"Environmental Engineering" 10th International Conference
Vilnius Gediminas Technical University
Lithuania, 27–28 April 2017
http://enviro.vgtu.lt

eISSN 2029-7092 / eISBN 978-609-476-044-0

Article ID: enviro.2017.247
DOI: https://doi.org/10.3846/enviro.2017.247

Concept of a Polish Database of a Multi-Dimensional Cadastral System with Particular Focus on Geo-Hazards

Agnieszka Trystuła

Department of Geoinformation Analysis and Cadastre, The Faculty of Geodesy, Geospatial and Civil Engineering, University of Warmia and Mazury, Olsztyn, Poland
E-mail: agnieszka.trystula@uwm.edu.pl

Abstract. The dynamic growth of contemporary cadastral systems depends on multiple factors, which include, e.g. economic policy of a given country and possibilities of implementing activities supporting innovation and transfer of new technologies. A modern cadastre should satisfy not only its leading functions, which include, e.g. fiscal, information, legal or record functions. It should also be oriented towards new challenges, including 3D geovisualisation, which will enable multidimensional visualisation of cadastral objects. New data visualisation methods will contribute to extending the existing functions of cadastral systems and to emergence of new functions, e.g. related to ensuring public safety as a basic aim of crisis management, being an important element of sustainable development. This paper presents a concept of a database of multidimensional cadastral system enabling, for instance, 3D visualisation of system objects, incorporating its known functions (e.g. fiscal, information or legal functions), and also a new purpose –support for crisis management. Additionally, the study indicates sources of data that should be used for this type of undertaking (e.g. flood hazard maps, maps of areas at risk of mass land movements, orthophotomaps).

Keywords: cadastral system, 2D, 3D geovisualisation, geo-hazadrs.

Conference topic: Technologies of geodesy and cadastre.

Introduction

Property cadastre is one of official systems recording land information as regards the actual status of land, without which its proper management would not be possible. Cadastral data form the basis for planning directions of spatial development, for issuing administrative decisions and for infrastructure management (Gotlib *et al.* 2008). Development and evolution of contemporary cadastral systems depends on many important factors, related e.g. to economic policy and possibilities of implementing activities supporting innovation and transfer of new technologies. A modern cadastre should satisfy not only its current leading functions, for instance, fiscal, information, legal or record functions. It should also be oriented towards new challenges, such as 3D geovisualisation, which will enable multidimensional visualisation of cadastral objects along with recording of related rights. New solutions will contribute to extending the existing functions of cadastral systems and to the emergence of new functions, e.g. related to ensuring public safety as one of the elements of sustainable development. In recent years, an alarming increase of various types of natural hazards (e.g. floods, landslides) has been observed, bringing tragic effects, contributing to the deaths of people, property losses and damage to the natural environment. 3D visualisation is one of various challenges which have been posed in the latest years, not only to cadastral systems. In view of innovative GIS tools, there is a real chance for a traditional 2D cadastre with potential and growth possibilities to become a cadastre of the newest generation, enabling, for instance, 3D visualisation of cadastral objects for the needs of broadly understood space management, including crisis management.

This paper presents a concept of database for a multi-dimensional cadastral system, enabling e.g. 3D visualisation of system objects, incorporating its well-known functions (e.g. fiscal, information or legal function) and also a new purpose, which is support for crisis management. Additionally, sources of data that should be used for this type of undertaking are also indicated.

Issues related to multidimensional cadastral systems in Europe and in the world

Efficient and effective cadastral systems in Europe and in the world are important for sustainability of economic development, for environmental management for stability of society. They are considered to be a part of a broader system of land administration referring to information infrastructure of the state, including the legal framework and relevant training initiatives concerning international standards that are designed to facilitate property market development and that will have significant relations with various cadastre users, particularly with the financial and banking sectors (Resolution of the Third International Cadastral Congress 2011).

The 3D cadastre was mentioned for the first time in 2001 during the "FIG 3D Cadastres Workshop" in the Netherlands. Since then, research work related to multi-dimensional cadastral systems has been carried out. However, no universal solution has been developed so as to enable an attempt to create a uniform cadastral system in the European Union countries and in the world. This is undoubtedly a result of a range of problems, related to (Oosterom *et al*. 2011):

- the type of objects to be registered in the cadastre – future structures, i.e. buildings, tunnels, transmission lines, as in Norway, Sweden or the so-called "airspace", as in Australia;
- the idea of registering linear objects, such as tunnels, transmission lines – as separated spaces based on the surface plot of land or as a separate cadastral object, as in Sweden;
- the method of cadastral registration of spatial objects – using coordinates within the reference frame (as in the 2D cadastre in most countries) or determined with reference to existing topographic objects and their boundaries (as in Great Britain).

Additionally, organization and the complexity degree of a cadastre in a given country depend on legal and organisational framework, the users' needs and technical possibilities. Therefore, the idea of a complete replacement of a two-dimensional cadastre with a three-dimensional one is not under consideration (3D Cadastres 2012). In 2012, the international ISO standard 19152 LADM came into effect, functioning in Poland as the Katastralny Model Administrowania Gruntami (Cadastral Land Administration Model), which presents a general conceptual model of 3D cadastre, but does not offer ready-made solutions. It rather determines the directions and activities which may help in future in the transition from a 2D cadastre to a multi-dimensional cadastre.

Five possible scenarios for creating multidimensional cadastre can be distinguished (www.gdmc.nl/3DCadastres):

1. Minimalistic 3D Cadastre – does not consider the infrastructural network, does not include roads or railways as 3D cadastre objects, which eliminates most sub-surface objects. Information on apartment units is available via layers. Other 3D objects are available by adding a 3D symbol to a 2D map, as a reference to the document being a source of spatial data.
2. Topographic 3D Cadastre – no own geometry is created for legal objects, but objects are defined by reference to the physical boundaries of objects.
3. Polyhedral Legal 3D Cadastre – 3D plots with volume have their own geometry which is represented by polyhedrons (bounded with flat surfaces).
4. Non-polyhedral Legal 3D Cadastre – similar to the previous one, but allowing other surfaces, e.g. cylindrical or patched (NURBS – *Non-Uniform Rational B-Spline*).
5. Topological Legal 3D Cadastre – 3D plots with volume are topological structures based on nodes, edges, surfaces and volume primitives. In this case, 3D cadastre objects adjoin the neighbouring objects on all sides.

Each of these options for implementing 3D cadastres has its advantages and disadvantages. For instance, the minimalistic 3D cadastre seems relatively easy to implement. Whereas it seems that such relatively simple registration of objects improves cadastre functionality to a low degree, and at the same time, it can be the cause of various problems in the future. A topographic 3D cadastre can be created when there is a topographic database that can be used as the basis for establishing such a cadastre. In this case, a legal object exists only when its equivalent exists in topographic database. It seems that this type of cadastre does not comply with principles applicable in contemporary two-dimensional cadastral systems. Polyhedral legal 3D cadastre seems relatively easy to introduce with the use of present technology. On the other hand, the lack of topologic structure and impossibility of using curved surfaces are its disadvantages. In turn, an advantage of non-polyhedral 3D cadastre is the possibility of using curved surfaces, which improves possibilities of registering cadastral objects. Disadvantages of this solution include implementation difficulties with the current state of technology. Also, such a solution does not ensure topology. An advantage of topologic 3D cadastre is the lack of redundancy in description of boundaries and a good quality of description (no empty or overlapping objects). Two options of constructing such a system are possible – with curved borders or without. However, the present level of technological solutions does not completely enable its introduction (Bydłosz 2012).

Polish cadastre system and geo-hazards

Cadastral systems are used by society in various domains, from calculating taxes, through supporting activities in the property market, to broadly understood land management (Wilkowski 2002). Technological progress, motivated by social and economic needs that grow with each day, brings new solutions that provide a chance for dynamic development of the property cadastre as one of the most important public registers, gathering data on land, buildings and apartment units, as well as on entities with specific legal status in relation to the above-mentioned objects (Trystuła 2014). Civilisation progress brought goods that make life easier, improve its standard and multiply communication possibilities. At the same time, an escalation of unpredictable natural hazards (geo-hazards), such as e.g. floods or landslides, has been observed. Therefore, it is necessary to be prepared and to organize activities in advance, so as to be able to act as fast as possible in case such an event occurs. This objective is fulfilled by crisis management, carried out by appropriate units of state and local government administration (Sienkiewicz-Małyjurek, Krynojewski 2010). The main stages of crisis management include:

1. Prevention of crisis situation (e.g. analysis of occurrence of potential hazards, determining the source of data necessary to examine and evaluate the risk of their occurrence, construction of flood control facilities, land-slide monitoring).
2. Preparation for the occurrence of crisis situation (e.g. preparing a forecast of results of potential hazards).
3. Response (e.g. alerting, alarming emergency services, evacuation of population).
4. Reconstruction (e.g. help for victims, reconstruction of safety measures, buildings and technical infrastructure).

Crisis management is a set of tasks requiring access to many current and accurately-selected land data, dispersed throughout various information systems, including cadastral data. Thus, cadastral systems also face extreme natural hazards. Regardless of the above-mentioned purposes, cadastral sets of information, supported with additional data from other sources, play a significant role in situations related to natural disasters, which may occur in specific areas of Poland (Mączewski, Wilkowski 2011). The present scope of information included in cadastral systems allow an inventory-taking of space before the occurrence of geo-threats, registration of damage to the cadastral system objects and implementation of tasks reducing the risk of the threat occurrence. As has been already mentioned, the property cadastre itself is not able to satisfy information requirements for crisis management. Dispersion of necessary data throughout various sources that individually are not able to satisfy all needs related to information on endangered land, e.g. at risk of flood or mass movements or on land where a dangerous event has already occurred, can result in a delay in undertaking immediate actions related to crisis situations which, in consequence, may lead to the death of people and increase material losses. Therefore, there exists a real need to supplement the cadastral base with data concerning lands at risk, e.g. of flood or mass movements. A cadastral system integrating this type of tabular-descriptive data could affect intensification and automatisation, e.g. of the crisis management process, by enabling fast access from one point to required high quality data concerning the land. Additionally, there is a growing awareness among users of cadastral system regarding the possibilities of using 3D models of cadastral objects (record plots, buildings) in spatial management, including crisis management. Thus, the accumulation of current and skilfully selected data is not enough. We should also ensure users with access to tools and solutions enabling 2D and 3D analyses, with geovisualisation of the results of those analyses. For instance, the application of 3D models of buildings will make it possible to reconstruct the buildings with the precision needed for the user and for its further analyses related to inventory taking of legal status of building properties or counteracting geo-hazards and liquidation of their dramatic effects.

The concept of the multi-dimensional cadastral system database architecture

The rate of changes occurring in space surrounding us determines the need for efficient management of land data. However, it is difficult to efficiently and effectively manage space resources without an effective GIS class information system (Głuszek 2009). GIS technology also provides limitless possibilities for supporting the process of crisis management. This is possible through spatial analyses, particularly, for instance, hydrographic analyses related to water flow modelling on the basis of a digital terrain model, or physiographical analyses of areas at risk of mass movements. The contemporary definition of property cadastre should therefore be closer to the notion of GIS systems and take into account issues related to data modelling, including spatial data of registered record objects, as well as rights related to them (Felcenloben 2009). 3D geovisualisation is one of the GIS development trends, which help to analyse the space surrounding us in an effective and efficient way (24GIS 2014). It is based on approaches from many disciplines, such as those existing in cartography, scientific visualisation, image analyses, information visualisation, exploratory data analyses and in GIScience (MacEachren, Kraak 2001). Various solutions have contributed to the formation of theories, methods and tools for exploration, analyses, syntheses, and presentation of data containing geoinformation (Medyńska-Gulij 2012). MacEachren (2004) claims that geovisualisation should be defined as the use of visual representation of geospatial information to facilitate thinking, understanding and building knowledge of aspects of the human environment and the physical environment typical for geographical rocks and to create visual representations for those aspects. The main focus in research concerning geovisualisation is put on representation of geographical phenomena, visualisation and interface (Dykes *et al*. 2005). The essence of geovisualisation is also the interpretation of graphically displayed information with a combination of knowledge of human perception and cognitive relations (Medyńska-Gulij 2012).

Currently, record plots, buildings and other cadastral objects, as well as rights related to them, are presented using 2D vectors (points of known x and y coordinates). The importance of the traditional property cadastre as an institution ensuring proper management of land is huge and unquestionable (Konieczna, Trystuła 2013). As has been already mentioned, cadastral systems currently face new challenges related both to their functions and implementation of new technological solutions enabling multi-dimensional visualisation of cadastral data. It is important and required in situations where we deal with the so-called "multi-level use of property". This applies mainly to objects constructed under the surface of the property (e.g. tunnels, underground car parks) and above its surface (e.g. bridges). Cadastral 3D information can also play an important role in the process of crisis management. Therefore, it seems purposeful to strive towards a GIS-technology assisted property cadastre to register system objects not only in 2D, but also in 3D (points of known x, y, z coordinates), while determining how high above the land surface and how deep under this surface the property rights extend (Konieczna, Trystuła 2013).

In this paper, a multi-dimensional cadastral system will be understood as GIS data base enabling 2D or 3D geo-visualisation of cadastral objects (a 2D or 3D cadastral map with elements of geo-hazard map content) with an extended tabular and descriptive database as regards areas at risk of hazard occurrence and in which the hazards have occurred. Development of the concept of database architecture, making a key element of the multi-dimensional cadastral system, was preceded by determination of its two main potential functions, i.e. inventory taking and analytic functions. It should be added that the concept of the architecture of a multi-dimensional cadastral system in this study is the development of previous 2D solutions (Konieczna, Trystuła 2013). Potential inventory-taking operations of a multi-dimensional cadastral database include e.g.: inventory taking of legal statuses on various property levels (on the ground and over and under its surface), inventory taking of areas at risk of flood or mass movements and inventory taking of land on which flood and mass movements have occurred.

Potential analytic functions include 3D spatial analyses of cadastral objects (e.g. 3D modelling of buildings, record plots, simulation of areas at risk of flood or mass movements). Figure 1 presents a block diagram of multi-dimensional cadastral database taking into account the scope of data and their sources important in creating multi-dimensional cadastre and in analysing and reporting the introduced data.

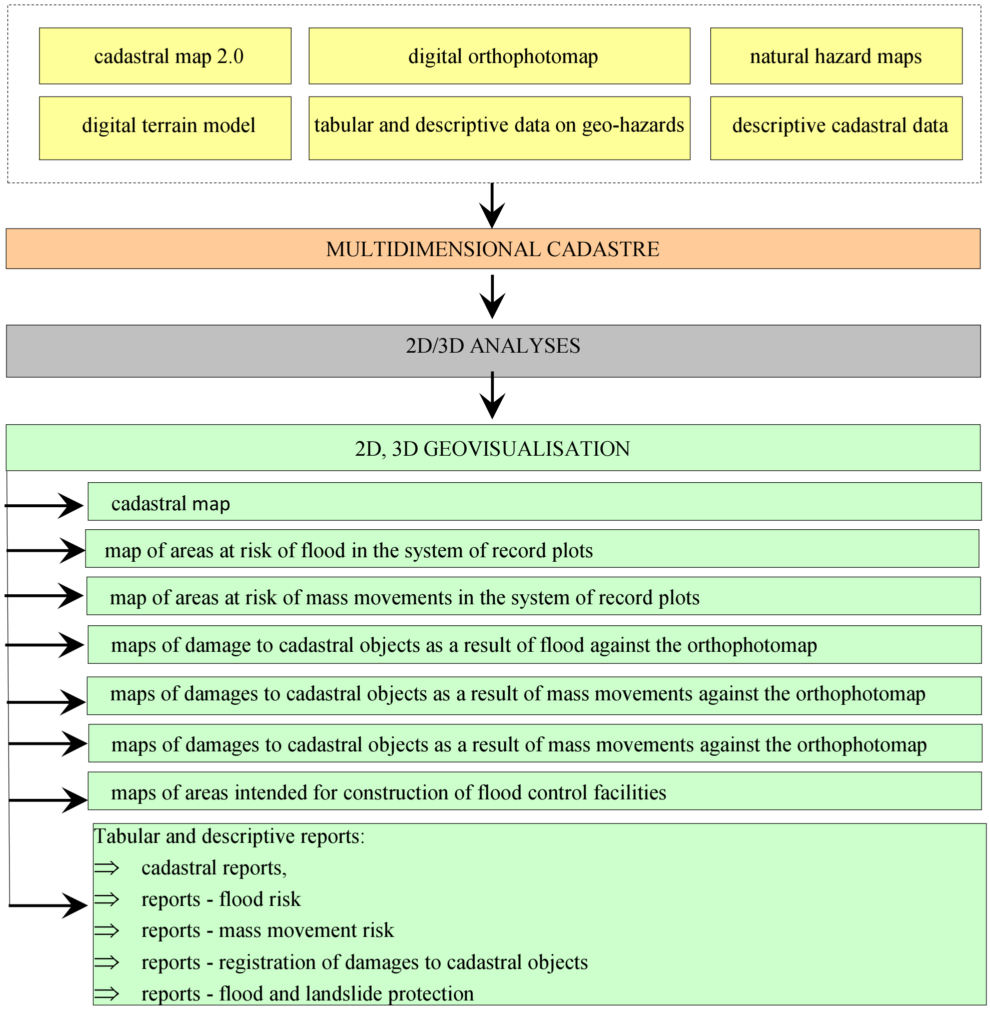

Fig. 1. A block diagram of multi-dimensional cadastral base (Source: own study)

A traditional two-dimensional property cadastre is one of the main data sources supplying the designed base, which results from the fact of the previous assumption of maintaining the existing cadastral system, with the possibility of e.g. 3D modelling of its objects. The remaining spatial data sources include digital orthophotomap, flood hazard maps, flood risk maps, maps of landslides and areas at risk of mass movements and a digital terrain model. The database should also be supplied with descriptive cadastral data and descriptive data concerning, e.g. mass movements.
The spatial and descriptive data made available from the property cadastre include e.g.:

- name of the record unit;
- name of the record section;
- number of the record plot;

- surface of the record plot;
- area of agricultural land;
- type of farmland and quality class;
- numerical description of boundaries of the record plot;
- boundaries of agricultural land;
- boundaries of classification contours;
- numerical description of building contours;
- building type;
- year of completing the construction and the material of which the external walls of the building are made;
- built up surface area;
- number of building floors;
- number of premises in the building;
- current data on owners, perpetual usufructuaries or other persons administering the land;
- current address of the land owner or administrator.

The flood hazard map and the flood risk map make planning documents related to flood risk management in the European Union countries. The content of both cartographic studies is described in Flood Directive adopted in 2007 by the European Parliament and the Council. The flood hazard map presents (Directive 2007/60/EC):

- the flood extent;
- water flow velocity;
- water depth.
- The flood risk map is a source of data concerning (Directive 2007/60/EC):
- the indicative number of inhabitants potentially affected by flood;
- the type of economic activity in the zones at risk of flood;
- installations that may cause accidental pollution in the case of flooding;
- protected areas at risk of flood.

In 2006, the Polish Geological Institute, which fulfils the role of state geological service in Poland, started implementation of the project entitled Landslide Protection System, the aim of which is to support maintenance of the register of areas at risk of mass movement of land and areas in which those movements occur, known as the landslide register. The register contains graphical data in the form of map presenting landslides and areas at risk of mass movements, as well as record sheets of landslides and areas at risk (Trystuła 2012). The content elements of map of landslides and areas at risk of mass movements, which should support a designed multidimensional cadastral data base, include, e.g.:

- landslide boundaries;
- record number of the landslide;
- elements of landslide internal features;
- landslide head;
- degree of landslide activity;
- underground and surface waters;
- boundaries of the area at risk of mass movements.

The record sheet of the landslide or areas at risk of mass movements is a source of information e.g. on:

- location of the landslide or areas at risk of mass movements, providing, e.g. the number of the cadastral plot,
- degree of landslide activity;
- geological system;
- type of landslide movement;
- morphological parameters of the landslide;
- landslide ground;
- land use within the landslide area (landslide slope coverage);
- land use within the landslide area (buildings);
- communication areas (roads and railway lines).

For the time being, 3D cadastral system object modelling is based on a pilot solution. There is an entire range of potential 3D information sources on buildings, which enable visualisation of the building shape, depending on its levels of detail (LOD). One of them is the property cadastre, which provides data concerning the two-dimensional ground floor of buildings and the number of their floors. This is the easiest and the cheapest method of 3D visualisation of housing estates – areas built up with multi-floor residential buildings (simple block models with flat roofs). Data for developing a three-dimensional model of developed areas may also be acquired on the basis of laser scanning, stereoscopic aerial photographs and satellite images and from laser measurement of surface, LIDAR (Medyńska-Gulij 2012). In case of using remote sensing methods, the level of details of 3D buildings takes into account not only simple block models, but also the shape of roof coverage and the structure of building fronts (Konieczna, Trystuła 2013). Cadastre, in its assumptions, also registers apartment units, the boundaries of which are determined by their walls. Boundaries registered in the 3D model of buildings and apartment units do not have full reference to actual coordinates. Although association of a 3D object with a cadastral map contour may ensure, under condition of preserving appropriate accuracy – the correctness of x and y coordinates, because of the assumption concerning identical surface on which the 3D model of the building is set, the "z" coordinate is of a fictional nature. Such visualisation is like building a 3D model of a town. The presented data could have a character of a 3D cadastre if each of the corners of the shape corresponded with its counterpart in the real world, namely, if it had a set of coordinates (x, y, z) corresponding to coordinates in the field (Karabin 2013).

The idea of introducing 3D cadastral plots is to create legal possibilities of carrying out investments without the need for holding ownership rights to the cadastral plot ("land plot") (Karabin 2013). From the point of view of crisis management, what should be aimed at is that a multi-dimensional cadastral plot should also cover the plane of the cadastral plot 2D (x, y). This will enable precise analyses concerning management and development of areas located within zones at risk of flood or landslides. Traditional solutions consisting in analyses of analogue topographical maps provide the user with necessary knowledge concerning relief features, but they are time-consuming and are characterized by a limited number of variables, which limit the scope of analyses. A much better solution is the use of the digital terrain model to obtain derivative information on relief features. It contains a record of topographic height, and an interpolation algorithm consistent with a drawn system of contour lines, which enables reconstruction of the land surface shape for a selected area. The data for a digital terrain model are obtained from vectorization of contour lines and elevation points from topographic maps, direct land measurements, processing aerial photographs, laser scanning and radar images (Medyńska-Gulij 2012). Spatial analyses are the main aim of GIS system construction, since they make it possible to convert source data into information helping to know the surrounding space. This information may become a basis for supporting the decision-making process (Gotlib *et al.* 2008).

Interpretation of prepared collection of spatial and attribute data, supporting management of infrastructure objects, may be made both *a priori,* and *a posteriori*. It predisposes users of a multi-dimensional cadastral database to develop a series of multi-criteria comparative analyses, taking into account the entire scope of input data – both "before" and "after" – by choosing an optimum solution (Konieczna, Trystuła 2011). This means the possibility of following and interpreting positive or negative results of the decision made, as well as the creation of forecasting scenarios concerning e.g. changes in the legal status of properties, planned investments, transformation in the spatial structure of the land, urban planning analyses or crisis management. Spatial analyses that may be carried out on data sets gathered in a multi-dimensional cadastral database are based on analytic algorithms – operations examining relationships between objects and phenomena referring to various elementary surfaces found on various geometric information layers, e.g. combining contents of two or more thematic layers, searching for and classification of geometric objects satisfying a posed logical condition and combining attributes – data from two tables – in one attribute table, with the assumption that those attributes concern the same places (they share the same location in space) (Konieczna, Trystuła 2011). A characteristic feature of GIS systems, as opposed to other systems, is the possibility of visualising spatial data in the form of a map. Although many spatial analyses and GIS functions can be performed without displaying the map, the availability of this function is of a fundamental nature in each spatial information system (Gotlib *et al.* 2008).
Examples of GIS analyses for the needs of crisis management taking into account cadastral data and data related to geo-hazards:

1. Determining a common part of the layer presenting the boundaries of cadastral plots, with individual spatial layers concerning e.g. legal status, population density, water flow rate, relief features, flood extent, water depth, areas at risk of mass movement of earth. This enables spatial examination of the land in terms of flood or landslide risk, with simultaneous analysis of e.g. population density in the system of selected cadastral plots.
2. Selective search for surface objects (record plots at risk of flood or mass movements) satisfying a criterion specified by the user, which will make it possible, e.g. to analyse the legal status of the property, population density, status of predicted depth of water in the system of cadastral plots.

Proximity analyses (creating buffer zones around objects) in order to single out areas located within the zone of flood risk landslide risk.

Conclusions

Directions of changes and development of property cadastre result mainly from the needs of the society for solving newly emerging problems related, among others, to globalisation, sustainable development, crisis management and development of spatial information technology. Property cadastre, because of its informative value used in an increasingly broader process of natural resources management, undergoes constant modernization. The level of cadastre modernity currently determines efficient management of properties (Konieczna, Trystuła 2013). Cadastral data play a significant role in crisis management process, which includes – as has been already mentioned – operations related, e.g. to prevention and preparation for crisis situations. They enable, e.g. spatial examination of the area in terms of flood or landslide hazard, with simultaneous analysis of its administration and usage status (Trystuła 2012). A multi-dimensional cadastral map with geo-hazard map elements will not remain only a simple visualisation of a selected area. Its task will be to discover spatial knowledge, which is essential in spatial management. However, it should be remembered that according to the current legal regulations in Poland, property boundaries are two-dimensional. Therefore, for the multi-dimensional cadastral map to fulfil its role, we should start with legal amendments by introducing a series of regulations making it possible to use multi-dimensional space in the cadastral system, and extending its existing information scope with data related to flood or landslide risks. While determining the course of property boundaries in a field in two-dimensional system, we often forget that landed property is a spatial form, the ownership right to which is also located above and under the ground surface. Determination of boundaries in the first case, after applying appropriate measurement techniques, is not a major problem. On the other hand, determination of spatial boundaries is not that straightforward. Problems related to determination of those boundaries emerge when it is necessary to determine the rights vested in the owner of a given property to mineral deposits or underground waters. This is referred to in issues concerning multi-dimensional cadastres. Dynamically-developing economic relations between entities, both private and public and the progressive development of the infrastructure give rise to the need to develop new legal solutions that correspond to the needs originating from the complexity of those relations. Therefore, for the traditional property cadastre to become a modern multi-dimensional system, first of all, legal changes are required in the scope of the multi-level use of property and support in the form of exchange of experience, information flow and help of those EU countries (e.g. Sweden) that have already developed legal and technical solutions facilitating for the optimal use of space above, under and on its ground surface (Konieczna, Trystuła 2013). The theoretical concept presented in this paper, concerning multi-dimensional cadastre system database and prepared on the basis of the above-mentioned source material, offers great possibilities for detailed characteristics of areas located in zones of flood risk or threatened with mass land movements.

References

Bydłosz, J. 2012. *The multi-dimensional cadastre around the world and its implementation conditions in Poland* [online], [cited 25 February 2014]. Available from Internet: http://www.gdmc.nl/3dcadastre/literature/3Dcad_2012_29.pdf

Directive 2007/60/EC of The European Parliament and of The Council of 23 October 2007 on the Assessment and Management of Flood Risks.

Dykes, J.; MacEachren, A. M.; Kraak, M. 2005. *Exploring geovizualization*. Amsterdam: Elsevier.

Felcenloben, D. 2009. *Cadastre*. Gall, Poland.

Gotlib, D., *et al*. 2008. *GIS. Areas of application*. Poland: PWN.

24GIS [online]. 2014 [cited 2 February 2014]. Available from Internet: http://www.24gis.pl

3D Cadastres [online]. 2012. Website of FIG joint commission 3 and 7 Working Group on 3D Cadastres [cited 1 February 2014]. Available from Internet: http://www.gdmc.nl/3DCadastres

Głuszek, K. 2009. *Benefits of functioning GIS in local government unit*. Typescript, Poland.

Karabin, M. 2013. *A concept of a model approach to the 3D cadastre in Poland*. Poland: Warsaw University of Technology Publishing House.

Konieczna, J.; Trystuła, A. 2011. Application of cadastral data in the land acquisition process for flood control investments, *Geomatics and Environmental Engineering* 6(2): 49–58. https://doi.org/10.7494/geom.2012.6.2.49

Konieczna, J.;Trystuła, A. 2013. Problems of the real estate cadastre against the background of economic, political, legal and technological transformations, *Geomatics and Environmental Engineering* 7: 16–24. https://doi.org/10.7494/geom.2013.7.2.79

MacEachren, A. M.; Kraak, M. J. 2001. Research challenges in geovisualization, in *Cartography and Geographic Information Science* 28(1): 3–12. https://doi.org/10.1559/152304001782173970

MacEachren, A. M. 2004. *How maps work: representation, visualization, and design*. New York: Guilford.

Mączewski, K.; Wilkowski, W. 2011. The Polish cadastre and spatial information with respect to the natural disasters threats, in *Third International Cadastral Congress*, 23–25 November 2011, Warsaw, Poland.

Medyńska-Gulij, B. 2012. *Geovisualization and cartography.* Poland: PWN.

Oosterom, P. Van; Stoter, J. E.; Ploeger, H.; Thompson, R.; Karki, S. 2011.World-wide inventory of the status of 3D cadastres in 2010 and expectations for 2014, in *FIG Working Week 2011 Bridging the Gap between Cultures Marrakech*, 18–22 May 2010, Morocco.

Sienkiewicz-Małyjurek, K.; Krynojewski, F. 2010. *Crisis management in public administration*. Poland: Difin.

Resolution of the Third International Cadastral Congress. 2011. 23–25 November 2011, Warsaw, Poland.

Trystuła, A. 2012. Real estate cadastre in crisis management, *Infrastructure and Ecology of Rural Areas* (2/III): 121–128.

Trystuła, A. 2014. Cadastral databases in Web Map Service supporting rural development policies, *Infrastructure and Ecology of Rural Areas* (2/I): 319–331.

Wilkowski, W. 2002. *Future cadastral system. Cadastre 2014*. Poland: SGGW.