PRISTOP GIS ZA IZDELAVO IN PREDSTAVITEV NAČRTA UREDITVE INFRASTRUKTURE KOMASACIJSKEGA OBMOČJA NA ČEŠKEM

GIS APPROACH TO PUBLISHING COMMON FACILITIES PLANS OF LAND CONSOLIDATION IN THE CZECH REPUBLIC

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IZVLEČEK

V članku je predstavljen postopek komasacije, s poudarkom na uporabi geografskih informacijskih sistemov (GIS), na Češkem. V primerjavi z zahodnoevropskimi državami so sodobne komasacije v državah Srednje Evrope novost, kar pomeni, da ni stalnega razvoja oziroma preteklih izkušenj, na katerih bi gradili. To pa prinaša tudi priložnosti za uvajanje sodobnih pristopov, kot je vključitev GIS-rešitev v sam postopek komasacije. Načrtovanje komasacij na Češkem je praviloma izvedeno s programsko opremo CAD, v prispevku pa je predstavljena možnost uporabe GIS pri komasacijah, pri čemer je posebej izpostavljen pomen standardizacije podatkov. Standardizacija omogoča samodejno obdelavo podatkov in tudi njihovo veliko enostavnejšo predstavitev. V ta namen je predlagan objektno usmerjen podatkovni model za komasacijski načrt, ki vključuje načrt infrastrukturne ureditve (angl. common facility plan*). Predlagani podatkovni model omogoča shranjevanje takšnega načrta v središčni podatkovni zbirki GIS. Podatkovni model, skupaj s standardizacijo, je predlog arhitekture novega GIS (geoportal) ureditvenih načrtov komasacijskih območij.*

ABSTRACT

This paper introduces the process of land consolidation and current use of geographic information systems (GIS) in the Czech Republic. Contemporary land consolidation in the Central European region, unlike Western Europe, has been implemented relatively recently, hence there is no contingency or previous experience to build upon. This brings about an opportunity for a modern design of GIS-based land consolidation. Although the design of land consolidation projects in the Czech Republic is mainly conducted in CAD software, this paper focuses on the utilisation of GIS and stresses the importance of standardisation of land consolidation data. Standardisation allows automatic processing of data as well as effortless publishing. The author proposes a new object-oriented data model of the landscape plan (Common Facilities Plan), which allows for the storing of such plans in a central spatial database and adding attribute information to each object, thus providing analysis of the data in a GIS. The data model alongside data standardisation lays the groundwork for the architectural proposal of a new GIS (geoportal) of Common Facilities Plans.

KLJUČNE BESEDE

geografski informacijski sistem, GIS, komasacije, komasacijski načrt, standardizacija, geoportal, prostorski podatki

KEY WORDS

geographic information system, GIS, land consolidation, common facilities plan, standardisation, geoportal, geospatial data

1 INTRODUCTION

The simple definition of land consolidation is quite narrow: "Land consolidation provide the tools for reallocation of parcels in order to remove the effects of fragmentation" (FAO, 2013). However, land consolidation has been associated with broader social and economic aspects, mainly to support the productivity of farmers. At present, land consolidation includes a wide range of rural development objectives, ranging from agricultural improvement to landscape development and protection, which can be summarized under the term "spatial planning" or "integrated rural development" (Molen and Lemmen, 2005). Land consolidation consist of two main components: land reallocation and spatial planning (Thomas, 2006). Land reallocation involves the rearrangement of the land tenure structure in terms of parcels (size, shape and location) and rights of landowners. Spatial planning involves the design and realisation of the necessary infrastructure, such as: roads, irrigation systems, drainage systems, environmental management measures, soil conservation measures, etc. altogether known as "common facilities".

Land consolidation in Western Europe has a long history dating more than 100 years ago, while the tradition in Central and Eastern Europe is relatively new: the "first wave" began after 1989 with the privatisation of collective farms. The second wave consisting of integrated rural development is in fact happening now (Hartvigsten, 2015). In his study for the Food and Agriculture Organization of United Nations, Hartvigsten (2015) categorizes the Central and Eastern European countries according to their experiences with land consolidation. In the advanced group are countries with ongoing land consolidation programmes, such as Slovenia, Czech Republic, Poland, Slovakia, Lithuania and Eastern Germany.

An important progress in land consolidation field in the most Western European countries are land banks. They have developed the institute of land bank during the last two decades. Land banking allows the state to buy parcels for future development of public measures or use in the land consolidation process. More about this process is to be found in the document "The design of land consolidation pilot projects in Central and Eastern Europe" (FAO, 2013).

This article describes the state of the art land consolidation in the Czech Republic. Since the process of land consolidation in the Central European region is relatively new, it brings about new opportunities for managing land consolidation data. Although the design of land consolidation in the Czech Republic is mainly conducted in CAD software, the paper focuses on the utilisation of geographic information systems (GIS) in this process and stresses the importance of standardisation of land consolidation data. The purpose of this article is therefore to introduce the methodology and design of a new approach to this process using GIS in order to publish the land consolidation outcomes to the public in an interactive manner – using a geoportal.

1.1 Land Consolidation in the Czech Republic

Land consolidation in the Czech Republic is administered by the State Land Office (SLO), an executive agency under the Ministry of Agriculture, according to the Act No. 139/2002 Coll. on Land Consolidation and Land Offices. SLO controls a network of 13 regional and 64 district Land Offices. Land consolidation in the Czech Republic is perceived as a multidimensional instrument for landscape planning. It has been primarily used for plot reallocation, however it currently fulfils additional important roles such as improving transportation infrastructure, water management and nature protection. Environmental conditions have been given increased priority over the last 10 years. Land consolidation allows for changes in land use patterns especially in areas endangered by soil erosion, frequent floods and droughts.

There are simple and comprehensive (in Czech "complex") land consolidation processes in the Czech Republic. Comprehensive land consolidation is versatile, it always includes the Common Facilities Plan and occupies larger areas. On the other hand, simple land consolidation focuses on particular issues, like reallocation or ecological measures. The spatial extent of simple land consolidation is site specific (local) and the Common Facilities Plan is not compulsory. Both simple and complex land consolidations are managed by the SLO. There is no voluntary approach to land consolidation so far in the Czech Republic unlike in other western European countries, such as in Netherlands.

The extent of land consolidation traces cadastral units (excluding built-up areas) or watershed units (see hydrological studies in section 2.2). Every year, SLO initiates approximately 200 land consolidation processes. The overview map in Figure 1 shows all finished comprehensive processes in the Czech Republic between 1990 and 2017. Almost 30 % of all cadastral units have been consolidated so far.

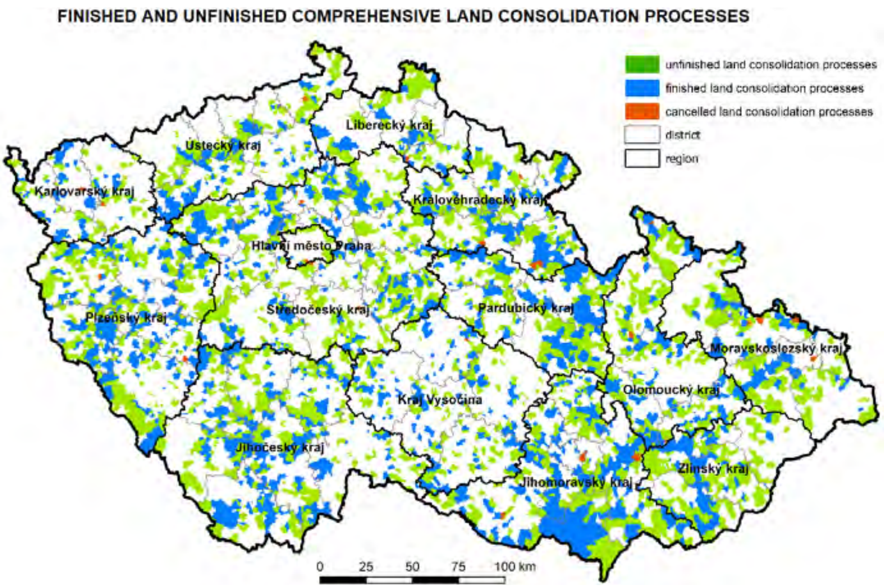

Figure 1: Overview of Comprehensive Land Consolidation Processes Between 1990–2017 (Source: SLO).

According to Act No. 503/2012 Coll. about the State Land Office, SLO is the Office obligated to hold a certain amount of land area as a so called "reserve". This land can also be used for land consolidation purposes. SLO also manages requests on land from other public authorities (ministries) for strategic developments (e.g. infrastructure). This reserve can be considered as the institute of land bank.

The land consolidation process consists of four phases, see Figure 2. The first three phases (Initial-Design) last, on average, 4-5 years. Realisation of common facilities depends on financial resources and other local circumstances. During the design phase, a series of plans and maps is created, among them the detailed consolidation plan of common facilities (Common Facilities Plan) and a new digital cadastral map.

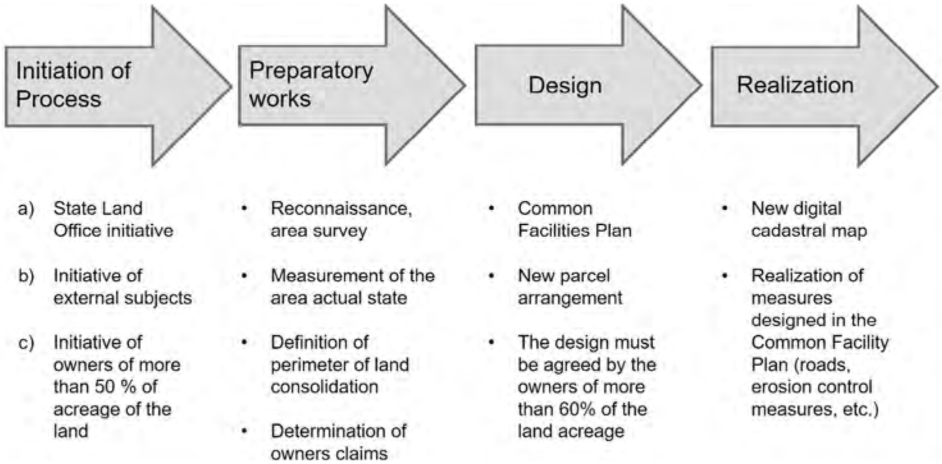

Figure 2: Phases of the Land Consolidation Process in the Czech Republic

1.2 Common Facilities Plan

The Common Facilities Plan (CFP) can be considered as a landscape plan, but in the Czech Republic this plan excludes built-up areas (which are the domain of urban planning) and usually excludes forests because another authority manages them. Common Facilities are, according to the Methodology for Executing Land Consolidation (SLO, 2017), divided into four groups: measures for land accessibility (field roads), soil erosion control measures (technical, agronomical, and organisational), water management measures and environmental measures (e.g. bio-corridors and bio-centres, which can be summarized under the term "green infrastructure"). CFP is one of the main outcomes of the design phase of land consolidation. An example of a section of such plan is displayed in Figure 3. Land consolidation process in the Czech Republic involves not only design, but also construction of those measures (depending on financial sources).

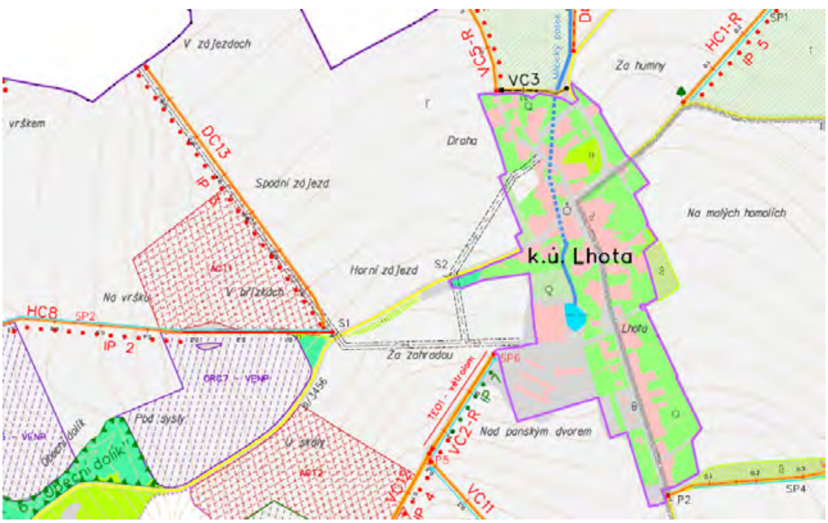

Figure 3: Section of CFP according the Technical Standard (Source: SLO, 2016).

Until now, CFP have been only published by the involved municipalities in analogue format and stored in archives of district Land Offices in various formats. Since the plan contains measures of public interest with high impact on the environment, it would be beneficial to publish those plans to the broad public.

1.3 New Digital Cadastral Map

The other important outcome of land consolidation at the end of the design phase is a new digital cadastral map (land re-allotment plan), which must be agreed on by at least 60% of the acreage of involved owners. It comes into force by recording in the Cadastre of Real Estates.

2 CURRENT GIS APPROACHES TO LAND CONSOLIDATION

Unfortunately, there are not many articles on the topic of GIS and land consolidation in scientific literature. This is due to the type of software used in land consolidation, which historically used to be CAD, and the practices of the software designers and users. Molen and Lemmen (2005) point out the need for GIS tools in the land consolidation process. Such tools would improve the quality of projects (Molen and Lemmen, 2005).

In 2013, Springer published Demetriou's Ph.D. thesis called „The Development of an Integrated Planning and Decision Support System (IPDSS) for Land Consolidation", which lists computation and decision supporting methods for land consolidation and proposes automated workflows and tools for GIS (Demetriou, 2014). Demetriou's thesis sets the groundwork for the use of GIS during the design and evaluation of plot re-allotment of land consolidation.

In the Czech Republic, GIS on the other hand is used for partial analysis during the initial, preparatory, and design phases. Plot re-allotment is currently still conducted solely in CAD. Current applications of GIS are further described in the following sections 2.1–2.4.

In Slovakia, Leitmanová proposed data infrastructure for the implementation of information system of land consolidation (Leitmanová et al., 2013). She categorized all datasets associated with land consolidation and published them in a case study in a form of a web map. However, she does not deal with the necessary data model of the actual land consolidation data (re-allotment plan nor the Common Facilities Plan).

2.1 Master Plan of Landscape Water Management

The Czech Republic is facing challenges such as climate change, as illustrated in Figure 4. Climate change causes droughts and flash floods which leads to increased soil erosion, thus negatively impacting soil.

The State Land Office responds to these challenges through land consolidation and with „Master Plan of Landscape Water Management", which identifies the most vulnerable locations and seeks new technical, economical, and legislative solutions. The first outcome of this project is displayed in Figure 5. A multiple criteria analysis identified the most vulnerable cadastral units threatened by drought and flash floods. This analysis shows that 50 % of agricultural land faces threats above the average. The State Land Office can aim land consolidation measures primarily to these areas. More information about this project and particular criteria used are to be found in the FIG article of the month (Pavlik et al., 2017).

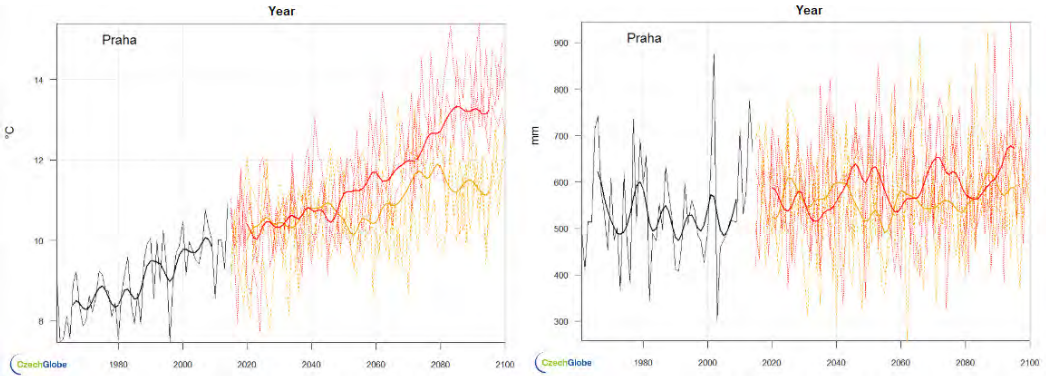

Figure 4: Time Series and Prediction of Mean Air Temperature (left) and mean precipitation (right) (Source: CzechGlobe, klimatickazmena.cz).

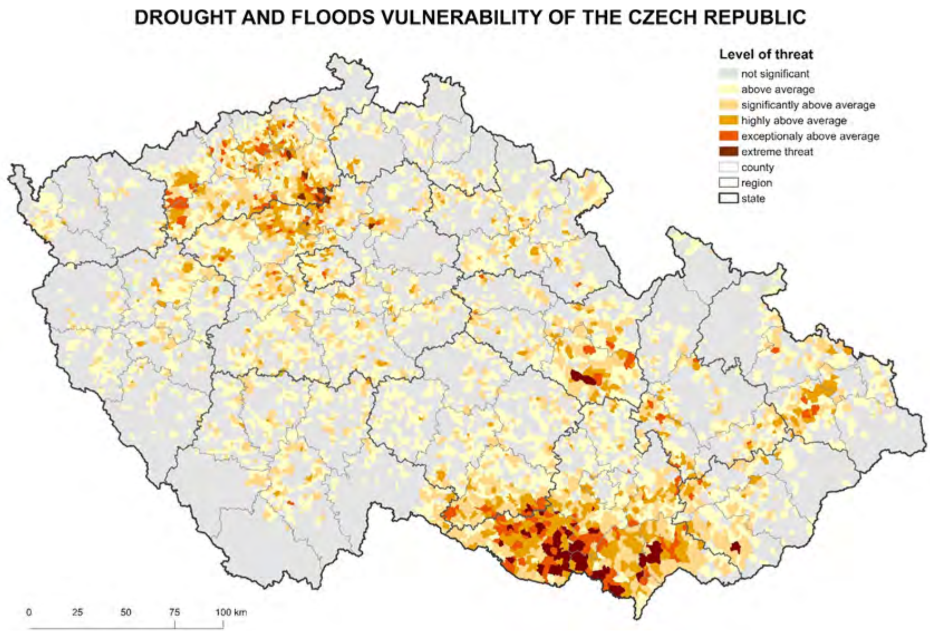

Figure 5: Multiple Criteria Analysis in GIS Showing the Most Threatened Areas by Drought and Flash Floods (Source: SLO, CzechGlobe).

2.2 Hydrological Studies

The State Land Office conducts hydrological studies in morphologically complex areas typically during the initial phase of the land consolidation process. These studies identify soil erosion and water runoff conditions (watershed), which help to define a meaningful perimeter of the area of land consolidation and propose necessary water management and soil erosion control measures. Most of these studies are conducted in GIS, one example of such study is shown in Figure 6.

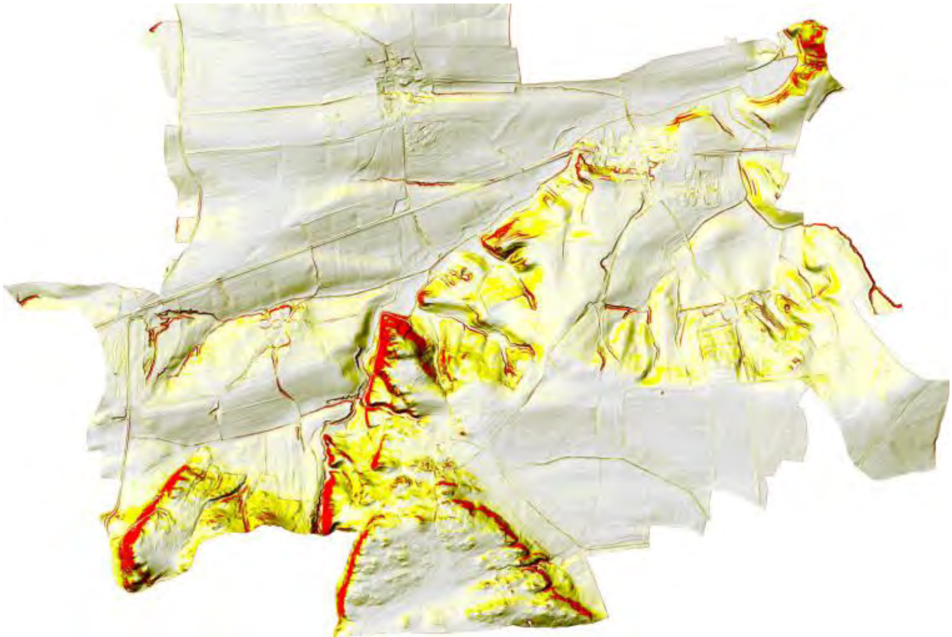

Figure 6: Example of Hydrological Study of Water Runoff Conditions Based on Digital Elevation Model (Source: http://www.g-servis.cz/reference-geologie).

2.3 Soil Erosion Analysis

Soil erosion analysis is calculated twice in GIS using the Universal Soil Loss Equation (Wischmeier and Smith, 1978) during land consolidation: prior to and after the design of common facilities. The design of common facilities includes various soil erosion control measures; an example of potential soil loss on agricultural blocks is displayed in Figure 7. The Research Institute for Soil and Water Conservation published two methodologies in 2014 that focus on the use of GIS in calculating simulation models and the design of technical soil control measures (Kadlec, 2014). The Institute also publishes a series of maps (e.g. potential water erosion, potential wind erosion, monitoring of actual erosion events etc.) in the geoportal http://mapy.vumop.cz/; see example in Figure 8.

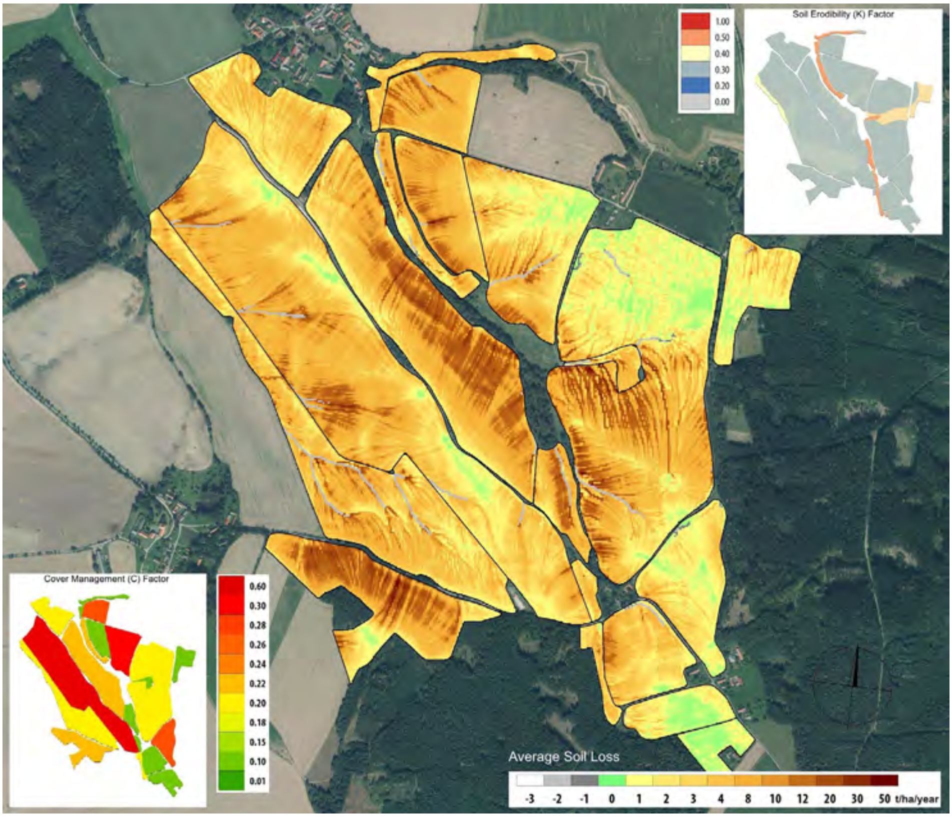

Figure 7: Example of Soil Erosion Analysis (Average Soil Loss) Calculated in Software Atlas DMT (Source: atlasltd.cz).

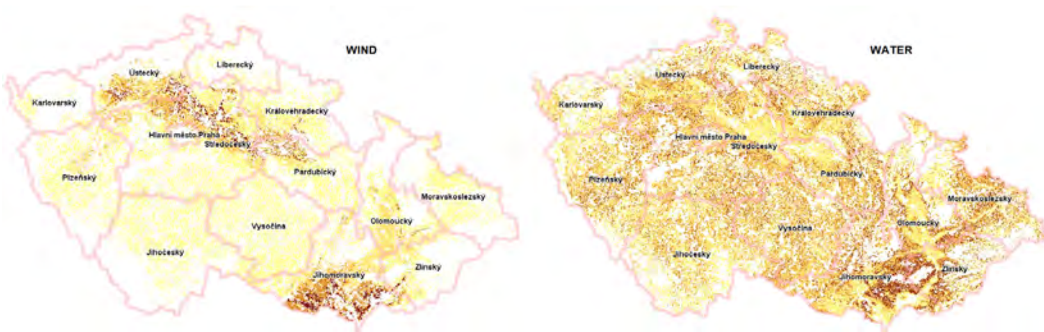

Figure 8: Left: Potential Areas Threatened by Wind Erosion, right: Long Term Average Soil Loss (USLE Equation) (Source: mapy.vumop.cz).

2.4 Drought Monitoring System

The State Land Office funds a unique system for drought monitoring called "Intersucho". Drought monitoring is the key tool for supporting agricultural production, business and political decisions. The development of the system has been based on the latest knowledge in the fields like agro-meteorology and bioclimatology. The goal of the system is to help farmers, horticulture industries, and foresters as well as municipalities and water management companies. The system is based on a network of ground stations and satellite images with the support of local correspondents. Drought monitoring results are provided every week for the Czech and Slovak Republic, and on a smaller scale, for Central Europe. The system provides predictions for one month ahead as well. Figure 9 displays thematic maps of drought intensity (weekly average deviation from the average condition in 1961-2010) based on the thickness of soil layer.

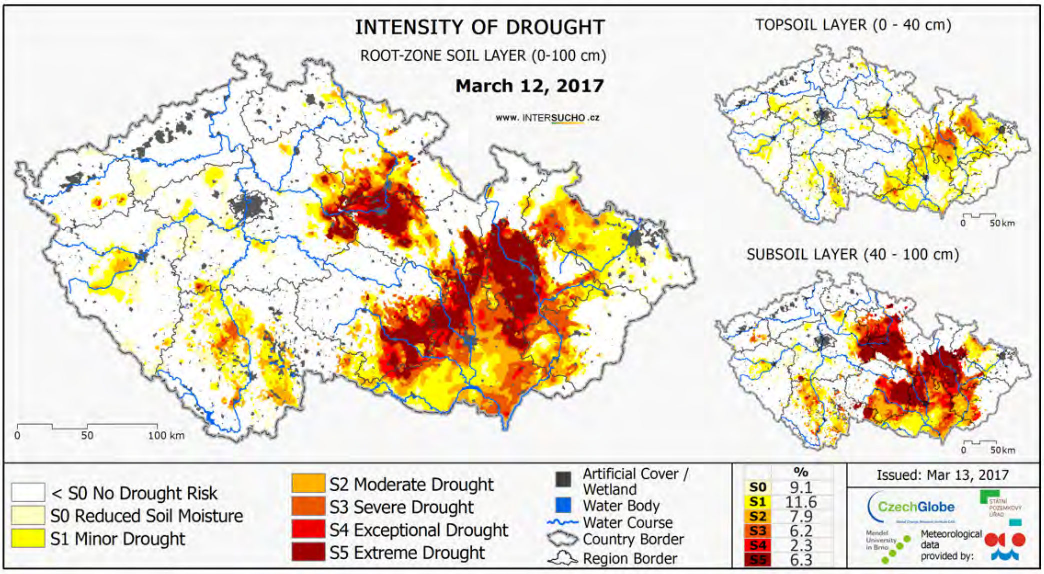

Figure 9: Example of Outcomes of the Intersucho Monitoring System (Source: intersucho.cz).

3 SPATIAL DATA INFRASTRUCTURE OF LAND CONSOLIDATION DATA

While the application of GIS for terrain assessment (in particular soil erosion) during the initial phase of the land consolidation process is already common, broader use of GIS in land management is currently an important challenge for the State Land Office. The state of the art land consolidation data processing in the Czech Republic, its current needs and future aims regarding management of spatial data have been evaluated. The main motivation of the SLO is to publish land consolidation data – Common Facilities Plans on the Internet using a geoportal.

3.1 Standardisation of Land Consolidation Data

3.1.1 Standardisation of the Re-allotment Plan

In 2001, the Information System of the Cadastre of Real Estate was introduced by the State Administration of Land Surveying and Cadastre and digital cadastral maps were standardized and provided in exchange TXT format. While this TXT format representing the cadastral map contains geometry and attribute information regarding final ownership structure of the re-allotment plan, detailed attribute information of the re-allotment process (such as claims and gains of each owner involved in the process) is stored in a separate XML file, which has been developed and put into practice by the SLO since 2012. The new exchange format is an open standard and includes various data integrity and logical checks described in the XSD schema.

The XML file is used together with the cadastral TXT file to exchange data between SLO and its contractors throughout the first three phases of the land consolidation process. At present, land consolidation data is created in CAD software by the contractor, handed over to the Office in the new XML exchange format and validated there in CAD software, as displayed in Figure 10. Since the final re-allotment plan is later on displayed in the form of a new digital cadastral map in the geoportal of the cadastre (State Administration of Land Surveying and Cadastre), there is no need to further standardize, nor publish this data by the SLO.

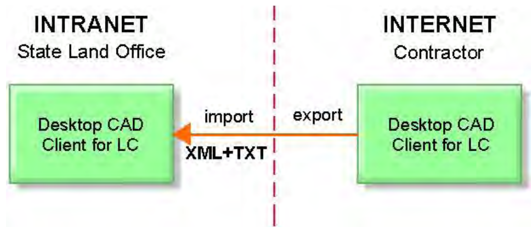

Figure 10: Land Consolidation Data Exchange and Processing at Present Using CAD Desktop Clients.

3.1.2 Standardisation of the Common Facilities Plan

From 1990 until 2010, Common Facilities Plans had been handed over from contractors to the SLO in various forms and formats such as paper maps, PDF, and CAD drawings as shown in Figure 11. In 2010, the Technical Standard of the Documentation of Common Facilities Plan was published, which unified the content and visualisation of the plan (SLO, 2016). This standardisation allowed for the semiautomatic processing of plans created in CAD into a spatial database as shown in fig. 11. From 2016 until 2018, the State Land Office ran a project on consolidating historical data into a single database, as illustrated in Figure 11. This process included scanning, georeferencing, vectorisation, adding attribute information, and data validation.

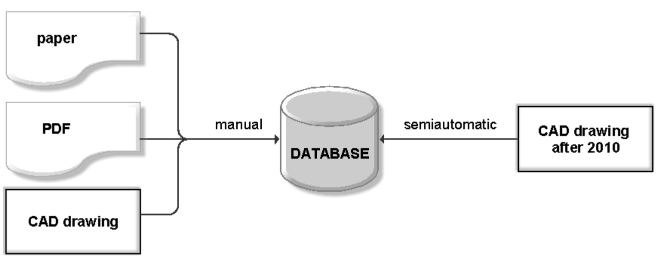

Figure 11: Consolidation of Historical CFP into a Single Spatial Database.

Since 2012, Common Facility Plans have been stored within the new data exchange format based on XML. The format bridges the gap between drafting software (CAD) and geographic information systems (GIS). More information about standardisation of land consolidation data can be found in Müller (2015).

In 2016, the Common Facilities Plan (CFP) was enriched by compulsory technical attributes, which need to be filled out by contractors. These attributes are stored within individual objects of CFP in the XML format. This new data model is object-oriented and thus the data becomes a solid groundwork for a future GIS, which is described in section 3.3. Data standardisation using the complex XML format allows for fully automatic importing and processing of CFP into a single spatial database (illustrated in Figure 12).

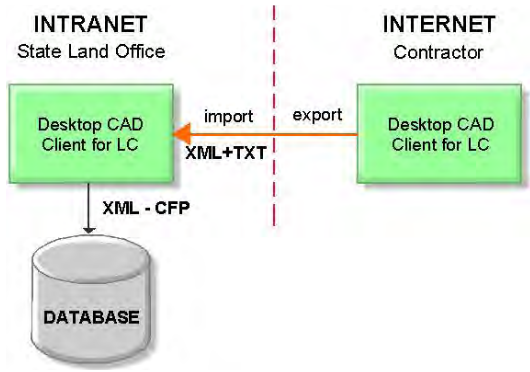

Figure 12: Importing Current CFP into a Single Spatial Database Using the XML format.

3.2 Proposal of the New Data Model of Common Facilities Plan

The first step in designing GIS should be modelling of (spatial) data, because data is the groundwork of every information system. Conceptual schema represents a unified view of substantial object classes. Object classes are divided based on their type of geometry, common attributes and relationships (associations). Conceptual schema describes what the information system is about and how it should be implemented. The proposed conceptual schema of the Common Facilities Plan in Figure 13 has been drawn in the UML notation.

As displayed in Figure 13, the Common Facilities Plan (CFP) consists of the Perimeter of LC class, the actual CFP class (designed measures) and the Realisations class (representing as built measures). The Perimeter of Land Consolidation class is related to the (boundary of) Cadastral Unit class – a cadastral unit may contain none or more perimeters of LC, while the perimeter of LC lies within at least one or more cadastral units. Attributes of individual object classes are described in table 1. The Realisations object class contains separate geometries (because, in reality, often only some part of the designed object is built; the geometry may therefore differ) and new attributes. Each object of the Realisation class (child) must have a relationship with the designed object within the CFP class (parent). Technical attributes of CFP class are filled by contractors in CAD software and transferred to SLO by the XML exchange format, while Realisation attributes are later on filled by the Office employees in a web GIS application, who may also create or modify the geometries of the Realisation features.

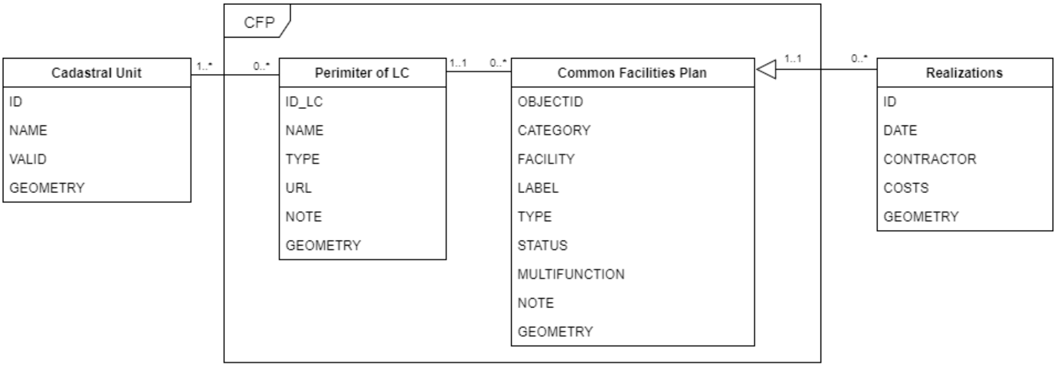

Figure 13: Conceptual Schema of the Common Facilities Plan

Table 1: Attributes of the Conceptual Schema

Attribute	Meaning
ID	Identification number (usually primary key)
NAME	Name of the object (cadastral unit / land consolidation)
VALID	Validity of the cadastral unit (valid/not valid – historical)
GEOMETRY	Geometry type (point, line, multi-line, polygon, multi-polygon
TYPE	Type of LC (simple/comprehensive) / Type of CFP (often a code-list domain)
URL	URL link to the text documentation (technical report)
NOTE	Description regarding the individual object, its state, condition, location, etc.
CATEGORY	Category of CFP (Accessibility/Soil Erosion Control Measures/Water Management/ Environmental)
FACILITY	Facility type based on category (e.g. field road/wind barrier/erosion ditch/water reservoir, etc.)
LABEL	Label of the individual common facility object, related to technical report
STATUS	Status of the individual common facility object (existing/designed)
MULTIFUNCTION	Each object may fulfil multiple functions (code-list related to categories)
DATE	Date of realisation
CONTRACTOR	Name of the contractor
COSTS	Total costs incurred in the realisation

The conceptual schema is followed by a logical schema, which represents the actual implementation in a specific database system. It describes in more detail each attribute type, primary and foreign keys, geometry types and other data integrity constraints. However, the logical schema of the Common Facilities Plan is beyond the scope of this article.

3.3 Design Proposal of GIS of Land Consolidation

3.3.1 Methodology

The methodology of a new GIS system is based on the following steps (illustrated in Figure 14): current state analysis, identification of user requirements, synthesis, and the actual design.

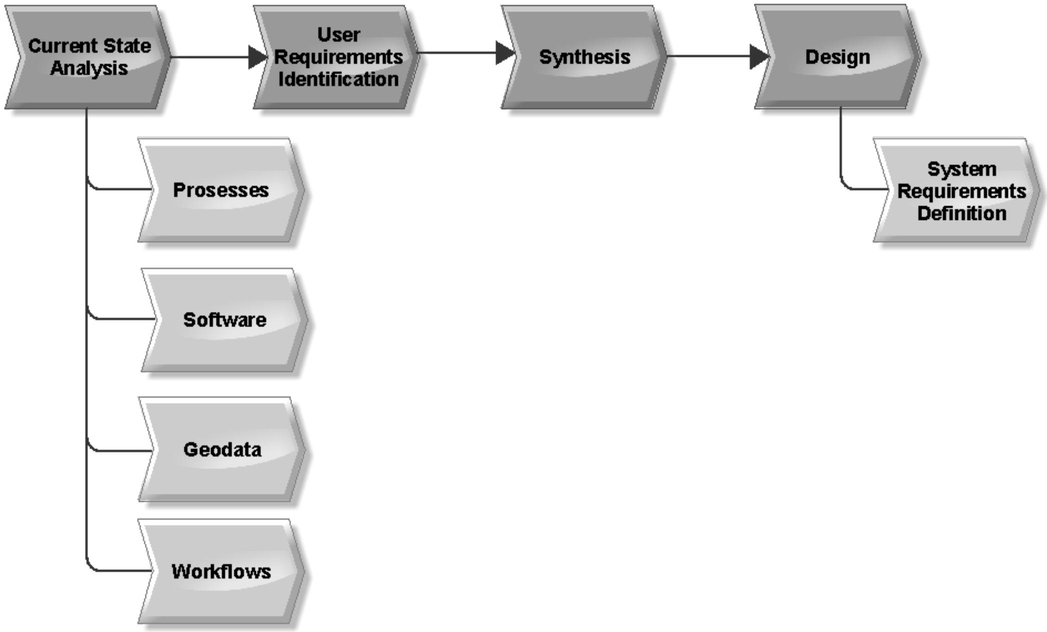

Figure 14: Methodology: Analysis and Design Workflow.

The current state analysis helps in understanding the business scope and needs, pain points, business processes affected, the stakeholders involved in these processes etc. The main purpose of the analysis is to present the "as is" state: the existing business processes, user workflows, software and geospatial data used in these workflows and processes. The sources for this analysis include legislation, external and internal directives of the organisation, technical documents, user manuals, and interviews with key users.

Interviews with key users help identify their needs and proposals on enhancements, i.e. requirements on the future system. Identified requirements were given priorities based on an on-line questionnaire, which was sent to all potential users within the Office (about 600 employees).The key part prior to the actual system design is synthesis. During this mental process, all inputs are put together based on common nature or common use: geodata, users, workflows, current and future software integration, and requirements. System design (future state) builds upon the synthesis and defines all system requirements, starting with basic architecture requirements up to the requirements on functionality.

3.3.2 Design

Thanks to the new data exchange format (XML) described in section 3.1, the CFP designed by contractors can be automatically imported into central spatial database including technical attributes (into the new data model described in section 3.2). This process is schematically shown in Figure 15 by orange arrows. Data stored within the database can be edited by both desktop (directly) and web GIS clients (indirectly using map server and services).

The system is designed following the Service Oriented Architecture (SOA) principle (client–server–database), representing three layers (presentation layer in green – application layer in blue or red – and database layer in grey), as shown in Figure 15. The core of the system consists of a map server, web server and desktop client (admin). The map server publishes services, which are accessed by clients (desktop GIS editor, web client and external clients) through the web server. Map services can be consumed by various internal as well as external clients, based on security settings. In order to ensure data interoperability and software independency the system must support standardized map services according to the Open Geospatial Consortium (OGC) such as WMS, WMTS, WFS etc. shown by green lines in Figure 15.

The public part of the system (accessed on the Internet) depicted on the right side of Figure 15 – geoportal consists of a public web client (and in the future, a mobile client) and an interface for publishing geodata in the form of open data and open map services. These services can be consumed "back" within the contractors' desktop CAD clients. Designers of land consolidation as well as architects of urban plans will thus have easy access to land consolidation data and will be able to connect their designs to adjacent areas with finished land consolidation. This proposal of systems architecture only accounts for viewing of spatial data by the public. User involvement (of participants, farmers, stakeholders and planners) during the design phase remains a future vision.

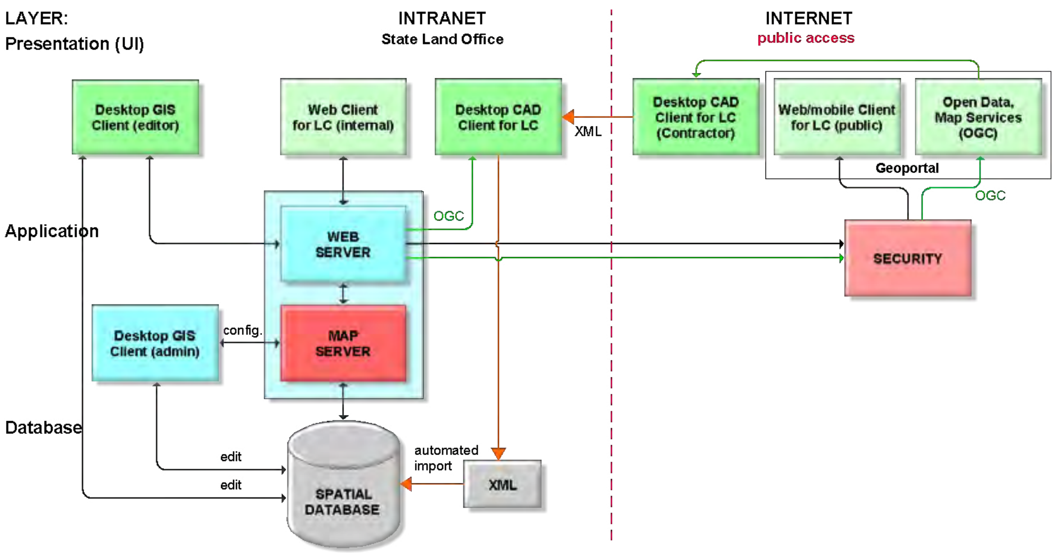

Figure 15: Architectural Proposal of GIS of Land Consolidation.

5 CONCLUSION

The paper introduced the state of the art land consolidation process in the Czech Republic and work on the design of a new geographic information system of land consolidation data. The design starts with the necessary data standardisation and consolidation of historical data (Common Facilities Plans), followed by the proposal of new object-oriented data model of CFP and design of a new system, which will allow effective processing and effortless sharing of data.

While historical CFP data have already been consolidated (between 2016–2018) and validated by the State Land Office (2018), the proposed GIS system is scheduled to be implemented between the years 2019–2020. The system will provide central evidence of land consolidation data, thus enabling a comparison of Common Facilities Plans, analysis, and execution of spatial queries. Additionally, it will provide easy access to data for land owners, landscape planning experts, as well as the general public. The intention is to publish CFP data as open data besides the interactive web client provided within the geoportal. Publishing CFP data could bring higher transparency of investments in realisations of public measures (common facilities) as well as higher demand on land consolidation by land owners.

5.1 Future Vision

The future vision includes providing enhanced geospatial technologies to the participants of the land consolidation process, so participants could express their opinions or wishes regarding land consolidation design (re-allotment or CFP) using a web GIS client (geoportal). If one leaves out the internal desktop CAD client in Figure 15 and processes the XML land consolidation data solely on the server side, the XML could be uploaded by the contractor to the application server, validated automatically by a geoprocessing service and then inspected by the relevant employee of the State Land Office within a web client. However, this step would require sufficient bandwidth of the intranet network connection, sufficient performance of the map server, and programming all validation procedures of land consolidation data on the server side.

The proposed system will not only serve the aims of the land consolidation process, but will also support the management of state-owned agricultural land administered by the State Land Office (the reserve, which can be considered as a form of a land bank). This way all geodata will be easily accessible from one place and within one client, and ready to support decisions regarding selling, leasehold, exchange of state land, or providing state land for national strategic intentions and developments including the realisation of common facilities of land consolidation.

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