares per capita (https://www.ec.europa.eu/eurostat). But, the total area of 577,000 hectares, as mentioned above, is not so reliable, despite being written in that report. For example, if we look at the value from the land cover dataset (section 4.3.1), in 2018, the agriculture area was 416,353 hectares. In either case, the agricultural land should be maintained and utilized as rationally as possible.

Beyond economic affordability, reliance on agriculture is also a social issue where agricultural activity is widespread in Kosovo as a safety net for the majority of the population. In an underdeveloped economy with over 40% of unemployment, agriculture remains the primary or secondary source of revenue for many families. The 2011 census shows that about 4.4% of employment is in agriculture, only counting for those formally employed. Adding here the subsistence farming, employment in agriculture is estimated to reach 35% of the labor force (https://www.efse.lu).

4.2.2 Analysis of existing legislative framework

The main goal of the legislative framework analysis is to identify the rights and obligations of the state and local authorities related to agriculture land administration and monitoring in Kosovo. Based on this,

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main focus further was to identify specific cases when respective institutions need to make decisions, which requires spatial data handling.

In Kosovo, the Law on Agricultural Land no. 02 / L-26 defines the use, protection, consolidation and lease of agricultural land for the purpose of preserving and protecting agricultural potential, based on the principles of sustainable development. In fact, the Law consists of eight chapters in total. For the purpose of this research, the third chapter is most important since it focuses on agriculture land protection related to the following three issues:

- ✓ Agriculture land use redesignation.
- ✓ Agriculture land pollution, and
- ✓ Agriculture land erosion risk.

Regarding the agriculture land use redesignation, the most important findings are identified as follows:

- Agriculture land in Kosovo must be used only for agriculture purposes, except for cases as specified in the Law.
- Legal authorities (central and local) involved in agriculture land use redesignation processes are obliged to keep records regarding the land converted and exchange them among themselves.
- One of the initial issues in agriculture land use protection is to develop a soil classification map that shows the agricultural land classified into eight classes.
- Agriculture land can be changed to other designation based on the spatial plans, which during the development of the soil classification should be considered to protect the best land quality.
- If the application for changing the designation of land use is received, it should be examined carefully and spatially analyzed with other spatial data such as: land use plans in municipal spatial plans, irrigated areas, soil maps.
- The decision-making process for reviewing the applications of agricultural land use change of designation involves many authorities which need to have proper communication among each other.

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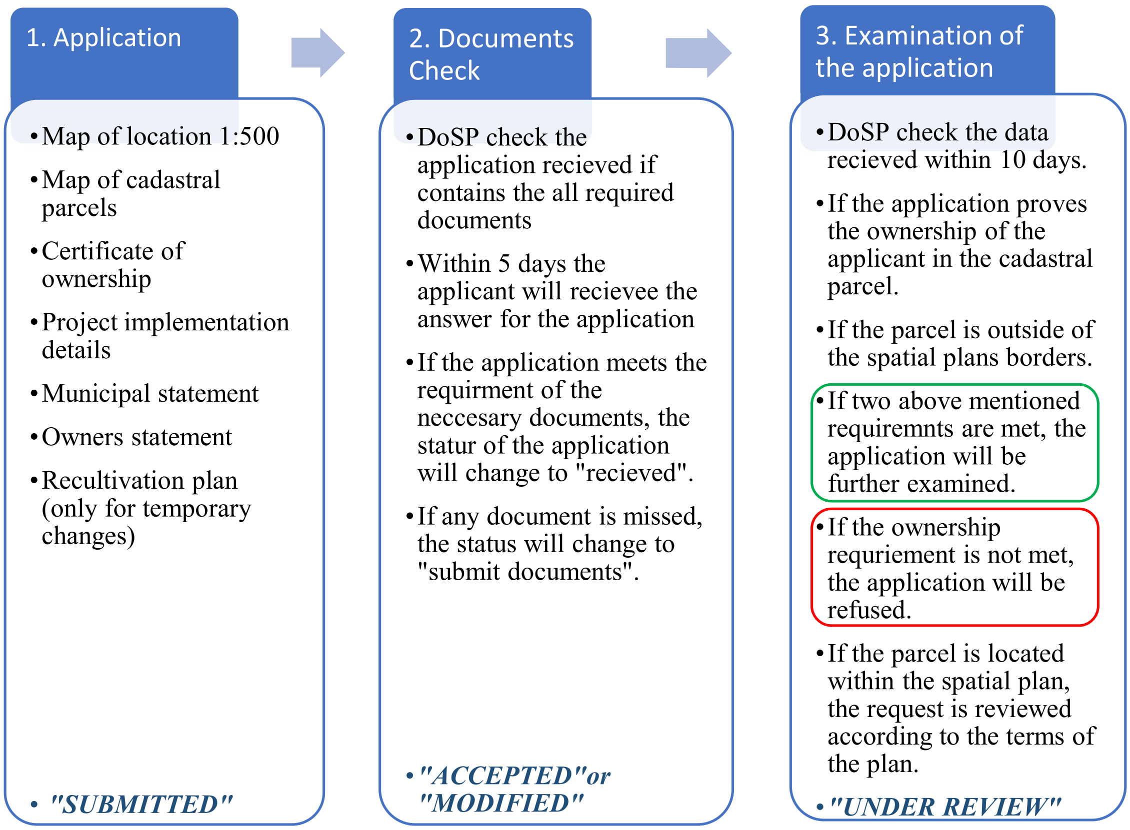

Figure 4.1 The status of the application

Based on figure 4.1, the process begins with the submission of the application by the landowner. The application must contain the required documents such as 1:500 location map, cadastral parcel map, ownership certificate, details on the project he wishes to implement, and the new cultivation plan if the demand is for a temporary change. After that, DoSP in the specific municipality checks all received documents. Within five days, the applicant will receive a response if the application is 'good to go' or additional documentation is required. Once the documentation meets the legal requirements, the examination of the application begins. If the conditions for the ownership of the parcel are met and the parcel is outside the spatial plan, the request will continue to be examined by the competent authority - this will be discussed in the next section. If the ownership is not proven, the request will be rejected. If the parcel is within the municipal spatial plan, the request will be handled by DoSP according to the specifics of the spatial plan.

The most important findings related to agricultural land protection from pollution are as follows:

- Protection of land from pollution is applied to ensure regular and safe production for the purpose of protecting humans, plants, animals, and the environment.

- Land is protected from pollution through stopping, limiting, and preventing direct exposal, exposal through water and air of harmful matter, and undertaking of measures for protection and improvement of fertility.
- To protect agricultural land from pollution, is required to continuously monitor the state and level of pollution of agricultural land from harmful matters including:
    - Defining the zone and scale of land pollution – inventory;
    - Continuous monitoring of state and all changes of agricultural land i.e., physical, chemical, and biological features;
    - Establishment of information system for polluted agricultural land.
- As a result of the inventory and map development, the responsible authorities (MoA and DoA in the respective municipality) will take decisions that may stop or limit the production of certain crops and use of plant protection means and other means on the specific land.
- The authorities must inform the landowners about the decision.

The most important findings related to agricultural land protection from erosion risk are as follows:

- Develop the actual and potential erosion risk map
- Based on that map, the MoA can undertake agro-technical measures, which may include:
    - Limit or prohibit the cutting of trees unless this is an agro-technical measure,
    - Limit the use of pastures by regulating the specie, time, and number of livestock that may be grazed as well as the mode of their utilization
    - Prohibit the plowing of meadows, pastures, and uncultivated surfaces of steep land for the purpose of transforming them into arable land with annual crops
    - Prohibit the removal of hummus or topsoil from agricultural land
    - A requirement for the seeding of grass of a specific kind on steep land.
- MoA should cooperate with DoA in the respective municipality for the measures undertaken.
- The authorities must inform the landowners about the decision.

4.2.3 Institutional authorities and responsibilities

According to the law and the Administrative Instruction on changing the designation of agricultural land use, state institutions i.e. MoA, and local institutions i.e. DoSP, DoA have the authority and are responsible for deciding for agricultural land use redesignation. In some cases, the municipal assembly must also make the final approval. In fact, the authority to decide for the requests for redesignation

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depends on the character of the change of designation and the class of agricultural land. Character refers to the time-span of the change: if it is a permanent or temporary destination.

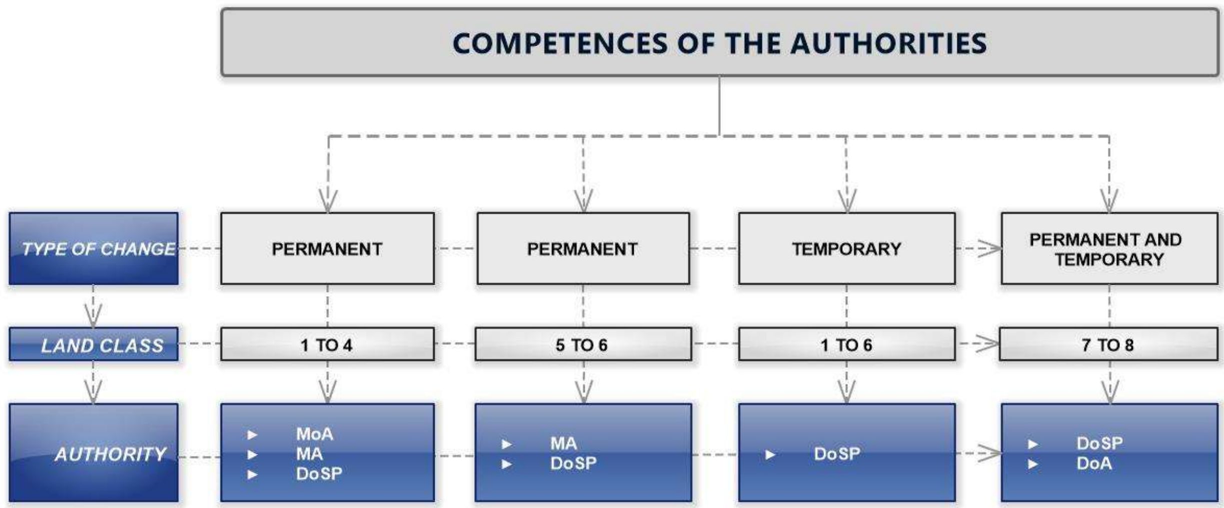

Figure 4.2 Authority competencies in the decision-making process for the land use designation

On the local level, the municipal assembly decides on the requirements for permanent change of designation of agricultural land: classified from first to sixth class. But the application must be reviewed by DoSP in advance. In cases of land classes 1 to 4, the approval of the MoA is also required, while for classes 5 to 6 this is not necessary.

The decision on the request for changing the designation of land use in classes 7 - 8 is taken by the DoSP and DoA. In cases of temporary redesignation of land use in classes 1 – 6, the decision can be made with the approval of the DoSP.

4.3 Needs assessments for the application of geospatial solutions

Considering the main findings as indicated in sections 4.2.2 and 4.2.3, the process of administration and monitoring the agricultural land use redesignation is quite unique. Firstly, the decision-making process includes many institutions. The process involves geospatial data, and cooperation among institutions is necessary to reassure the option of the application of geospatial solutions.

When geospatial information systems are practically applied, they have a very strong management capability. Technical geospatial knowledge or experience alone is not sufficient for a successful implementation. From an organizational perspective, these failures occur often because of improper

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communication, leadership did not support or was not interested in a spatial project, and citizens are not consulted. These are not technical or geographic but management issues (Pick, 2008). This approach has many significant advantages for solving complex problems. Also, this is very important when a group of decision-makers need to collaborate between themselves (Armstrong and Denshman, 1995).

4.3.1 Analysis of agricultural land loss

There are a number of factors that motivate landowners to redesignate their lands for other uses; however, most of them are related to economic reasons. It often happens that low incomes earned from the sale of agricultural products have made the sector less lucrative (Appiah, Asante and Nketiah, 2019). The constant impact coming from human activities results in the degradation of land areas causing both adverse environmental and socioeconomic consequences.

Principally, the main factors that affect the loss of land are (figure 4.3):

- Settlements (unplanned construction);
- Industry (solid waste, surface mining);
- Construction of roads and highways
- Household waste and landfills;
- Erosion;
- Uncontrolled gravel exploitation.

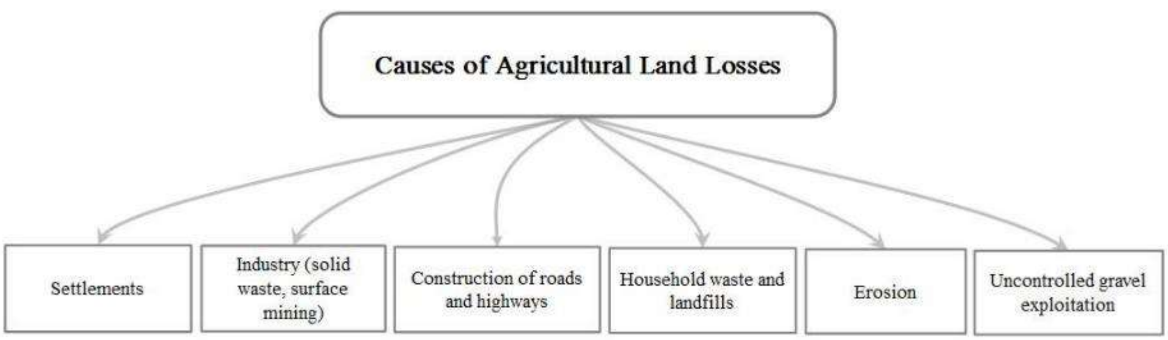

Figure 4.3 Causes of agriculture land loss

In Kosovo, mainly in urban areas, the demand for new houses has risen in recent years due to the population's need for new living spaces (figure 4.4). As a result, this situation of redesignating the land for construction use has become one of the most common forms of the loss of agricultural land. Given that there is no register, it is difficult to find more accurate information on the degree of lost agricultural

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land. There are various documents that present different values on the lost areas of agricultural land in Kosovo. According to MoA data provided by the Municipal DoA, during the period 1999-2008, about 2,580.50 *ha* of agricultural land was redesignated without permission, whereas about 198.24 *ha* of agricultural land area has redesignated with the permission of the local authorities. These data are referred to a report of the Kosovo Environmental Protection Agency (https://www.ammk-rks.net). In fact, these data contradict another document of the same agency, which is also referred to as data from the MoA, stating that around 2600 - 3000 hectares of agricultural land are lost in Kosovo within the year.

Figure 4.4 A case of the agricultural land redesignation to residential and road infrustructure areas

For the purpose of this research, it is significant to know if there is any exact information on agricultural land redesignation to other purposes over the years. Hence, some analysis on agriculture land redesignation is conducted. The data from Corine Land Cover are analyzed (https://land.copernicus.eu), in two different periods: 2000 and 2018 (figure 4.5). The aim was to find out an approximate value of the agricultural land areas redesignated/lost in years. From the maps shown in the figure below, it is possible to see the reduction of agricultural areas, namely the increase of artificial areas.

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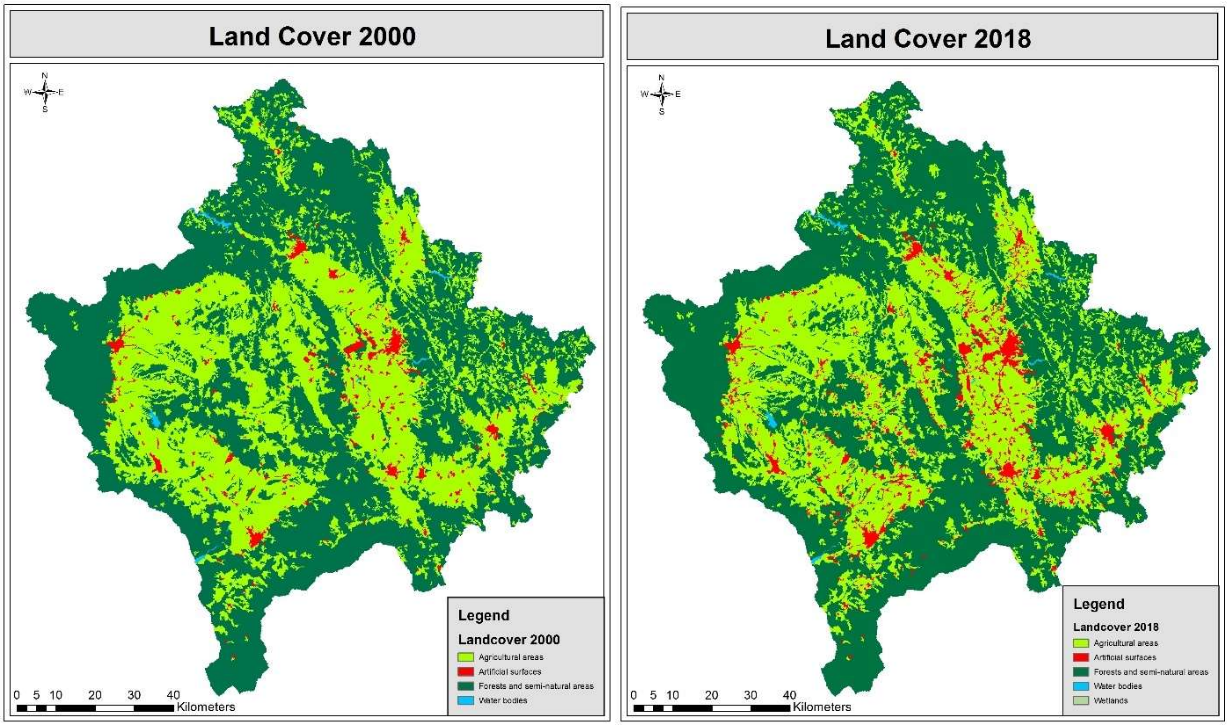

Figure 4.5 Land cover maps 2000 – 2018

Table 4.1 shows that the reduction of agricultural areas is considerable. Out of the 444500 hectares in 2000, 416353 hectares remained in 2018. Over 18 years, agricultural land in Kosovo has shrunk by 28,147 hectares or 6.33%. It turns out that the average annual reduction in agricultural land area is 1563 hectares.

Table 4.1 Land cover data between two different periods: 2000 - 2018

LAND COVER 2000			LAND COVER 2018		
No.	Level	Area [hectares]	No.	Level	Area [hectares]
1	Artificial surfaces	24901	1	Artificial surfaces	50955
2	**Agricultural areas**	**444500**	**2**	**Agricultural areas**	**416353**
3	Forests and semi-natural areas	619056	3	Forests and semi-natural areas	621005
4	Wetlands	0	4	Wetlands	129
5	Water bodies	2324	5	Water bodies	2339
	Total	**1090781**		**Total**	**1090781**

Compared to data from the same source, Corine Land Cover, in the period between 2000 - 2012 agricultural land area in EU countries declined by 1.2%, or 0.1% annually

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(https://www.ec.europa.eu/agriculture/). The annual average percentage in Kosovo is 0.3%. Since considerable agricultural areas are lost, monitoring and protecting the agricultural land is a must.

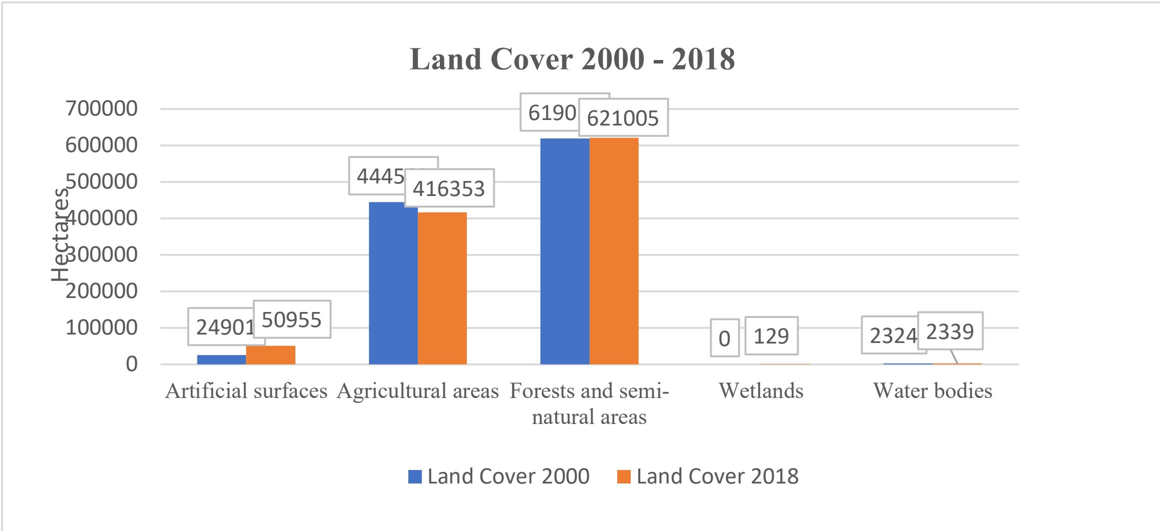

Figure 4.6 Graphical comparison of coverage data 2000 - 2018

4.3.2 Analysis of the current situation from the spatial decision-making perspective

As presented in the previous section, there is a lack of accurate information on agricultural land areas indicating the current situation in the field. There are only some non-spatial data that show the agricultural land, but they do not represent the factual situation of the field. Such data was created many years ago. Since then, many changes have occurred. Also, the cadastral system is accessible only to the cadastral state agency and municipal cadastral offices. None of the agriculture institutions responsible for agricultural land monitoring can access the system. It is a kind of paradox that the responsible institutions for administering the agricultural land, have no access to accurate data for agricultural land areas in the country or in their administrative zones. On the one hand, they are responsible for monitoring the agricultural land use and protecting it from degradation, but on the other hand, they are not able to answer some of the fundamental questions, such as:

1) What is the agricultural area in the country or at the local level?
2) Where is this area? In what condition is it?
3) Where is the temporary or permanently agriculture converted area to another destination?
4) What are the soil classes, and where are they located?
5) Where is the soil most at risk from erosion?
6) Which is the level of soil pollution?

If such questions cannot be answered, it shows a lack of accurate analog data. It is clearly understood that spatial information on this issue does not exist at all, or it merely exists. Such approximate data is not sufficient for institutions responsible for managing spatial information related to agricultural land areas and other processes linked to this subject. If the above-mentioned questions are difficult to answer, further decisions related to such information are hard to be made. For example, a missing soil map is a drawback in analyzing the suitable location for a specific agriculture crop.

4.3.3 Needs assessment and user requirement analysis

Needs assessment is based on a basic principle that the improvement of agricultural land administration issues in Kosovo to meet the requirements for good governance and to address the demands of non-governmental institutions and the public at large (United Nations Economic Commission for Europe, 1996).

As mentioned in the previous section, there are various official documents, such as annual reports, annual plans, strategic documents, and statistical data, which in fact do not provide consistent information regarding agricultural land in Kosovo. They often contain significant differences. So, there is no viable register and map that show the actual agricultural land. In addition, referring to the process of changing the designation of agricultural land, as described in section 4.2.3, it is necessary to establish and maintain a database that shows redesignated areas. Currently, the central and local institutions involved do not provide such data. In the case of applications, the data are only temporarily analyzed until the decision is made. They are not archived in a register and maps. During an application process, landowners have to physically submit the documentation from one department to another or sometimes to the MoA. Applications are stored in various textual formats in local computers. The formats and the manner of storing information are not standardized.

Also, the decision-making process for agricultural land use redesignations involves spatial and municipal development plans. In the latter, land use planning is presented. However, by analyzing the state of the data management of such plans, it appears that this management in the relevant municipal departments is not properly done (Ameti, 2012). Generally, these data are stored locally in various formats, and random software is used to manipulate them. There is no specific software or system used to manage the data. There is no centralized geodatabase that officials of the spatial planning departments, agriculture, etc., could access and update as needed. From such a situation, we realize that even the basic purpose of the law on agricultural land, re-introduced at the beginning of this section, is not even closely complied with.

Based on the current legislation in Kosovo, there are cases where redesignations can be made provisionally, i.e., when agricultural land can be re-used for agricultural production after a certain period. Such cases involve the exploitation of surface minerals, waste dumps, industrial ash, and waste from the wood industry. When such requirements exist, final decisions should also be archived for monitoring purposes. The location would be identified as the location where the change of designation is only temporary; thus, enabling responsible officials to monitor the exploitation and re-cultivation phase. In such cases, the public institutions should have accurate data on agricultural land areas, which can also be used for other purposes.

4.3.3.1 Needs assessment from NSDI perspective

The first definition of the National Spatial Data Infrastructure was formulated in the US and published in the Federal Register on April 13, 1994, which states: “National Spatial Data Infrastructure (NSDI) means the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve the utilization of geospatial data.” Global Spatial Data Infrastructure (GSDI) follows closely this definition, which states: “A coordinated approach to technology, policies, standards, and human resources necessary for the effective acquisition, management, storage, distribution, and improved the utilization of geo-spatial data in the development of the global community” (Nogueras-iso, Zarazaga-soria and Muro-medrano, 2005).

Basic components that makeup SDI are policies and standards, technology, human resources, inter-institutional cooperation, geodatabases and metadata, data network (Coleman and Nebert, 1998).

SDI should be built on the basis of technologies that provide sustainable management of spatial data through the basic functions of their acquisition, storage, analysis, presentation, and distribution. The policy should be developed based on the basic standards that enable better coordination and communication between stakeholders. The development of SDI should be done on the basis of user requests, and qualified persons should do its maintenance. Inter-institutional coordination and cooperation is a very important component of SDI, because it helps national institutions in better management of geospatial phenomena, and it helps interstate cooperation for such purposes. Geospatial data as part of the SDI should include as many geospatial features as possible within a state, and this data should contain metadata as a basic part of the SDI. In addition, this data should be part of open networks, where it should be accessed remotely and through web services.

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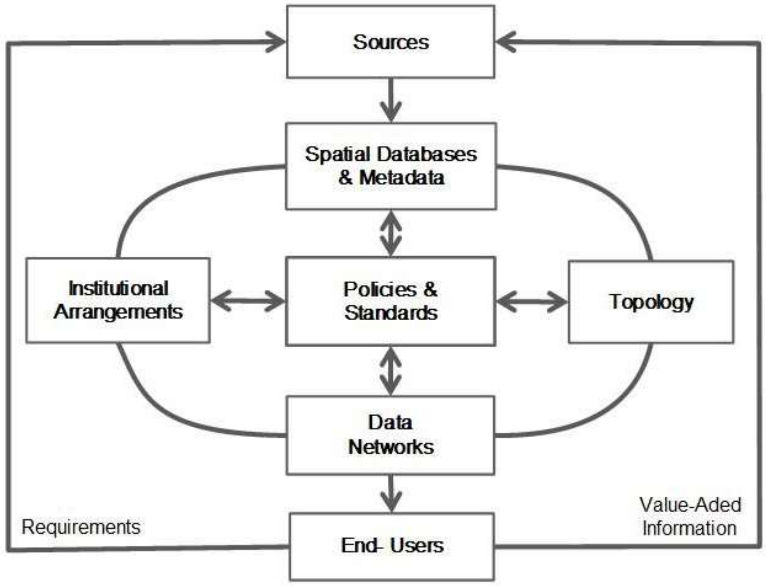

Figure 4.7 SDI components (source: Coleman and Nebert, 1998)

Most of the spatial data related to the administration and monitoring of agricultural land in Kosovo, as it will be described in the fifth chapter, are not collected, stored, and managed in a structured way. Consequently, they are not available for use for other purposes. Spatial data can be collected at once and in case they are stored and structured properly, they can be used in the future by other users and for multiple purposes. Therefore, such a situation may have the following consequences (http://www.kca-ks.org):

- It affects the increase of cost and decrease of efficiency in the management of different spatial phenomena by public institutions because data for the same feature can be collected more than once.
- It prevents the use and integration of geospatial information in decision-making and policy development for specific sectors.
- It prevents the initiatives of institutions to improve services for citizens. For example, the lack of a proper spatial data infrastructure prevents central institutions from publishing spatial data on the agricultural land consolidation initiative in a specific region.
- It creates difficulties for citizens to be properly informed about the processes involving geospatial information and hinders its participation in contributing to geospatial problems' overall development. For example, failure to disseminate land use planning data to relevant locations makes it impossible for citizens to be informed about using their property or a potential property that may be part of a sale agreement.

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4.3.4 Analysis of existing spatial analytical tools for decision support

Principally, geospatial analytical methods are used in land management to collect, store, retrieve, manipulate, analyze, and present geographically referenced data to support the decision-making process. In recent years, some state and local institutions in Kosovo are trying to impose GIS in several application areas. But, so far, GIS has been used without any national strategy.

A questionnaire is conducted to better understand the situation of application of analytical tools within the MoA, namely geospatial information management systems. The following conclusions achieved from this questionnaire are as follows:

1. There is no sustainable consolidated division that uses spatial tools for managing information related to the general management of agricultural land. Consequently, there is a lack of professional capacities and resources in using analytical tools.
2. There is no spatial information system that helps monitor agricultural land use, namely the possible change of its use for other purposes and the risk from erosion and pollution.
3. There is no spatial information system in place that helps monitor and plan the irrigated areas and the agriculture land consolidation data and process.
4. There is no Web-based platform that enables the spatial distribution of information related to agricultural land areas.

The level of application of GIS analytical tools is also analyzed. Site visits were completed in two municipalities at the DoA and DoSP. As a result, the following issues have been identified:

- ✓ None of the departments are using GIS tools regarding the agricultural land conversion process.
- ✓ The submitted documents are checked only textually, while spatial analysis is not considered.
- ✓ When applications are submitted, they are examined locally in each of the departments.
- ✓ The final decisions are saved locally and archived only within the archiving office for the municipal administration.
- ✓ Some kinds of excel registers are created, but they are not standardized from the designing, saving, and security perspective.
- ✓ There is no activity supported by geospatial functions regarding the monitoring of soil erosion risk
- ✓ There is no activity supported by geospatial functions regarding soil pollution monitoring.

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Generally, there is no defined means to identify and resolve technical and institutional barriers to successful GIS deployment and to plan for technical, staffing, organizational development, and the resources necessary to apply GIS effectively. Currently, there is no local-government-wide strategy for developing, organizing, managing and sharing spatial data. Kosovo municipalities depend on data to provide services to the community. What essentially remains is a road map to guide the organization to a successful implementation of GIS as an efficient supporting tool.

Municipalities are using GIS applications to support the work of individual departments. They are not using them as a unified system, which integrates most of the major services related to agricultural land administration, spatial planning, etc., and provides commercial and residential customers with improved customer service via a map-based interface on the Municipal website. Furthermore, it has been obvious that there is no unique level of using GIS in the visited municipalities. Principally they are using ArcGIS to check, identify, and in some cases to modify urban plans in a simple way. There is a lack of information in open-source GIS applications. None of the municipalities have a standardized geodatabase. There is not sufficient information about the elementary operations such as geo-referencing, digitizing, mapping, and data exchange formats. Nevertheless, there is a vast interest in interoperability between departments based on GIS integrated systems.

Based on the findings above, the shortcomings of the institutions in the perspective of the application of spatial analytical tools in the management of information are also analyzed. Therefore, in principle, it is concluded that the application of spatial analytical tools for information management within the ministry is at a low level. In fact, this has served as an additional motivation to conduct the research.

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Chapter 5

5 Conceptual modeling of geospatial information system for agricultural land use administration and monitoring in Kosovo

When structured or ill-structured interdisciplinary spatial problems are faced, in many cases the experience shows that individual actors do not address them. This is mostly true when such problems need to be solved by the public sector, where they normally have the policy component (Armstrong and Denshman, 1995). Additional factors are equally important and should be considered, for example, specific laws, the organizational structure, specific strategies, etc. These make it more difficult to identify an existing geospatial information system that meets such requirements.

Principally, a geospatial information system is a computerized environment whereby utility programs perform specific functions used in an integrated environment, in which the user is shielded from the details of computer processing in order to achieve some goal for decision-making (Laurini and Thomson, 1992). The inherent form of geospatial data representation and organization must be designed to support effectively and efficiently the kinds of query and analysis required by many users.

Geospatial information systems are capable of helping all levels of planning and decision-making processes related to agriculture land monitoring. By applying such methodologies, principally, we are able to closely monitor natural phenomena and the human impact on them. This is achieved by storing data of these phenomena in a digital format on a relevant geodatabase. Information obtained from the data analysis process will help to understand the spatial and non-spatial relationships of the relevant features (Vibhute and Gawali, 2013).

Principally, several software technologies can be applied while solving spatial problems, starting from GIS software, which can be based on open source or commercial platforms. CAD solutions can also be used; even though they do not support the side of spatial analysis capabilities, recently developed software started to include that capability too. Hence, the current systems do not offer enough flexibility to allow new users to adapt them to solve their problems. There are unique cases where the existing software from any of the technologies cannot support the solution of a spatial problem - the solution to the problem as a whole, not partially. For example, a GIS desktop software can partially manage the problem of agricultural land use and land redesignation. It can be used for data collection, saving,

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analyzing, displaying processes from any of the departments at the state or local level. Yet, a GIS desktop software lacks some capabilities; for example, it cannot integrate all the users working on different scales and from various locations.

5.1 Conceptual model of the system

According to the analysis and need assessments as presented in Chapter 4, the responsible institutions do not use any geospatial information system. In fact, such systems must be used by MoA and all municipalities in Kosovo to effectively and efficiently manage information related to the processes of agriculture land administration, i.e., land use redesignation, land use planning, other natural-related phenomena such as monitoring the erosion risk and land pollution. Therefore, the system which is modeled conceptually further in this chapter will reflect and accommodate the requirements of the users of those institutions related to the processes mentioned above (figure 5.1). Active users must be from central and local institutions. A limited public access is important as well.

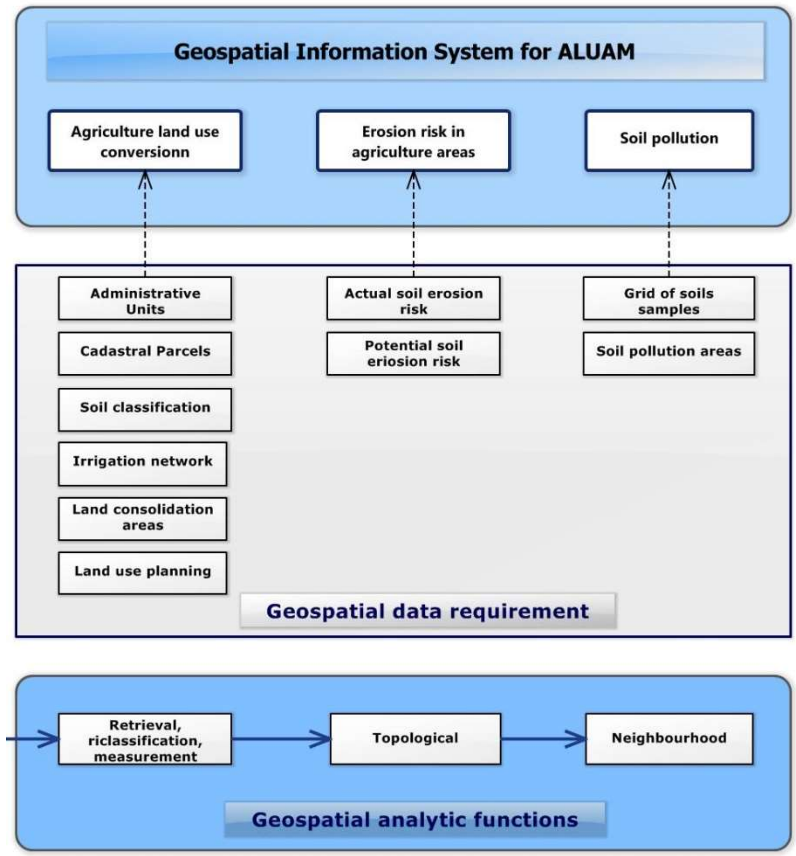

Figure 5.1 Conceptual design of the geospatial information system

The system must provide functionalities to administer and monitor the processes related to:

1) Agricultural land use redesignation
2) Actual and potential of erosion risk in agricultural areas
3) Soil pollution from different factors in agricultural areas

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5.1.1 Agricultural land use redesignation

As explained in Chapter 4, the process of monitoring the agricultural land use redesignation is quite unique. Issues related to this problem are difficult to solve by applying any existing GIS-based systems. The redesignation of agricultural land into construction land is one of the common cases, especially in a country like Kosovo, where the development of residential areas and other infrastructure is high. For example, figure 5.2 shows a case of redesignation of agricultural land into construction for a new residential zone. It is important that such cases of redesignation of agricultural land to construction are done through a well-managed and monitored process and follow the relevant land use plans.

Figure 5.2 A case of the agricultural land conversion to residential and commercial areas

Redesignation of agricultural land may be interim or permanent (law on agriculture land):

a) Any change of designation done for the construction of domiciles, industrial plants, railways, road communication, water reservoirs, airports, various installation lines, or other facilities which permanently unable utilization of agricultural land for agricultural production is considered as permanent redesignation of agricultural land.
b) Facilities of interim character, use of surface minerals, waste disposal, industrial ashes and waste of wood industry are considered as interim change of designation of agricultural land. Agricultural land may be used again for agricultural production after a certain period of time.

From an operational perspective, the system must enable receipt of applications from the landowners, including documents that need to be attached, which are necessary according to the AI for redesignation of agriculture land use. Figure 5.3 shows the workflow process of changing the designation of land use according to the law and the AI.

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The land parcel as part of the application must be identified by selecting or digitizing it, and after can be exported as a sketch in an appropriate digital format, i.e. pdf. The respective departments within each municipality will have access rights in the system. They will be able to identify all of the applications from the landowners for the redesignation of agricultural land.

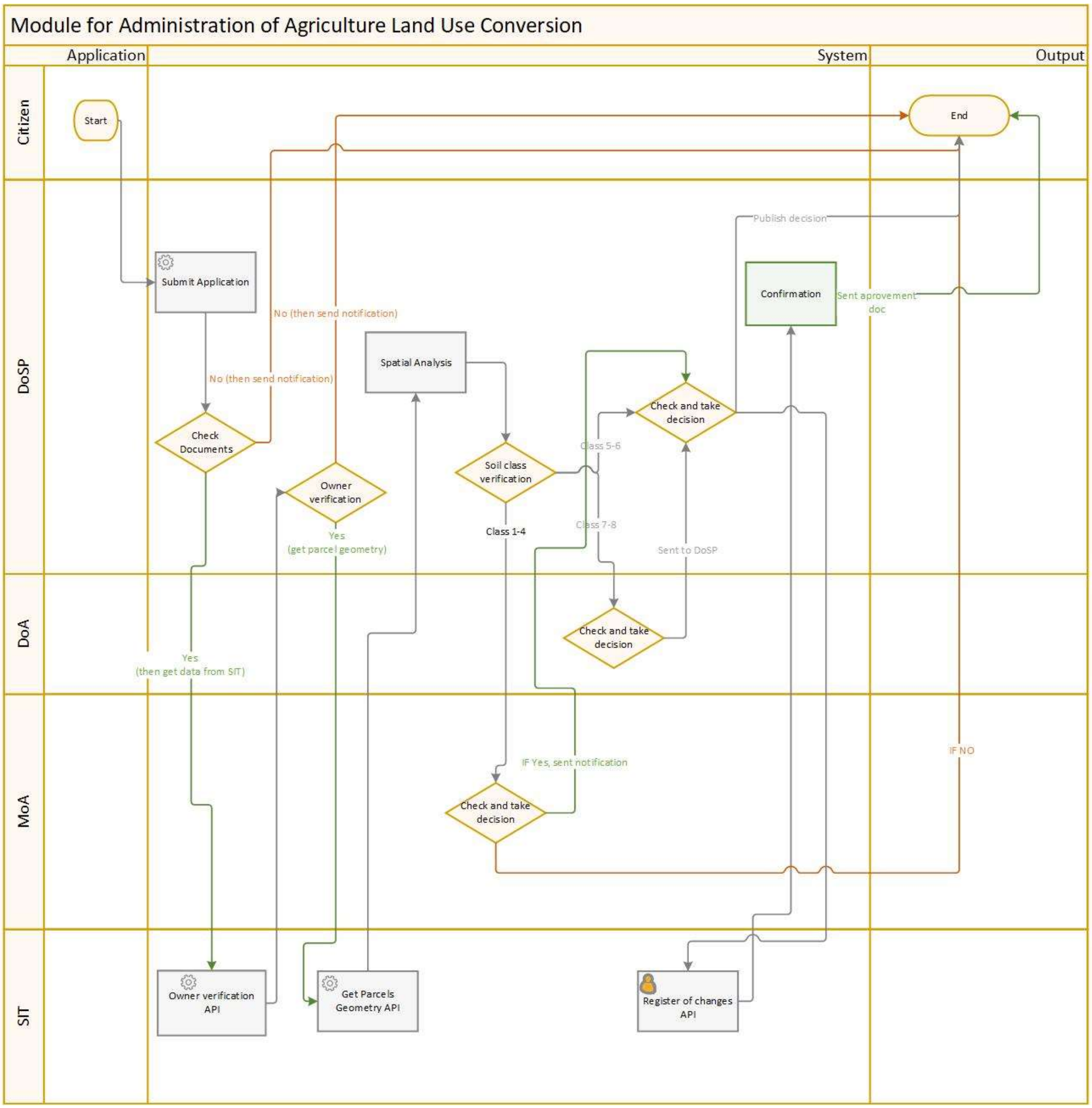

Figure 5.3 Workflow of the decision-making process for land conversion requirements

Moreover, they will be able to communicate among themselves to control the application and follow the procedure until the final decision for approving or rejecting it. In some other instances, they will be able

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to communicate with the respective department in the MoA. The officials of such departments will have the right to control the applications and give the answers back to the municipality. Such system capabilities will improve the communication between all potential users of the system, at the same time will save time and increase the efficiency in the respective institutions. The applicants will have the right to check their applications and see the progress. Also, municipalities will be able to see all applications, approvals, rejections, etc., in real-time.

In addition, monitoring is also important from a strategic perspective, where e.g., MoA and municipal institutions in certain periods of time are able to analyze the existing areas of agricultural land, redesignated areas, their locations, and plan in the long term how to use them. As a result, more accurate monitoring of agricultural land use will be done.

5.1.2 Actual and potential erosion risk

Soil degradation comes as a result of several factors. Erosion, as one of the main factors of degradation, causes physical loss of soil and removal of nutrients from it (figure 5.4). The removal of elements is one of the main risks to soil pollution. In such cases, regardless of the shape of the soil's topographical surface, erosion significantly reduces the soil's stability and fertility. This phenomenon in the lowlands is a serious threat to surface and groundwater pollution, as it directly affects the physical and chemical degradation of the soil. Therefore it is important that public institutions properly address such a natural phenomenon. Also, the aim is to reduce the human impact on soil erosion risk. From this perspective, the system will support the central institutions to make decisions based mainly on the law, including appropriate measures to protect agricultural land from erosion.

Figure 5.4 Soil erosion (source: https://www.eurekalert.org)

The current erosion map and potential erosion risk map on agricultural land areas will be a separate spatial layer fully integrated in the geodatabase. The creation of such maps requires an extensive workflow and application of the relevant spatial analysis functions. This will be further elaborated in section 5.5.2. The main goal of utilizing such maps is to spatially identify and present the protected agricultural land areas that could be at risk of erosion. This approach will support the institutions to monitor the human impact on soil erosion risk in agricultural land areas.

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At the same time, it is very important that the system is accessible to the public through web services and that decisions on land protection are illustrated with relevant maps. In this case, the interested farmers can view the agricultural areas and their spatial extent that may eventually be part of the agro-technical measures. For example, they can view restricted or prohibited areas for woodcutting, restricted areas for pastures, restricted cultivation of meadows, pastures, and other sloping surfaces.

5.1.3 Soil pollution

Another critical factor that affects the degradation of agricultural land is its pollution. Soil pollution occurs due to human activities, either directly or indirectly. Among other things, such activities relate to the following issues:

- ✓ Industrial (e.g., heavy metals impact) and
- ✓ Excessive use of the pesticides, herbicides and fertilizers.

Industries are by far the worst polluters of the soil with all the chemicals they release into the environment, be it in liquid or solid form. The increased demand for food has forced farmers to use fertilizers and pesticides that release toxins into the soil, killing useful microorganisms that are important in plant growth (https://www.permaculturenews.org).

The central and local institutions are responsible for continuous monitoring of pollution of agricultural areas in Kosovo. After active monitoring, they can take specific measures to prevent contamination of agricultural land by relevant factors whenever required. In these cases, the central institutions may decide on the prohibition or restriction of certain agricultural products and the use of plant protection and other means in certain areas. The map that reflects the areas indicating its pollution is further analyzed in relation to other spatial layers, e.g., cadastral parcels can accurately represent the boundaries of potentially polluted lands and inform landowners about their condition.

The application of geospatial solutions can significantly support decision-making based on geospatial analysis. For example, when for certain land areas determinant elements indicate the level of soil pollution, and further through spatial interpolation methods, we reflect the results in maps for the respective area (Balamurugan, Duraisami and Stalin, 2014). If from such an analysis the areas in which the level of pollution is high are identified, decontamination is required to continue the agricultural activity. The results for eventual areas identified at a high level of pollution can be published through web services and be accessible as a view to all stakeholders, including landowners.

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5.2 Main goals and objectives

The main goals of this geospatial information system are the following:

1. To help the central and local institutions to implement and monitor agriculture land redesignation.
2. Support the decision-making process to issues of agricultural land use redesignation, aiming to reduce human impact on this process.
3. Help for sustainable development of the agriculture sector by improving the capabilities to protect the agricultural land from degradation.

Also, the system should meet the following objectives:

1. Integrate all necessary spatial data related to the process of agricultural land use redesignation, erosion risk, and soil pollution.
2. Provide geospatial analytical functions to edit, analyze, and map the spatial data. This will help the institutions to improve data analyses and use data more efficiently.
3. Interoperate with other existing systems and other spatial data sources.
4. Be accessible to three levels of the users located in different places. These users are from local and state institutions, as well as the public to view the maps and other information shared through the web.
5. Improve the communication between users.
6. Enhance the transparency of the institutions. This means that certain departments in local and state government will have accurate information regarding the agricultural land areas such as its redesignation, and such information will be published online.

5.3 The fundamental components

In order to provide a solution to the above-mentioned issues, the geospatial information system should consist of the three fundamental components (figure 5.5): 1) data integration and manipulation, 2) analysis and 3) visualization of the results (Daras, Agard and Penz, 2019).

1) Data integration is one of the main capabilities of any spatial information system. Regardless of their format, it is important to integrate such data formats in a unified geodatabase. Data manipulation is another important segment of the data integration process. This may involve converting a certain data format to another one that may fit the purpose of their application. For

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example, transformations the data based on reference systems, the conversion among spatial data formats (raster to vector or vice versa) etc.

2) Since the system is modeled to manage spatial data and support the decision-making process related to them, it is essential that analytical functions are an integral part of the system. This capability enables the system to provide analyses of spatial data according to their spatial relationships. For example, let analyze the feature of agriculture parcels with land consolidated areas, or with irrigated areas, or with planned urban areas in municipal development plans etc.
3) The visualization of spatial data and map creation is significant while handling spatial information. Such capabilities allow the users to present data on maps and share them with each other. The visualization part makes the information easily understandable for non-professional users as well.

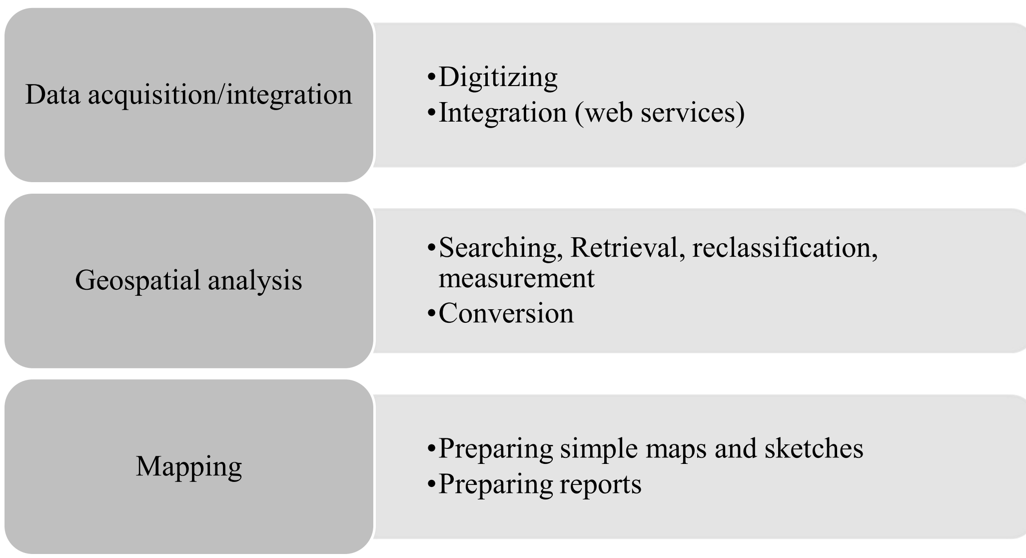

Figure 5.5 The fundamental components

5.4 Geospatial data requirements

Geospatial data modeling enable to represent and connect the real spatial phenomena (explained in chapter 4 and in section 5.1). In fact, data are among the most important components that make up a geospatial information system. The very purpose of building such a system and the success of its application depends on the selection, collection, preparation and analysis of data. Data is important almost in all phases of planning, developing, and implementing a geospatial information system. In the planning stage, it is important to plan for the requirements in the implementation and their possible sources. In the developing phase, data are collected and becomes part of a geodatabase which is managed with specific functions through analysis and their presentation in graphic form, tables, reports, diagrams, etc. And finally, they will serve for needed information in the decision-making process, which derives from the spatial and non-spatial presentation of data in the mentioned formats. However, due to the dynamic changes of some data they can not all be integrated in a unified geodatabase, for example the ownership of land parcels. For such reasons they can be integrated in the system by using API, which enable the integration of cadastral data while reviewing the application.

5.4.1 Conceptual data model

A geospatial data model is an abstraction of the real world that employs a set of data objects that support map display, query, editing, and analysis (Zeiler, 1999). In the initial period of using computer systems for cartographic representation, spatial data was stored in binary file formats to represent points, lines, and polygons. The attributes of these data were mainly presented on the map through specific layers in textual form. This was done until the late 1970s. In the 1980s ESRI developed the first GIS software, ArcInfo, which provided a combination of spatial data with textual data that was stored in tables. At the end of the 90s, the possibility of modeling data in geodatabases was introduced, where based on the real relations of spatial phenomena, modeling of the connections of features between them is enabled.

The conceptual model of the data is realized in the initial stage of the design of the geodatabase by specifying the data and the type which will be stored. Identification and description of data is specifically concerned with the definition of entities, the relationships between them, and their attributes. The purpose of the conceptual data model is the clear and detailed preparation of the data that will become part of the geodatabase. This is achieved when: 1) it is understandable to the intended users of the system, and 2) it is sufficiently structured so software developers can implement the data operation process properly (Calkins, 1996).

Data stored in rows of the tables represents an independent record, and each column represents its corresponding attribute. Each record has a unique identifier, data type, and data size (Bello-Dambatta, 2010). The entities which will be used in the geodatabase are presented in table 5.1.

It is necessary to divide the data into: 1) Base data (digital base maps); and 2) Operational features. 1) Base data is also selected based on the system it will be used. In this case the base data can be satellite images, orthophotos, DEM, state or municipal administrative boundaries and cadastral zones. Such data are static because the dynamics of change, in reality, is very slow (https://enterprise.arcgis.com). For example, administrative boundaries can only be updated after long periods of time, orthophotos within two or more years. 2) Operational data are mainly data that we use directly to generate the analysis results through the relevant function. Such layers can mainly be accessed in this form by professional and authorized users of the system. For example, to prove the ownership of the applicant during the process of changing the designation of the land, the access is granted only by a user authorized by the DoSP. Also, the layers resulting from the analytical models which can further be added as new layers and used for interpretation by users. For example, if we analyze a cadastral parcel if it intersects the irrigated land areas, and the agriculture land areas of class 1 to 4, as a result a new layer will be created.

Table 5.1 Entities with its attributes, type and description

Entity	Attributes	Geometry type	Type	Description
State administrative boundary	st_name	Polygon	Base map	Represents the administrative border of the state
Municipal administrative boundary	st_name, mu_name	Polygon	Base map	Represents the administrative boundary of the municipality
Cadastral zone administrative boundary	mu_name, cz_name	Polygon	Base map	Represents the administrative boundary of the cadastral zone
Orthoimages		Raster	Base map	Represents aerial images for the whole country area
Cadastral parcels for the entire territory of country	mu_name, cz_name, parc_number, owner	Polygon	Operational feature	Preserves parcels that are part of the cadastral register. This feature can be part of the system through the service provided as wms or wfs.
Land classification	class_type	Polygon or raster	Operational feature	Preserves the types of land classes at the level of cadastral parcels
Agricultural land irrigation system network	name	Line	Operational feature	Represents the network of the irrigation system.
Agricultural land under consolidation	mu_name, cz_name,	Polygon	Operational feature	Represents the areas of agricultural land under

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(unfinished)	parc_number, owner, class, lc_status			consolidation, which are totally completed and are registered in the cadastral register
Agricultural land in the process of land consolidation	mu_name, cz_name, lc_status	Polygon	Operational feature	Represents the areas of agricultural lands which are in the process of land consolidation, i.e, processes that may be ongoing
Land use planning	urban, extended urban areas	Polygon or raster	Operational feature	Represents the area of the current settlements and the areas planned for the expansion of settlements.
Areas according to the level of pollution of agricultural land	sp_code; sp_description	Polygon	Operational feature	Represents areas that indicate the level of pollution of agricultural lands
Actual erosion risk map	era_code, era_description	Polygon or raster	Operational feature	Represents areas that indicate the level of risk of current erosion
Potential erosion risk map	erp_code, erp_description	Polygon or raster	Operational feature	Represents areas that indicate the level of risk of potential erosion

Within the geodatabase, there will be internal data and data which are integrated from other sources, such as layers that are part of other spatial information management systems, and as such are available for use as web services. For example, the layers of administrative boundaries are static data and are part of the state geoportal of Kosovo. As such, based on OGC standards, they can be utilized and become an integral part of the system. Other layers that are not provided as web services must be part of the internal geodatabase.

Based on the necessary data presented in table 5.1, the conceptual model of the database in the form of a diagram would be as follows:

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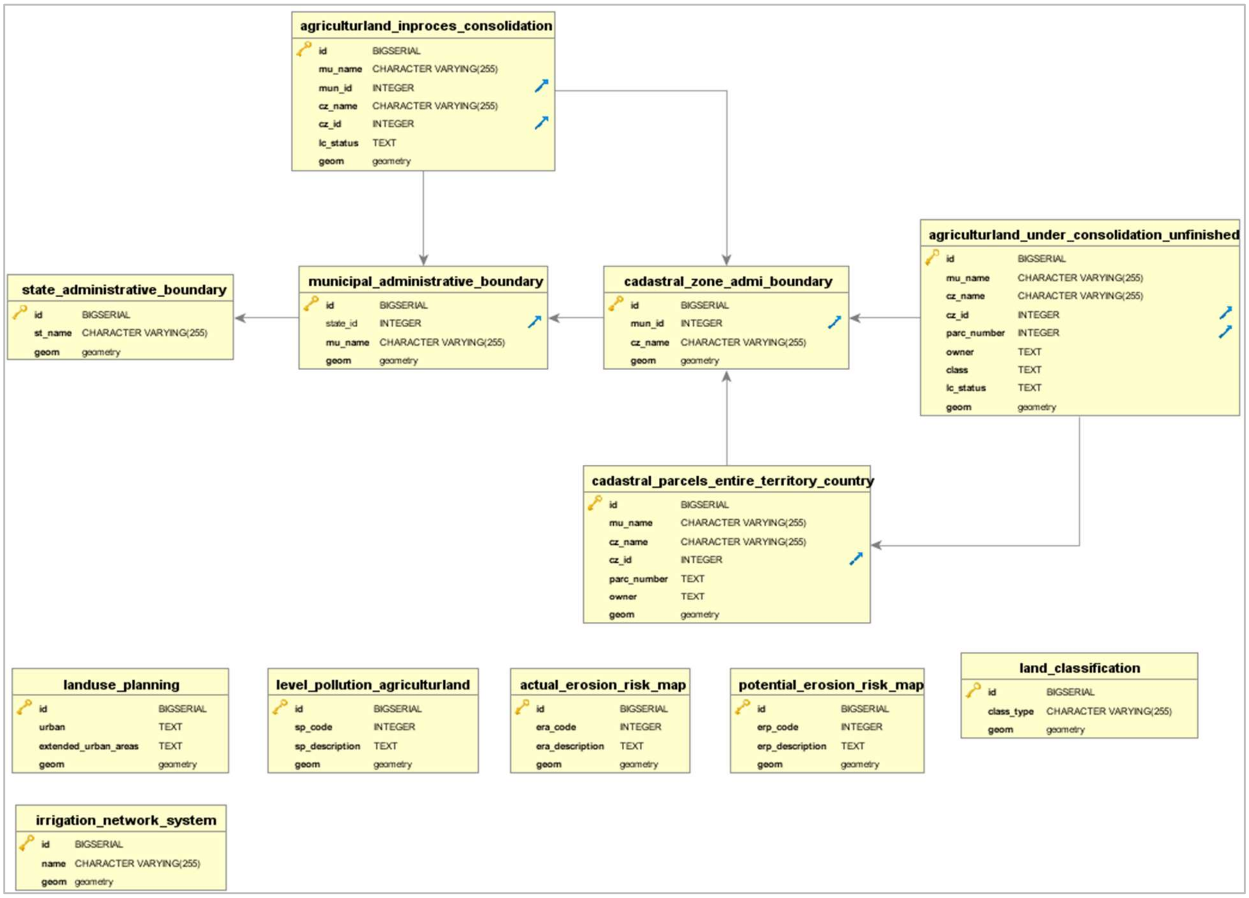

Figure 5.6 A conceptual geodatabase model

5.4.2 Data acquisition approach

There are two basic methods of how spatial data can be integrated into a geodatabase:

1) Capture, and
2) Transfer

Spatial data capture for both models, vector and raster, are classified according to an initial resource allocation, as: 1) primary source and 2) secondary source. When referring to the raster model, their primary source is digital satellite remote-sensing images and digital aerial photographs, while secondary sources are scanned maps and DEM generated by topographic maps. In the vector model, the primary source refers to direct field measurements via GPS or other traditional methods, while the secondary sources are topographic maps or other types and toponymy databases.

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Spatial data collection is carried out following a specific work process, which goes through several stages, such as (figure 5.7): 1) planning, 2) preparation, 3) digitization/transfer, 4) editing, 5) control or evaluation (Fazal, 2008). The planning phase includes the analysis of the user requirements, the necessary resources, including the relevant persons, equipment, and technologies to be used during the collection phase.

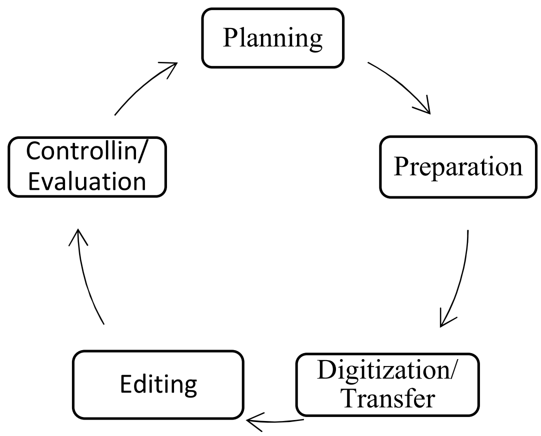

Figure 5.7 Stages in the data collection process

Preparation is about improving the baseline data that can be used during collection, e.g., maps. Digitization is often among the phases where most of the time is spent compared to other phases, and this point also includes transferring data that may be from existing sources. The editing phase refers to the validation of data, i.e., the correction of eventual errors in order to increase the quality. Evaluation as a final stage refers to the process of identifying achievements or failures during all the preliminary stages of spatial data collection.

In addition to the methods of directly capturing spatial data, one of the most frequently applied methods is that of transfer. Transfer implies specific features that may be part of any other existing system. This can be achieved through web services, as explained in section 5.7.2.

5.4.3 Data sources

Referring to the data specified in table 5.1, a search and analysis of their possible source was made. For the data identified, the existing sources, their condition, and the way of integrating or transferring to the geodatabase are elaborated. For data for which no existing source has been identified, the methodology of capture and integration in the geodatabase is described. Also, for all identified data, additional reasons are provided why they should be part of the geodatabase.

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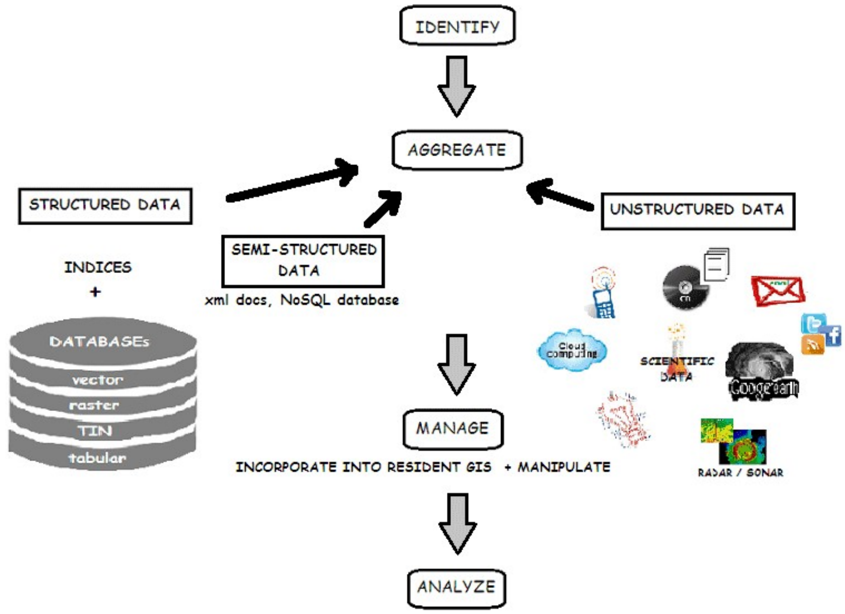

Figure 5.8 Several data sources (source: https://www.gislounge.com)

Geospatial data sources can be as (figure 5.8): 1) unstructured, 2) semi-structured and 3) structured. Unstructured refers to various sources such as those published on social networks or other online sources, stored within other documents locally, stored on disks such as CDs and in various formats, etc. Semi-structured such as xml documents, non-SQL databases, etc. And structured data, such as existing geodatabases with raster data, tabular, vector, TIN, etc.

State administrative borders, municipal cadastral zones and cadastral zones. These data derive from cadastral maps in Kosovo and are published in the state geoportal (http://geoportal.rks-gov.net/). Since this data in principle is static, it is sufficient to be integrated into the system from existing external sources, and it will be accessible for viewing. These features are not expected to be part of any necessary spatial analysis. In this case, these can be integrated into the system through web services like WMS.

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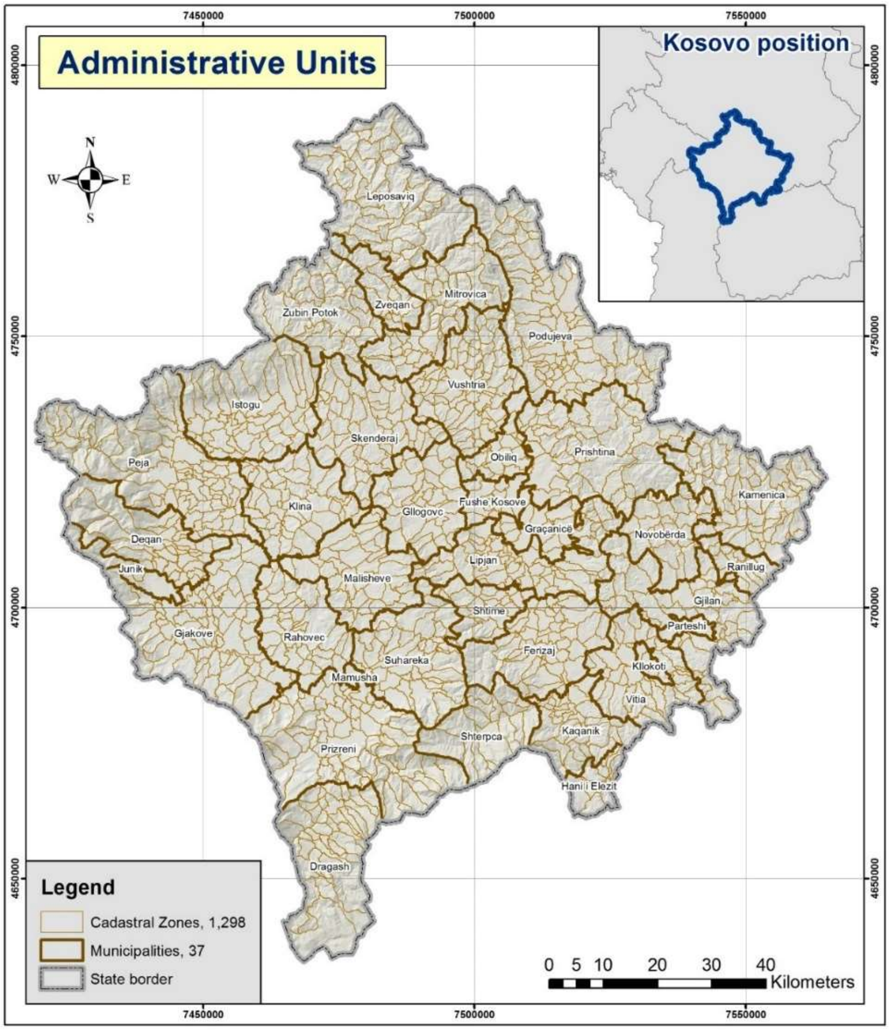

Figure 5.9 Administrative units of municipalities and cadastral zones in Kosovo

Cadastral parcels. Cadastral parcels are an essential part of the cadastral information system (CIS) in Kosovo. They are presented in the form of polygons that indicate the property boundaries of the respective owners. They contain attributes for ownership, land use, land class, area, etc. Their primary source has been cadastral maps on paper that were digitized and further modified through regular maintenance based on the requirements of the owners. The graphical part of the cadastral parcels is accessible for the public by state geoportal. For the administration of the redesignation of the agricultural land process, ownership information for the parcel is essential. The request for change and the decision for acceptance or rejection is mainly based on the condition of the cadastral parcel, in particular the land class and ownership. The proper way would be to integrate the cadastral parcels into the system. This can be achieved by developing a specific API, where users from the directorate of spatial planning will be able to view and analyse the cadastral parcels and their attributes (figure 5.10). When reviewing the

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requests for changing the destination of agricultural land, it is important to verify if the applicant/owner does not possess other plots that may be in non-agricultural use or even agricultural use but of the lower class.

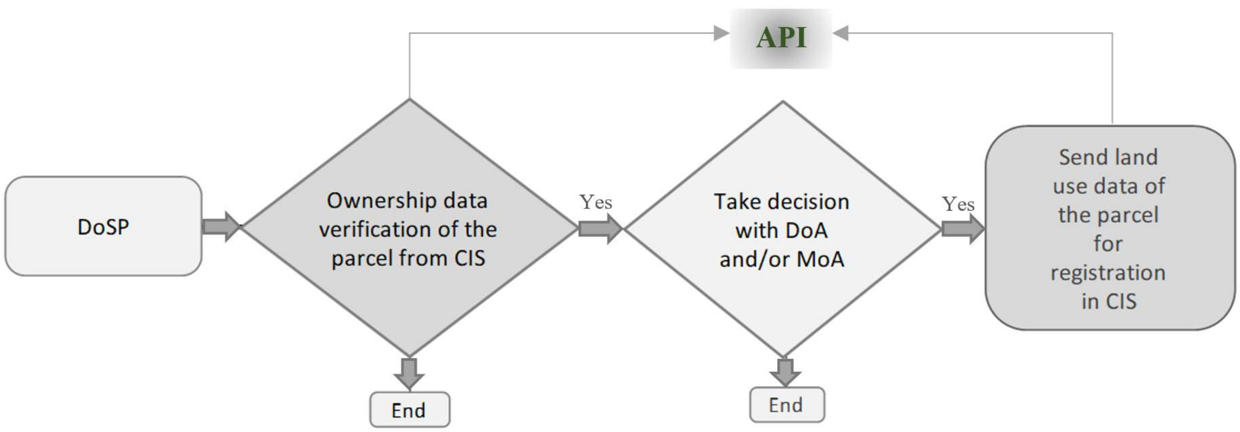

Figure 5.10 API for communication with CIS

After verifying the ownership data from CIS, DoSP with DoA and, depending on the land class, the MoA can decide. If the decision is positive, the changes can be sent through API for the final registration in CIS.

Soil map classification. In cadastral registers, the land use is indicated for each parcel, e.g. agricultural, its class is also shown, e.g. soil of class 4. The soil class, as cadastral data, was obtained at the time of collection of property data for the parcels. As such, this is found only as a descriptive attribute of the cadastral parcel in a register independent of the spatial boundaries of the parcel. There are also cases where a parcel within its spatial boundaries has more than one type of its use and class. As a result, problems for specific landowners can be different, such as when planning the use of such a parcel for construction purposes or even for agricultural purposes. The maintenance of cadastral data is not at a satisfactory level. Consequently, there are significant discrepancies with the real situation.

Given the situation explained above, the land suitability map should derive from a process of studying the physio-chemical properties of the soil, where samples taken from the field are analyzed in relevant laboratories and the results obtained are analyzed through geospatial functions until the final mapping. Moreover, once such a map has been created, it could, among other things, be used to define the soil classes within the boundaries of cadastral parcels.

The following geospatial data need to be analysed for developing the land suitability map:

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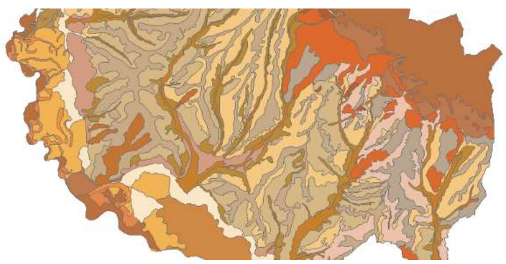
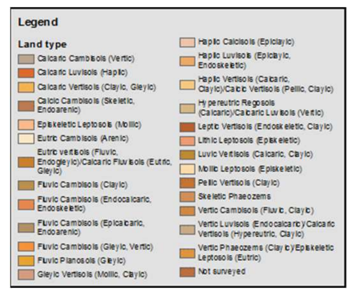
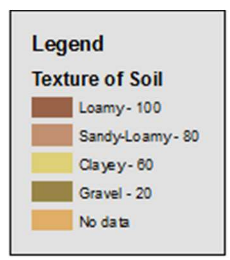
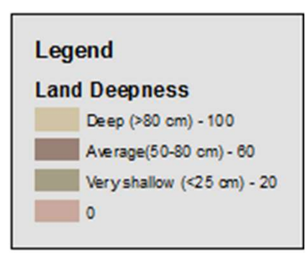
- Soil type;
- Soil texture;
- Depth of soil;
- Soil drainage;
- Slope;
- DEM;
- Average annual rainfall.

To prepare the soil suitability map are used some sample data for an area of 10200 hectare. Based on this, the geospatial data as presented in table 5.2 are used.

Table 5.2 Features needed to create a map of agricultural land classes

<table>
<tr><td>Feature</td><td>Figure (map)</td><td>Legend</td></tr>
<tr><td>Land type</td><td></td><td>
</td></tr>
<tr><td>Land texture</td><td></td><td>
</td></tr>
<tr><td>Deepness of land</td><td></td><td>
</td></tr>
</table>

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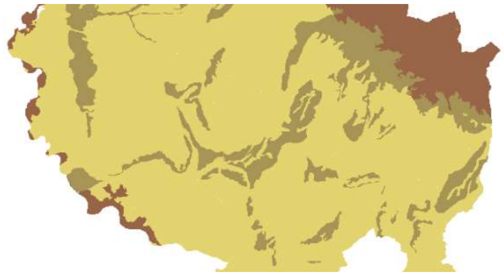
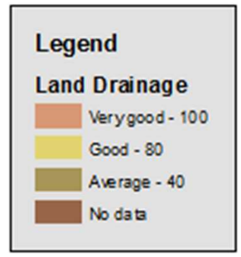
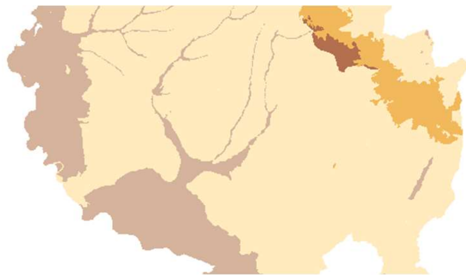
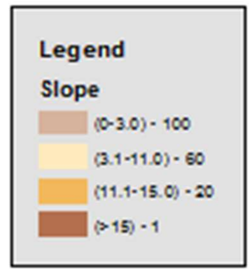
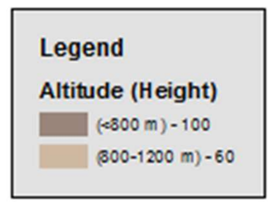
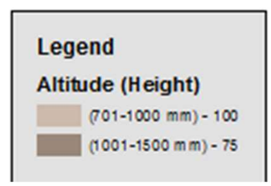
Drainage of land		
Slope		
Elevation		
Annual mid atmospheric rainfall		

The criteria for preparing this map are based on the technical requirements presented in the AI on the suitability of agricultural land in Kosovo. The following diagram describes the methods of classification of each of the features.

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Table 5.3 Workflow of land suitability analysis

No.	Land type
1	Cambisols
2	Luvisols
3	Vertisols
4	Leptosols
5	Planosols
6	Calcisols
7	Regosols
8	Phaeozems
9	Podzols
10	Fluvisols

No.	Classes of land texture
1	Gravel
2	Sand
3	Sandy – loamy
4	Loamy
5	Clayey

No.	Classes of Deepness of land
1	Very shallow (<25 cm)
2	Shallow (25-50 cm)
3	Average (50-80 cm)
4	Deep (>80 cm)

No.	Classes of and drainage
1	Low
2	Average
3	Good
4	Very good

No.	Classes of sloping (levels) [%]
1	0-3.0
2	3.1-11.0
3	11.1-15.0
4	>15

No.	Classes of height [m]
1	<800
2	800-1200
3	1201-1500
4	>1500

No.	Classes of rainfalls [mm]
1	500-700
2	701-1000
3	1001-1500
4	>1500

Classes SAL	Suitability of agricultural land
1	Very good
2	Good
3	Above average
4	Average
5	Under average
6	Weak
7	Very weak
8	Unsuitable

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After joining all the relevant layers and attributes, the values are calculated using the formula: SAL=A*Wa+B*Wb+C*Wc+D*Wd+E*We+F*Wf+G*Wg

- ✓ A = the points for the factor 'land type'
- ✓ B = the points for the factor 'land texture'
- ✓ C = the points for the factor 'land deepness'
- ✓ D = the points for the factor 'land drainage'
- ✓ E = the points for the factor 'sloping'
- ✓ F = the points for the factor 'height'
- ✓ G = the points for the factor 'mid annual atmospheric rainfalls'
- ✓ W[a..g] = coefficient of the value for every factor

The suitability classification is presented in the table 5.4 and the results are presented on map (figure 5.11).

Table 5.4 Suitability classification

No.	Factors	Code of factor	Coefficient of the assessment
1	Land type	A	0.45
2	Land texture	B	0.05
3	Deepness of land	C	0.1
4	Drainage of land	D	0.05
5	Sloping	E	0.25
6	Height	F	0.05
7	Annual mid atmospheric rainfalls	G	0.05

Table 5.5 Points of suitability classification

Classes SAL	Points	Suitability of agricultural land
1	85-100	Very good
2	76-85	Good
3	66-75	Above average
4	56-65	Average
5	46-55	Under average
6	36-45	Weak
7	1-35	Very weak
8	0	Unsuitable

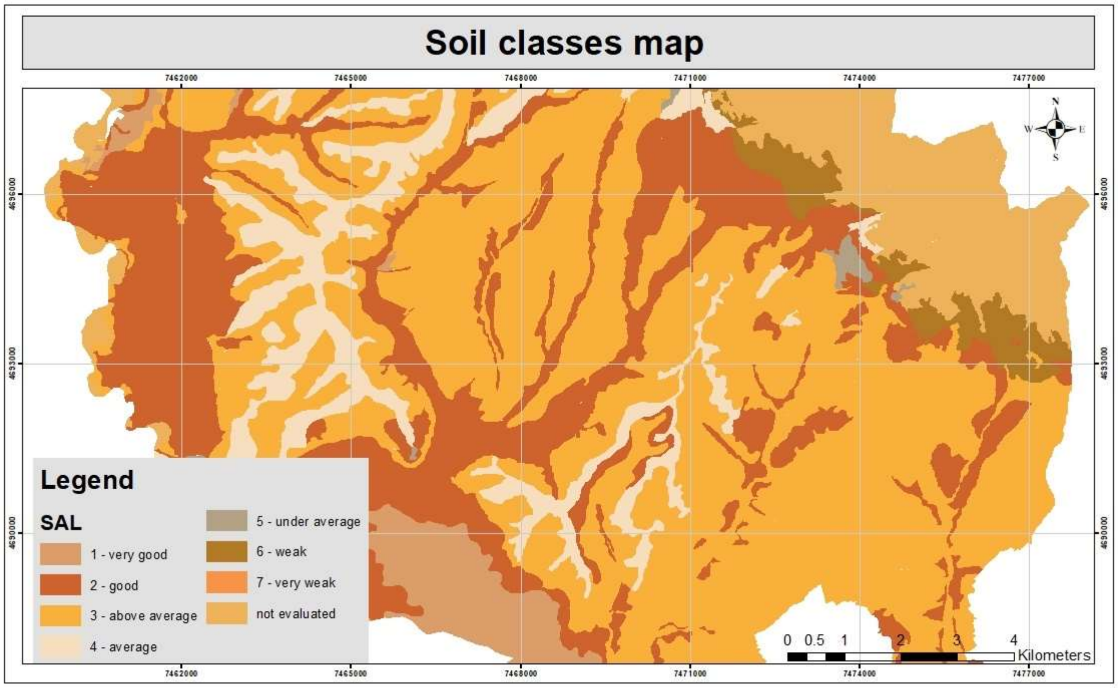
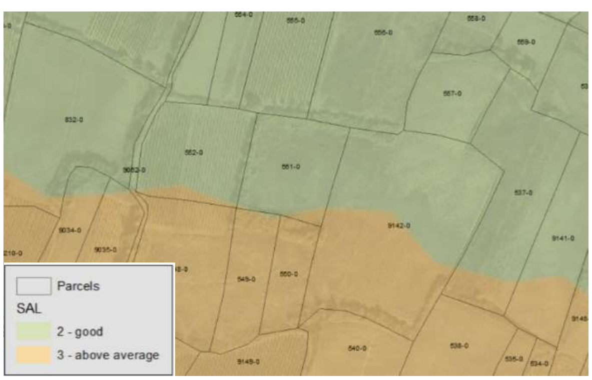


Figure 5.11 A map with soil classes

The map with the soil classes is integrated to cadastral parcel borders, and finally, the parcels have updated data for the soil classes (figure 5.12). As such, they will be used in case of agricultural land use redesignation.



No.	Municipality	Cadastral zone	No_zone	Land Use	Parcel_numbers	Soil Class
1	Rahovec	Bernjake	71510002	Arable land	71510006-520-0	2 - good
2	Rahovec	Bernjake	71510002	Arable land	71510006-886-0	2 - good
3	Rahovec	Bernjake	71510002	Arable land	71510006-523-0	2 - good
4	Rahovec	Bernjake	71510002	Arable land	71510006-525-0	3 - above average
5	Rahovec	Bernjake	71510002	Vineyard	71510006-557-0	2 - good
6	Rahovec	Bernjake	71510002	Vineyard	71510006-887-0	2 - good
7	Rahovec	Bernjake	71510002	Arable land	71510006-524-0	2 - good
8	Rahovec	Bernjake	71510002	Grasses	71510006-9097-0	2 - good
9	Rahovec	Bernjake	71510002	Grasses	71510006-515-0	3 - above average
10	Rahovec	Bernjake	71510002	Arable land	71510006-512-0	3 - above average
11	Rahovec	Bernjake	71510002	Arable land	71510006-492-0	3 - above average
12	Rahovec	Bernjake	71510002	Arable land	71510006-514-0	3 - above average
13	Rahovec	Bernjake	71510002	Arable land	71510006-516-1	3 - above average
14	Rahovec	Bernjake	71510002	Vineyard	71510006-516-1	2 - good
15	Rahovec	Bernjake	71510002	Arable land	71510006-513-0	2 - good
16	Rahovec	Bernjake	71510002	Vineyard	71510006-514-0	2 - good

Figure 5.12 Soil classes integrated with cadastral parcels

Irrigation network for agricultural land areas. The importance of including spatial features for the irrigation system network is different, as:

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- In the decision-making process for changing the designation of agricultural land. Agricultural land areas included in the irrigation system can not be redesignated for other purposes. This is according to the law on agricultural land.
- When planning the use of agricultural land, financial investments in the construction of water supply networks are costly; therefore, the areas which are currently under the irrigation system should be excluded from being used for purposes other than agriculture.
- During the analysis of potential agricultural land areas for constructing new network of irrigation systems. In such a case, by applying the relevant criteria and functions of geospatial analysis, a map will be prepared that reflects the potential areas in question.

Currently, the irrigation system in Kosovo is administered by the central public enterprises: The Public Enterprise "Hidrosistemi Iber Lepenc" and two companies for Regional Irrigation: "Drini i Bardhe" and "Radoniqi-Dukagjini" (https://www.ammk-rks.net). About 10% of the total agricultural land area is covered by the irrigation system.

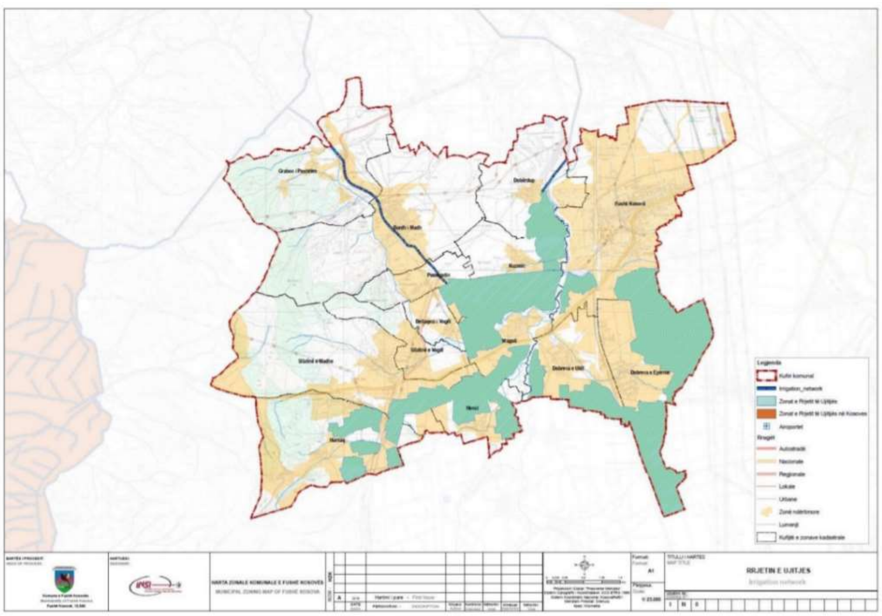

Figure 5.13 Map indicating irrigation areas (source: zonal map of Fushe Kosove)

There is no open-source system which can provide access by web services, except that it can be found in spatial planning related documents when presented on a map in pdf format (figure 5.13).

The state geoportal does not provide information on the network of the irrigation system of agricultural lands, and also none of the responsible institutions has ever published the data in this topic. Based on the

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purpose and importance of integrating this feature into the geodatabase, this could be as data transferred from external sources or internally integrated into the geodatabase. Since there are currently no other platforms that provide existing data for this feature, the only way it remains is to collect all existing documentation (maps, sketches) that represent the network of the irrigation system at the country level. This documentation must undergo through the step of processing and evaluation. Processing means digitizing data (when it is in paper format) and converting (when it is in digital format). Evaluation means controlling the quality of data. The data must also be accompanied by specific attributes which textually describe the state of the feature. So, to be integrated into the geodatabase, the feature for the irrigation system network must exactly present the current state of this geospatial feature. This approach is followed in building the map, as shown in figure 5.14.

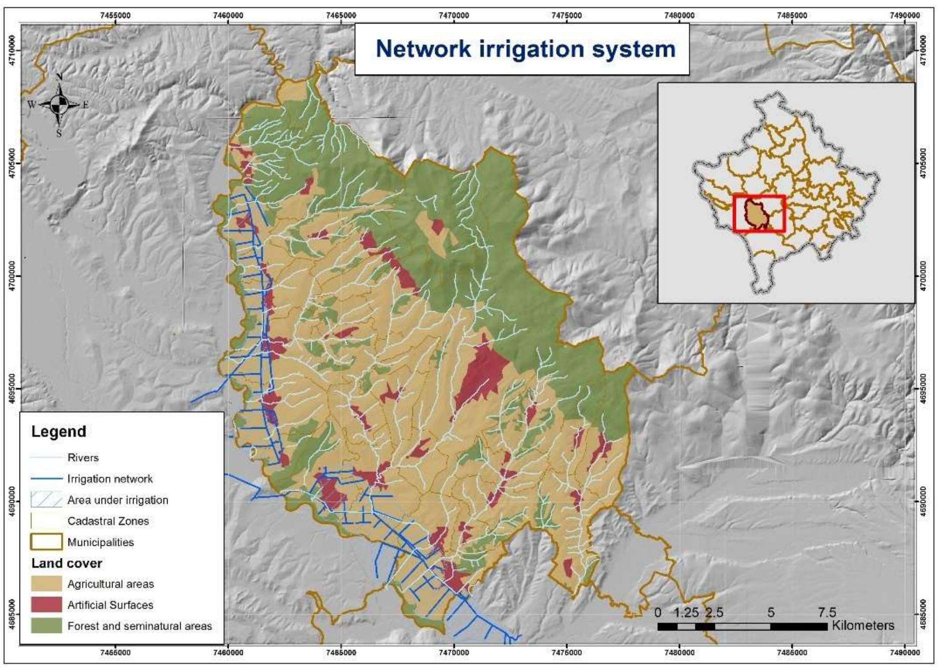

Figure 5.14 Irrigation system network in Rahovec

Agricultural land under consolidation. The implementation of land consolidation projects in Kosovo started in 1980, but it has not been completed as a whole process yet for many reasons. From today's perspective, this process is called unfinished land consolidation. If we refer to the Law on Land Regulation in Kosovo, two main approaches exist regarding the land consolidation projects: unfinished land consolidation and voluntary land consolidation. The unfinished land consolidation is called as such for the following reasons: 1) all legal administrative procedures have not been resolved against farmers' community claims and complaints; 2) only a few cases are registered in the cadastral registers and maps. Also, a voluntary approach to land consolidation could be applied for initiatives of new projects.

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Since the data of unfinished land consolidation are almost digitized but not registered, it is essential to include them in the geodatabase for two reasons: 1) to analyze whether the parcel is part of the data from the unfinished land consolidation during the process of changing the designation of agricultural land, and 2) such areas may be excluded from the planning for non-agricultural use during the land use planning process. Also, while implementing new land consolidation projects, the land consolidation project area must be defined in the system to prevent new requirements for land conversion. Such cases must not happen since the participants in the land consolidation projects must be informed that any land redesignation is not allowed. Anyway, this is an additional preventive measure since the land consolidation projects can take a long time to finish.

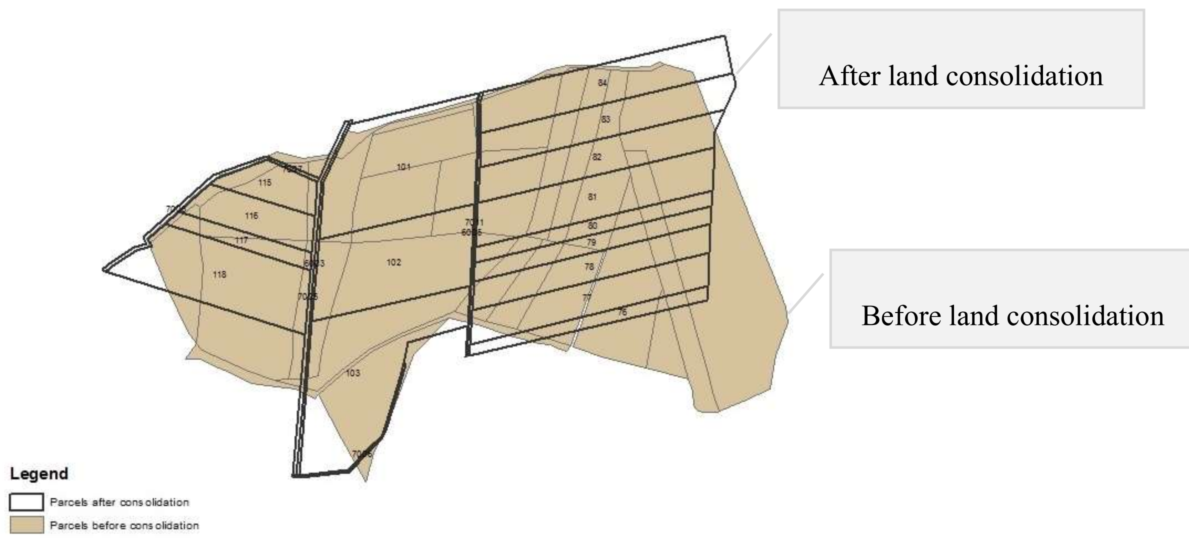

Figure 5.15 Cadastral parcels in the state before and after consolidation

Figure 5.15 presents a situation of the parcels before land consolidation, which in cases of unfinished land consolidation projects are officially registered in the cadastre system. The regulated parcels in black are not registered yet.

Land use plans. There are two levels of spatial planning in Kosovo:

- ✓ Spatial planning at the national level, such as:
  - Kosovo spatial plan;
  - Zonal map of Kosovo; and
  - Spatial plans for special zones.
- ✓ Spatial planning at the local level, such as:
  - Municipal development plan

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- Municipal zonal map and,
- Detailed regulatory plans.

During the drafting of land use plans, several features need to be considered, among others, agricultural land areas and their features, such as soil classification, areas under consolidation or in process, and land areas under irrigation system, etc.

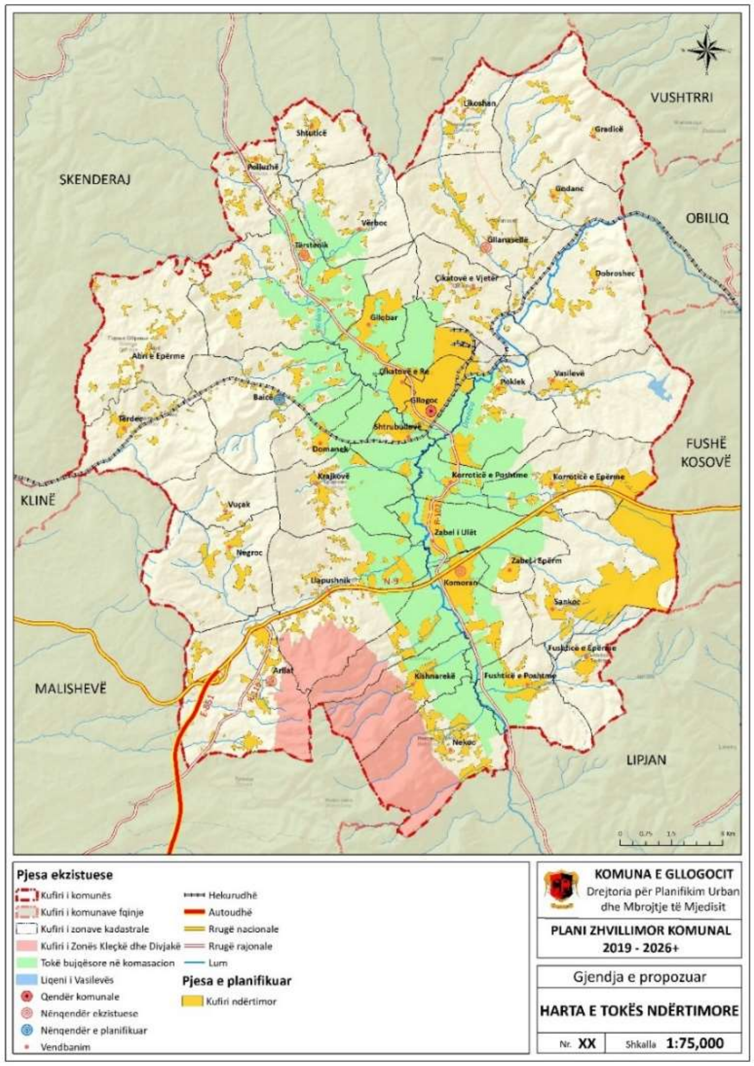

Figure 5.16 Map with land use plans (source: municipal development plan of Drenas)

Another inverse case is when the spatial data derived from the spatial planning documents have already been created and as such should be accessible for specific uses, e.g., during the review of requests for redesignation of agricultural land, where it should be analyzed whether the property in question is part of the areas already planned for residential use. Also, in another example, analyzing the potential agricultural land areas for land consolidation projects. In this case, the spatial planning data will help to identify such areas better.

In order to analyze the source data of the land use planning, a map of the planned land use in the Municipality of Drenas is reviewed (figure 5.16). This map is part of the municipal development plan. It is found in pdf file format on the municipality's website, but the spatial data which it consists are not accessible in an appropriate digital format. The same happens with other documents, for example, the spatial plan and zonal maps at the national level are published on the website of the Ministry of

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Environment. Thus, in order to integrate the data from spatial planning documents, firstly, they must be processed or find the source data.

As discussed above, it is clear that agricultural land use is part of interactive processes. As such it should be modeled on a central geodatabase, able to be accessible through web services to different users such as land use plan developers, decision-makers for redesignation of agricultural land, planners of agricultural land consolidation projects, etc. This will contribute toward more sustainable land use planning.

Soil areas under pollution. The process of monitoring agricultural land pollution requires spatial data that accurately represent polluted areas in maps. Such a map identifies the level of pollution of agricultural lands, as well as the polluting factors.

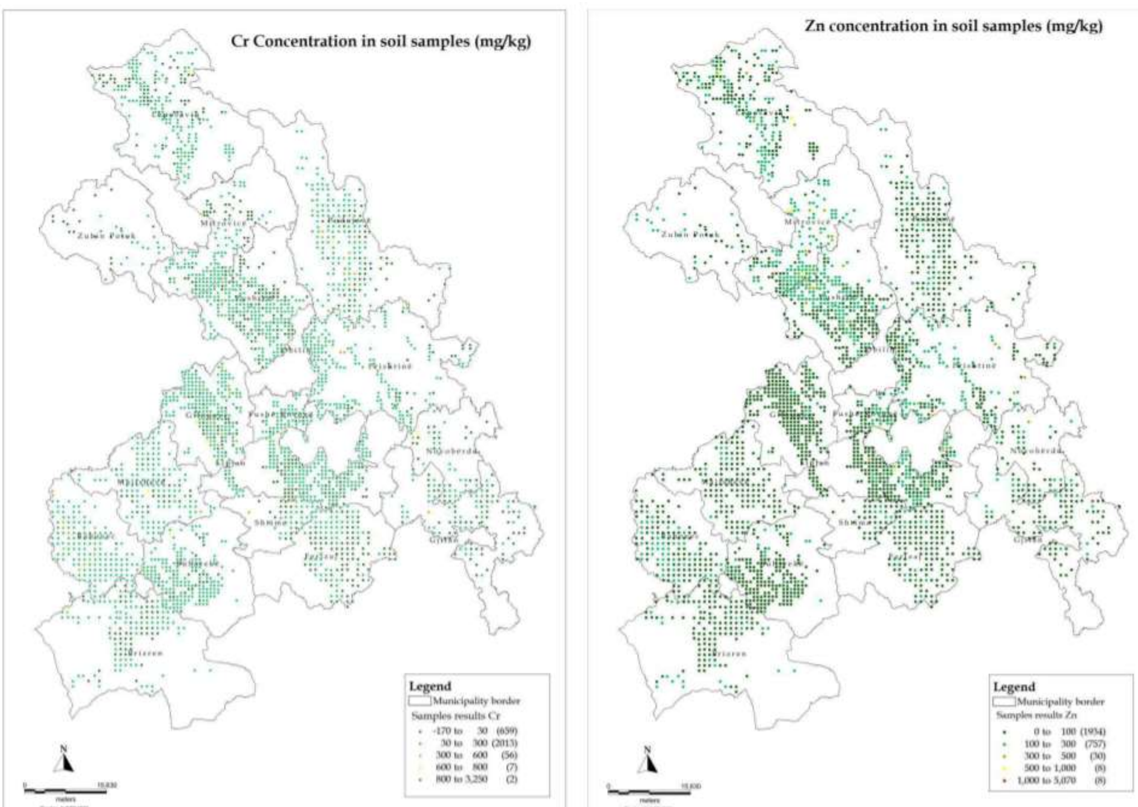

Figure 5.17 Condition of Cr and Zn

Between 2015 and 2017, a study was conducted on the level of pollution of agricultural land in Kosovo. 2804 soil samples were taken from 17 municipalities by applying international methodologies (ISO). The total selected area is 4101 km^{2,} or about 38% of the land area. All parameters to be analyzed are satisfied,

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including heavy metals, soil fertility and organic pollutants. As a result, maps are developed (GIZ and NIRAS, 2015).

Referring to the project reports as above, there are some illustrative maps on the achieved results of different chemical elements such as Chromium (Cr), Zinc (Zn) and Lead (Pb) (figure 5.17). These maps show the locations where field samples were taken and for each of them the result obtained from the field is presented. In these cases, spatial interpolation methods can be used to represent the results for each chemical element for the whole territory. It is important to use methods that offer higher interpolation accuracy (Balamurugan, Duraisami and Stalin, 2014; Ajvazi and Czimber, 2019) as in figures 5.18.

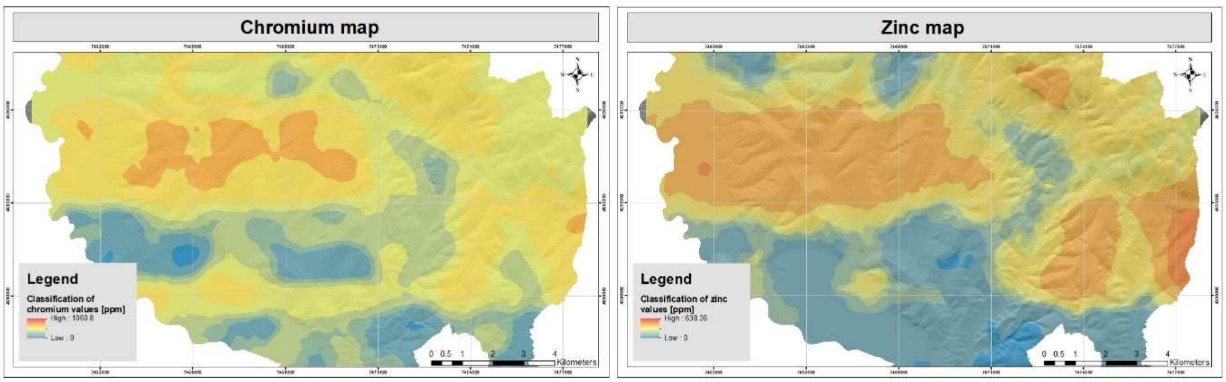

Figure 5.18 Maps with chromium and zinc

Maps showing the level of pollution of agricultural land must be an integral data in the geodatabase, and as such they must be maintained for different purposes, e.g., expanding the study area; updating the current situation, etc. The process of agricultural land pollution must be monitored continuously. Sources of pollution can vary, and consequently, the surfaces and degree of pollution as well.

Agricultural land areas under the erosion risks. Currently, there is no detailed study of agricultural land on the risk of current and potential erosion impact. Consequently, there are no data that show the situation for this spatial phenomenon. However, this research uses some samples taken in the field, in the municipality of Rahovec. The digital map creation for the potential and current risk of soil erosion is done based on the CORINE model (figure 5.19). Several factors are considered to determine the degree of erosion in agricultural lands, such as:

- ✓ soil texture assessed in four classes
- ✓ soil depth estimated in three classes
- ✓ the content of stones assessed in two classes

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- ✓ Fournier index assessed in five classes and
- ✓ drought index assessed at four classes.

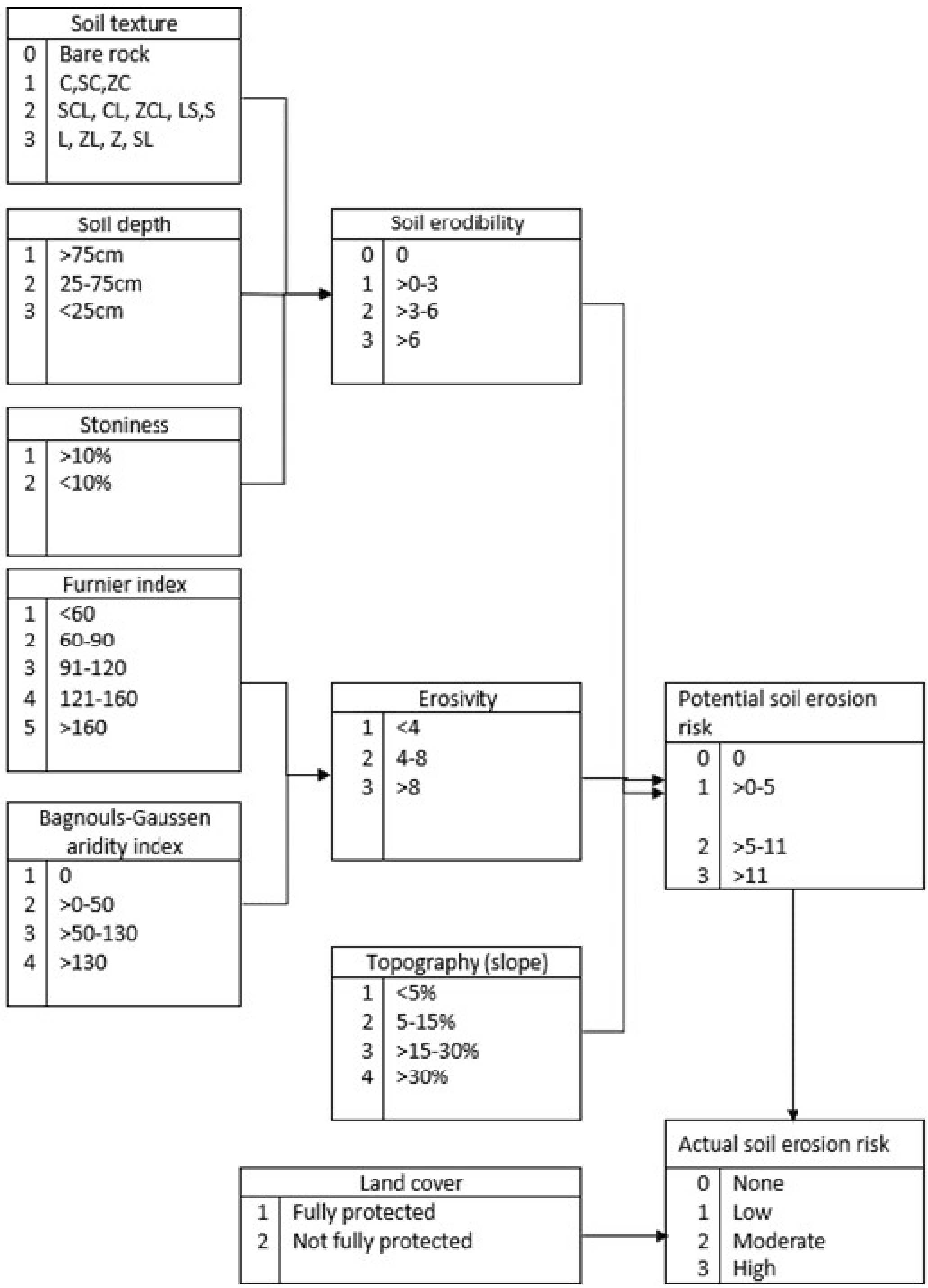

Figure 5.19 Soil erosion assessment CORINE model

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Based on the CORINE model, calculation of the erodibility index is classified in four groups, erosion in three and slope in four. Once the 4-point potential soil risk index is defined, this index together with the assessment of land cover with 2 indices give the current risk of soil erosion estimated in 4 groups. The process must be performed in two stages. First, the potential risk of soil erosion is calculated by combining the soil erodibility index, erosivity, and slope. This indicates the potential risk of erosion, despite the current land use. Second, the current risk of soil erosion assessment is made with reference to the present level of risk and the current land use. This is done by including the vegetation cover index to change and assess the potential risk of erosion.

According to the CORINE model, soil erodibility is a product of soil particle size class, soil depth class, and a class of the cover with stones. This indicator is considered one of the primary factors in assessing soil erosion. The output shows the results of the erodibility (figure 5.20).

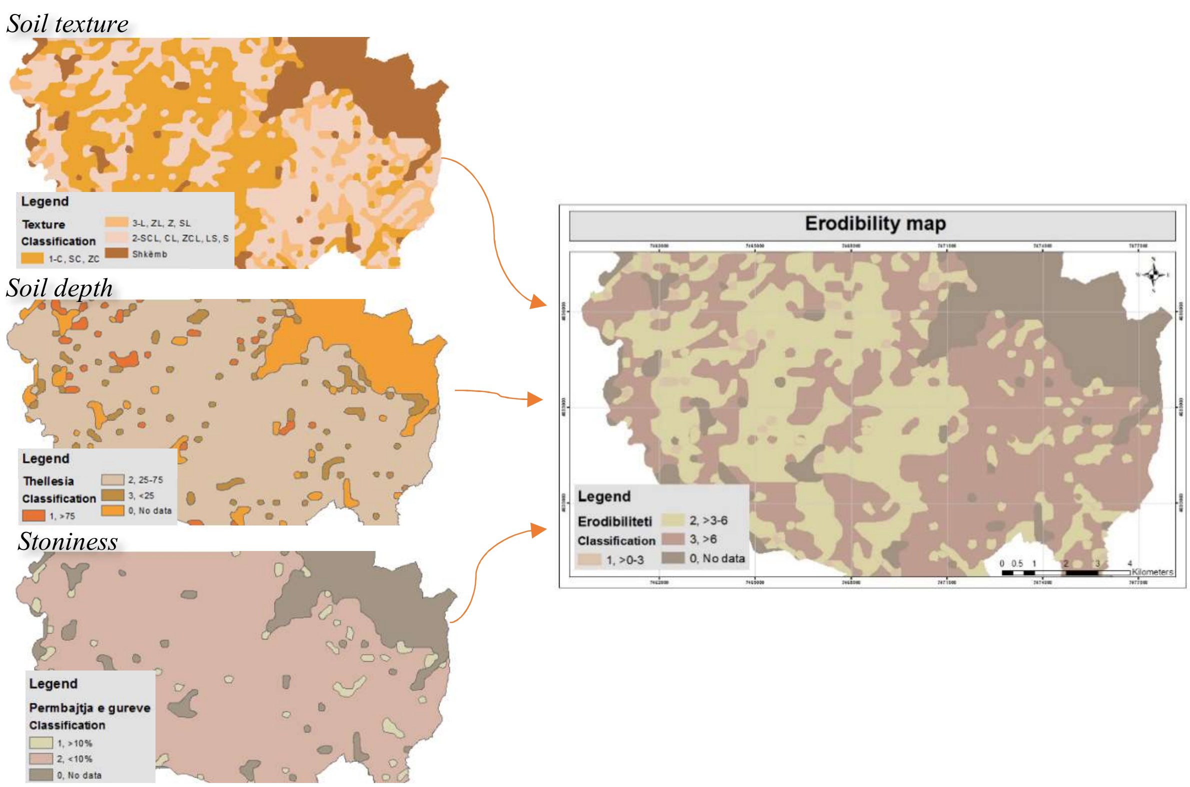

Figure 5.20 Spatial analysis for erodibility map

Another important element is the climate index. This index is a product of two other indices, temperature, and precipitation. Through these indices, the soil moisture is evaluated, and its lack of moisture is determined. Both of these elements are determinants in the magnitude of soil erosion; in this case, this

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factor is the same regardless of whether the land is hilly or plain. Therefore, the interpretation of this factor will be common. Topography is undoubtedly one of the most important elements that influence soil erosion, given that the erosion becomes serious when the slope of the terrain in certain areas is high. The sloping index is used to determine the topographic factor. This index takes into account the slope of the terrain in percentage. The slope map was created based on the classification of four groups. The assessment of the potential erosion risk is obtained as a product of soil erodibility with the erosion index and the slope index. Potential soil erosion risk index = Soil erodibility index x Erosion index x Slope index (figure 5.21).

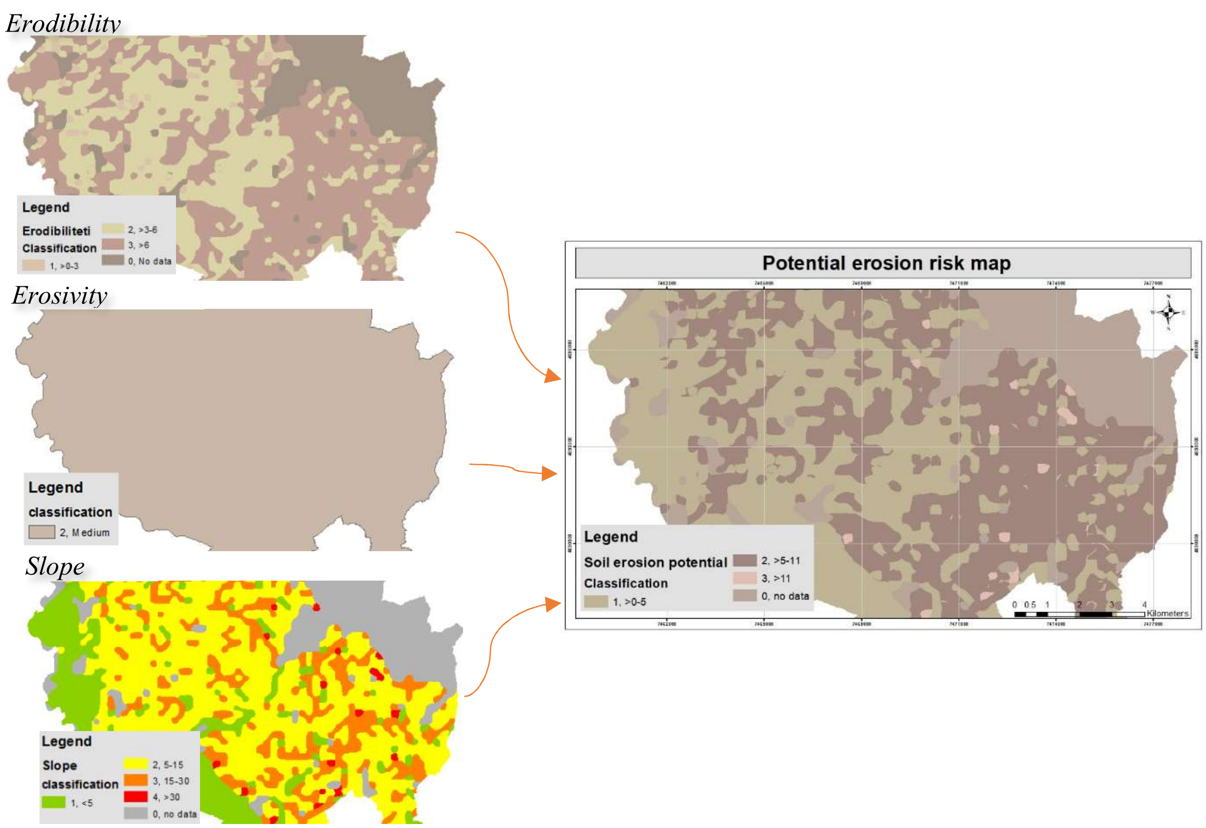

Figure 5.21 Potential erosion risk map

The actual soil erosion risk takes into account the potential soil erosion risk index and the vegetation index (figure 5.22). Vegetative cover is the most important element in the erosion model and provides an opportunity to control erosion. It is a fact that even minor adjustments to the vegetative cover affect the degree of erosion. Detailed information on land use and vegetation cover is therefore required. This factor is a result of soil vegetation and is determined through the vegetation index and depends on the degree of vegetation cover and the type of vegetation.

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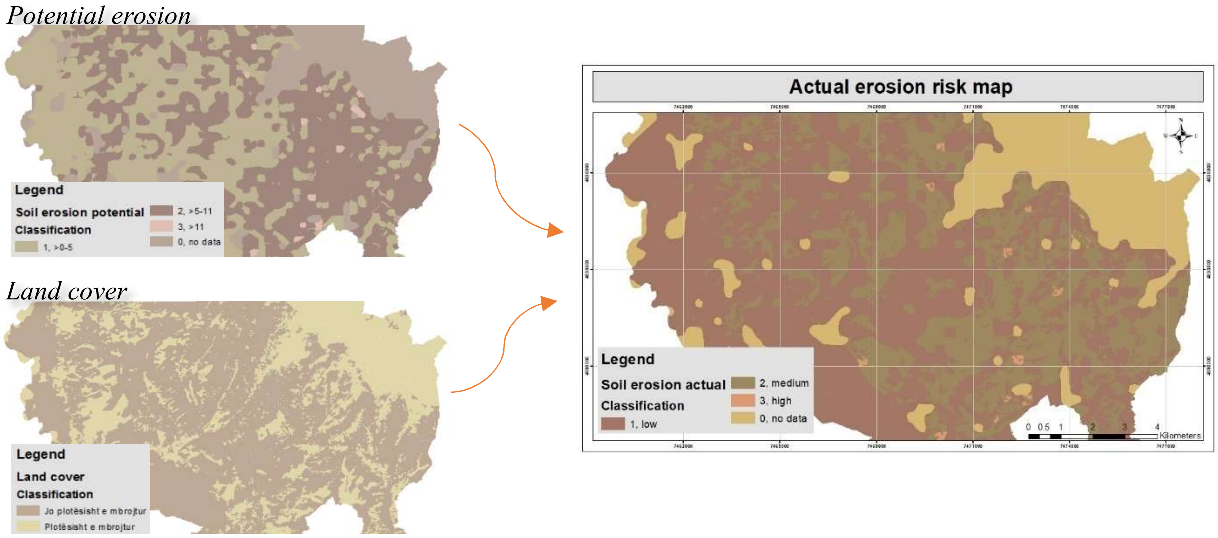

Figure 5.22 Actual erosion risk map

An actual and potential erosion map will help analyze agricultural land areas where the risk is at a high level. According to the results, the responsible central and local institutions can make decisions that will implicate such areas and respective farmers. Finally, these decisions visualized in maps can be published through the Web GIS system, and the farmers can easily access it through the internet. Let see below a specific example.

Example. Identify an area where there is a high degree of erosion risk, land use is meadows, pastures, uncultivated agriculture area, and where the slope of the terrain is greater than 15%.

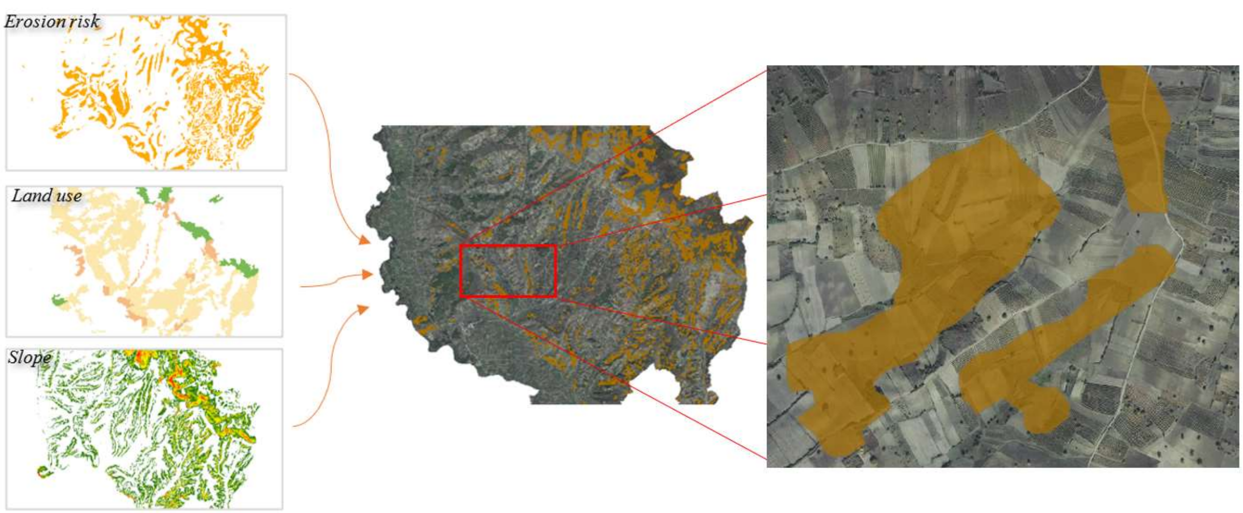

Figure 5.23 Results in map for the example

5.4.4 Data representation models

From the perspective of representing the entities from the real world and the structure of the spatial data in a geodatabase, two different data models exist:

- Raster model and
- Vector model.

Geospatial data in the raster model are represented through arrays of cells, where the geographic variations are then expressed by assigning attributes to these cells (Longley *et al.*, 2015). Raster-based representation can be organized as a set of pixels with common pixel values. In this case, a region quadtree is a suitable hierarchical data structure (Kainz, 2004).

Using raster model for data representation, the variation which may exist in a smaller value than the size of the cell will not be displayed. For example, we want to represent the land use in a specific area as a raster. Each cell is represented with a single value to identify an area of agricultural land, so we need to define the rule to apply when a cell falls in more than one polygon area. We can set the rule of the largest share of the cell's area gets the cell, or we can set the other one based on the central point of the cell, and the agriculture area will finally be assigned to the whole set (figure 5.24). The largest-share rule is mostly recommended, but the central-point rule is sometimes used for faster computing and is often used in creating raster datasets of elevation (Longley *et al.*, 2015).

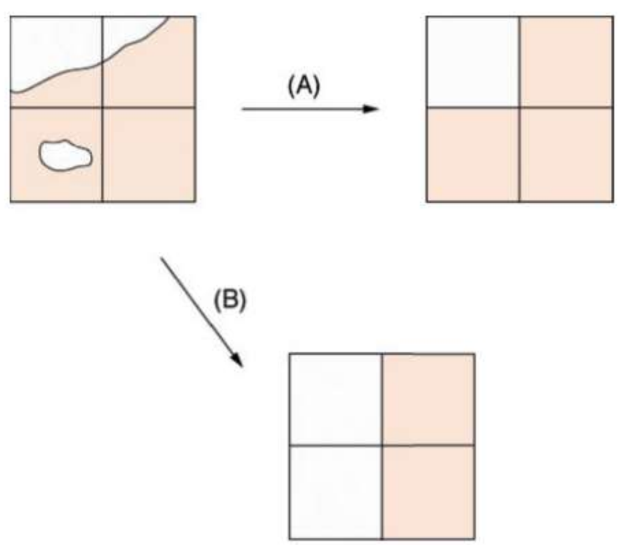

Figure 5.24 Effects of presentation on the raster model using (A) the largest-share rule and (B) the central-point rule

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There are two general categories of raster data: thematic data, where the values of raster cells can represent a measured quantity such as elevation, pollution, rainfall etc., and image data, where the raster data is captured by satellites, airplanes, or other similar systems.

By using the vector data model, entities in the real world are divided into spatial features represented with a point, line, or polygon geometry (figure 5.25). The simplest used geometry are points, which depending on the mapping scale, can represent entities such as trees, houses, towns, etc. (Sugumaran and Degroote, 2011) The second geometric structure of the vector model are lines which are defined by points. Depending on the goal and the scale of the map, lines can be used to represent several entities, such as roads, rivers, different administrative borders, etc. Polygons are captured as a series of points connected by lines. For this reason, the coordinates of the points are necessary to be defined. Also, the quality of the entity represented in the vector model often depends on the accuracy of the points' locations.

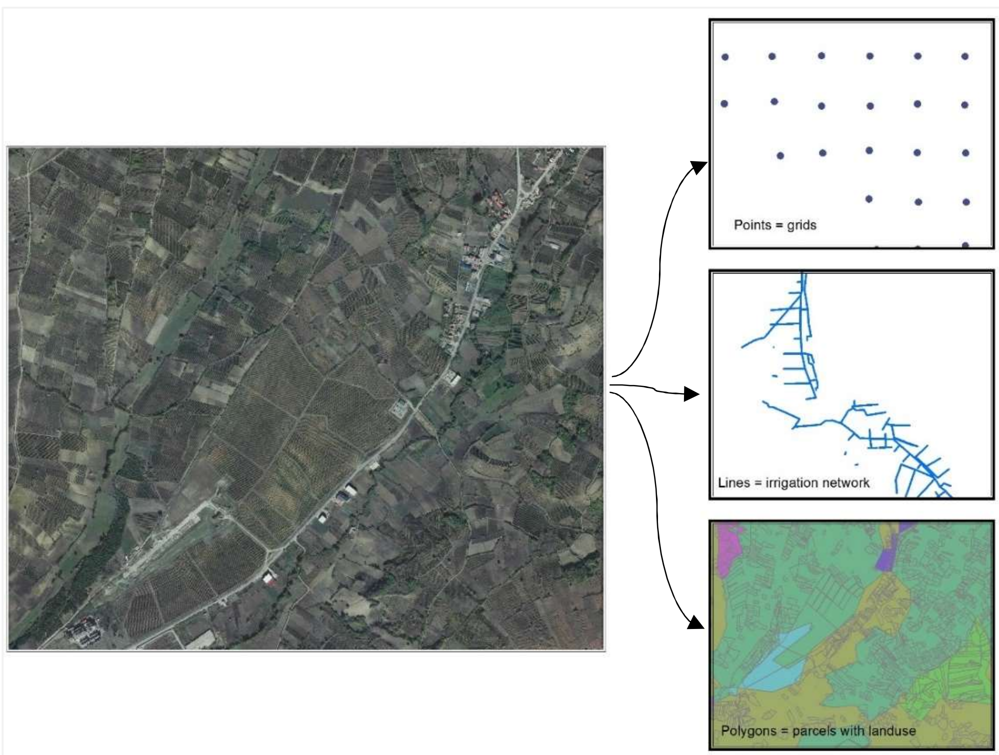

Figure 5.25 Points, lines and polygons in the vector model

5.4.4.1 Raster or vector

The choice between raster and vector is not simple as it may seem since several advantages and disadvantages among the two models exist. In fact, while analyzing which data model matches the real-world phenomena better, it is important to understand if the phenomena are a discrete or a continuous pattern (https://www.learngis.org). In some cases, this division is not easily defined. Therefore, entities that can be defined with clear geometry, such as state or municipal borders, buildings, roads, and so on, can more accurately be represented in the vector data model. Such features are more discrete. Spatial phenomena that vary continuously, such as the erosion risk, elevation, climate, etc., are better represented in the raster model. Such spatial phenomena are more continuous. The file size is also significant; usually, the raster file is larger, but the opposite may happen if the wrong format is used. For example, if the elevation map is represented in a vector model, the number of the polygons would be significant, and as a result, the file size will be large. It depends on the map scaling or the size of the geographic areas which is mapping. For example, the land use map. The map is generated based on the image analysis methods at small-scale mapping for larger areas. Whereas for smaller areas, this may not be sufficient, so the manual digitizing can be used. This will define discrete land use areas.

Referring to the data described in section 5.4.1, the raster model can be used for agricultural land classification, agricultural land pollution, agricultural land areas under the influence of current erosion risk, and agricultural land areas under the risk of potential erosion. These data could also be presented through conversion to the vector model. However, the raster model is recommended as the initial source for creating the spatial data based on the method of cell analysis in satellite images and spatial interpolation methods.

5.4.5 Metadata

When integrating data into geodatabases and managing them through the system information on the data itself must be provided. This enables a better understanding of the data that is being integrated and used. The very existence of a spatial data from a relevant source does not mean that it meets the quality requirements to become part of the geodatabase. In this context, it is important that each of the data is analyzed, among other things, to ensure that it does not conflict with other data by way of acquisition, standards, accuracy, etc. So, the information that describes the data is called metadata. Another shorter definition might be that metadata represents data about data (Jones, 2003).

Various standards help document and present metadata, such as ISO metadata standards, INSPIRE metadata standards, FGDC metadata standards, DCMI standards, etc. Such standards are important because they provide users with valuable information such as quality, use, data source, etc., that increase the quality of results from spatial analysis. ISO is one of the largest developers and publishers of international standards. From the geospatial metadata perspective, ISO has developed and published the following metadata standards (https://www.learningzone.rspsoc.org.uk):

- ISO 19115 - defines data for geographic information, such as quality, resolution, spatial reference, and distribution.
- ISO 19110 - defines the methodology for the cataloging features of spatial features
- ISO 19119 - is related to geospatial web services and
- ISO 19139 - defines the XML Schema.

INSPIRE offers standards for metadata that have been selected from some other existing standards as the most important and efficient. They include EN ISO 19115, EN ISO 19119, ISO 15836.

The main features that metadata must contain are (figure 5.26):

- Title, author, time, the abstract, purpose of creation, status, and keywords.
- Quality data that includes resources used to obtain the data.
- Spatial representation that includes models used to represent spatial data.
- Reference system.
- Content data such as entities and attributes.
- Distribution data that includes methods on how data can be used.

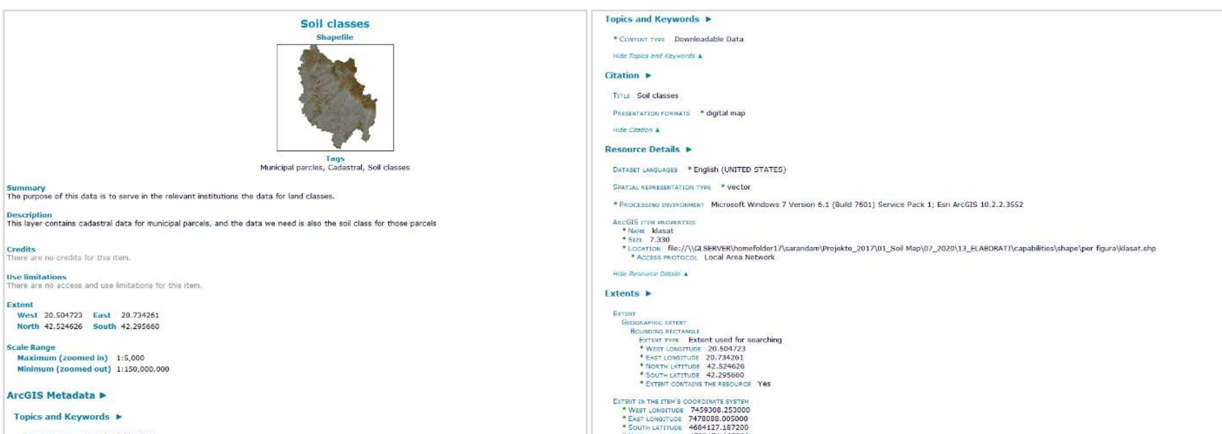

Figure 5.26 Example of metadata for soil classification layer

For metadata to be usable, the mechanism for storing, editing, and displaying must be fairly straightforward and concise. In addition, tools that enable metadata management for certain layers should be used. This management should include editing, viewing, exporting, importing, and validating.

There are several tools for creating and managing geospatial metadata, which can be:

- Open-source (GeoNetwork, Mapbender, pycsw, MEtadata Editor, CatMDEdit, ISO Metadata Editor (IME), DCLite4G, MIG EDITOR, ANZMetLite, Metatools for QGIS, INSPIRE Metadata Support in GRASS GIS 7, MATT, pygeometa, etc);
- Comercial (ArcCatalog, Geomedia Catalog, MapInfo Manager, etc.).

5.4.6 Data quality assessment

Nowadays, access to spatial data is much easier than a few decades ago, when mainly manual spatial data handling methods were used, and the Internet wasn't used as a communication opportunity to disseminate data between individuals or organizations. However, the ability to access an existing resource and obtain relevant spatial data does not necessarily make them usable for a particular spatial decision. This is because the data may contain errors that affect the quality.

The quality of spatial data is essential in spatial decision-making (Markus, 1997). The quality of spatial data can be presented through different criteria, which can be based on different international standards such as e.g. ISO 9113 (ISO, 2002), which recommend the use of the following criteria:

- Completeness: the presence and absence of features, attributes, and their relationships.
- Logical consistency: the degree of compliance with the logical rules of structure, descriptive characteristics, and data relationships.
- Position accuracy: feature position accuracy.
- Timeliness: the accuracy of temporal attributes and temporal relationships of features.
- Thematic accuracy: the accuracy of quantitative attributes, the correctness of non-quantitative attributes, and the classification of their features and relationships.

Characteristics as above refer to the internal quality of spatial data, which describes the state of the data produced relative to those that were to be produced.

However, depending on the case of use and geographical extent, spatial data may meet the quality requirement and be usable, partially usable, or unusable at all. This approach refers to the external quality of spatial data, which can be analyzed through the following features (Devillers and Jeansoulin, 2005):

- Definition: evaluate whether the exact nature of a data and the object it describes (the "what") corresponds to user needs.
- Coverage: evaluate whether the area and the period for which the data exists meet user needs.

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- Lineage: find out the acquisition methods used to obtain the data and see whether the data meets user needs.
- Precision: evaluate what data is worth and whether it is acceptable for an expressed need.
- Legitimacy: evaluate the official recognition and the legal scope of data and whether they meet the needs of de facto standards, respect recognized standards, have legal or administrative recognition by an official body, or legal guarantee by a supplier, etc.;
- Accessibility: evaluate how easily users can obtain the data analyzed (cost, time frame, format, confidentiality, respect of recognized standards, copyright, etc.).

If the spatial data from a relevant source contains information (metadata) on the quality, the user can decide to use or not use the data. In case such information is lacking, it is important to assess data quality before it becomes part of spatial decision-making.

5.4.6.1 *Thematic accuracy assessment*

To assess the data quality, analysis needs to be performed. One of the approaches used for quality assessment is the validation of sample data using information from another source. This approach has been followed by assessing the thematic accuracy of a land cover map. In this case, accuracy refers to the degree of correspondence between classification and reality. To assess it, it is compared a land cover map from Copernicus of the year 2018 with a reference map which is a land cover classification from aerial image of the year 2018 as well (figure 5.27). The latest is assumed to be true.

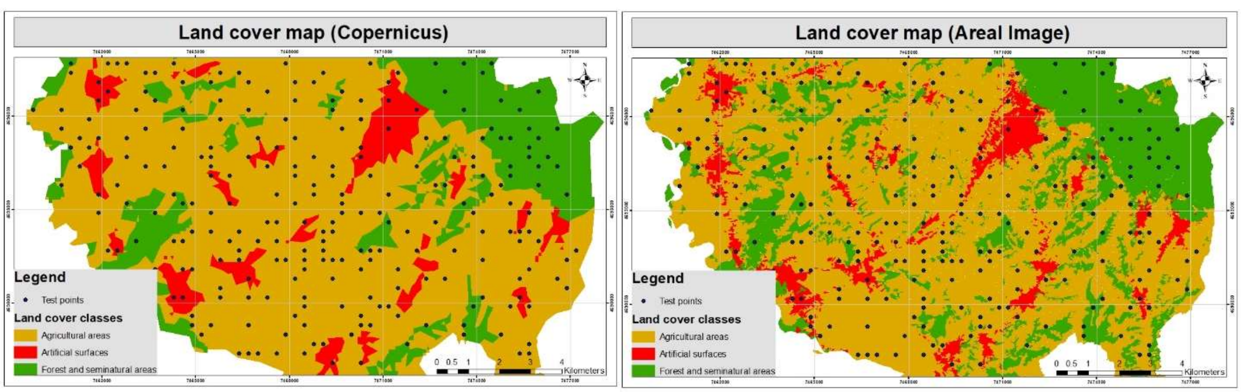

Figure 5.27 Land cover maps with test points

To calculate the thematic accuracy of the land cover map is used the confusion matrix by selecting random test points (European Communities, 2001). Table 6 shows the confusion matrix, which is used to calculate the overall accuracy (OA), user accuracy (UA), and producer accuracy (PA) of the land cover classification map.

Table 5.6 Confusion matrix with reference and mapped land cover classes

	Classification	Reference classes: Artificial surfaces	Agriculture areas	Forest and semi-natural areas	*Sum*	**User accuracy (%)**
Mapped classes	Artificial surfaces	13	7	0	*20*	**65.00**
	Agriculture areas	4	161	19	*184*	**87.50**
	Forest and semi-natural areas	2	4	40	*46*	**86.97**
	Sum	*19*	*172*	*59*	*250*	
	Producer accuracy (%)	**68.42**	**93.60**	**67.80**		

The overall accuracy of the data is calculated based on the following equation (Sari *et al.*, 2021):

$$OA = \sum_{i=1}^{m} \frac{n_{ii}}{n} = 85.60\%$$

Where n_{ii} – are the elements of the matrix in diagonal; n – is the total number of the sample size.

The results of the accuracy may help us decide if the land cover classification from Copernicus may be used to build land cover maps or if the data needs to be reprocessed.

5.5 The base concepts of geospatial functionalities

In order to provide users with a solution to a particular spatial problem, it is essential to meet the following requirements:

1. Enable collection and integration of data from multiple sources and in various formats.
2. Have functions concerning spatial prospects for storing, editing, and analyzing spatial phenomena. Users require functions that help them accomplish their assignments.
3. Spatial functions are also conducive to reorganizing or converting data from one format to another, as well as their verification and validation.
4. Facilitate the solution of spatial problems by designing questionnaires.
5. Generate results for users in various forms, such as charts, maps, graphs, etc.

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The requirements as above can be solved through the functions of collecting; storing, editing, and analyzing; integrating; converting; questioning; and displaying.

5.5.1 Analytical capabilities

Many geospatial functions can support the users in analyzing spatial phenomena. Geospatial analytical functions, as presented in section 2.4, are classified into four categories: 1) retrieval, reclassification and measurement; 2) topological; 3) neighborhood; and 4) connectivity.

Spatial selection. These functions make up the basic tools of any geospatial information system. The selection of spatial layers can be made based on the attribute features and spatial location. After decisions to redesignate parcels to residential areas, users of DoA at the municipal level may select the parcels based on the attribute of the year redesignated or the type of the redesignation. For example, where are agricultural land parcels redesignated in 2019? Where are agricultural land parcels temporarily redesignated? To answer these questions spatial selection is made by attribute conditions, which are formulated in SQL (Huisman and By, 2001). The data can be selected based on topological relationships while using spatial selection functions. Many methods exist, such as 1) selecting features that intersect another feature; 2) are within a distance of the other feature; 3) are inside of the other feature etc. Figure 5.28 shows the selected parcels within the sixth class agricultural land areas and do not intersect with the irrigation system.

Figure 5.28 The selected parcels within sixth class agricultural land areas that do not intersect with the irrigation system

Reclassification. If the soil classification layer from class 1 to class 8 is a vector format, they can be regrouped according to their name, for example, "1-4", "5-6", and "7-8". Among other reasons, this can be done to review the decision-making by level, where the first group includes the MoA and the Municipal Assembly, the second group the Municipal Assembly and DoSP, and the third group DoSP and DoA. The designations of these classes can be stored within a new parcel attribute. These groups can be used in the case indicated above or in other cases when further analysis is needed. Input data are reclassified in a new way but without changing the spatial characteristics of the input data (figure 5.29).

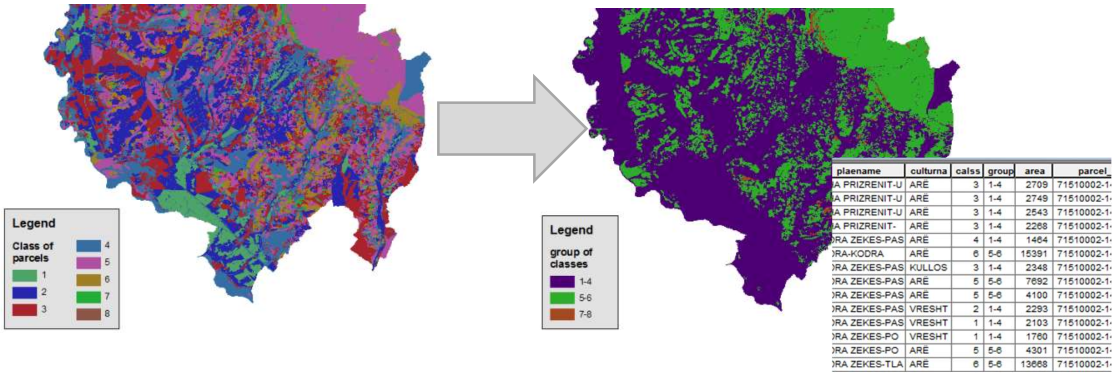

Figure 5.29 Agricultural parcels reclassified into groups according to the level of decision-making for conversion to another destination

In addition to the above-mentioned case, the reclassification of data in vector format may also include changing the input data after reclassification, namely for creating a more generalized feature. This is enabled through data processing with geospatial functions like spatial merging, aggregation, or dissolving (Huisman and By, 2001). For example (figure 5.30), if the soil map which contains its units exist, but a classification based on suitability for vineyards is needed, the input layer will be reclassified based on the attribute for suitability for the vineyard cultivation by using dissolve function.

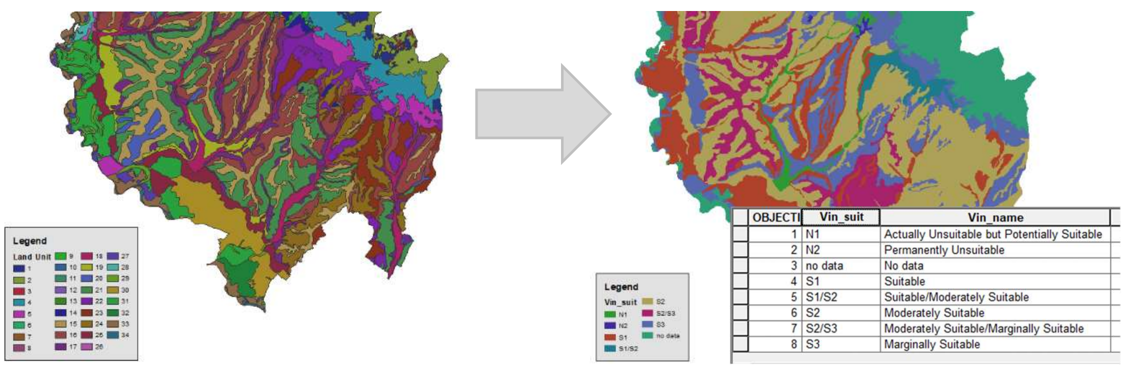

Figure 5.30 Reclassification of soil suitability layer for vineyard cultivation

An example of reclassification referring to raster data is that through the resample function we change the resolution of the input layer by either reducing or enlarging it. The reclassify function will reclassifiy the input data according to a defined grouping, e.g. to identify the location where the degree of erosion risk is high, the land use is meadow, pastures and uncultivated land, as well as the slope is greater than 15%. All

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input layers referring to the raster format, in this case, must be reclassified before they are finally analyzed (figure 5.31).

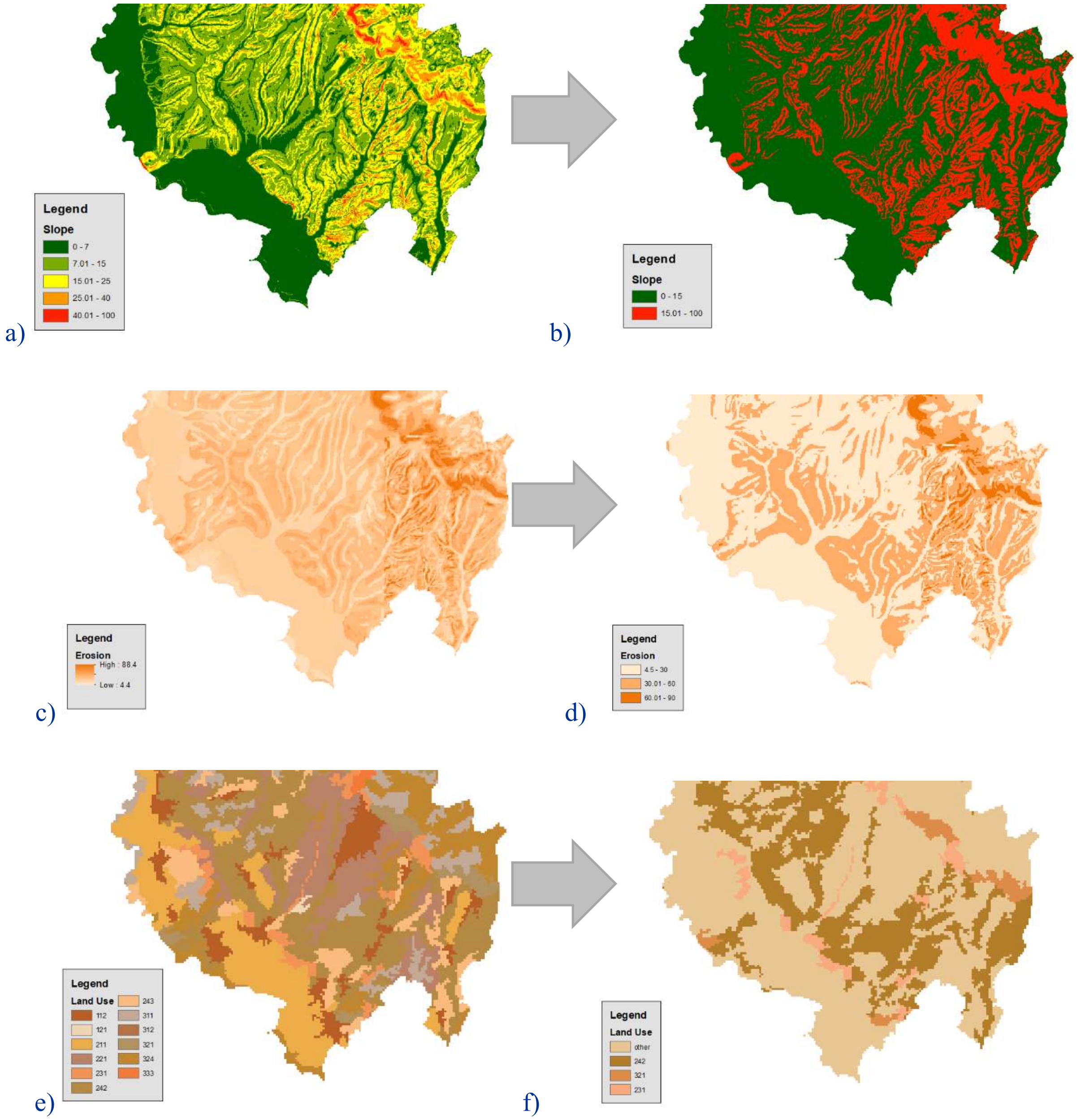

Figure 5.31 Reclassification a) and b) Slope, c) and d) Erosion, e) and f) Land use

Measurement. Geometric measurements can be made in the spatial features of the vector and raster model. The required measurements for vector features that include points, lines, and polygons are length, distance, and area. In the case of measurements of a feature, then the length refers to the type of line geometry or polyline, where it is defined as the value of the geometry itself. Area refers to polygon type

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features, which can be calculated but usually are stored as separate attributes. In addition to the above, another important function is to measure the distance between two features, which can be of different geometric types, for example, the distance between a line feature and a polygon feature. In such cases, the distance means the minimum distance between the line's location and the polygon's location. Therefore, when these two features intersect or meet each other, it turns out that the distance is 0. This principle is used by all geoprocessing functions that calculate the distance.

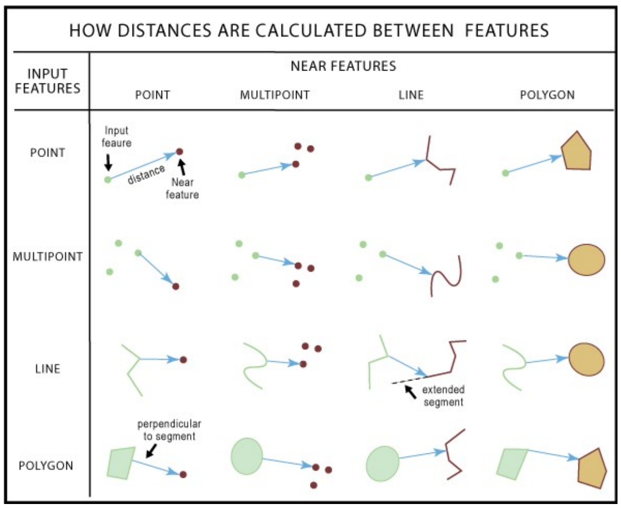

Figure 5.32 How is the distance calculated between features? (source: https://pro.arcgis.com)

Figure 5.32 shows the possible cases of the distance calculation between two vector features involving different geometric types. The measurements on raster data layers are simpler because of the regularity of the cells. The area size of a cell is constant and is determined by the cell resolution. The distance between two raster cells is the standard distance function applied to the locations of their respective mid-points. Whereas the raster represents line features as strings of cells, the length of a line feature is computed as the sum of distances between consecutive cells.

Overlay. As shown in Figure 5.33, overlay vector analysis includes many operators, such as 1) union, 2) intersect, 3) symmetrical difference, 4) identity, 5) clip, 6) erase, and 7) split.

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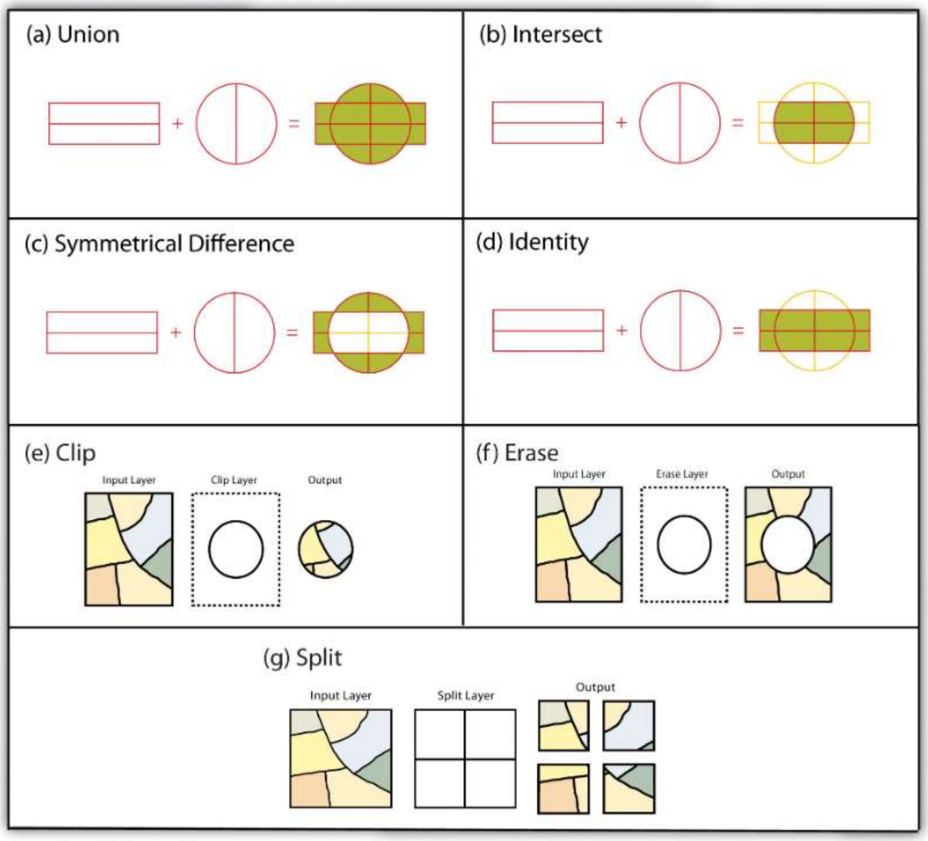

Figure 5.33 Overlay vector functions (source: https://pro.arcgis.com)

Application of such functions can help us answer some of the most basic geospatial questions:

- What is the land use in the first and second soil classes (figure 5.34)?
- What parcels are at 15% sloping areas (figure 5.35)?
- What are agricultural land areas within the planned residential areas in municipal spatial plans?
- What are the pastures under the soil erosion risk (figure 5.36)?
- What are the parcels within the soil pollution areas?
- What is the land use in the first and second soil classes?

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Figure 5.34 Identification of land use in first and second land class

What parcels are at 15% slope areas?

Figure 5.35 Identification (intersection) of parcels that lie on the sloping up to 15%

What are the pastures under the soil erosion risk?

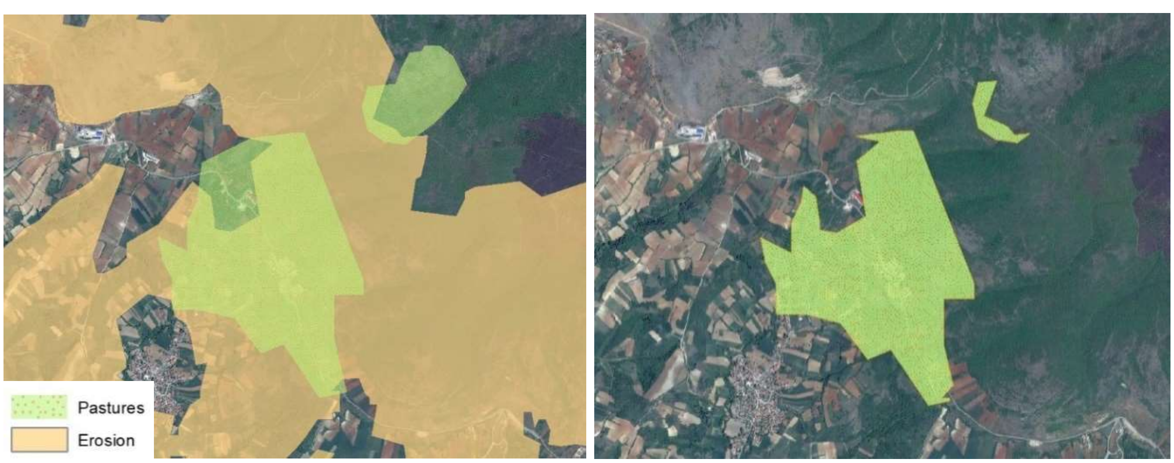

Figure 5.36 Identification (clip) of pastures which are in areas endangered by potential erosion

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The quality of information generated by the spatial data analysis process initially depends on the very accuracy of the measurement or the acquisition of the feature in question. However, despite the processing of spatial data through GIS tools, there are some cases where errors can occur (Sae-jung, Chen and Phuong, 2008). For example, if we have a base map in raster format and we have digitized it, and during the process, we have caused errors where the polygons of one or more features intersect with each other or have gaps (figure 5.37). Before analyzing such vector data for the spatial relationships between them, they must be cleared of possible topological errors.

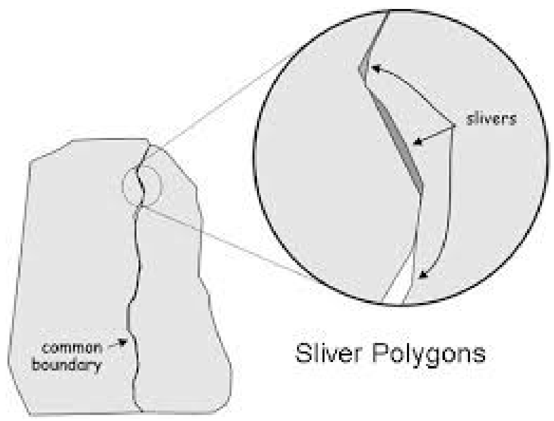

Figure 5.37 Sliver polygons (source: http://gis.humboldt.edu)

In cases where polygons share the same location and shape with another neighboring polygon, but when the data do not reflect this reality, then the features have polygons that intersect with each other (sliver polygons) or have space between them. In such cases, the polygons must be cleared of these errors. This can be achieved in several ways, e.g.:

- Using the *align to shape tool,* we choose an existing path to which other features will be placed.
- Using *topological rules* in geodatabase.
- Using the *snapping tool* to modify polygons manually.
- Identifying polygons in small areas by *selecting attributes query.*

The sliver polygon problem has long received attention in error modelling. The number of composite map polygons (Nc) is related to the number of polygons on the individual layers (Ni), as presented in the following equation (Markus, 1997):

$$N_c = \left[\sum_{i=1}^{n} \left(\sqrt{N_i}\right)\right]^2$$

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Here, n is the number of layers. This equation shows that Nc tends to rise exponentially as *n* increases.

Overlay analyses with raster data are performed by combining the characteristics of cells in each layer with the same geographic location. These characteristics are expressed through numerical values. They are calculated using the corresponding raster analysis function and finally are assigned to a new single layer, where each cell gets a new value. Figure 5.38 shows how the change in redesignated land areas is identified in case there are two raster layers representing the land use in a certain location in different time periods, where raster 1 shows the year 2012 and raster 2 refers to the year 2018. As shown in Figure 5.38, applying one of the relational functions *equal* will result in a new raster layer representing the surfaces where land use is different. The *diff* function can be used for the same purpose, where the same cell values will be zero, while the values of the first raster when they are different (figure 5.39).

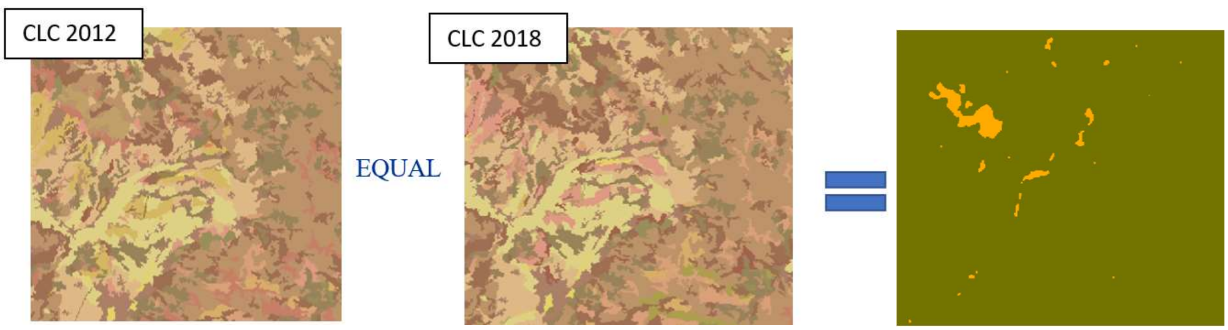

Figure 5.38 Identification of the difference in land use between the period 2012 and 2018 through the operator equal to

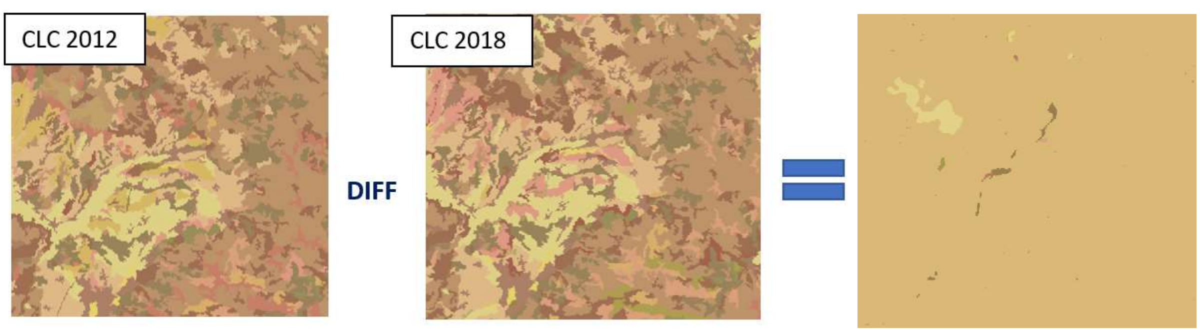

Figure 5.39 Identification of the difference in land use between the period 2012 and 2018 through the operator diff

If another arithmetic *add* function is used in the same example, it will result in a new raster layer that shows differences. In another example (figure 5.40), using a *boolean* operator identifies the location where the slope is over 45° and the altitude above 1000m.

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Figure 5.40 Using the boolean operator in identifying the location where the slope is over 45 degrees and the altitude above 1000m

Neighborhood. Neighborhood functions find wide application mainly in analyzing potential locations because locations are identified by analyzing the vicinity of a potential location. For example, during spatial analysis for a potential location, among other requirements are: not more than 1000m away from settlements, not more than 200 m away from the road, etc. Such conditions usually refer to vector data. Among the most common techniques for resolving such cases is the generation of the buffer zone. The principle of the buffer function is simple: we select the spatial feature to which we want to generate the buffer zone and define the distance. For example, for the settlement feature, we define the distance 1000 m and the buffer zone is generated as in figure 5.41. The same applies to the road feature; we choose the distance 200m. The obtained polygon type layer can be used for further analysis.

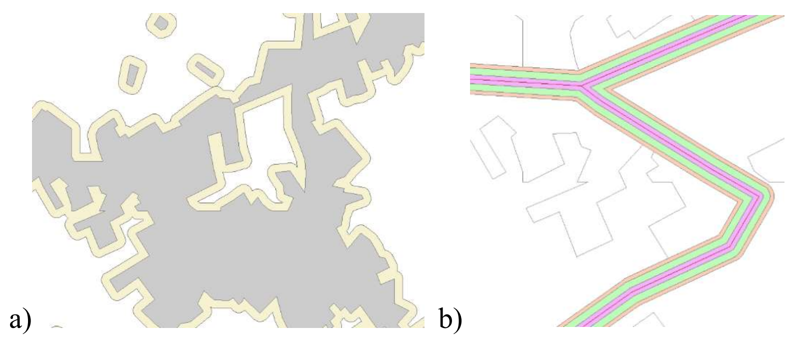

Figure 5.41 Generation of buffer zone: a) to residential areas 1000m and b) to roads 200m

There are several functions in raster data that are based on the principles of neighborhood analysis, such as analysis in DEM, as continuous data. Functions of Analysis for DEM are slope (figure 5.40), aspect (figure 5.42), hillshading, viewshed. Among the functions that find a wide application are the *slope* and *aspect*. For example, slope and aspect layer is applied during the analysis of potential locations for vineyard cultivation (Ajvazi, 2015). In another case, slope and aspect layers are applied during the analysis for soil classification or current erosion in agricultural lands.

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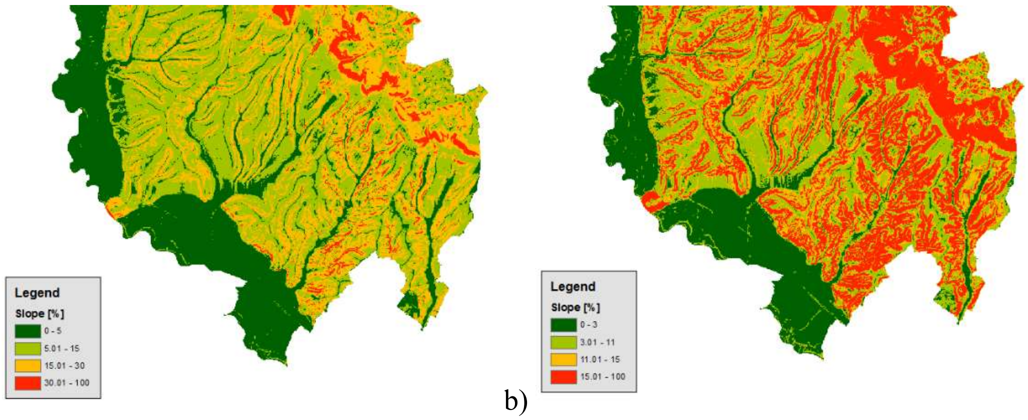

a) b)

Figure 5.42 Slope classification: a) for erosion risk analysis and b) for soil classification

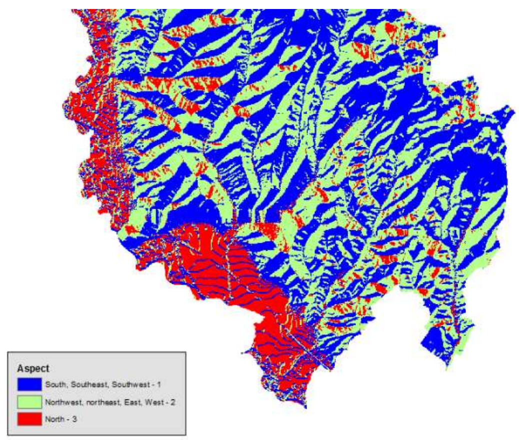

Figure 5.43 Using aspect map for vineyard suitable location analysis

5.5.2 Mapping capabilities

Geospatial data displayed in the form of digital maps must be interactively accessible. The user can display the data at his request, e.g., zoom in or zoom out, add or remove information in the work window, and identify descriptive features of any of the features on the map, etc.

Another reason for proper user interaction with map data is the need to generate new results from existing data. Users may have different roles and levels, such as technician, manager, or leader. Often users use these systems only to produce maps (Longley *et al.*, 2015). However, surely this is not the only purpose of the system. So, the results presented in the form of maps will be used to support the spatial decision-making process.

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Maps help users solve various real-world related problems. They are a source of knowledge that leads to the solution of spatial problems through interpretation. The multipurpose perspective of using maps is very important, as some users may find it multi-dimensional and can use the same map or interpret it in different contexts (Duckham, Goodchild and Worboys, 2003). For example, the map which contains the network of the irrigation system of the agricultural lands can be used for the presentation of those data in graphical form for the identification of lands that are or are not under the irrigation system, reviewing the requests for land redesignation, quality control of irrigation water, the expansion of the irrigation system network for other areas of agricultural land, maintenance purposes, etc. (figure 5.44). Each of the users will come up with different results depending on their purpose for using the map.

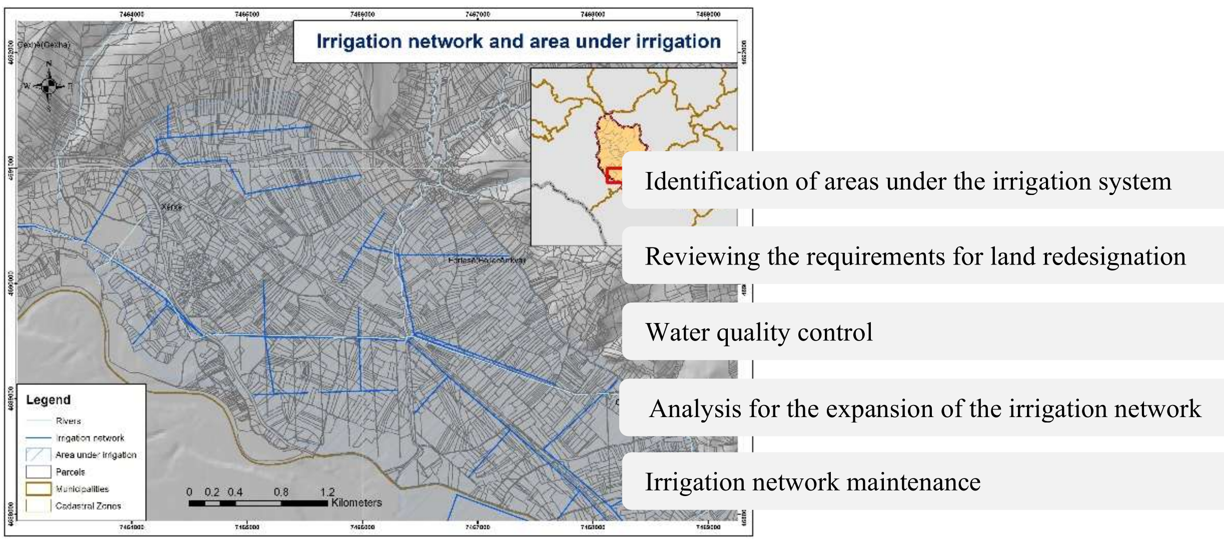

Figure 5.44 Multipurpose use of irrigation network map

From the cartographic point of view, it is important to follow principles that ensure the created maps satisfy the objective of presenting and representing the real world. Such principles guarantee users reliable communication to solve spatial problems. Support to the decision-making requires that maps are clearly interpretable to the decision-maker where the basic purpose of transmitting information to the real world must be satisfied.

Within geospatial information management systems, geospatial data are presented in the form of interactive maps where the user has the opportunity to manipulate it through specific functions. The functions that enable users to manipulate the digital map are largely part of the basic functions that the system must provide. Such functions are: pan, zoom in and zoom out, full extent, previous and next extent. It is also important to define the reference scale that the integrated layer represents. A layer could

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be displayed within a defined reference scale and invisible outside that reference scale. This feature helps the user to view the layers on the principle of generalization of the map.

In addition to interactive mapping, systems should offer the ability to create a mapping for hard copy formats (Aronoff, 1989). What are the basic functions that a map of this format should provide? Let us see the table as follows.

Table 5.7 Function to prepare the layout maps

Function description
Map annotations such as map title, legend, scale, and north symbol are among the most common designations a map should contain. All of these should be flexible for their placement position.
Grid generation with coordinates
Setting appropriate textual designations
Map scale selection
Transmission of the prepared map to a suitable format resolution ang pdf, jpeg.

Graphic symbols are also used to create maps, interactive or hard copy, through which the respective spatial objects are marked with symbols – for example, marking of locations where samples for controls of the level of soil pollution were taken, marking of the location where samples for water quality control were taken within the irrigation system for certain areas of agricultural land, etc. In addition to proper symbolization on the map, the labeling of spatial features is also important, which must be done according to some basic principles, including cartographic ones.

5.5.3 Report generation

As the data is analyzed, the results are generated. In addition to presenting the results on maps, another form of presentation of results is also through the generation of reports. Hence, this system will provide the results in the form of reports for the following subjects:

- ✓ The final decision on the application request for redesignation of agricultural land.
- ✓ Statistical data report for the already redesigned agricultural lands at the local and state levels for whatever period of time users select.
- ✓ Report with data on permanent and temporary redesignation of agricultural land at the local and state levels for whatever period of time selected by users.

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- ✓ Generation of a statistical report on agricultural lands under the impact of erosion, presented in area for each municipality and in a total area for the whole country.
- ✓ Generation of statistical report about the level of pollution of agricultural land, presented in area for each municipality and in a total area for the whole country.

5.5.4 Interoperability

Interoperability is the ability to interact with different sources to share information and data, even between different infrastructures. Organizations are able to share, coordinate, and communicate between departments within an organization or between separate organizations using geospatial systems as the central spatial data infrastructure (ESRI, 2003).

The main reasons for the inclusion of interoperability tools can be:

- Distribution of data in different formats;
- Coding is not necessary;
- Communication in different standards;
- Data synchronization between systems, etc.

In addition, geospatial data interoperability has some other advantages:

- ✓ Easy access to data, which affects the increase of efficiency, cost reduction, and saving time for obtaining data from existing platforms;
- ✓ The data becomes ready for use on many platforms;
- ✓ Improves geospatial data management because it prevents possible duplication by different users for the same spatial phenomena, etc.

Web services play a key role in sharing information via the internet, enabling data management from different environments and formats (see section 5.6.2.2). Web services can be accessed via various devices such as mobile, desktop, where communication is enabled through XML-based protocols, known as Simple Object Access Protocol.

5.6 Defining the most appropriate software approach

The basic principle to be followed in selecting the geospatial system from the software aspect is that it must fully meet the end user's requirements. These requirements include the need for access to the system

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(remote access, classified access for different users, etc.), the need for communication between users, the need to include geospatial data of various formats, the need to manage this data through integration, storage, analysis, presentation and distribution (interoperability). Altogether, they should better support the spatial decision-making process, with the primary goal to provide sustainable management of agricultural land use and its protection from possible degradation.

In this case, a comprehensive geospatial information system should include various software technologies. In fact, the task of selecting the right system is never an easy one. In addition to the above requirements, one should also consider the cost, end-user expertise, and software platforms: desktop, web-based, or mobile.

Based on the specifications for the user requirements, indicated in Chapter 4 and in the previous sections of this chapter, it appears that in this case, a comprehensive system should provide a Web GIS-based software to enable communication between different users such as officials from local institutions of the directorate of urbanism and agriculture, relevant officials from the department of land use, GIS, drafters of municipal development plans and citizens. Also, to meet the requirements of analysis and manipulation with spatial data, i.e., the integration of various analytical functions, it is important to use a Desktop GIS. Let's elaborate on the latest one.

5.6.1 Desktop GIS solution

When analyzing and planning for the use of a Desktop GIS, the initial principle to be followed is to analyze existing solutions that can provide the necessary functions for editing, analysis, and presentation. There are several software solutions based on GIS Desktop, which are basically classified as commercial software and open-source software. Among the largest companies in the world that have developed commercial software are ESRI, Intergraph, Bentley, MapInfo, etc. The most popular open-source software is QGIS, GRASS GIS, ILWIS, uDig, etc.

Both platforms provide fundamental analytical capabilities. The analytical capabilities required for this case are within the classification of: retrieval, reclassification and measurement; topological; and neighborhood. Specifically, the desktop GIS must provide the analytical functions as presented in figure 5.46.

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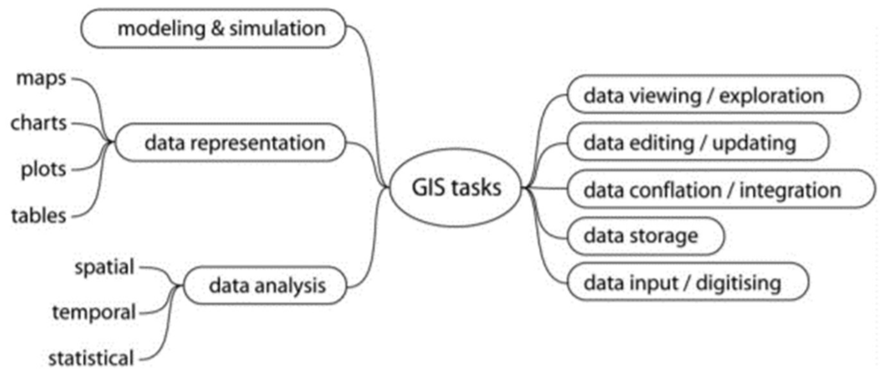

Figure 5.45 GIS tasks

The abovementioned functions will be used to solve spatial problems for the three specific modules that will be part of Web GIS.

- For the first module – redesignating agricultural land, support from the desktop GIS will be mainly in the preparation and processing of the basic data, such as 1) Land classification data, 2) Irrigation system network, and 3) Agricultural land under land consolidation. After such layers are processed, they will be integrated into the central geodatabase and further managed through Web GIS.
- For the second module – management of soil monitoring from current and potential erosion risk, the desktop GIS is important during the phase of map creation, as described in section 5.5.2.
- For the third module – soil pollution monitoring, the desktop GIS is required during the phase of map creation that reflects the level of pollution of agricultural lands. In these cases, it is necessary to record the results of the analysis of soil samples for grid points and the use of interpolation methods for generating maps.

5.6.1.1 Comparative analysis between commercial and open-source software

Multiple authors have analyzed the differences between commercial and open-source software platforms (Chand and Sahib 2014; Eldrandaly 2007a; Eldrandaly and Naguib 2013; Rinaudo, Eros, and Ardissone 2007; Steiniger and Hay 2009; Tsou and Smith 2011; Zamir, Kamis, and Khuizham 2014). In order to make the right selection, it is necessary to consider various factors, such as cost of purchase, cost of maintenance, support from the manufacturer, the best technological possibilities, etc. In fact, for this research, we are classifying the most significant factor into two main categories: 1) technological and 2) economic (Sánchez *et al.*, 2020).

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Technological factors mainly include technical issues, such as: compatibility, reliability, usability, maintenance, etc. Compatibility refers to adapting data from various formats and other software systems. From this perspective, open-source software have an advantage due to the interoperability with more databases, e.g., QGIS uses libraries like GDAL / OGR to read geospatial data formats, and it can read and write about 70 vector model formats. In addition to interoperability with PostGIS, there is the possibility of other databases, such as shapefile, MapInfo formats, Microstation file formats, AutoCAD DXF, SpatiaLite, Oracle Spatial, MSSQL Spatial databases, etc. Reliability depends on how much software is used for certain issues and in what time period. How well tested is it? Potential users can freely plan its use for solving specific spatial problems. From this perspective, commercial software has an advantage as leading companies in the world develop them and test them simultaneously. There is a considerable group of experts who deal only with the testing part. Commercial software have started to develop earlier, have an almost global reach, and consequently are more proven. Usability has to do with how user-friendly the software is, i.e., how easy and operational the user interface is. From this perspective, commercial systems take priority over open-source ones, as the latter do not consider the user interface as the most important aspect. In fact, this is a very important factor in selecting the system in our case. It should be noted that the level of application of desktop GIS software in the state and local sectors is below the desired level. So, there are no or very few people prepared to use desktop GIS software. If a type of software is more user-friendly, the staff can be trained to use it more quickly. Additionally, commercial software offer better support, as long as the company manages the sales and maintenance process. However, with the increase in the number of users of open-source software, the capacities of IT providers are also expanding. As a result, the relevant institution has the opportunity to engage such people for support and maintenance purposes.

Economic factor. Undoubtedly the economic aspect that includes the purchase and maintenance is a very important factor in selecting the most suitable software. In commercial software, the cost of the license is a factor that is very different from the free software. Further, the costs of maintenance and support, as well as training of staff shall also be considered. If we compare the cost only for licenses, then commercial software has a certain cost, while free ones have none . If we compare the cost of support and training of staff, both types of software involve certain costs. In this case, for free software the user has to hire experts for training and support, while in commercial software, this is provided by the software vendor, and in most cases, these are part of the cost along with the purchase of the license. So, the maintenance and support costs may be lower for commercial software. However, in economic terms, free software has an advantage over commercial software.

To conclude, both commercial and free desktop GIS, have disadvantages and advantages in terms of technological and economic factors. Two factors distinguished from those discussed above are user-friendliness as part of technological factors and cost as part of economic factors. In the first, commercial software took precedence, while in the second, open-source software. Along with these two factors, it is important to relate to another aspect explained in Chapter 4, section 4.3.5 - the aspect of current knowledge and the state of use of GIS desktop software in responsible institutions such as MoA and relevant departments in municipal institutions. This section clarified that in MoA there no desktop GIS is used at all to manage geospatial data. Also, in local institutions, desktop GIS is not used for the administration and monitoring of agricultural land, although it is used for some other issues: DoSP uses ArcGIS only at the basic level, in a completely individual form and not in a systematic manner. Considering this fact as well as the initial level of knowledge of the staff in traditional software that is usually commercial, then it is thought that the use of such software would be an advantage over open source software. The initial challenge for starting the use of geospatial technologies is converting from manual to digital methods and how to encourage the staff to use these technologies. Although the economic aspect is significant, in this situation is not the most important aspect. Using open-source software may have lower costs than another commercial one, but if potential users hesitate to use it, it becomes useless.

5.6.2 Web GIS-based solution

From today's perspective, geospatial information systems are no longer just systems that maintain a spatial database and can be used by a certain group of users within an organization. Technological developments can generate important information from data and distribute it to several users in multiple organizations. Such systems enable easy access to potential users and thus help cooperation and interaction between them. This approach goes beyond the capabilities of traditional systems, which were used to solve interrelated spatial problems within a specific organization. Nowadays, it is not enough just to collect and store data, but to convert it into information and distribute it to all interested users within one organization, or within multiple organizations, and to the public.

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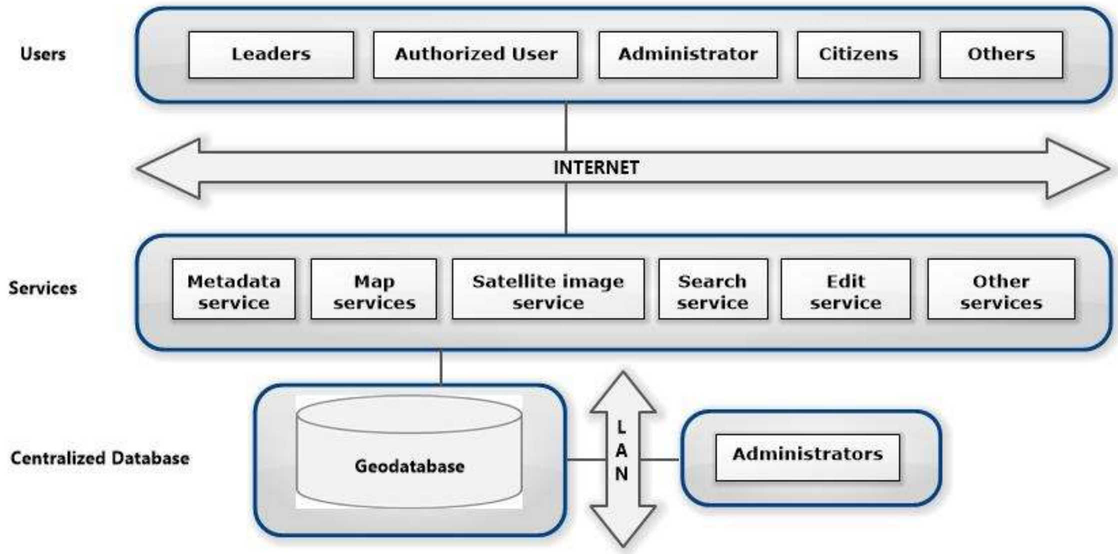

Figure 5.46 Web GIS architecture (modified from: Trung, Tam 2018)

Web-based GIS systems enable the modernization of data handling and spatial problem solving (figure 5.47). Web GIS can provide all GIS functions on the Web and these functions apply to different disciplines and industries (Sylka *et al.*, 2018). They offer remote access, access to the same data regardless of the user, in which case it minimizes errors and increases efficiency. Further, the ability to analyze spatial and non-spatial data and generate specific results is crucial, which in fact are information that can be very important for decision making.

5.6.2.1 Web GIS architecture

Web GIS architecture is based on the client-server model, where geoprocessing is shared between the server and the client, where the client is a web browser, and the server is a web server (Alesheikh et al. 2002). Such an architecture is three-tier (figure 5.48):

1) Presentation tier – where the information of static and dynamic data, as well as the graphic part and maps are presented.
2) Logic tier – where data generation and processing are done.
3) Data tier – where the management of logical database entities takes place.

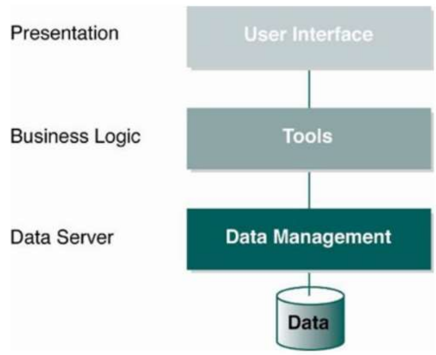

Figure 5.47 Three-tier architecture

The development of a Web GIS can be done in open-source technologies and commercial ones. Table 5.8 presents some of the possible platforms for Web GIS development according to the respective layers.

Table 5.8 Three-tier architecture technologies

Tier	Commercial	Free
Presentation tier	ArcGIS API for java script, ArcGIS API for Flex	Bootstrap / HTML5, OpenLayers, jQuery / Ajax / JSON / jqGrid
Logic Tier (Application server)	ArcGIS Server	JAVA, Apache Tomcat, Hibernate Spatial, JTS Topology Suite (JTS), GeoServer, MapServer, Mapbender
Data Tier (Database)	ORACLE, MSsql, ArcSDE	Mysql, Postgresql

The proposed Web GIS is a system dedicated to a specific discipline. Indeed, it is not a comprehensive system, which could be used in many areas. It is dedicated to disseminating information regarding the administration and monitoring of agricultural land use. As such, it is divided into three main modules:

1. Module for managing the process of redesignation of agricultural land
2. Module for managing the monitoring of soil from current and potential erosion risk, and
3. Module for soil pollution management.

Access to these modules should be scalable for potential users (figure 5.49). The first module will be accessible to users from the local government level, such as DoSP, DoA, as well as from the central level, MoA, officials from the GIS and Lands division. The second and third modules will be accessed by officials from the GIS and Lands Division in the MoA, and officials from the agriculture department in the municipal government. The public will have access to information in a view-only mode.

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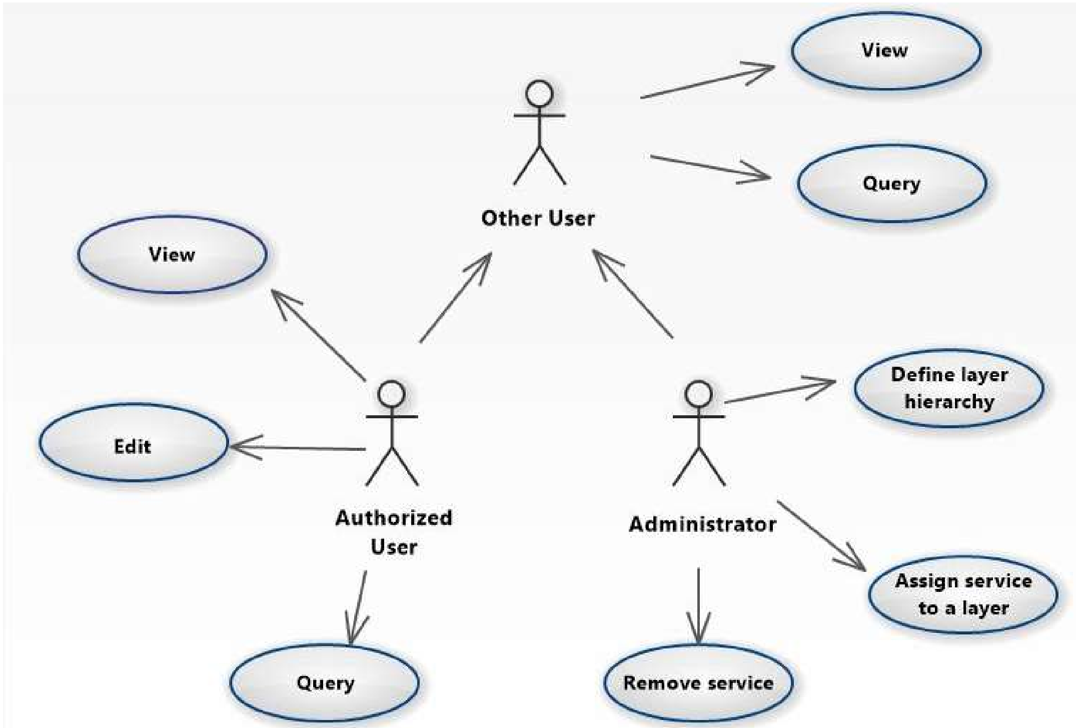

Figure 5.48 Access user rights

5.6.2.2 *Geospatial web services*

Geospatial web services enable the integration of spatial data into various geoinformation systems via the Internet and the web. This integration is often not visible to users. Web GIS systems provide a centralized and uniform interface for access to various distributed sources and data services. Usually, such systems are designed for specific topics, specific data, and targeted users. The geodatabase of a similar Web GIS may not provide all the spatial layers that users may need. Therefore, through geospatial services, the integration of data from systems or other existing web portals is enabled (figure 5.50).

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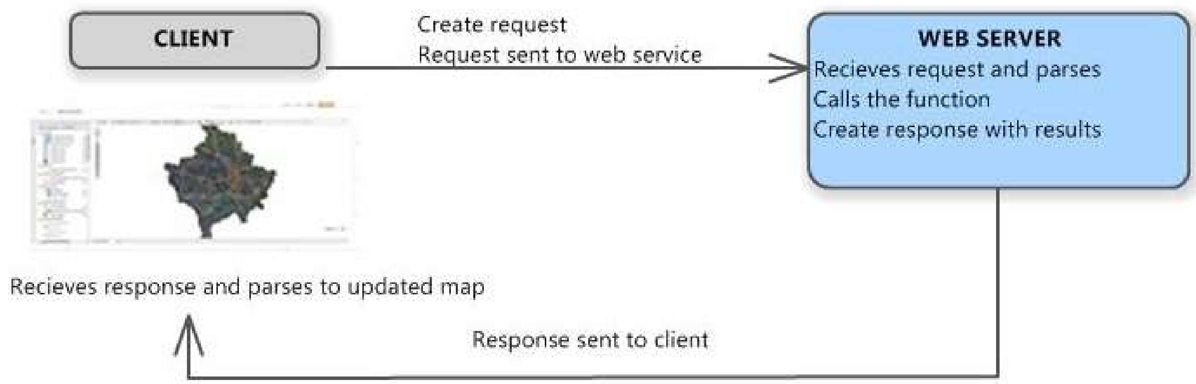

Figure 5.49 Map service operation

Web Map Service (WMS) – provides a simple HTTP interface to search for images created from the geospatial database. A WMS request specifies the geographic layer and area of interest one want to proceed with. Response to requests is one or more map images (which are run by JPEG, PNG, etc.) that can be displayed in a web browser or GIS software. The interface helps specify whether map images should be made transparent so that the layers from different servers can be combined with each other. Generally, the following functions are available: map display and navigation; zoom to layer; layer control; and identify feature. There is no option available to select and proces the features as well as it cannot display the attribute table.

Web Feature Service (WFS) – defines the interface and operations provided through the HTTP protocol for accessing and manipulating spatial data stored in a geodatabase. Operations include requests containing spatial and non-spatial restrictions, creating, deleting, and updating new features. A WFS request usually results in a response involving a load of data in GML2, GML3, GeoJSON, etc.

Web Coverage Service (WCS) - defines a standard interface and operations that enable interoperable access to geospatial "coverage" (http://www.opengeospatial.org/ogc/glossary/c). The term "grid coverage" typically refers to content such as satellite images, digital aerial photos, digital elevation data, and other phenomena represented by values at each measurement point.

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Chapter 6

6 Conclusion and Recommendations

This research initially analyzes the techniques to support spatial decision-making in public institutions. The spatial decision supporting systems are elaborated in more detail. Furthermore, this research looks at the possibilities of applying such techniques in the administration and monitoring of agricultural land in Kosovo. In this regard, research has included the need for agriculture land planning and monitoring, the analysis of the legislative framework, and the institution's authorities and responsibilities related to this sector. Next, it analyzes the current state of application of geospatial analytical tools in the selected institutions. Based on the findings, the paper derives detailed user requirements for a geospatial information system in the protection of agricultural land from three potential factors:

- ✓ Agricultural land redesignation,
- ✓ Erosion risk, and
- ✓ Soil pollution from industrial activities and the application of intensive agriculture, i.e., the use of pesticides, herbicides, and fertilizers

The fifth chapter covers the conceptual modeling of the system for the management and monitoring of agricultural land use. This modeling has also included the geospatial data requirements, conceptual data model, data acquisition approaches, data sources, data representation models, metadata, and data quality assessment. In addition, it presents the base concepts of geospatial functions, with the main focus on analytical capabilities. The chapter ends with an analysis on the selection of the most suitable GIS software platforms.

The system consists of three main modules related to three potential factors in soil degradation. The main module is the administration and monitoring of agricultural land redesignation. Decision-making for this process is shared between three different public institutions at the central and local level. As discussed above, the system in question will provide significant support in this process based on the following principles: information management, interoperability between different institutions and citizens, interoperability with other existing systems, increased efficiency, time-saving, and greater transparency of institutions for the public. This will also have a significant impact from the perspective of improving the management of spatial information at the national level, as a requirement of the EU INSPIRE directive to

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establish the NSDI. Monitoring the use and capacity of agricultural land is also essential because it will directly affect the preservation of agricultural land in Kosovo, particularly higher-class soil. This is most important during the land use planning process, where the responsible institution will be able to access the system and get the spatial data for soil classes. Based on this information and the relevant legal requirements, the higher quality land areas will be limited to agricultural use only, and redesignation will not be permitted. In addition to soil class data, the system will provide other important information from this perspective, such as land areas under the irrigation system and land areas under consolidation, which should also be excluded as potential areas for uses other than agriculture. As a result, the system will fully meet its primary goal defined in the introduction of this research.

The second module covers monitoring of the erosion risk in agriculture areas. At first, the system provides functionality for mapping the actual and potential erosion. The CORINE model will enable us to model the process and include data in the final maps. These maps will serve decision-makers to identify locations with the highest risk of erosion. Consequently, the responsible institutions may decide on the limited use of certain agricultural land areas. Such decisions will also be published along with maps on the Web GIS platform. All landowners will be able to see potential locations and are therefore obliged to abide by institutional decisions regarding eventual restrictions on the use of certain land areas. This will ensure continuous monitoring of erosion risk as a natural phenomenon that affects the degradation of agricultural land.

The third module of the system will monitor the pollution level of agricultural lands. In this regard, the mapping will be based on the samples taken on specific locations and laboratory results for potential pollutants such as chemical elements chromium, zinc, lead, etc. At this point, the utilization of known spatial interpolation methods will be needed. Such maps will be open access data in the Web GIS platform to the public, i.e, landowners. If the map shows a high concentration of specific metals, the MoA, based on the law, can make decisions that prohibit agricultural activity in certain areas until they are decontaminated.

The application of geospatial analytical functions and systems for the management of spatial information requires adequate infrastructure and sufficient human resources. Based on the results achieved in this research, it is recommended that public institutions part of this research start fulfilling these two preconditions and finally implement a system like the one modeled here. The benefits will be to all parties involved in land use issues in Kosovo. Lastly, exploring options for additional functions or modules to the proposed system is recommended.

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7 New scientific results

1) Analytical tools in government services for the spatial decision-making process

Different categories, such as unstructured, semi-structured, and structured spatial problems faced by government institutions related to land use are analyzed. The needs from the operational and strategic perspectives of the respective institutions to support the spatial decision-making process have been assessed. As a result of needs, different analytical tools and techniques are compared, such as GIS, expert systems, and SDSS. SDSS, with its components, has been reviewed to support the spatial decision-making process to be data-driven, model-driven, and coordinated between decision-makers at different levels. The research done for this scientific result is presented in Chapter 3.

2) Analysis and needs assessments for a new approach in agriculture land use administration and monitoring

The loss of agricultural land areas is analyzed based on the land use maps of 2000 and 2018 for the territory of Kosovo. Results show a loss of 6.33% of the total area. Further, the paper analyzed the current methodologies of the responsible institutions used for the spatial decision-making process related to agricultural land use protection from further degradation. The results showed that the application of spatial analytical tools is almost non-existent. Based on the authorities and responsibilities of the state and local institutions in charge of the administration and monitoring of agricultural land use, a new approach in agriculture land use administration and monitoring is required. Such an approach will greatly impact the protection of agricultural land from eventual degradation. The research done for this scientific result is presented in Chapter 4.

3) Geospatial data modeling for agriculture land redesignation, erosion risk, and soil pollution

Based on real spatial phenomena, the necessary geospatial data, as well as their sources, have been identified. Each identified spatial feature is further defined if it is a base or operational data. A conceptual model with the necessary data has been developed. Based on the analysis of spatial data sources, if specific data is absent, they were created based on some samples. For example, laboratory analysis results for grid points in an area of 10200 hectares are used. Based on these results, a soil class map is generated. This map is used as input data for updating the soil class attribute in cadastral parcels. The same approach has been followed for developing actual and potential erosion risk maps. In addition, the data quality assessment accompanied by an example using land cover maps is elaborated. The research done for this scientific result is presented in Chapter 5, section 5.4.

4) Geospatial functionalities for administration and monitoring of agricultural land redesignation, erosion risk, and soil pollution

To support the decision-making process related to the administration and monitoring of agricultural land redesignation, erosion risk, and soil pollution, the necessary analytical functions are selected. These functions are classified into four categories: 1) retrieval, reclassification, and measurement; 2) topological; 3) neighborhood, and 4) connectivity. For each category, these functions are analysed and applied through practical examples, using spatial data in an area of 10200 hectares. In addition, the methodology for interoperability among users from different locations is presented. The research done for this scientific result is presented in Chapter 5, section 5.5.

5) Critical analysis on the potential of open-source and commercial software in supporting spatial decision-making

This research includes a comparative analysis for selecting the most appropriate software solutions based on critical aspects such as technological and economic. This analysis is presented in Chapter 5, sections 5.6 and 5.7. Several factors from these two groups have been analyzed, but the cost and usability have been selected as key factors in determining the solution. These two factors are mainly used to analyse the current state of implementation of software systems in relevant public institutions. From this perspective, the proposed software solution represents a solid basis that these institutions can use in the future.

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