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A GEOSPATIAL FRAMEWORK FOR MANAGEMENT OF THE INTEGRATED ADMINISTRATION AND CONTROL SYSTEM (IACS) IN THE REPUBLIC OF MOLDOVA

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Abstract. The paper proposes a methodology and a validation framework for the development and implementation of the Land Parcel Identification System (LPIS) in the Republic of Moldova. The main purpose of the paper is to analyze the theoretical and technological foundations of the IACS and LPIS systems in the European Union countries, as well as to present the existing context and the possibilities for its development and implementation in the Republic of Moldova. The research aims to highlight how geospatial technologies contribute to the efficiency of land administration and the optimization of decision-making processes in priority areas, such as agriculture. The objectives of the paper include, among others, examining the fundamental concepts related to the IACS system, analyzing the role of existing spatial data and modern spatial technologies in monitoring land. At the same time, a design exercise for physical blocks delimitation was carried out, taking into account the existing data in the national spatial data infrastructure and the existing regulatory framework in the Republic of Moldova, adapted to specific institutional and operational requirements. The research methodology is based on the critical analysis of the specialized literature, international/European regulations and standards relevant to the field. At the same time, specialized platforms and programs were used in the research, such as the QGIS software, as well as other modern GIS solutions, which facilitated the practical understanding of the processes of integration, administration and analysis of spatial data. The principal limitations of this work arise from its predominantly conceptual research approach, in the absence of full access to official data sets and institutional resources, since these are regulated by the legal framework, cooperation agreements, spatial data sharing protocols, also the need to protect the confidential data of landowners.

Keywords: *Land Parcel Identification System (LPIS), Geographic Information Systems (GIS), remote sensing, orthophoto, QGIS.*

***R*ezumat.** Lucrarea propune o metodologie și un cadru de validare pentru dezvoltarea și implementarea Sistemului de Identificare a Parcelelor Funciare (LPIS) în Republica Moldova. Scopul principal al lucrării este de a analiza fundamentele teoretice și tehnologice ale sistemelor IACS și LPIS în țările Uniunii Europene, precum și de a prezenta contextul existent și posibilitățile de dezvoltare și implementare a acestuia în Republica Moldova. Cercetarea își propune să evidențieze modul în care tehnologiile geospațiale contribuie la eficiența administrării terenurilor și la optimizarea proceselor decizionale în domenii prioritare, precum agricultura. Obiectivele lucrării includ, printre altele, examinarea conceptelor fundamentale legate de sistemul IACS, analiza rolului datelor spațiale existente și al tehnologiilor spațiale moderne în monitorizarea terenurilor. A fost realizat un exercițiu de proiectare pentru delimitarea blocurilor fizice, luând în considerare datele existente în infrastructura națională de date spațiale și cadrul de reglementare existent în Republica Moldova, adaptat cerințelor instituționale și operaționale specifice. Metodologia cercetării se bazează pe analiza critică a literaturii de specialitate, a reglementărilor și standardelor internaționale/europene relevante domeniului. În același timp, în cercetare au fost utilizate platforme și programe specializate libere și deschise, cum ar fi programul QGIS, precum și alte soluții SIG moderne, care au facilitat înțelegerea practică a proceselor de integrare, administrare și analiză a datelor spațiale. Principalele limitări ale acestei lucrări derivă din abordarea predominant conceptuală a cercetării, rezultată din absența accesului deplin la seturi de date oficiale și resurse instituționale, deoarece acestea sunt reglementate de cadrul normativ, acorduri de cooperare, protocoale de partajare a datelor spațiale, precum și de necesitatea protejării datelor confidențiale ale proprietarilor de terenuri.

Cuvinte cheie: Sistemul de Identificare a Parcelelor Agricole (IACS), Sisteme Informaționale Geografice (SIG), teledetecție, ortoimagini, QGIS.

1. Introduction

Current developments regarding the processing, storage and use of spatial data and their use in various fields, including agricultural land information management, have undergone fundamental changes. Furthermore, innovative and integrated methods are meant to support the development and modernization of agriculture, through more efficient and transparent administration. A suitable example at EU level is Integrated Administration and Control System (IACS), which comprises a variety of interconnected digital elements, technology, institutions and databases (Figure 1). It also integrates two key geospatial subsystems: the Land Parcel Identification System (LPIS) and the Geospatial Application (GSA). The LPIS identifies agricultural lands eligible for payments under the EU Common Agricultural Policy (CAP) within designated areas. In IACS terminology, these areas are called reference parcels. Each reference parcel can consist of several agricultural parcels, which are the main spatial units represented in the GSA geodata [1].

Beyond this, one of the important framework that regulates and supports the agricultural sector within the Union is the Common Agricultural Policy [3, 4], and according to information published by the European Commission, it represents one of the most important and oldest common policies, implemented since 1962, with the main aim of supporting farmers, ensuring food security and, at the same time, the sustainable development of rural areas. Thus, the IACS represents a current, administrative and informational mechanism developed within this complex framework, first introduced in 1992 by the European Union with the aim of managing, monitoring and controlling direct payments granted to farmers [5]. This system has the role of ensuring the correct and transparent distribution of agricultural funds, by verifying the eligibility of beneficiaries and the land areas for which financial support is requested. The IACS system is based on the use of electronic registers and databases that store information relating to agricultural activity, land parcels used for agricultural purposes and subsidy applications submitted by farmers.

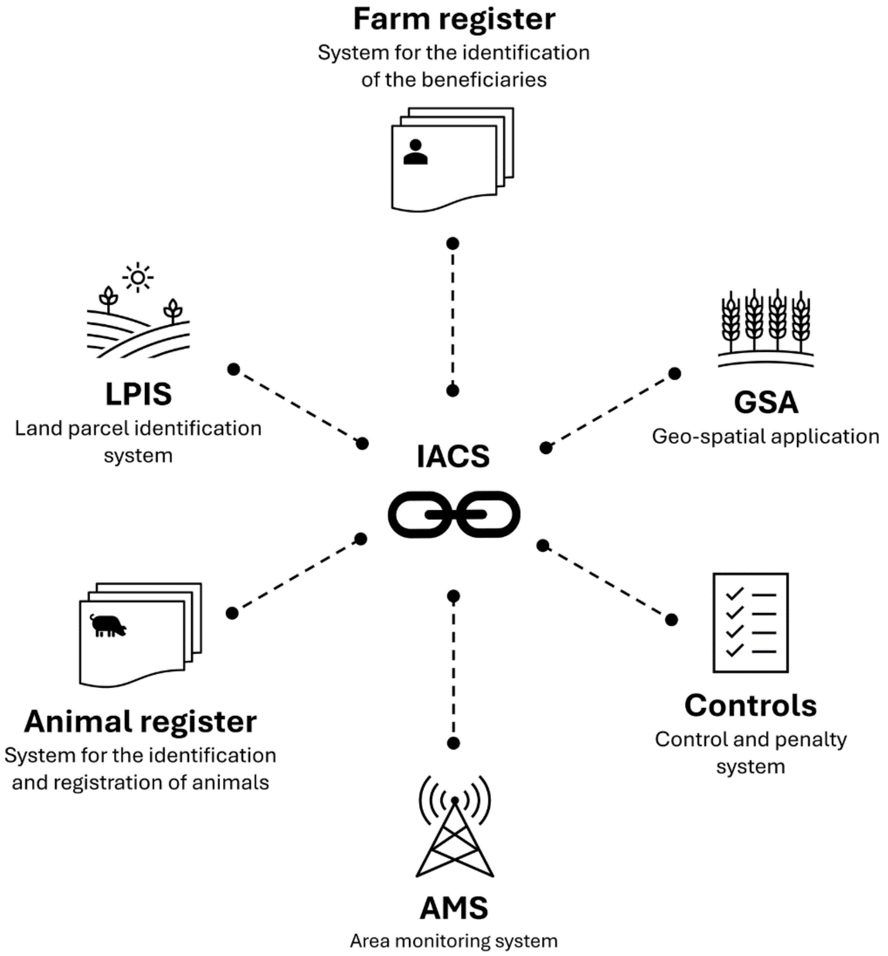

Figure 1. Overview of the digital components, systems and databases that make up IACS.
Source: Jänicke, C., Petersen, KA, Schmidts, P. et al. [2].

By correlating and analyzing this data, the system allows for the precise identification of agricultural areas, verification of compliance with eligibility criteria, etc. In this context, it should be noted that the Republic of Moldova obtained the status of candidate country for accession to the European Union in October 2024. The process of negotiating accession chapters requires compliance with community norms in all areas, including Chapter 11, Agriculture and Rural Development. This chapter requires, among other things, the implementation of a functional Integrated Administration and Control System (IACS), which allows for the management of direct payments to farmers and the verification of the compliance of subsidy applications [6].

The fundamental geospatial component of IACS is the LPIS, which is an agricultural parcel identification system based on high-resolution orthoimagery, which allows the unique location, precise delimitation and measurement of areas eligible for payments. According to Regulation (EU) 2021/2116 Art. 66-68 [7], each Member State adopting the system must establish and maintain an LPIS based on reference maps or cadastral data, complemented by modern remote sensing techniques. More specifically, the specific regulatory framework of this approach includes the following reference acts:

1. Commission Delegated Regulation (EU) 2022/1172 of 4 May 2022 supplementing Regulation (EU) 2021/2116 of the European Parliament and of the Council with regard to the integrated administration and control system in the common agricultural policy and the application and calculation of administrative penalties for conditionality [8], Articles 2-4,

laying down detailed rules on the LPIS, including the definition of the reference parcel, the minimum mandatory attributes and the quality requirements for spatial data;
2. Commission Implementing Regulation (EU) 2022/1173 of 31 May 2022 laying down rules for the application of Regulation (EU) 2021/2116 of the European Parliament and of the Council with regard to the integrated administration and control system in the common agricultural policy [9], Articles 8, 10, 12 lay down the technical rules for the implementation of IACS, including the requirements for LPIS quality control and data acquisition;
3. International standard ISO 19157:2013. Geographic information - Data quality [10], used as a reference for quality control of spatial data produced for the implementation of IACS;
4. Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) [11], which ensures the creation, existence and interoperability of spatial data and metadata;
5. Law No. 254/2016 on the national spatial data infrastructure [12], which regulates, develops and implements policies in the field of spatial data infrastructure in the Republic of Moldova;
6. Law No. 71/2023 on subsidies in agriculture and the rural environment [13], which regulates the duties in this fields;
7. Technical Guidelines on IACS Spatial Data Sharing - Part 2 – Interoperability [1], which details information regarding Land Parcel Identification System (LPIS) and Geospatial Aid Application (GSAA), data models and solutions to address the lack of harmonisation of GSAA datasets in Europe, which is, among other considerations, the main obstacle to the interoperability of spatial datasets of IACS.

The list of normative acts, technical specifications and standards that contribute to the development of this integrated system can continue, because in the implementation, official information will be accessed from several state registers and geographic information systems (parcels, administrative boundaries, land cover, roads, water bodies, rivers, utility networks etc.) being designed to be interactive, for the permanent update of information. At the same time, the national framework already indicates certain technological aspects in regard to systems' development, including the creation of a technological solution compatible with the common government technological solutions and platforms, namely MCloud and MConnect, or the principles that must be taken into account such as: legality, division of the architecture into levels, expandability, security by design, modularity and scalability, etc.

The system will also include administrative and technical control mechanisms that allow permanent updating of data regarding agricultural land use and the changes' monitoring at the farm level. Through these functions, IACS contributes to increasing the efficiency of the agricultural payments administration process, reducing errors and fraud, and strengthening transparency in the management of funds for the agricultural sector.

2. Materials and methods

The research on the implementation of a Geographic Information Systems (GIS) framework for the efficient management of the Integrated Administration and Control System (IACS) in the Republic of Moldova is based on an interdisciplinary approach, which combines specific methods to the fields related to geoinformatics, land administration, spatial analysis and information systems management.

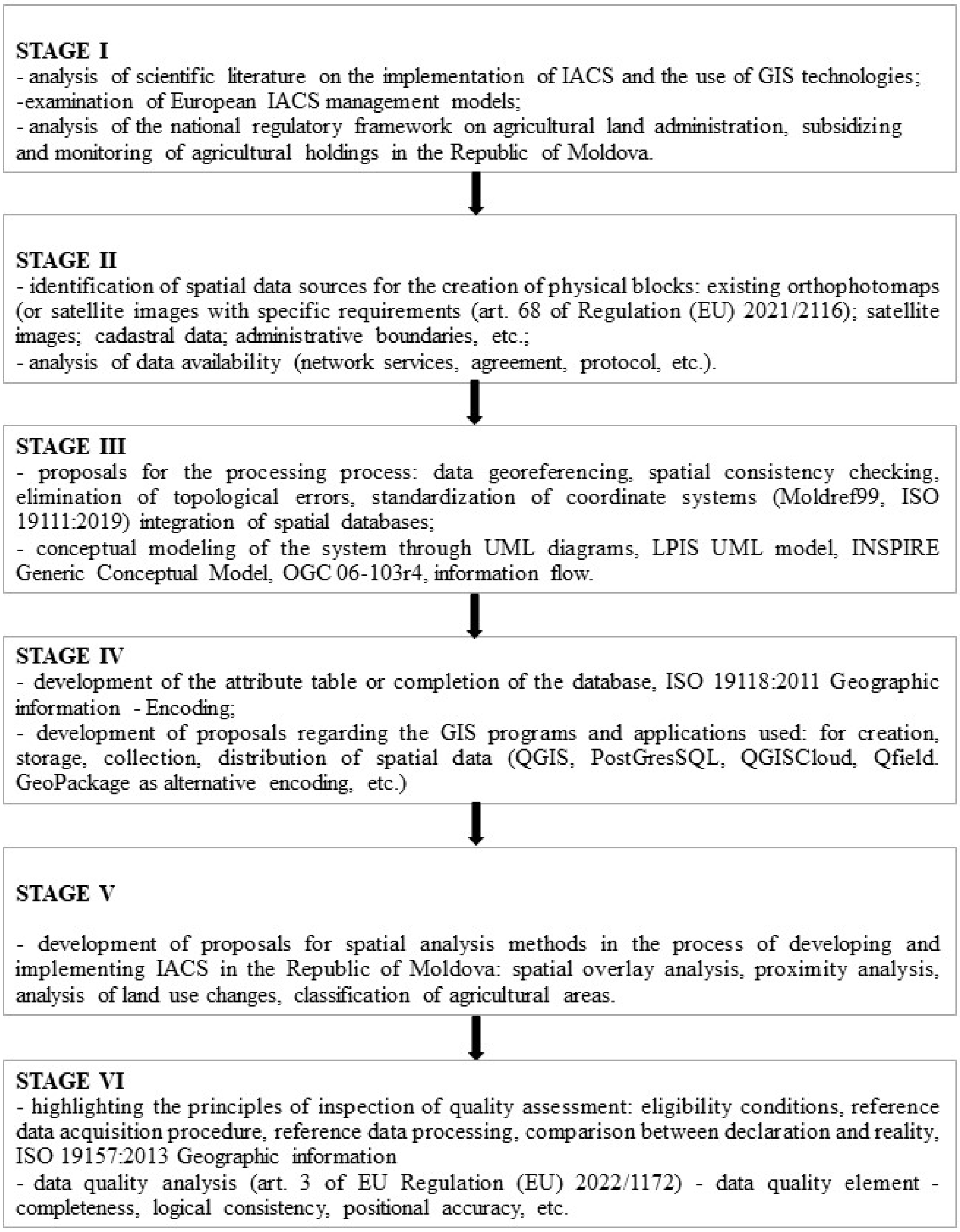

Figure 2. Methodology applied for the study.

Source: prepared by the author.

The proposed methodology aims to assess the current structure of IACS, identify the limitations of existing administration and control processes, design an integrated GIS framework, test spatial analysis and monitoring functionalities, formulate recommendations for optimizing administrative and agricultural control processes This system supports the authorities in making strategic decisions and contributes to the sustainable development of the agricultural sector. Thus, at the moment, the Government of the Republic of Moldova has adopted GD No. 597/2024, by which the "Farmers' Registry" Information System was established as a component part of IACS, strengthening the legal and digital framework necessary for the management of subsidies, transparency of public funds and modernization of agriculture [9] and is in the process of developing the Government's decision on the approval of the IACS concept. The research is of an applied nature and uses both quantitative and qualitative methods, and in more detail, the addressed methodology is presented in Figure 2.

Also methodology is based on the realities and spatial data existing in the Republic of Moldova. At the same time, it is important to clarify with reference to two important terms, namely: Declared area (or requested area), which is the area declared by the beneficiary as eligible for payment within a certain unit amount. The declared area can be applied both to individual parcels and at the farm level. Therefore, the declared area excludes any areas well known/recorded as permanently ineligible, included in the outer perimeter of a requested parcel; Eligible area, being the area corresponding to the number of hectares for which all the conditions related to a requested unit amount have been met. The eligible area can be applied both to individual parcels and at the farm level, depending on the criteria submitted for the creation of the data set [14].

3. Results

The proposals made in this paper start from the assumption that the Republic of Moldova has been administering and managing the Farmers' Register for several years and the Ministry of Agriculture and Food Industry (MAIA) is responsible for the administration, maintenance and development of the system, being the official owner of the Farmers' Register [13]. The Agency for Intervention and Payments for Agriculture (AIPA) manages farmers' data and coordinates the application of subsidies, ensuring the fairness and transparency of the allocation of funds. It works in collaboration with other public institutions and is integrated with the MConnect interoperability platform, which facilitates the data exchange between the different registers and government entities. There is also a similarity in the scope of application between certain types of LPIS and GSA elements and the types of elements of the following INSPIRE spatial data themes, or in national terms, Law 254/2016 [12]:

1) Annex I: Cadastral parcels (CP): similarity (in specific cases, coincidence) between reference parcel (ReferenceParcel) and LPIS cadastral parcel (CadastralParcel - CP) INSPIRE element types.

2) Annex II: Land Cover (LC): similarity between the LPIS Landscape Feature and the INSPIRE Land Cover Unit (LC) element types.

3) Annex III: Land Use (LU): similarity between LPIS Agricultural Area (AgriculturalArea) and Existing Land Use Object (ExistingLandUseObject - LU) INSPIRE element types. Thus, there is similarity between the GSA element type of Agricultural Parcel (AgriculturalParcel) and Existing Land Use Object (ExistingLandUseObject - LU) INSPIRE element types. Accordingly, these similarities allow new INSPIRE-compliant LC/LU datasets to be derived from LPIS/GSA datasets and existing INSPIRE-compliant CP datasets to be reused to generate LPIS datasets.

Therefore, in order to develop the space component in IACS, spatial data modeling and creation is the process by which real-world objects and phenomena are transformed into a digital form usable in GIS systems. Within the framework of data modeling and analysis activities for the development of LPIS in the Republic of Moldova, it is recommended to use the free and open-source specialized software – QGIS [15], intended for visualization, processing and manipulation of raster (Figure 3) and vector (Figure 4) spatial data.

The implementation of the LPIS in the Republic of Moldova involves the development of a geospatial infrastructure capable of managing, updating and controlling agricultural areas eligible for the administration of agricultural subsidies within the IACS system.

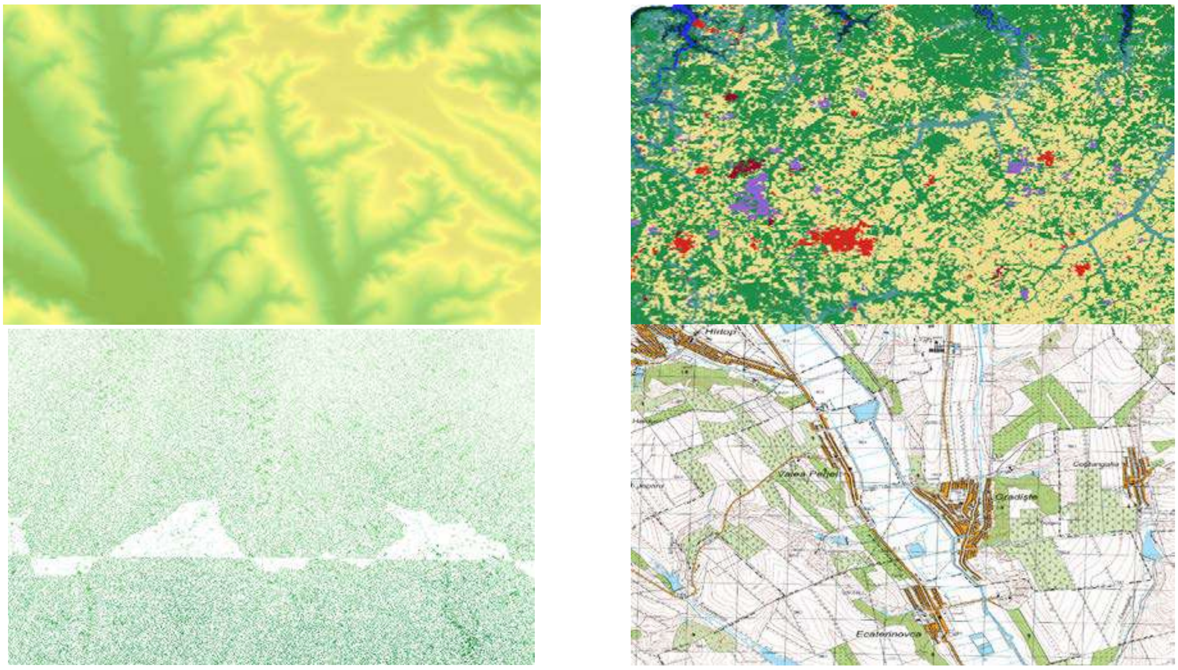

Figure 3. Viewing and managing raster data used to create new data.
Source: developed by the author based on data from GEODATA.

Thus, an important role in this process is played by the classification of cadastral information referring to land, administrative boundaries, addresses, digital terrain model, orthophoto with a resolution of at least 50 cm for the last year, land cover, etc., but also the integration of spatial data and the use of modern GIS and remote sensing technologies for the analysis of multi and hyperspectral images for crop mapping, vegetation indicators, etc.

It should be noted that land cover mapping plays an essential role in providing the necessary information for many areas, including the implementation of IACS in the Republic of Moldova, territorial planning, environmental management, agricultural activities and natural resource management. As a solution for this process, the Google Earth Engine [16, 17] is proposed, which can have an essential role in mapping agricultural crops and land cover for the LPIS development, due to its capacity to process large satellite and spatial data. Google Earth Engine allows the use of images from various archives such as Google Earth Engine Data Catalog [18], European Space Agency Sentinel-1 and Sentinel-2, NASA Landsat, which can be used for delimiting agricultural plots, identifying crop types, automatically classifying agricultural areas, and periodically updating maps. At the same time, it must be taken into account that for good data accuracy a resolution of ⩽ 0.5 m is required.

Therefore, the use of open-source solutions reduces implementation costs and provides flexibility in data management and updating. It is also recommended to use in the system design the use of network services (WMS, WFS) or modern APIs [20] and other interoperability standards that facilitate data exchange between institutions and the automation of verification and monitoring processes of agricultural areas. For the creation of spatial data management, it is proposed to use the GeoPackage format, which allows storing in a single file the geometry and attributes associated with agricultural parcels (data collection date, name/surname of the engineer who collected the data, land cover, classifier, etc.). Also, for the management of large amount of spatial data and the performance of advanced queries, the PostgreSQL database [21] with the PostGIS spatial extension can be used.

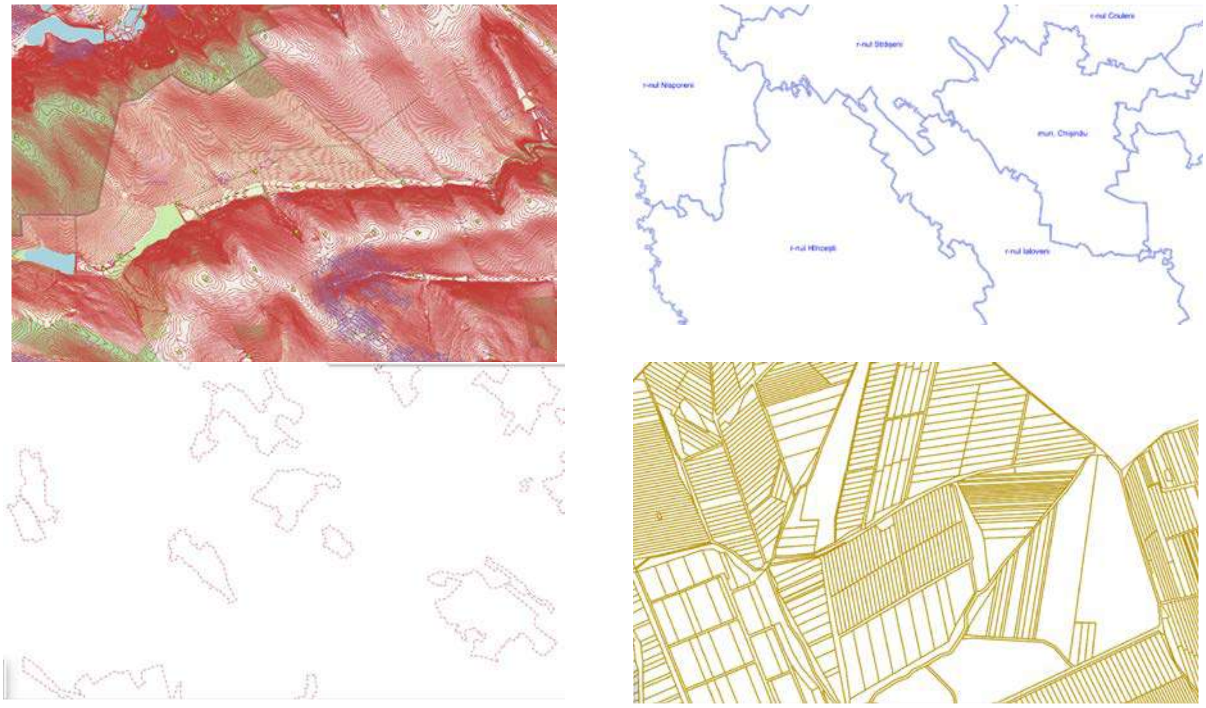

Figure 4. Viewing and managing vector data used to create new data.
Source: developed by the author based on data from GEODATA [19].

The use of open-source solutions reduces implementation costs and allows the development of a flexible and interoperable system. It is also important to choose a GIS infrastructure that ensures data interoperability and the integration of diverse sources, such as satellite images, cadastral data and field information.

Thus, the relationship between physical blocks, agricultural parcels and other data in the system is defined as follows: the physical block represents the reference cartographic unit, and the agricultural parcel represents the area declared by the farmer within this physical block. For the exercise of analyzing the possibilities and realities of the Republic of Moldova, QGIS software was used, an open-source geographic information system, which allowed the processing, analysis and visualization of spatial data. The management and storage of geospatial information was carried out through the GeoPackage database, chosen due to its advantages compared to traditional formats (such as Shapefile), offering a single integrated file, support for multiple layers and better data consistency.

As for the data sources, among others, orthophoto 2020 was used, which constituted the main basis for the interpretation and delimitation of land units. Although the use of annually updated orthophotomaps is recommended for the operational implementation of the LPIS, these data were used in the case study as a support for spatial analysis and methodological example. Additionally, the reference data from Public Institution Real Estate Cadastre [23] was used, which provided a basic cadastral framework for correlating and verifying the geometry of physical blocks. These data allowed a easier recognition between cadastral information and visual interpretation of land cover, contributing to increased accuracy of the process of spatial units' delimitation and validat [25].

For the purpose of implementing the LPIS in the Republic of Moldova, each Reference Parcel receives a unique classification according to the European Land Cover Groups nomenclature. The classification is carried out based on photointerpretation of orthoimages, supplemented where necessary with auxiliary data (Sentinel-2, CORINE Land Cover, cadastral data).

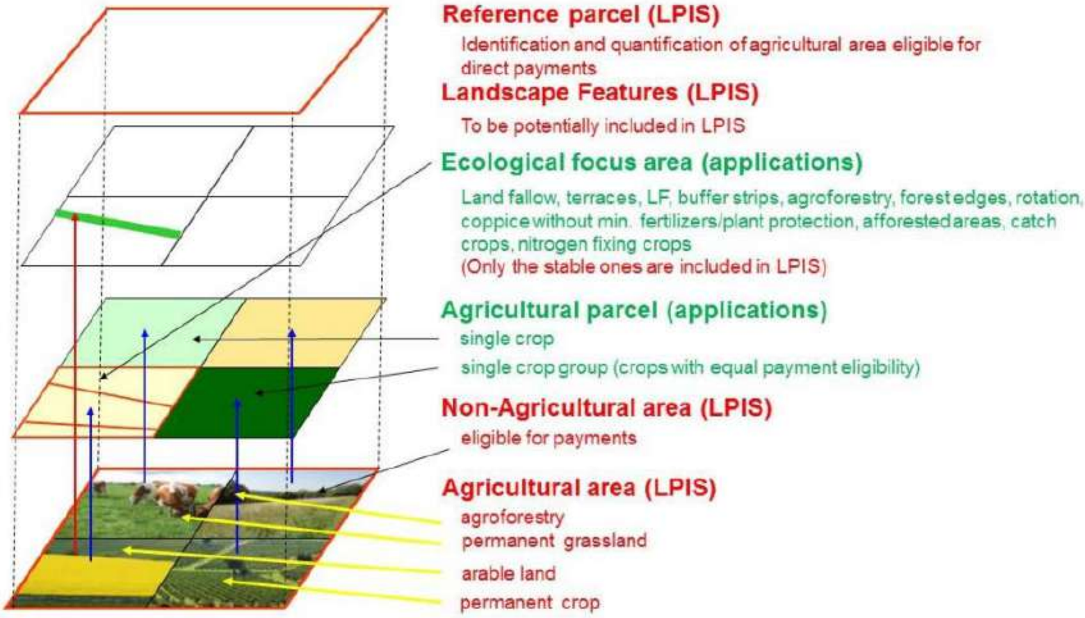

Figure 5. Conceptual structure of the LPIS system and classification of agricultural land use within INSPIRE.

Source: [1].

Table 1

LCG categories and classification criteria for LPIS

LCG code	Full name	Definition and identification criteria
AL	Arable Land	Areas used for annual or crop rotation, without permanent vegetation. Including cereals, technical crops (e.g., sunflower, soybean, beet), vegetables, land left fallow or temporarily uncultivated (less than 5 years). They are recognizable on the orthophotomap by their uniform appearance, traces of agricultural work and the presence of crops.
PC	Permanent Crops	Areas occupied by perennial plantations that produce fruits, nuts, grapes or flowers and that remain on the same plot for at least 5 years. Includes vineyards, orchards (apple, plum, cherry, walnut), horticultural nursery and fruit shrub crops. Identified by regular alignments and constant spacing between rows.
PG	Permanent Grassland	Land covered with perennial herbaceous vegetation (grasses and forage plants), which has not been part of the crop rotation for at least 5 years. A minimum vegetation cover of 20% is required. Includes pastures, hayfields and meadows in meadow or mountain areas.
N	Non-eligible	Areas that cannot benefit from direct agricultural payments. This includes forests (over 0.5 ha and with a canopy cover greater than 20%), buildings and infrastructure, permanent waters, degraded lands (severe erosion, salinization), landfills, mining operations, industrial areas etc.

Source: developed by the author based on [22].

It should be noted that, for the delimitation of parcels, there are already methodologies developed according to each approach. For example, in the case physical blocks, are represented as continuous area of agricultural land, delimited by stable features in the terrain, such as roads, rivers, forests, fences or settlements. A physical block can include one or more agricultural parcels, several farmers and different crops. It is important to note that not all land areas are mapped within the LPIS system, and there are clear exclusion rules (Table 1).

Table 2

Examples of some exclusion rules for physical blocks delimitation

Non-eligible areas	Exclusion threshold	Identification method	Observations
Roads, access roads, ditches	Width greater than 2 m	Determination on orthophoto plane at scale 1:2000	Completely removed from the RP; roads with a width of ⩽ 2 m are considered an integral part of the RP
Groups of trees and shrubs	Area greater than 300 m^2	Crown contouring on RGB images	Isolated specimens or small groups (⩽ 300 m^2) remain included in the RP
Water surfaces (lakes, ponds, basins)	Area over 100 m^2	Contour tracing on orthophoto plane	Narrow and elongated watercourses are treated similarly to roads (if they exceed 2 m in width)
Artificial constructions and arrangements	Total exclusion (100%)	Identification on orthophoto map and based on cadastral data	Any building is removed from the RP, regardless of size
Cliffs and rock outcrops	Area greater than 100 m^2	Visual analysis based on texture in images	Areas without a layer of agricultural soil, with rock on the surface
Material warehouses, silos	Total exclusion (100%)	Visual interpretation + cadastral verification	Includes all fixed structures intended for storage

Source: Prepared by the author.

Thus, within the IACS and LPIS, the rules for delimiting physical blocks establish which areas are not considered eligible and, therefore, are not included in the agricultural contour used for granting payments. Although there may be slight variations between Member States, the general principles of the European Union are common. In this respect, the main categories of areas excluded are: buildings, concrete yards and platforms, roads, parking lots, quarries, industrial land, as well as areas permanently covered by water, compact forests, dense scrub, permanent forest vegetation, cliffs, ravines and marshes. Linear elements that exceed the permitted limits, such as wide hedges, canals, internal roads wider than 2 m and forest curtains, are also excluded, as they are not considered part of the eligible agricultural area. The exclusion rules derive mainly from the documentation of the European Commission, namely the CAP/IACS regulations, the LPIS system, the JRC (Joint Research Centre) technical guides.

4. Results and Discussions

The IACS is the fundamental IT architecture through which EU Member States administer direct payments to farmers and check the compliance of subsidy applications and comprises the following main components, defined in Regulation (EU) 2021/2116:

- the geospatial component that ensures the unique identification, location and measurement of eligible agricultural areas. The LPIS uses Reference Parcels (RP) as basic units, each RP having location, eligible area (MEA), classification (LCG) and associated metadata attributes;

- the geospatial application through which farmers graphically submit payment applications, indicating agricultural parcels on the digital map. GSA is based directly on LPIS data and the most recent orthoimages;
- the area monitoring system through remote sensing (Copernicus Sentinel-1 and Sentinel-2 satellites), which permanently verifies the declared agricultural activity on parcels (AMS - Area Monitoring System);
- the system of checks by continuous monitoring, which partially replaces physical on-site inspections with analyses based on satellite and remote sensing data (CbM - Checks by Monitoring);

Thus, the LPIS constitutes the foundation on which all other IACS components are built. The quality and accuracy of LPIS data directly determine the efficiency of the entire agricultural payment system. To create a real example of delimitation of physical blocks, cadastral sectors 5501102 and 5501103 from Ialoveni district were selected (Fig. 6). The choice of these sectors was based on the existence of compact agricultural areas, the diversity of land use types and the presence of natural and artificial boundaries easily identifiable on orthophotos and satellite images. To create the working layer, a new Shapefile (.shp) vector layer was designed within the QGIS application, using polygon geometry (Layer → Create Layer → New Vector Layer → Polygon). The choice of polygon geometry is justified by the fact that physical blocks and agricultural parcels represent spatially delimited areas, which require precise storage of boundaries and attributes associated with them, including the area.

Since the initial phase of the project opted for the use of vector data of type .shp, four separate layers were created, each having a distinct role in the organization and management of spatial information. Separating the data into individual layers facilitates the digitization, topological verification and subsequent management of the information within the spatial database. Thus, the following Land Cover Group (LCG) layers were defined and used, corresponding to the classification used within the LPIS (Table 1).

Figure 6. Creating layers according to LCG categories and classification criteria for LPIS.

Source: prepared by the author.

Since the data used were, in many cases, unclear or insufficiently precise for the correct delimitation of physical blocks and LPIS parcels, it was necessary to use additional geospatial data sources and satellite images. For this purpose, platforms and services such as ArcGIS Satellite, Bing Maps Satellite, OpenStreetMap, as well as QGIS plugins such as QuickMapServices and Send2GE (Fig. 7) were used. These tools were used to better understand the real situation on the ground and to compare information from different cartographic sources and satellite images. The integration of multiple image sources allowed for a clearer identification of the boundaries of agricultural parcels, roads, canals, forest curtains, built-up areas and other stable elements used for the delimitation of physical LPIS blocks. In some cases, the available orthophoto images had strong shadows, low resolution or seasonal differences in vegetation, which made it difficult to correctly interpret agricultural areas. By comparing images from different sources, it was possible to reduce digitization errors and obtain a more accurate delimitation of agricultural land.

Figure 7. Use of SENT2GE plugin for current field analysis.

Source: prepared by the author.

In the context of implementing a modern agricultural monitoring and spatial data management system within an LPIS system, it is proposed to use the QField application as a solution for automating and optimizing field activities. QField is an open-source mobile application developed for working directly with projects created in QGIS. The application allows the use in the field of the same spatial layers, forms, symbols and rules defined in the main GIS project, without the need for complex data conversion. This approach facilitates the continuity of the workflow between the office stage and the field activity. Implementing the mentioned solution would allow the automation of several essential processes, such as:

1. direct collection and updating of geospatial data in the field;
2. editing the boundaries of agricultural parcels and physical blocks;
3. automatic topological validation of geometry;

4. completing personalized digital forms for each plot;
5. capturing GPS coordinates in real time;
6. attaching georeferenced photos;
7. automatic synchronization with the central database;
8. verifying mandatory attributes and reducing data entry errors;
9. offline operation in areas without internet connection;
10. integration of satellite images and orthophotos for rapid verification of land use.

In the implementation of an LPIS system in the Republic of Moldova, the use of the QField application could represent an effective solution for the digitalization and automation of agricultural monitoring processes, contributing to increasing data quality, reducing human errors and streamlining the control and updating activities of the spatial database. For the centralized storage and management of spatial information, the project used a PostgreSQL relational database together with the PostGIS extension. This solution allows for the efficient management of large volumes of geospatial data, the execution of complex spatial queries and simultaneous access of multiple users to the same database.

For the web visualization component of spatial data, the QGIS Cloud platform is proposed, which allows for the rapid publication of projects created in QGIS directly on the internet. Through this platform, maps can be accessed from the browser, without installing a program or an additional solution.

An important advantage of the platform is the possibility of rapid data updates. For example, if an operator changes the delimitation of a parcel in the database, the change can automatically appear on the web map. In addition, QGIS Cloud allows the display of satellite images and orthophotos, useful for checking agricultural land and identifying crops. The platform also supports services such as WMS and WFS, which allow the connection and exchange of data between different GIS systems. Projects can also be managed centrally, which facilitates collaboration between multiple institutions or users involved in managing the LPIS system.

For example, physical blocks and agricultural parcels delimited in QGIS can be exported to an interactive web map, where the user can select a parcel and view information such as the parcel code, area or crop type. At the same time, different thematic layers can be activated or deactivated for easier analysis of agricultural land. By using the qgis2web plugin, the LPIS project becomes more accessible and user-friendly, as spatial data can be consulted directly from the browser, contributing to improving the monitoring and management of agricultural land.

5. Conclusions

The paper showed that spatial reference data from the Republic of Moldova must be the main component of the LPIS implementation. The integration of multiple data sources, such as orthophotos, cadastral data and satellite images, allows obtaining a real and updated picture of the situation on the ground, reducing errors and increasing the accuracy of delimitation.

It was also demonstrated that the use of open-source GIS technologies and remote sensing tools plays an important role in the modernization of the system. Applications such as QGIS, PostgreSQL/PostGIS, QField and QGIS Cloud offer the possibility to manage, analyze and visualize spatial data in an efficient, flexible and accessible way and should be considered in IACS development and implementation in Republic of Moldova. At the same time, the use of Sentinel satellite images and spatial analysis methods allows for continuous monitoring of agricultural lands and rapid updating of information according to changes in the field.

For the implementation and operation of the LPIS system in the Republic of Moldova, the following main recommendations can be stated:

- Orthophoto should be updated every two years, which is used as the main basis for the operational implementation of the LPIS;
- PostGIS-type spatial databases, for managing large volumes of data and performing advanced queries;
- GeoPackage format used for storing and managing spatial data, due to the advantage of keeping the geometry and associated attributes in a single file;
- Implementation of the QField application in the field, for collecting, validating and updating spatial data and images in real time;
- QGIS Cloud platform, for publishing and accessing GIS projects online.

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