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ORIGINAL ARTICLE

Site-specific efficient management of soil resources using GIS and BIM technologies

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Abstract

The spatial data sets of soil resources are essential for the interpretation of the site-specific ecosystems, not only concerning process investigations, but also for sustainable soil management The objective of the study was to attempt identification of the primary parameters influencing the rational management of soils available without the necessity of carrying out time-consuming and costly field and laboratory research. The research was carried out in the Pawłów commune (north-eastern part of the Świętokrzyskie Voivodeship, Poland). The research included the application of different methods and interpretation of source materials, including (i) digital soil-agricultural map, (ii) annex to the soil-agricultural map at a scale of 1:5000, (iii) soil quality contours, (iv) digital terrain model, and (v) orthophotomaps. Obtaining data concerning soil type and/or agricultural usefulness complexes would require conducting a generalisation process. Publicly available ortophotomaps and cartographic materials in the form of topographic maps and a numerical terrain model were analysed to determine the extent of soils to be protected. The rational management of space and soil resources can be visualised and documented using BIM technology; however, relying on GIS data is not the most straightforward task due to the lack of integration on the BIM-GIS line. This paper presents the current state of the art and attempts to address selected problems in this area.

Key words: orthophotomaps, soils management, BIM, GIS, agricultural usefulness complex, contour of soil quality class, sustainable development

1 Introduction

The soil water, energy, and food nexus illustrate the need for a holistic approach to sustainable soil management (Biggs et al., 2015; Ludwig et al., 2018; Jónsson et al., 2016). The challenge facing a growing population is the increased and intensified use of the ecosystem services provided by soils (Blum, 2005). Soils are a renewable, but exhaustible resource. Therefore, the rational management of the soil environment is a strategic direction of development, as well as a subject of research and a reflection of the phenomena and trends occurring in the Polish economy today, determined by the principles of the Eureopean Union (EU) Common Agricultural Policy (CAP) and activities Rural Development Programme (RDP) 2021–2027 (The EU Action Plan on Integration and Inclusion 2021–2027); European Agricultural Fund for Rural Development (EAFRD); as well as Proposal for a Soil Monitoring Law (European Commission, 2023). The differentiation of Poland's agricultural production space potential is due to the spatial variability of soil cover, landforms precipitation and temperature (Krasowicz et al., 2011).

From the point of view of the land use potential of an area, besides soil properties, relief (topography) is an important factor (Pham et al., 2018). In areas with heterogeneous topography, soil is

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spatially variable (Ayele et al., 2019) and topographic variability is one of the main factors influencing soil properties and crop production (Florinsky et al., 2004; Rabia et al., 2022). The relationships between soil and topography are highly complex (McKenzie and Ryan, 1999; Zhu and Lin, 2011). McKenzie and Austin (1993) found that relationships between landforms and soils are more strongly expressed in younger alluvial units than in older landscape units. In lowland areas, almost any change in relief (even at the microrelief scale) results in altered water relations and altered soil morphology (Skłodowski, 2014). As a result of degradation processes, particularly erosion, causing macro- and micronutrient displacement, soils located in depressed areas tend to be more abundant (Warra et al., 2015; Radziuk and Świtoniak, 2021).

Digital soil mapping (DSM) has evolved from traditional soil classification and mapping to the creation and population of spatial soil information systems using field and laboratory observations in combination with environmental co-variables (Carré et al., 2007; Bielska and Jaroszewicz, 2012; Ma et al., 2019). In Poland using soil-agricultural maps at a scale of 1:5000, publicly available data on soil properties from geostatistical portals, geomorphometric techniques, and topographic metrics such as slope gradient and curvature have been developed analogue and applied to investigate the spatial variability of soil properties and to create soil maps (Kwiatkowska-Malina et al., 2016, 2019). All agricultural areas of Poland have a specific soil class delineated on classification maps – from I (the best) to VI (the weakest from the agricultural point of view). Soils of classes I–III (a and b), according to Polish law, are protected against exclusion from agricultural use (Act, 1995). Soil-agricultural maps are used, for example, to identify classes of soil truncation (Pindral and Świtoniak, 2017). Databases, including vector data and descriptive complexes of agricultural soil suitability, are developed for Poland based on analogue maps at scales 1:5000 or 1:25000 made in the 1960s–1980s. They constitute a basic source of information about agricultural production space and soil resources in rural areas. A practical example of the use of the information contained in this database was the development of the Agricultural Production Space Valorization Index (APSVI) (APSVI, 2023; Witek and Górski, 1977); by The Institute of Soil Science and Plant Cultivation – State Research Institute (pl. IUNG-PIB). The digital format of the map enables its wide use in, among others, developing spatial development plans, agricultural development strategies, protection and shaping of rural areas (Jadczyszyn and Smreczak, 2017).

With the development of computer and geophysical technologies, more and more researchers are using digital elevation models (DEMs) (Li et al., 2020). These, in turn, can be used in both built Geographic Information Systems (GIS), Machine learning-based (ML) techniques, and the rapidly developing innovative Building Information Modeling (BIM) technology or its offshoots Heritage Building Information Modeling (HBIM), Landscape Information Modeling (LIM), etc. (Rehman et al., 2022; Borkowski and Łuczkiewicz, 2023). The information models of buildings and their surroundings that are currently being built are fully parameterised and hierarchically structured, and the relationships within them make it possible not only to model efficiently but also to quickly apply changes or automatically generate drawings and documentation. Data on land parcels, soils, or planned development can be transferred from GIS systems to BIM. Sometimes, this is relatively easy thanks to built-in functionalities in popular applications, but sometimes it is necessary to assist it with middleware or programming, e.g. visual programming (Borkowski, 2019; Rao et al., 2000).

The principles of rational soil management should encompass various aspects of the many soil functions and ecosystem services involved in this linkage (Baveye et al., 2016; Lal, 2014). The area of agriculturally used soils in Poland is decreasing due to the allocation of significant areas for non-agricultural purposes, e.g., urbanisation, and transport. In 2020 alone, 4819 ha were excluded from agricultural production in Poland (Statistics Poland, 2021) and these are exclusively areas protected under the Act of 3 February 1995 on the protection of agricultural and forest land (Act, 1995). Between 2010 and 2020, a total of 189.5 ha of agricultural land was lost, and this was mainly land allocated to settlements and communication (Pindral et al., 2022). These processes also concern high and very high-quality soils with a big productivity potential and ecosystem services, which pose a threat to the country's food self-sufficiency and the possibility of securing biomass production for energy purposes. Nowadays, the rational management of soil resources should take into account the type and properties of soils, in accordance with the idea of sustainable development, notice all functions of soils: production, habitat, retention, and sanitation, as well as identify threats and designate sensitive areas, most exposed to degradation processes. According to the Food and Agriculture Organisation of the United Nations (FAO-UN), soils have eleven major functions: providing food and raw materials for industry, enabling carbon sequestration, purifying water and reducing pollution levels, influencing the climate, participating in the elemental cycle, providing habitat for living organisms, reducing the risk of flooding, providing a source of medicinal substances and genetic resources, providing a basis for infrastructure, providing materials for industry, providing cultural heritage.

The competition for space between different functions is subject to certain rules that organise spatial land use and environmental protection. Urbanisation transformation is seen as a manifestation of pressure on agriculture and landscape diversity, resulting in a reduction in the buffer capacity of soils and their resistance to degradation processes.

The term "resilience" exists in many different areas. For terrestrial ecosystems, there are two different definitions of resilience, although both relate to aspects of system stability. One defines stability based on the attributes of performance, control, constancy, and predictability, referred to in the literature as engineering resilience. It determines the time necessary for the system to return to the equilibrium state after the influence of the degrading factor ceases (Pimm, 1984). The second uses durability, adaptability, variability and unpredictability to emphasize the stability of the system and is referred to as ecological resilience. It emphasizes the dynamic features of the ecosystem concept without a single state of equilibrium (Holling, 1973). More precisely, engineering resilience comprises maintaining the effectiveness of a function, while ecological resilience deals with preserving a function (Roostaie et al., 2019), which implies essentially different understanding, assessment, and management of complexity and change of multifunctional systems such as the soil environment.

Soil resilience was introduced to address the sustainability of soil resources and combat soil degradation. The assessment of the resistance of the soil environment to degradation and its capacity to regenerate should be part of the rational management process (Nowak and Tokarczyk, 2013; Rega and Bonifazi, 2020). The assessment of the resilience of soils to anthropopressure should be based on reliable data on type, texture (structure), granulometric composition, organic matter content, management status, and use of the soil environment.

The sorption properties of soils mainly depend on the soil's colloid and humus content, granulometric and mineralogical composition, and soil pH. An exponent of the sorption properties of soils is the sorption capacity, which describes their ability to store ions. As the sorption capacity of soils increases, their mineral abundance and buffering capacity increase, as does their resistance to degradation.

The quantity of organic matter in soils is a fundamental factor that determines their physico-chemical properties, such as sorption and buffering capacity, and biological transformation processes, important for habitat functioning and referred to as biological activity (Henry et al., 2012; Kwiatkowska-Malina, 2018). The high humus content of soils is a factor that stabilises their structure, reducing their susceptibility to degradation (Du Preez et al., 2011).

The geographical distribution of soil degradation depends on several factors. Soil problems are influenced by the diversity, distribution, and specific vulnerability of soils across Europe. They also depend on geology, relief, and climate (European Environment Agency, 2000). Soils in Poland due to their high differentiations, vary greatly in terms of resistance to degradation. Podzolic soils are acidic and very acidic by nature, poor in humus and minerals (other than quartz) and with poor buffering properties. Despite a possible improvement in properties under the influence of human activity, these soils still represent poor-quality land with little resistance to degradation processes (Shevtsova et al., 2003). Eutric Cambisols and Dystric Cambisols and Albic Luvisols (washed) soils are soils of average and sometimes even good quality, therefore they are relatively resistant to degradation (Baude et al., 2019). However, it should be remembered that many soils considered to be Cambisols are, in fact, degraded, eroded – Luvisols (Świtoniak et al., 2016). Chernozem, black earths, rendzinas, and alluvial soils are resistant to degradation (Kabała, 2019). The rational use of soils should involve harmoniously combining a productive function with the reduction of environmental risks and the provision of public goods that are also relevant for future generations. The absence of scientific soil inventories, especially in arid areas, leads to mistaken decisions about soil use that, in the end, reduce a region's capacity to feed its population or guarantee a clean water supply (Shahid et al., 2013).

There is a need to adopt a complex approach when planning for land use and soil management. Data is the most important "fuel" of modern management and strategic direction action. Data analysis provides the information on the basis of which strategic decisions are made. The key factors are, therefore, the type and quality of data, the ability to analyse it, and translate the resulting information into action to achieve strategic goals.

DSM, as a tool to generate spatial soil information, provides solutions for the growing demand for high-resolution soil maps worldwide (Behrens and Scholten, 2006). Datasets – spatial collections (maps) of soil data: soil-agricultural map at a scale: 1:5 000, 1:25 000, 1:100 000, 1:500 000 contain data: soil genetic types, agricultural land suitability category (complexes). Spatial data characterising the natural environment in the system: soil, water, relief, climate, presented on maps can be used for the analysis of changes and forecasts in land use structure, soil properties, soil and water pollution, degradation processes, biodiversity, and landscape components, climate change, as well as in the development, implementation, and evaluation of strategies for sustainable use of soil resources. Spatial data on soils can be used to support decision-making in land management and rational management of soil resources. The variability of soil influences the use for different purposes. Such decisions are taken at different levels of endeavour based on soil surveys (Mandal, 2013; El Baroudy, 2016).

The aforementioned spatial data can be used to build a three-dimensional model to visualise potential land use. However, BIM and GIS technologies still do not work well together despite the maturity of both. The integration of BIM and GIS is one method to produce a coherent dataset for both urban and rural areas including topographic and soil data. GIS and BIM have some common features in particular with regard to data error checking mechanisms (collision analysis and topology analysis), the ability to create 4D simulations, with both systems relying on data processing mechanisms and the systems' vulnerability to expansion (Zhu et al., 2018). Thus, it can be said that GIS and BIM systems share common features. The most significant is that they both operate on spatial data, are used to record information about space, and allow spatial analysis and visualisation. The data model used in BIM systems is the parametric Industry Foundation Classes (IFC) model, while the data model most commonly used in GIS systems to describe urban spatial data is the CityGML model, which is a semantic model. BIM uses local coordinate systems, while GIS most often uses a global geodetic coordinate system. Data presentation in BIM systems is implemented using architectural and building standards, GIS systems use cartographic presentation principles. There are also differences at a technical level. Data in BIM systems is stored in its own native data file formats, whereas GIS uses spatial databases. Web services commonly used in GIS systems are not used by BIM applications (Borkowski and Wyszomirski, 2021). Designers (architects, urban planners, landscape architects), at this point, use different solutions to problems that are current in BIM-GIS integration.

The aim of the study was to assess the usefulness of soil-agricultural and classification maps at the scale of 1: 5000 in the context of the identification of factors determining sustainable soil management. This is particularly important from the point of view of costs and reliable determination of the extent of soil contours, which is labour-consuming. To avoid the error that updated data will not replace or obscure historical data, detailed data included in the extensive annex to the soil and agricultural map and publicly available databases regarding weather conditions should be used. The rational management of space and soil resources can be visualised and documented with the help of BIM technology; however, relying on GIS data is not the easiest thing to do due to the lack of integration on the BIM-GIS line. There are three integration concepts. The first is integration around the database, the second is integration around the data exchange format and the third is integration around the interface. The paper mainly uses this third concept, using different applications and the possibilities offered by plug-ins or converters. Although BIM is primarily architecture-oriented and GIS is landscape-oriented, both systems can be integrated at an application level. They can draw data from each other and complement each other.

2 Study area and materials

The research was carried out in the commune Pawłów area (Figure 1). In administrative terms, the commune is located in the Starachowice poviat in the north-eastern part of the Świętokrzyskie Voivodeship, Poland (Figure 2). This is a rural location in the Starachowice district.

This area was chosen due to the diversity of soil quality and relief. The basic economy in Pawłów is agriculture. In terms of climate, the commune has favourable agricultural conditions with soils of varied value and usefulness for agricultural production compared to communes in Poland (Zieliński and Sobierajewska, 2021). The study area is located at an altitude of 300 m a.s.l. to 307.5 m a.s.l., sloping towards the south-west (Figure 2), with the greatest slope of 2.7%.

Due to the labour-intensive nature of the analyses and modeling, an area of 24.7902 ha located within Pawłów was selected for detailed analysis. Agricultural land, including arable land, built-up agricultural land, and orchards, which are covered by the soil classification of the national system, is classified as evaluation class IIIa 22.9182 ha, and IIIb 1.1317 ha, respectively. These are soils of good quality, protected from exclusion from agricultural and forestry production under the Act of 3 February 1995 on the Protection of Agricultural and Forestry Land (Act, 1995). Considering the soil types and their agricultural land suitability category, 84% (20.7910 ha) of the area is made up of soils classified as Chernozems according to the IUSS Working Group World Reference Base (2021) Calcic/Haplic Chernozems and belong to the 1st agricultural land suitability category (complex), the remaining soils (3.9980 ha) are classified as Cambisols (WRB, I.W.G) and agricultural land suitability category – complex 2nd (Table 1). Soils belonging to the 1st and 2nd agricultural land suitability category (complex) are land that can be used for the cultivation of the most demanding crops, such as wheat, sugar beet, corn, and rapeseed (Strzemski et al., 1973). These are soils with appropriate water conditions, high productivity, and suitable for the cultivation of demanding crops.

The scope of this research covered the interpretation of source

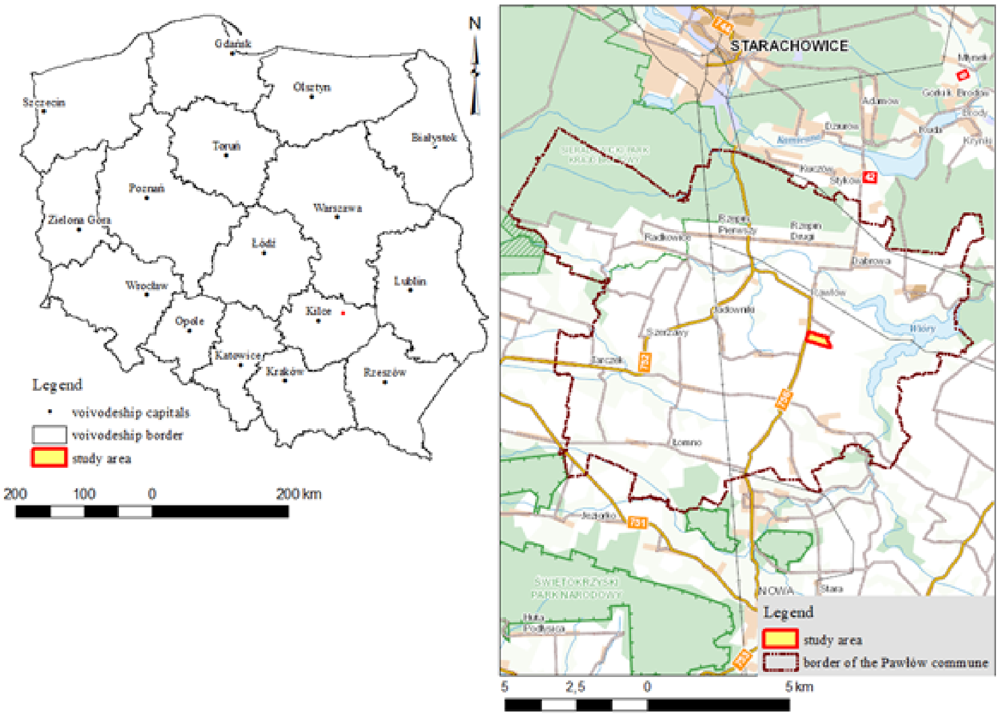

Figure 1. Location of the study area in Poland

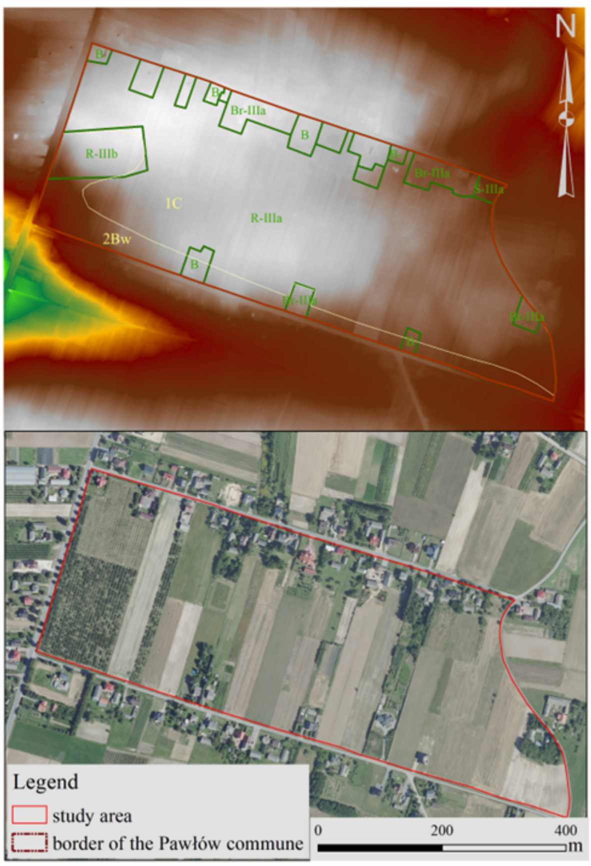

Figure 2. Precise location of the study area of the Pawłów commune

Table 1. Summary of the study area according to the basic parameters of soil conditions

Type of use	Area of use [ha]	Evaluation class	No of complex of agricultural land suitability	Soil type
B[1]	0.7403		2[2]	Bw[3]
B			1[4]	C[5]
Br[6]	2.1670	IIIa	2	Bw
Br		IIIa	1	C
R[7]		IIIb	2	Bw
		IIIa	2	Bw
	21.6147	IIIb	1	C
R		IIIa	1	C
		IIIa	1	C
S[8]		IIIa	1	C
S	0.2682	IIIa	1	C
Sum of areas	24.7902			

[1] housing areas
[2] good wheat
[3] Leached Brown Soils and acidic brown soils (World Reference Base (WRB): Cambisols)
[4] very good wheat
[5] Chernozems (WRB: Calcic/Haplic Chernozems)
[6] agricultural land with buildings
[7] arable land
[8] orchards

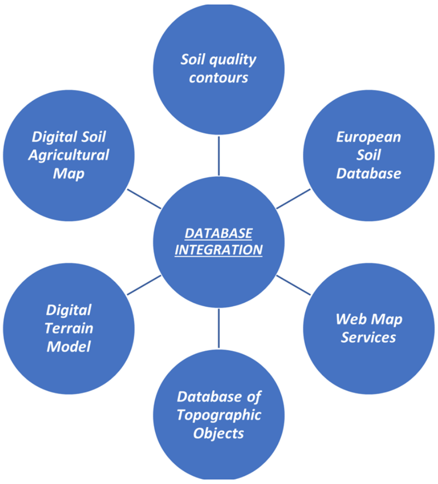

Figure 3. Selected spatial data sources

materials including: (i) soil quality contours, (ii) soil-agricultural contours (polygons) from the digital soil-agricultural map, and (iii) Digital Terrain Model (DTM).

Based on data obtained from the Central Voivodship and Poviat Geodetic and Cartographic Documentation Centre, a database was developed for the Pawłów commune, including (Figure 3):

i. The European Soil Database (ESDB);
ii. Soil quality contours from the land and building register including descriptive data on type of land;
iii. Digital soil-agricultural maps were made based on analogue maps at a scale of 1:5000, including:
   - soil-agricultural contours (polygons) and descriptive data included in the table of attributes, in particular, agricultural land suitability category complexes.
iv. Web Map Services (WMS):
   - topographic map,
   - orthophotomap.
v. Database of Topographic Objects (DTO);
vi. Raster form of DTM in the hypsometric version;
vii. Raster form of DTM in the shaded version:
   - with the mean error value not higher than 0.20 m in the ASCII XYZ format,
   - with mean error value from 0.80 to 2.00 m in the ESRI TIN format.
viii. Data from the Bank of Local Data of Central Statistical Office.

Integrating spatial data in a GIS environment is relatively easy and has been used for many years in various cases (Figure 4). It is definitely more challenging to integrate this data in a BIM environment.

3 Technology and system integration

The topic of spatial data integration has for many years been discussed in the context of data exchange between the databases of various institutions and the information they collect. However, it is now being addressed more frequently in relation to GIS and BIM. GIS technology is a key element of spatial planning and is widely used in the pre-design phase. BIM systems, on the other hand, are a set of tools that enable the modeling and management of an investment. To a large extent, however, they are associated primarily with architectural design, which may lead to the perception that they cannot be used in other areas, including spatial management. Over the years, both technologies have provided a number of solutions in the areas of analysis and design, without which it is now difficult to imagine the process of realising investments. However, they have functioned side by side, as it were. As the next step in their development, it seems natural to integrate them, which increases the design capabilities of many industries, especially those in the areas of spatial planning and urban planning. This is because it is a collaboration of two key systems in this field, which have hitherto operated in parallel, but the challenge has been to bring them together. The fact that there is a need to integrate spatial data in GIS and BIM technology can be seen from the gaining popularity of the acronym CIM (City Information Modelling) (Martensen, 2021). This is the idea of combining data from a variety of sources, including GIS and BIM technologies, with which interactive 3D models of urban spaces can be created, including both what is above ground and underground elements (Borkowski et al., 2022). This, in turn, makes it possible to manage and analyse the city's problems and increase its efficiency.

Figure 4. A fragment of the municipality of Pawłów as an example of Integration of basic spatial databases necessary to know the field situation

In addition, two of the largest software providers on the GIS and BIM technology arm i.e. ESRI and Autodesk, respectively, announced in 2017 that they are collaborating on GIS and BIM integration. The result of their efforts so far is the ArcGIS GeoBIM application launched in October 2021. This is a cloud-based platform used for investment management, allowing project teams to work together on projects and solve project challenges using data from different systems. ArcGIS GeoBIM combines geospatial data with design and construction information to better coordinate projects in a geographical context. Because the application is linked to Autodesk Construction Cloud and/or BIM 360 platforms, multiple projects can be connected to the application simultaneously, allowing you to both better coordinate the progress of each project and build your portfolio (Figure 5).

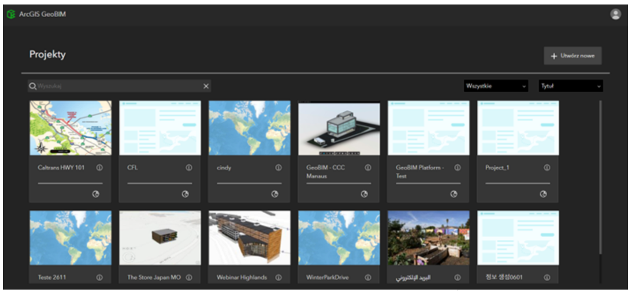

Figure 5. View of all projects connected to ArcGIS GeoBIM platform

4 Methodology

When building a BIM model, designers work in stages. In the first stage, they usually use reference data from GIS spatial databases to locate the designed object in space. This is often done using large-scale map primers obtained from surveyors. In the second stage, designers perform analyses related to the impact of existing and designed elements of the BIM model. The concept of sustainability involves checking the prevailing hydrological, soil, topographical, or climatic (or microclimatic) conditions on the site for future development. Again, designers carrying out the analysis may have doubts about which classes a particular land use element should fall into. In the third, and most important, stage, designers building the model clearly indicate, usually with a dedicated tool in the application, the object class to which it falls into. This is extremely important for the subsequent export of the model to the IFC format, which ensures interoperability when working with the model and also provides an opportunity for subsequent feeding into the GIS database. In the fourth stage, where analyses (e.g., insolation) are carried out in connection with previously designed land use elements, the potential shape of cubature or infrastructure investments or land use plans can be visualised or documented.

The examples presented earlier, such as ArcGIS GeoBIM, can be described as methods of directly integrating GIS and BIM data from within two applications. However, there are also ways to use additional, intermediary software to apply data from one technology to applications running in the other. One example of indirect integration of spatial data is taking the geometry of land parcels from a QGIS application and placing it as a reference in Revit.

In the first instance, in order to be able to do this in the free QGIS application, one needs to install a plug-in called GIS Support, which allows access to the Land Parcel Location Service (LPLS) launched by the Head Office of Geodesy and Cartography (GUGIK). It allows the geometries of cadastral parcels to be searched for and saved in the vector form. The land parcel search engine then identifies the location of at least one land parcel with a known number, which can be obtained, for example, from a publicly available Geoportal. If the geometry of more than one parcel is to be retrieved, then further parcels can be selected by uploading the WMS Land-Parcel Identification System (LPIS) to the map and using the LPLS identification function to manually indicate the relevant parcels. The result is a temporary vector layer, which is worth saving in SHP format on a disk or computer for future use. Otherwise, the layer will be lost when the project file is closed. Furthermore, as the geometry of the parcels is extracted and their descriptive information, such as precinct, TERYT (Territorial Division of the Country), parcel number, or area, it is also possible to add a label to each parcel with its number displayed inside the polygon. This can be done in the layer properties by adjusting the size, colour and font of the text so that it is readable when uploaded to Revit (Figure 6).

Then, in order to be able to further import the parcel geometries into Revit, the project needs to be exported to DXF (Data Exchange Format). Importantly, this should be done from within the entire QGIS project and not just the created layer. When exporting, it is

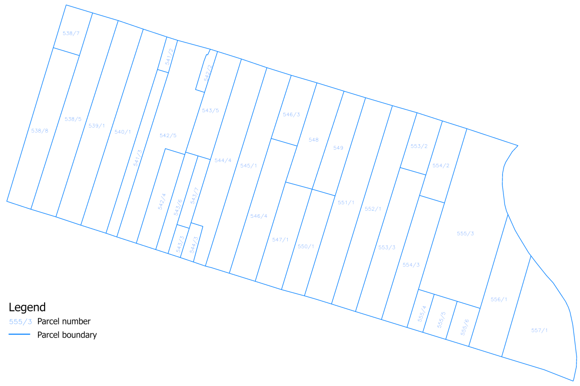

Figure 6. Parcels of land imported into the BIM model

Figure 7. Orthophoto view in the BIM model

important to take into account whether the parcel geometry should ultimately take a polygon or linear form. If the second option is selected, it is necessary to force the 2D objects in the export window to transform the polygons into lines. Another important issue is the coordinate system, which needs to be checked when exporting the project because if it is done in the wrong system, the geometries will be distorted. Adjustments can then be made in AutoCAD, e.g., to plot designations, colours or line thickness, so that the file is fully ready for import into Revit. The next step is to upload the prepared land parcels into Revit. This can be done in two ways: via CAD connection, when modifications to the DXF file are planned, or via the import CAD function, when no changes will be made to the file. Regardless of the selected option, the appearance of the parcels will be analogous in the application. In addition to uploading evidential parcels, additional supplementary elements can be included in the application, such as an orthophotomap, the sheets of which can be obtained from the Geoportal (Figure 7).

The boundaries of registered parcels of land are the basis for starting any design regardless of phase. The ground surface modelled on the basis of the DTM should be sufficiently detailed, and the prepared terrain model can be used as the basis for designing buildings and landscaping in their surroundings. As a rule, investments are developed with reference to a specific plot or several registered plots. Therefore, it is possible to place them in a reference form above the terrain model and plan them in detail. Simplified landforms can be created independently in BIM programs, but if a detailed model is to be included in the project, the method will be very tedious and time-consuming. In this situation, the data published and available for download from the Geoportal can be used.

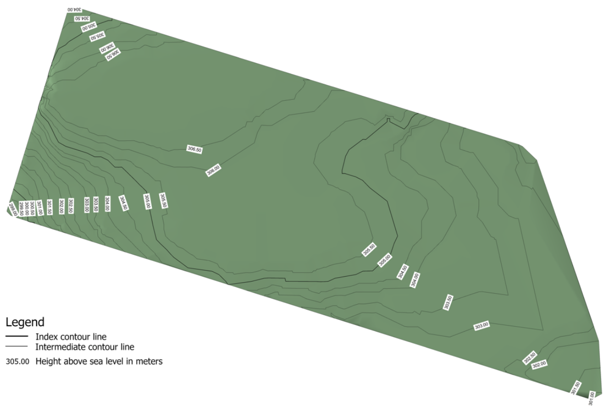

Figure 8. Terrain model surface in BIM created from NMT

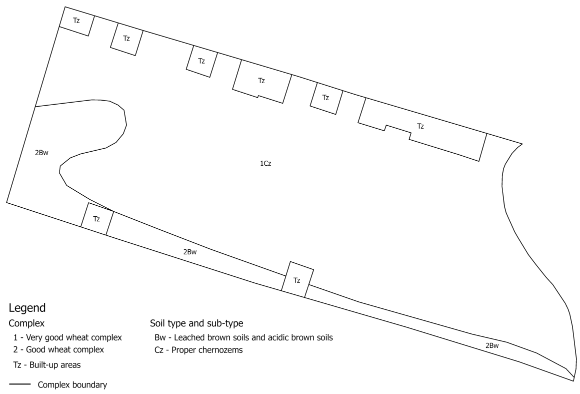

Figure 9. Classification contours imported into BIM models

There are two ways of obtaining the DTM from the Geoportal: from the map content panel, in the Data for download → DTM folder, it is possible to download a specific sheet covering the selected area in ASCII format. If, on the other hand, the area for which the terrain model is to be created is not fully contained in the sheet indicated in the Download panel, it is possible to obtain the DTM (Arc/Info ASCII Grid) from the Web Coverage Service (WCS) also in ASCII format. The extent of the terrain is then defined manually, but what is important is that the area of the downloaded model must not exceed 7 km^2. As the ASCII extension is not supported by Revit, it is necessary to adapt the acquired data to a format compatible with the software. Also, in this case, you can use the functionality of the Geoportal, because on the main page of the platform, in the Applications tab, there is a downloadable converter for data saved in ASCII format to the XYZ extension.

Once the application has been downloaded, data conversion is very simple and consists of entering the path to the location of the ASCII file in the programme's main field. The inconvenience is that you have to paste the path manually, as there is no option to indicate the file location in the pop-up window. Unfortunately, the XYZ format is also not compatible with Revit, so the next step in preparing the data for import into the programme is to use ReCap Pro from Autodesk. The file with the extension XYZ is uploaded to the application as a point cloud and then exported to the PTS format without any changes. In the next step, the created PTS file is saved in TXT format using the system's Notepad and can then be inserted into MS Excel. In the spreadsheet, the data is uploaded from the text file, and, using a comma delimiter, one column is created from the default 6 columns, storing all coordinates at once. Then, the column created is split three times, with the spacebar furthest to the right as a separator. This is done so as to leave only the first 3 X, Y, and Z coordinates in the spreadsheet. The 3 extracted columns are then deleted and the first column containing the desired values is opened in Excel. The final step in preparing the data for import into Revit is to replace the spaces between the coordinates in one column with commas and save the spreadsheet file in comma-separated CSV format (CSV UTF-8). The data prepared in this way can then be imported into Revit to create a terrain model by pointing to the point file created in CSV format. The result is a detailed landform on which the project is planned (Figure 8).

Vector data on soils in the form of classification contours were imported into the BIM space easily via the .dwg format, which was created after exporting data from a DXF vector file (Figure 9). Data exchange along the CAD-BIM line is simple and fast due to the long-standing evolution of CAD systems towards BIM.

Properly integrated GIS spatial data in a BIM environment (Figure 10) is the basis for the designer's further work and enables rational land use in accordance with his vision.

Figure 10. Integrated GIS spatial data in a BIM model

5 Results

The basic economy in commune Pawłów is agriculture, where agricultural land is the dominant form of the land structure. The soil resources of commune Pawłów are very large and require protection and rational use. However, the average quality of agricultural production space varies. Protection of soils should absolutely concern the best lands.

Based on legal regulations, development related to the protection of agricultural land is proposed, taking into account environmental considerations and sustainable development principles.

The representation of potential land use in three-dimensional space has its advantages, both visually (quality of perception) and in terms of design (quick possibility to make changes or analyse different variants). In the analysed area, the following spatial solutions were proposed and presented at level 2 of the Level of Detail (LoD) in the CityGML classification (Figure 11, 12):

- densification of development on soils of poorer quality (Brown Soils, WRB: Dystric Cambisols),
- allocation of the remaining land along the road to single-family houses,
- supplementing spaces between buildings with greenery where good quality soils exist (Chernozems WRB: Calcic/Haplic Chernozems),
- retention of the predominant agricultural function (arable land) on good quality soils (Chernozems).

Figure 11. Axonometric view of the proposed development of the site

Figure 12. Detailed view of the proposed development (brown blocks) and landscaped green space

6 Discussion

Rational use and protection of agricultural land are among the basic activities of the state, which should protect and properly manage soils of good quality. In Poland, soils of the highest quality account for only a small share of land. Therefore, their rational management and protection are important issues influencingfood security, the possibility of exporting food surpluses, and the fulfilment of sustainable development principles. Poland ranks 9th in Europe in terms of area. In the total area of Poland, agricultural land occupies 60.1 %. The area of agricultural land has been decreasing for several years but is still well above the European average (35.5%). Most agricultural land is found in the central-western and central and eastern parts of Poland, especially in the Lublin Upland and the southern part of Wielkopolska. Arable land occupies 76.2% of the agricultural area. Their highest concentration is in the flatlands of central Poland, mainly in Kujawy, Opole Silesia, Wielkopolska and the western part of Mazovia. Grasslands, i.e. meadows and pastures, occupy a total of 22.4 % of agricultural land. Permanent crops, i.e. orchards and fruit bush plantations, occupy only 1.4 % of agricultural land. Forests occupy 30.7 % of the total area, while built-up and urbanised land accounts for 5.1 %. Other land accounts for the remaining share of the total area. The quality of Polish soils is among the lowest in Europe. The production potential of an average ha of soils corresponds to that of an average 0.6 ha of arable land in European Union countries (Gawronski et al., 2013).

The legal basis for the protection of agricultural and forest land and the reclamation and improvement of the use value of land in Poland is the Act of 3 February 1995 (Act, 1995). Within the meaning of this Act, the protection of agricultural land consists in: (i) limiting its use for non-agricultural purposes; (ii) preventing the processes of degradation and devastation of agricultural land and damage to agricultural production caused by non-agricultural activities and mass movements of the land; (iii) recultivation and development of land for agricultural purposes; (iv) preserving peat bogs and ponds as natural water reservoirs; (v) limiting changes in the natural relief of the earth's surface.

The issue of limiting the use of land for non-agricultural and non-forest purposes is governed by the following principles. First of all, land designated in the land register as wasteland may be used for non-agricultural and non-forest purposes or, in the absence thereof, another land of the lowest bioproductive capacity. Secondly, the designation of agricultural and forest land for non-agricultural and non-forest purposes is carried out in the local spatial development plan (Act, 2003). Allocation for non-agricultural and non-forest purposes of agricultural land of agricultural evaluation classes I–III of the national system, if its compact area planned for allocation exceeds 0.5 ha – requires the consent of the Minister of Agriculture and Rural Development. Allocation for non-agricultural purposes of agricultural land of class IV, if its compact area exceeds 1 ha, and of land of class V and VI, formed from soils of organic origin and peatlands (if their compact area exceeds 1 ha) – requires the consent of the provincial marshal, expressed after obtaining the opinion of the chamber of agriculture.

According to the Law on the Protection of Agricultural and Forestry Land, the landowner is obliged to prevent soil degradation, especially erosion and earth mass movements. The administrative authority may order the landowner to afforest, or bush the land or establish permanent grassland on it.

The assessment of the natural conditions for agriculture requires a detailed classification not only of the individual components of the natural environment but also their synthesis, which should take into account the essential factors, namely soil resources, agroclimate, relief, and water conditions.

For the purpose of rational management of agricultural land in Poland, the agricultural departments of marshal offices prepare spatial analyses concerning the diversity of natural and economic conditions in individual voivodeships, which are used in the preparation of the voivodeship development strategy. Similar analyses may be conducted for administrative units of the basic level – communes. These analyses can be used in the development of strategies for municipalities, which will definitely enhance the rational use of soil resources.

7 Conclusion

The database based on soil quality contours is more detailed than that based on the soil-agricultural map because no loss of important data concerning the division of land occurs. In general, due to the fact that soils with high agricultural evaluation cover a small area of Poland, greater emphasis should be placed on the protection of land by limiting its use for non-agricultural purposes. Limitations can be topological inaccuracy or topological errors in vector data from disjointed reference databases. Furthermore, it would be appropriate to take action to create in each commune a spatial delimitation of the best lands (I–III evaluation classes) and to recognise them as a national asset, in order to protect them unconditionally. The competent institutions in this regard should be the local authorities at the municipal level. The integration of BIM and GIS data gives value to the designer, user, and decision-maker alike. Given the dwindling space resources and the need to protect natural resources, including soil, it is very important to use modern digital tools, among others, in the spatial planning process. The results obtained by the authors constitute an element of research in this field. Their application may significantly contribute to making optimal decisions on spatial planning and management. The study area presented in this paper is not very diverse in terms of terrain and soils. This is due to the fact that both the acquisition of data and its integration is a rather complex process. On the other hand, the use of the presented model for areas with relatively high gradients and diverse soil conditions can significantly contribute to the protection of land of particular natural and economic value (Lourenço et al., 2020). This way of collecting, processing, and sharing data can also be used with data obtained not only from traditional data sources, as shown in the article, but can also be supplemented with data from e.g., drones or laser scanning.

In the future, it is important to ensure that data on soil conditions (physical and chemical properties of soils changing mainly due to changes in use and weather conditions) or climate change can be updated on an ongoing basis. The updating of data, based on current legislation, is the responsibility of the local government (Zhang et al., 2020). Research work should be carried out to develop a methodology to update soil data cheaply and quickly using the latest digital technologies. Another research and implementation challenge regarding the integration of digital soil data is the simultaneous use of three-dimensional DSM (3D-DSM) which quantifies both the horizontal and the vertical variability of soil properties with the BIM model proposed by the authors. Ongoing research into, among other things, multiscale modeling taking into account the spatial context and structural dependence on environmental properties in machine learning models, will undoubtedly contribute to a better understanding of the soil environment and thus offer a greater possibility of protecting it. The proposed methodology can be applied on a regional (city) or local (public space) scale.

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