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A LAND CONSOLIDATION GEOPORTAL AS A USEFUL TOOL IN LAND CONSOLIDATION PROJECTS – A CASE STUDY OF VILLAGES IN SOUTHERN POLAND

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ABSTRACT

Motives: The area of consolidated land plots as well as numerous social and legal factors prolong and complicate land consolidation projects. Land consolidation projects require massive investment and the involvement of consolidation experts and all landowners. The required information can be made available online to streamline this process. The data available in an online map portal can be used to perform visual and substantive analyses of spatial changes in land consolidation projects.
Aim: This study addresses the issues related to the design of a map portal for a land consolidation project covering villages in southern Poland. The proposed geoportal will support communication between land consolidation participants and surveyors.
Results: The geoportal is available at: https://arcg.is/15Wirj1, and it provides users with access to information about the land consolidation project. Portal users can submit their opinions and objections online.

Keywords: web map, social communication, land consolidation, online services, Poland

INTRODUCTION

Recent years have witnessed significant social and economic changes in Poland (Bieda et al., 2014; Buśko et al., 2022; Pawlikowska et al., 2017). These changes were undoubtedly driven by the European Union funds which supported the development of many cities and villages. Land consolidation is one of the most effective measures which supports the restructuring and modernization of rural areas (Basista & Balawejder, 2020). The first law regulating the process of land consolidation in Poland was the Law of 1923, and land consolidation has been performed in rural areas for almost 100 years (Balawejder et al., 2021).

Land consolidation and land exchange became priority measures in land management to improve land-use conditions in agricultural and forest areas. The main objective of land consolidation is to reduce the number of land plots in a farm and to provide

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them with access to a public road (Harasimowicz et al., 2021; Janus & Ertunç, 2023). The high fragmentation of land plots, especially in southern Poland, calls for urgent land consolidation measures (Balawejder & Leń, 2016; Cienciała et al., 2022; Gniadek et al., 2017; Janus, 2018; Janus & Taszakowski, 2018; Noga et al., 2017; Stręk & Noga, 2019). According to the literature, excessive land fragmentation is a problem that affects many countries, including Bulgaria (Di Falco et al., 2010; Moteva, 2020), in the Republic of Belarus (Hrybau et al., 2022), Cyprus (Demetriou, 2016), Czech Republic (Sklenicka, 2016), Estonia (Jürgenson, 2016), Finland (Hentunen & Konttinen, 2022), Hungary (Cegielska et al., 2018), Latvia (Jankava et al., 2014), Lithuania (Pašakarnis & Maliene, 2010), the Netherlands (Stańczuk-Gałwiaczek et al., 2018), Slovakia (Muchová & Petrovič, 2019), Spain (Touriño et al., 2003), Turkey (Boztoprak et al., 2016), and Ukraine (Martyn et al., 2022).

The area covered by land consolidation and land exchange projects, as well as numerous social and legal factors prolong and complicate the implementation of these projects (Balawejder & Noga, 2016; Çoruhlu et al., 2019; Janečková Molnárová et al., 2023; Yin et al., 2022). Land consolidation projects require massive investment and the involvement of consolidation experts and all landowners. To streamline this process, various solutions should be considered to identify the participants of the consolidation project (Basista, 2013). The required information can be made available online to facilitate the process. Online data can be used to perform in-depth analyses of spatial changes in individual cadastral units.

A map portal aggregating land data would support both visual and factual analyses of spatial changes. In an era of widespread Internet access, interactive maps are becoming increasingly popular (Bieda et al., 2021). Interactive maps differ in scope and subject matter, ranging from national services presenting geodetic and cartographic data, through administrative geoportals of individual municipalities and counties, to thematic maps relating to various industries (Çoruhlu & Çelik, 2022; Dawidowicz et al., 2022; Dudzińska et al., 2020; Ogryzek et al., 2020).

During a consolidation project, surveyors meet with landowners several times to appraise their land, inquire about the desired location of their land, present the consolidation project, or consider the landowners' objections to the project. However, it is often the case that the interested parties are unable to attend the meeting to review the land consolidation draft, or need more time to analyse the proposed changes. In addition, the communication process during land consolidation can be disrupted by factors that remain beyond the parties' control, as was the case during the recent COVID-19 pandemic. This problem could be resolved by making land consolidation drafts available online in a dedicated geoportal.

An analysis of the literature indicates that most of the institutions involved in land consolidation do not make scale projects available, and projects that are made available consist only of raster images in pdf format. Consolidation drafts do not contain personal data; therefore, they can be made available online without violating legal regulations. However, the access to the geoportal can be restricted to a specific group of users.

Various IT solutions (Bacior et al., 2019), especially geographic information systems (GIS) (Çelik & Yakar, 2023; Coruhlu et al., 2022), have been proposed to support the land consolidation process (Basista, 2015, 2020; Cui et al., 2022; Dou et al., 2007; Jiang et al., 2021; Touriño et al., 2003). However, these solutions have been designed specifically for planning the structure of rural areas (Dudzińska et al., 2018), without taking into account the accessibility of information for landowners participating in consolidation projects. A limited number of online maps supporting the land consolidation process have been described in the literature, but they are based on other web solutions and do not enable the participants to submit objections (Basista, 2013).

In this study, an online map portal was developed for a land consolidation project in the villages of Słupia Jędrzejowska (Słupia) and Wielkopole in Poland. This land consolidation geoportal was designed to support communication between landowners and surveyors. The map portal was developed based

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on data from a land consolidation exercise. However, the actual land consolidation geoportal was not used in this process. The geoportal can be accessed at: https://arcg.is/15Wirj1, and it provides users with access to information about the land consolidation project. Portal users can submit their opinions and objections online.

STUDY AREA

The map portal for the land consolidation project covers the area of two cadastral districts: Słupia Jędrzejowska (Słupia) and Wielkopole. These districts belong to the cadastral unit of Słupia in Jędrzejów county, Świętokrzyskie Voivodeship, Poland (Fig. 1).

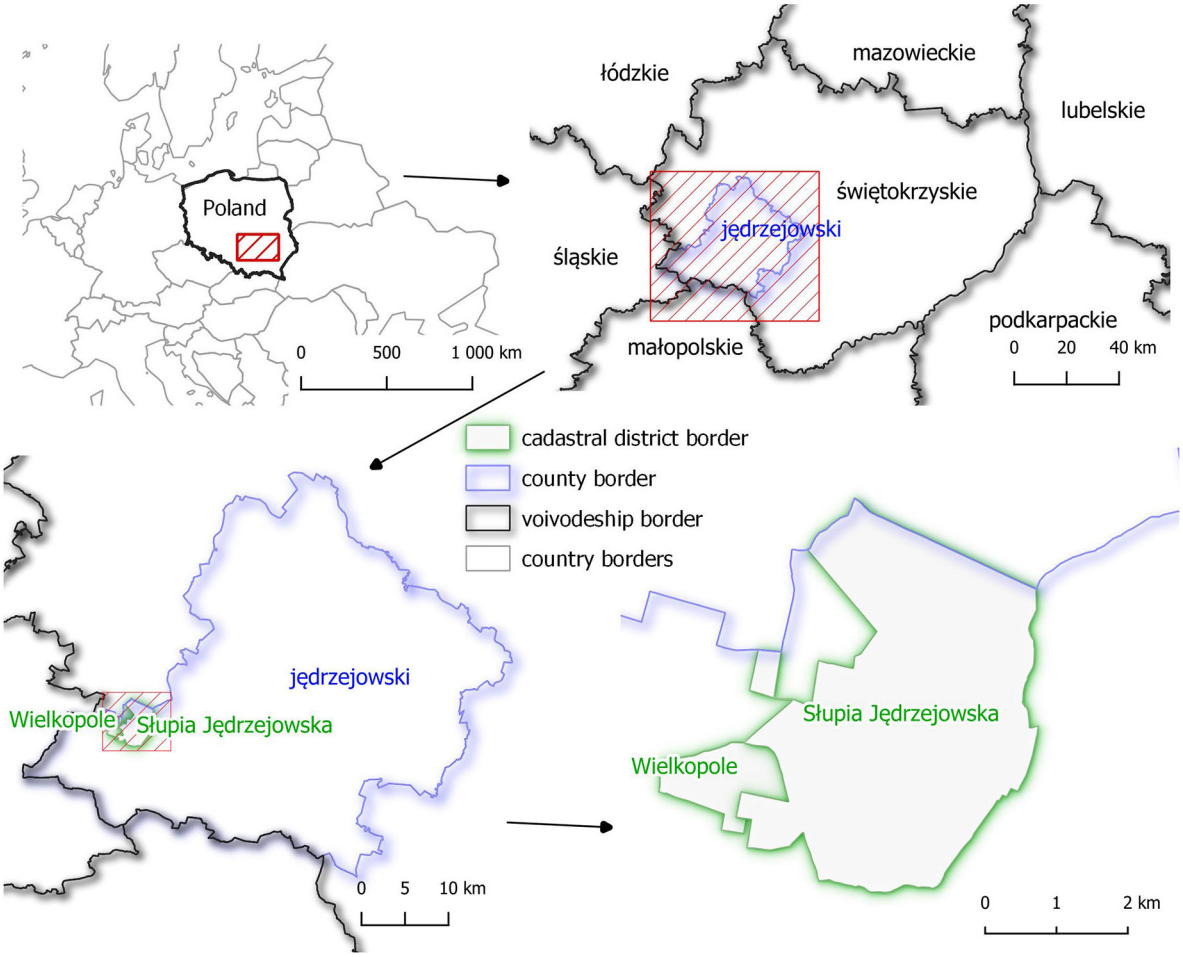

Fig. 1. Location of the area covered by the land consolidation project
Source: own elaboration.

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The Słupia cadastral unit has an estimated area of 1,447.5 ha, and the Wielkopole cadastral unit has an estimated area of 130.5 ha. The land consolidation project was conducted over a period of 5 years, from 2015 to 2020. The number of plots decreased by 31.7%, from 1,720 before consolidation to 1,175 plots after consolidation.

METHODS

The geoportal was developed with the use of data acquired from the Department of Geodesy and Agricultural Land of the local branch of the Małopolska Voivodeship Office in Tarnów which conducts consolidation works in Małopolska. The data were acquired in two formats: shapefile and dgn. The following information was obtained: location of land plot boundaries before and after consolidation (shapefile format), location of buildings (dgn format), and land-use boundaries (dgn format). Spatial data were recorded in the PL-2000 coordinate system, zone 7 (EPSG code: 2178) (Maciuk et al., 2023).

Five layers of data were generated for the needs of the developed geoportal:

1. land plots before consolidation and exchange process (current state);
2. land plots after consolidation and exchange (planned);
3. land use before consolidation and exchange (current state);
4. land use after consolidation and exchange (planned);
5. buildings.

The acquired data were imported into the file geodatabase (Fig. 2). The topology of buildings in each layer was checked and corrected during data preparation. Redundant fields in the layer attribute table were removed. The names of individual columns were changed to improve readability and facilitate data analysis by geoportal users.

The development of the land-use layer was the most time-consuming task (Fig. 3). The layer had to be prepared based on the boundaries of the designed plots and the existing land-use classes. All land-use boundaries were moved to the boundaries of the designed plots. The snapping tool was used to maintain the proper topology of objects.

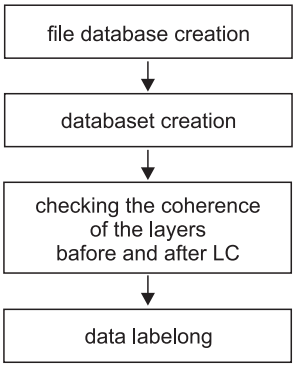

Fig. 2. General diagram for the preparation of layers
Source: own elaboration.

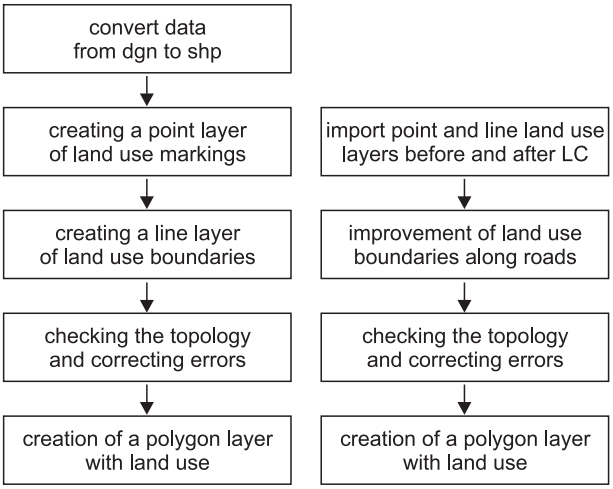

Fig. 3. General diagram of land-use layers. The layers for the existing plots are presented in the left column, and the layers for the designed plots are presented in the right column
Source: own elaboration.

This classification proved to be very problematic because some of the newly created roads divided land-use classes into two or more parts (Fig. 4). In addition, the location of many agricultural roads was corrected, and the boundaries of neighbouring land-use areas had to be snapped (Fig. 5).

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Fig. 4. Error correction in the land-use layer. Improvement of the land-use layer (red colour) to the parcel layer (black colour) *Source*: own elaboration.

Fig. 5. Error correction in the land use layer. Improvement of the land use layer (red colour) to the parcel layer (black colour) *Source*: own elaboration.

A spatial intersection GIS tool was used in the initial step to create new layers showing cadastral units and their estimated values before and after land consolidation. Parcel and land-use layers were intersected to obtain a single layer containing the numbers of cadastral units and land-use values in each of the obtained fragments of these units. To obtain the estimated values of land in a given cadastral unit, a "Value" column was created in the attribute table of the newly created layers from the spatial intersection. The estimated values of all unit fragments were then calculated with a field calculator (by multiplying land-use values by land area). All parts of cadastral units were combined by summing up the land area and all fragment values based on the field with the numbers of cadastral units.

The resulting layer was generated in the form of tables containing 631 cadastral units before land consolidation and 644 units after land consolidation. Information about the total area and the estimated value of all land plots in cadastral units was provided for each object. An aggregation GIS tool was used to obtain a polygon class of objects for cadastral units. This was done based on a layer of plots, where the number of cadastral units was indicated in the aggregation field. In the final step of the process leading to the creation of an optimal layer of cadastral units, the polygon layer created by aggregation was merged with the generated table of estimated values based on the common field in the attribute tables (number of cadastral units) (Fig. 6). Information about the area and estimated value of the entire cadastral

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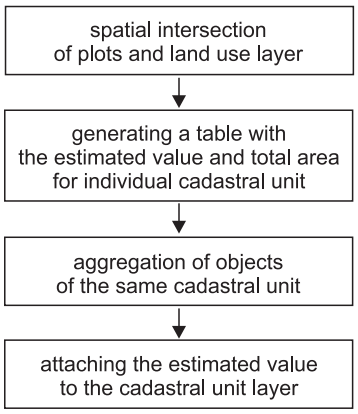

Fig. 6. General diagram for creating layers with cadastral units
Source: own elaboration.

unit is displayed in a pop-up window when the user selects a plot belonging to a given cadastral unit.

The resulting object layers presenting cadastral units before and after the land consolidation process are polygons that contain all land plots in a given unit. When a plot is selected, other plots in the same unit are automatically highlighted. The layer attribute table includes information about the area and the estimated value of the entire cadastral unit.

Development of a Land Consolidation Map Portal

The land consolidation geoportal was developed with the use of Web AppBuilder and Survey123 applications available from the ArcGIS Online service. A web application presenting spatial data was prepared in several steps. First, a map (Web Map) was created using the Map Viewer application as the basis for the geoportal. Next, a website was created in the Web AppBuilder application containing the base map (Web Map) and a set of necessary widgets. To enable future users to submit their objections to the land consolidation project, a survey was developed in Survey123, and it was attached to the land consolidation portal. Figure 7 presents the services and applications used in the process of developing a map portal for the land consolidation project in Słupia and Wielkopole.

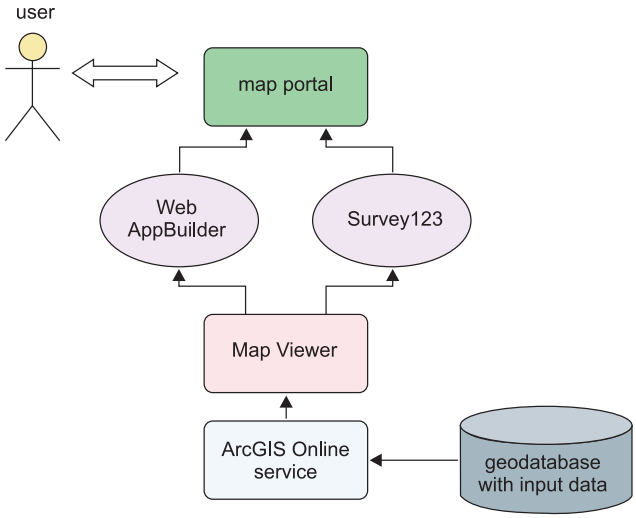

Fig. 7. Diagram of the process of developing a map portal
Source: own elaboration.

In the first step, two base maps were prepared as the main elements of the geoportal. The first base map (Web map) contains the map base (topographic map) and the previously generated layers:
- buildings;
- land plots before consolidation;
- land plots after consolidation;
- land use before consolidation (double layer for large-scale and small-scale visualisation);
- land use after consolidation (double layer for large-scale and small-scale visualisation).

Subsequently, pop-up windows displaying object information were configured for each layer. When all layers were enabled, only parcel information was displayed when an object was selected. The objects were provided with the appropriate symbols, and a range of scales for displaying individual objects and their labels was established. The map has several zoom levels. Double layers were added for land-use classes to ensure that the presented geographical information is legible. Objects were displayed on a smaller scale for illustrative purposes only; therefore, they were not labelled, and information on individual land-use classes was included in the legend. Labels and land use symbols are displayed (second layer with land-use classes) by zooming in on the map view.

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A similar approach was used to create the second base map (Web Map) displaying cadastral units before and after consolidation. Four layers were added to the map viewer:
– cadastral units before consolidation;
– cadastral units after consolidation;
– land plots before consolidation;
– land plots after consolidation.

The purpose of the second base map was to facilitate the analysis of gains and losses resulting from the land consolidation process. The map contains information about the location of all parcels in each cadastral unit, as well as their estimated value and total area. Parcel layers were added to the map for illustrative purposes only, and they are disabled by default in the application. These layers are displayed at a scale of 1:5,000 and smaller. The layers were provided with the same symbols as those applied in the first base map. The pop-up windows in each layer were configured to display only information about a selected object in a cadastral unit when all layers are enabled.

The Web Map application was used to develop two key maps: the master map which constitutes the basis of the land consolidation geoportal, and a map of cadastral units which facilitates an analysis of gains or losses resulting from the consolidation procedure.

In the next stage, the created base maps were used to develop two web applications in Web AppBuilder. The first application enables the users to conduct a visual and factual analysis of land plots/land-use classes before and after consolidation. The application features various tools for viewing, searching and analysing objects, including *zoom in/zoom out, home (default view), my location, legend, layer list, overview map*, *coordinates, scale, search tool, compare before/after, measure, filter, base map gallery,* and *print*. The second application is based on a map of cadastral units, and it features only the necessary widgets – *zoom in/zoom out, home (default view), my location, legend, layer list, overview map, coordinates, scale, search tool,* and *compare before/after*. Object information was provided in two different applications to ensure the legibility of the final map portal.

In the subsequent step, a survey was developed with Survey123 to obtain feedback from geoportal users who are land consolidation participants. The respondents can submit their objections to the consolidation project and to mark the appropriate location on the map.

In the last step, three applications were developed: the main map ("Land consolidation web map – Słupia and Wielkopole"), a map of cadastral units ("Cadastral units"), and a questionnaire survey enabling the participants to submit their objections to the consolidation project ("Objections to the consolidation project"). The main map contains a link to the map of cadastral units and the survey, and the map of cadastral units contains a link to the main map and the survey. The links ensure seamless transition between applications.

RESULTS

The developed geoportal supports communication between land consolidation participants and surveyors (consolidation contractors). The homepage of the application, where maps with parcel and land-use layers can be compared before and after land consolidation, is presented in Figure 8. In the default map view, only graphic land-use symbols are displayed on a scale smaller than 1:7,000, and they are not labelled. This solution was adopted to preserve legibility. In addition, all widget icons are displayed in the user's line of sight. The scale and the coordinates are displayed in the bottom left corner, and the overview map is displayed in the bottom right corner. The legend and the list of layer icons are displayed in the top right corner, and the remaining tools are displayed on left side.

When the user zooms in gradually on the map view, other layers that can be viewed on a larger scale are displayed. In Figure 9, the objects are shown on a scale larger than 1:4,500. All layers are displayed with the accompanying labels. Graphic land-use symbols were replaced by no-fill land-use symbols to improve the legibility of data display.

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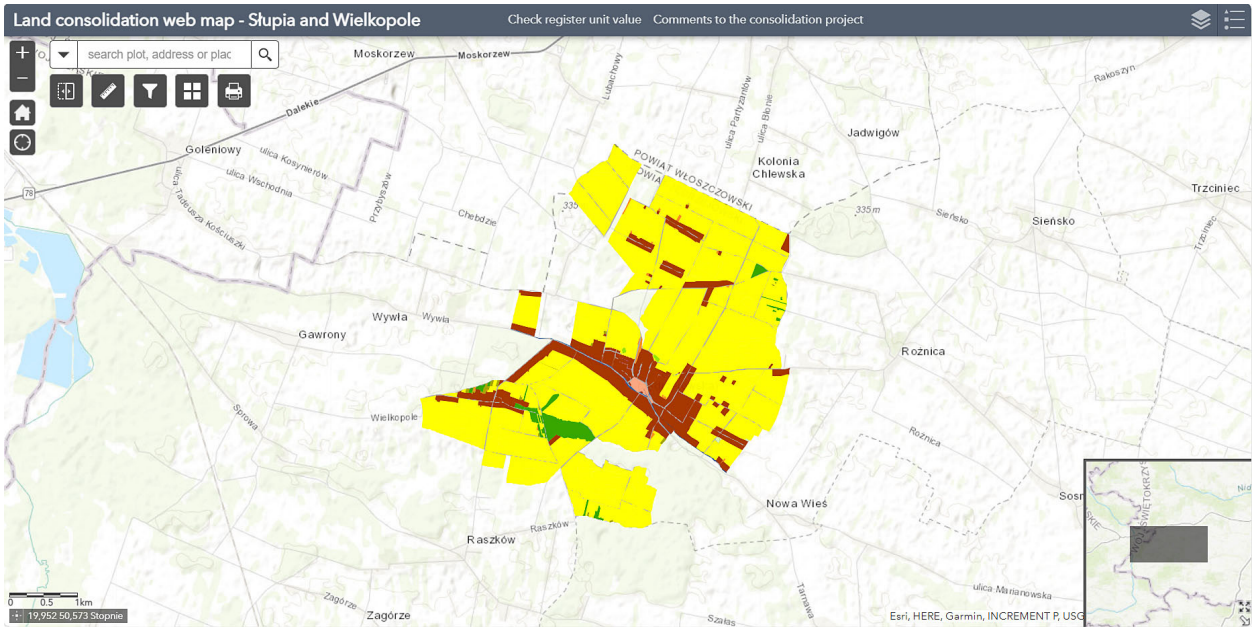

Fig. 8. Homepage of the land consolidation map portal
Source: own elaboration.

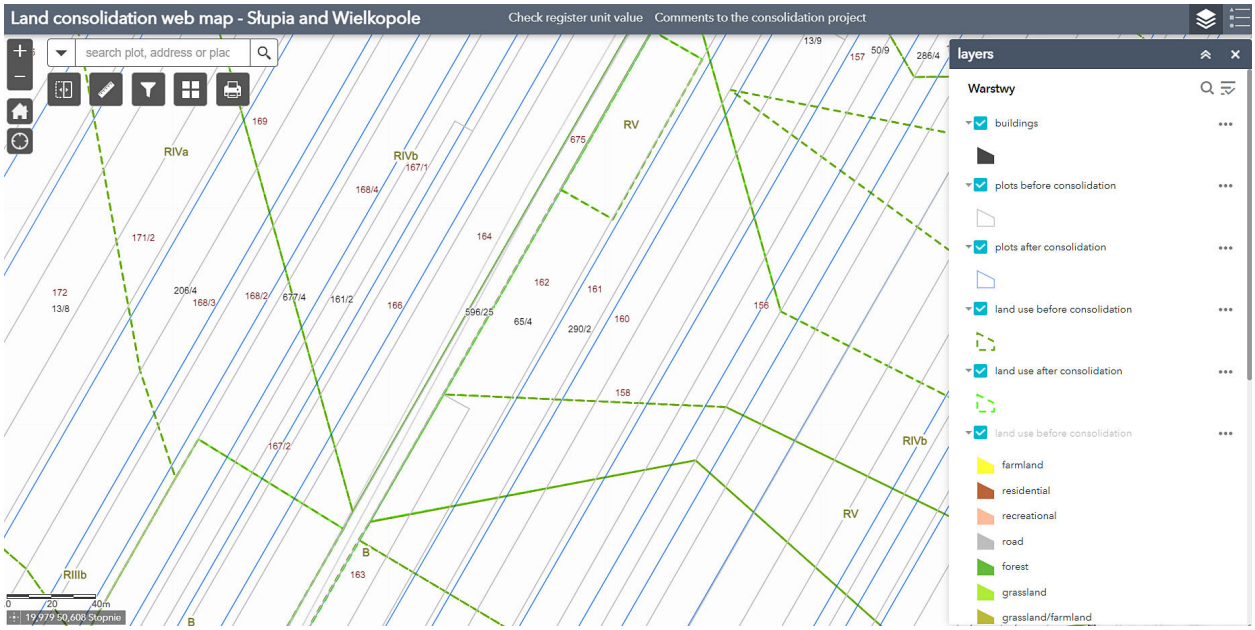

Fig. 9. Zoom-in view of the map on the homepage of the land consolidation geoportal
Source: own elaboration.

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Pop-up windows are presented in Figure 10. A pop-up window containing information about a given object is displayed with the user hovers the cursor over a selected land plot.

The functionality of the map portal has been enhanced by adding widgets. In addition to the standard view navigation tools (*zoom in/zoom out, home (default view)* and *my location*), *search*, *compare before/after* (slider for comparing objects), *measure, filter, base map gallery* and *print* tools are displayed in the top left corner. The search function enables the user to find specific addresses, places, and plots on the map, based on plot numbers before and after land consolidation (Fig. 11).

The *compare-before/after* widget is a quick and convenient tool for comparing land plots before and after consolidation with the use of a moving slider (Fig. 12).

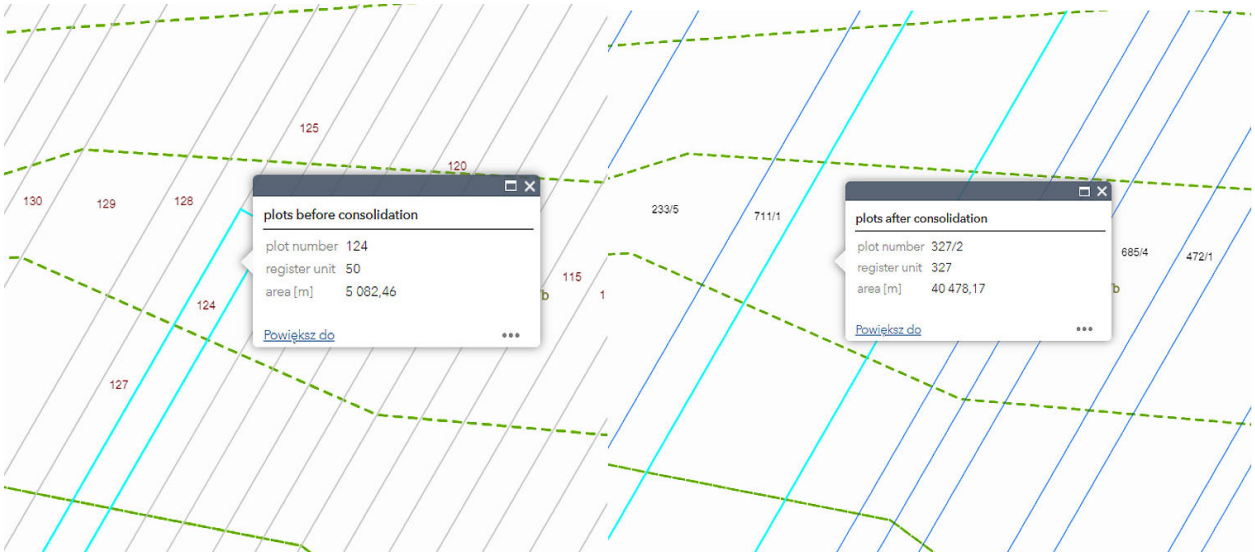

Fig. 10. Comparison of plots using pop-up windows
Source: own elaboration.

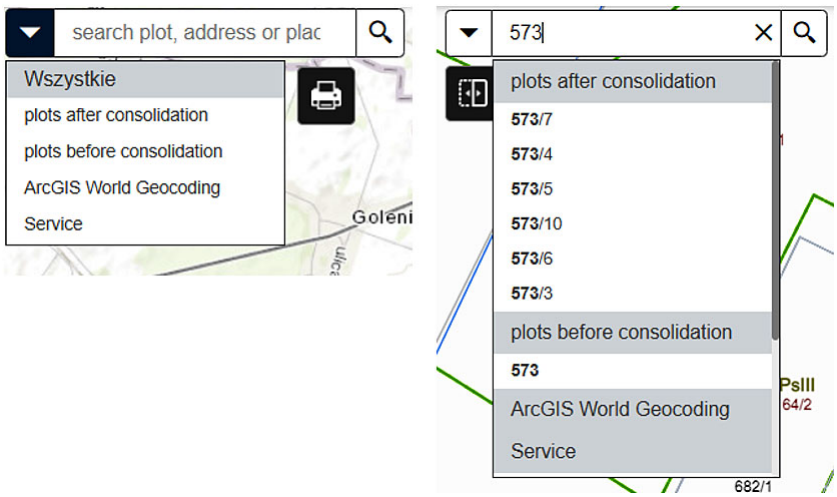

Fig. 11. Object search tool
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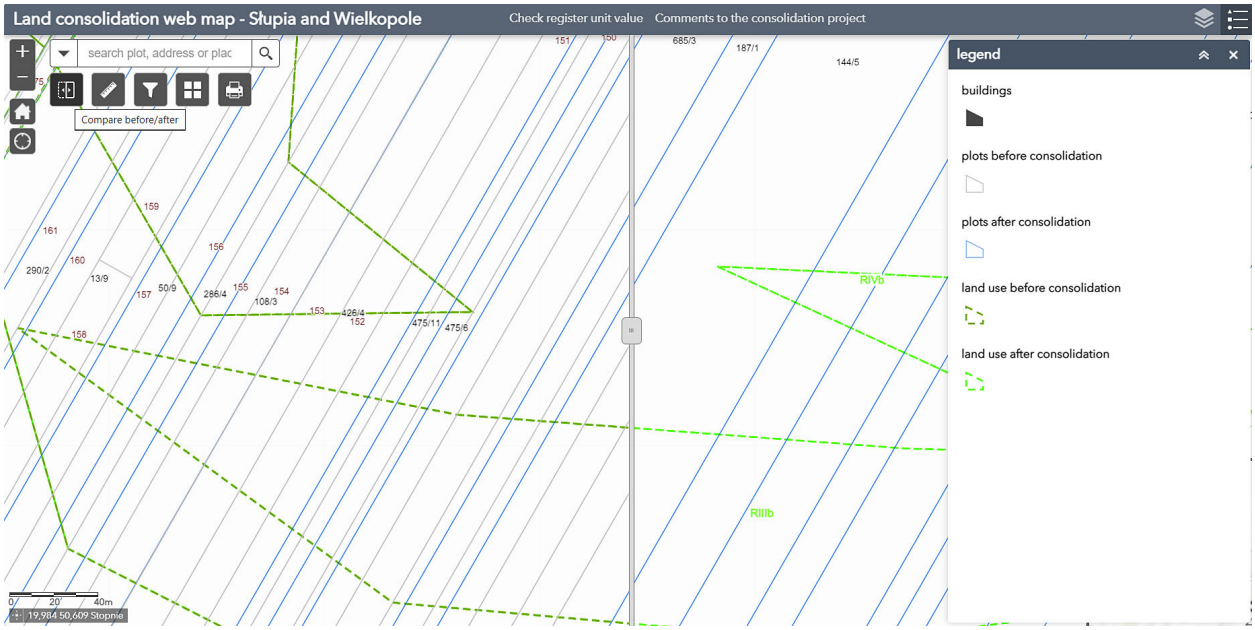

Fig. 12. *Compare before/after* tool
Source: own elaboration.

The *measure* tool enables the user to determine the area, length and coordinates on the map. The *filter* widget displays land plots in a selected cadastral unit based on the number of the cadastral unit entered by the user. The *base map gallery* contains a large collection of base maps that can be used as a reference. The current map view can be saved in pdf format with the use of the *print* tool.

The geoportal header features two links: "Check cadastral unit value" and "Objections to the consolidation project". By clicking on the "Check cadastral unit value" link on the homepage, the user opens an application displaying cadastral units before and after consolidation, including information about their area and estimated value (Fig. 13).

The application interface features fewer options than the homepage. By default, only the layers presenting cadastral units before and after land consolidation are displayed. The legend also includes the parcels, but these are blanked out by default. The *compare before/after* widget on the left can be used to compare cadastral units before and after consolidation.

The main purpose of this portal is to compare the point values of individual cadastral units to analyse the gains/losses resulting from the land consolidation process (Fig. 14).

The "Objections to the consolidation project" redirects the user to the survey (Fig. 15). The survey questionnaire consists of two elements: a description field, where the user enters objections to the project, and a map field, where the area in question can be marked.

The submitted objections are reviewed by surveyors with the use of Survey123. All objections are presented in the form of an interactive list. A number of tools are available for identifying users, objections, and locations that the objections refer to (Fig. 16). The survey application enables users to express their opinions and comments on the preliminary design of the land consolidation project. All geoportal users participating in the consolidation process will be provided with login/authentication details.

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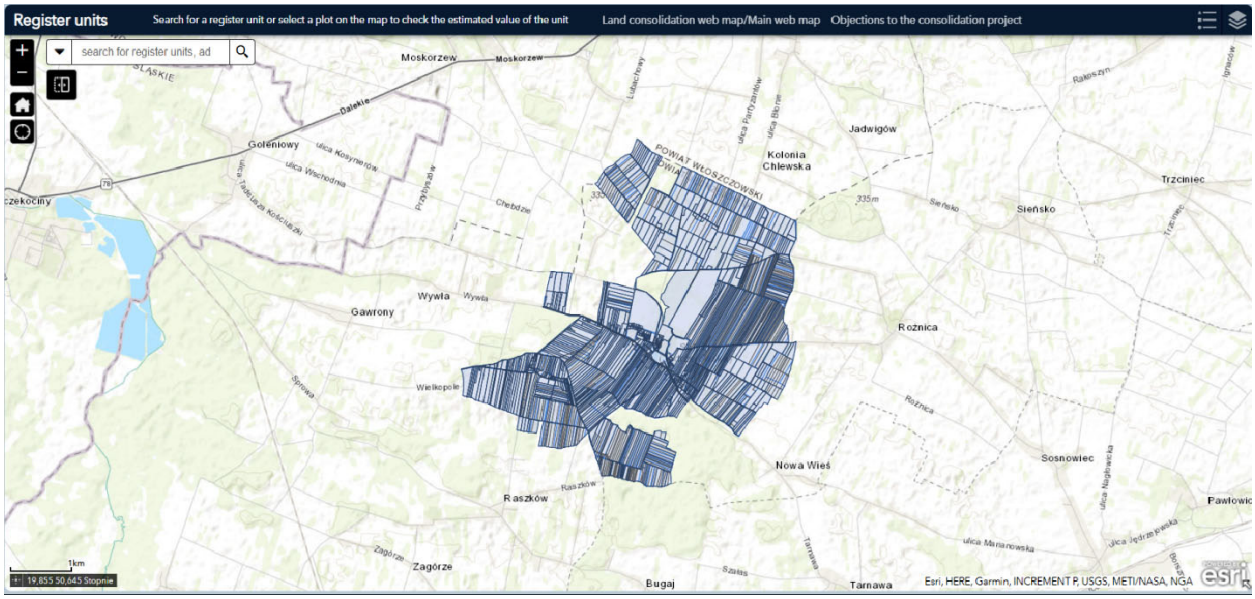

Fig. 13. Homepage of the web application presenting cadastral units
Source: own elaboration.

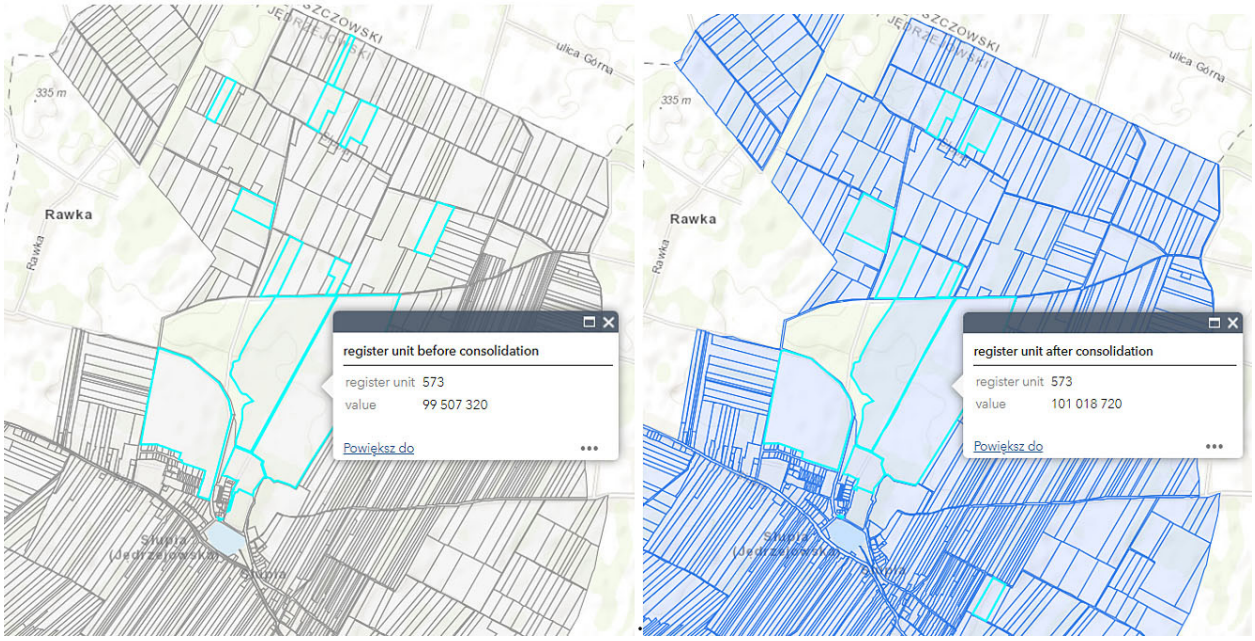

Fig. 14. Comparison of cadastral units before and after land consolidation
Source: own elaboration.

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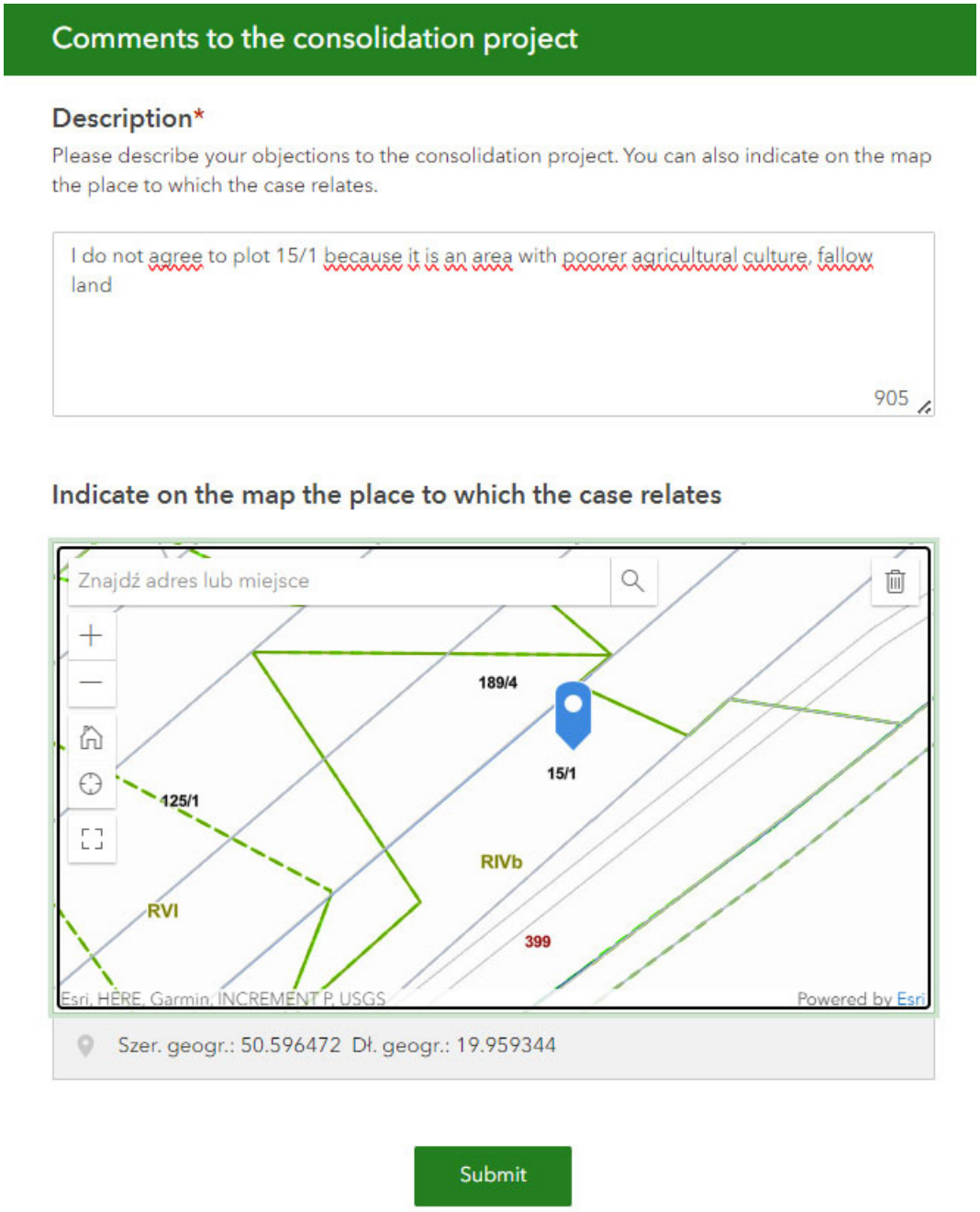

Fig. 15. View of the survey window for submitting objections to the consolidation project
Source: own elaboration.

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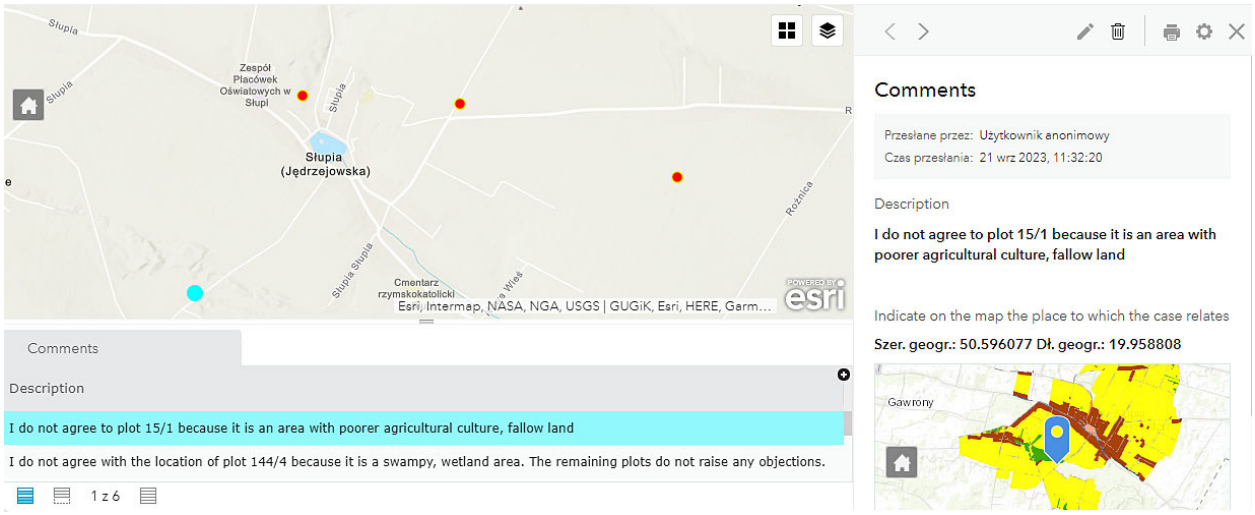

Fig. 16. View of the survey window for submitting objections to the consolidation project. A number of tools are available for identifying users, objections, and locations that the objections refer to

Source: own elaboration.

DISCUSSION

In Poland, land consolidation projects have been implemented for 100 years based on the legal regulations adopted in 1923 (Balawejder et al., 2021). Land consolidation has long been regarded as the optimal land management method for resolving land fragmentation problems and improving land cultivation practices (Jiang et al., 2021, 2022). Land consolidation decreases the cost of farming operations by improving the system of agricultural roads (Janus & Ertunç, 2023; Warchoł & Balawejder, 2022). Modern land consolidation practices have been introduced over the years (Li & Song, 2023). The Internet is not only as an additional channel for distributing information, but also a means of interactive communication (Hącia & Łapko, 2023). In an era of widespread Internet access, map portals are a functional and transparent way of presenting reality (Dawidowicz & Kulawiak, 2018; Izdebski, 2022; Senetra et al., 2023). Geoportals facilitate browsing, and they enable users to analyse and search for multidimensional information about space. Therefore, a land consolidation geoportal is an excellent solution that can significantly improve the efficiency of this process (Basista, 2020). The access to an online land consolidation geoportal could increase public interest in land consolidation (Dudzińska, 2016). Various IT solutions (Bacior et al., 2019), especially GIS (Çelik & Yakar, 2023; Coruhlu et al., 2022), have been proposed to support the land consolidation process (Basista, 2015, 2020; Cui et al., 2022; Dou et al., 2007; Touriño et al., 2003). However, these solutions have been designed specifically for planning the structure of rural areas (Dudzińska et al., 2018), without taking into account the accessibility of information for landowners participating in consolidation projects. A limited number of online maps supporting the land consolidation process have been described in the literature, but they are based on other (than those described in this study) web solutions and do not enable the participants to submit comments on consolidation projects (Basista, 2013).

CONCLUSIONS

The study presents the process of designing and implementing a map portal for a land consolidation project in villages in southern Poland: Słupia Jędrzejowska (Słupia) and Wielkopole. A land consolidation geoportal was created to support communication between land consolidation participants and surveyors. The land consolidation geoportal is available

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at https://arcg.is/15Wirj1, and it provides users with access to information about the land consolidation project. Portal users can submit their opinions and objections online.

The main advantage the developed land consolidation portal is that it provides users (landowners participating in a land consolidation project) with quick and easy access to information about the distribution of land plots in cadastral units, before and after consolidation. The map portal developed for the purpose of land consolidation is based entirely on commercial ESRI software that requires the purchase of a license. The applications and tools available on the ArcGIS Online platform do not require installation and are available from a web browser.

The ArcGIS Online environment meets the current requirements because it enables users to browse or search for individual objects. This fully functional tool contains windows that are tailored to the users' individual needs. In addition, geoportals do not have to be designed or administered by IT experts or individuals with computer programming skills. Service users can rely on templates that have been previously developed by experts. Geoportal designers are tasked only with selecting tools and functions to be included in the map portal. The map portal has been developed for research purposes. Data from a real-life consolidation project that was carried out in 2015–2020 was used in the study, but the developed geoportal was not used in that project. However, the proposed geoportal can be applied in real-life consolidation projects by replacing the relevant data layers and providing a link to the geoportal on the website of the company implementing the land consolidation process. The participants would be able to view the prepared project and forward their comments directly to the surveyor. User accounts would have to be created, and land consolidation participants would have to be authenticated to ensure that the submitted comments are not anonymous.

The presented solution significantly facilitates communication between the parties. The purpose of the developed land consolidation geoportal was to demonstrate that a functional map portal can be developed without knowledge of a programming language. All tools and functions were discussed in detail to demonstrate the capabilities of the ArcGIS Online platform. The proposed solution was developed to raise awareness about the existing tools and their applicability in the land consolidation process. A short implementation training should be sufficient to teach project staff to use these tools in practice.

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