Support of Disaster Management by Land Administration and SDI

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Key words: Spatial Data Infrastructure, Land Administration, GIS, Disaster Management

SUMMARY

Institute of Geodesy, Cartography and Remote Sensing (FÖMI) as a part of the Hungarian Land Administration has a key role in Hungarian SDI. FÖMI's activities (e.g. GNSS services, Geodynamics research, Operation, Support and Development of Unified Land Registry IT systems, Remote Sensing activities, Data Services, Topographic mapping) cover an important, large part of national SDI.

Active participation in international (mainly EU funded) projects is an important resource to increase the number and quality of services for citizens and national SDI.

On 4th October 2010 a red-mud catastrophe happened in Ajka, Hungary. A sludge reservoir of an alumina factory damaged and approximately 1 million cubic meters of red-mud flooded the environment. Red-mud is an alkaline, which means not only the flood, but the alkaline also ravaged the built and natural environment and the people itself (10 people died, because of directly the flood and/or the injuries on their skin, and 123 injured). The Government immediately needed data and analyses for decision-making on disaster management.
FÖMI was asked to complete and analyse data on the catastrophe hit territory. The paper deals with the different data productions, actions and analyses carried out by FÖMI for disaster management support.

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1. INTRODUCTION

Institute of Geodesy, Cartography and Remote Sensing (FÖMI) as a part of the Hungarian Land Administration has a key role in Hungarian SDI. FÖMI's activities (e.g. GNSS services, Geodynamics research, Operation, Support and Development of Unified Land Registry IT systems, Remote Sensing activities, Data Services, Topographic mapping) cover an important, large part of national SDI.
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On 4th October 2010. a red-mud accident happened at a sludge reservoir of alumina factory Ajka-Hungary. The red-mud broke through at the corner of the dum of a sludge reservoir at 12:10 o'clock. The watered red-mud flooded about 800 hectare plough-land and pasture and about 3,5 hectare built-up area (Devecser, Kolontár). 96-98 % of the red-mud settled remained in the sludge reservoir (first estimation). The watered red-mud is alkaline, therefore it is dangerious for the nature and it causes a corrodent injury on the skin surface. It is expected that the heavy metals had settled in the red-mud during the years therefore not too much run out from the sludge reservoir together with the watered red-mud. At the area of Alumina Factory Ajka there are ten sludge reservoir. About 50 million m^3 grey-mud and 30 million m^3 red-mud are storaged in that. There is no any information about similar accident in the history of the Hungarian alumina production. 9 people died and 123 injured by the alkaline watered red-mud (pH value was 13!) in the catastrophe.

Because of the heavy losses in people's life, in the built and natural environment, the Government had to decide on many problems as soon as possible. Therefore FÖMI was put to serve and analyze data on the territory of the catastrophe.

Based on the wide-range of SDI data, managed at FÖMI, FÖMI satisfied the requirements, defined by the Government.

2. THE HUNGARIAN LAND ADMINISTRATION AND FÖMI

The structure of Hungarian Land Administration is shown on Figure 1.:

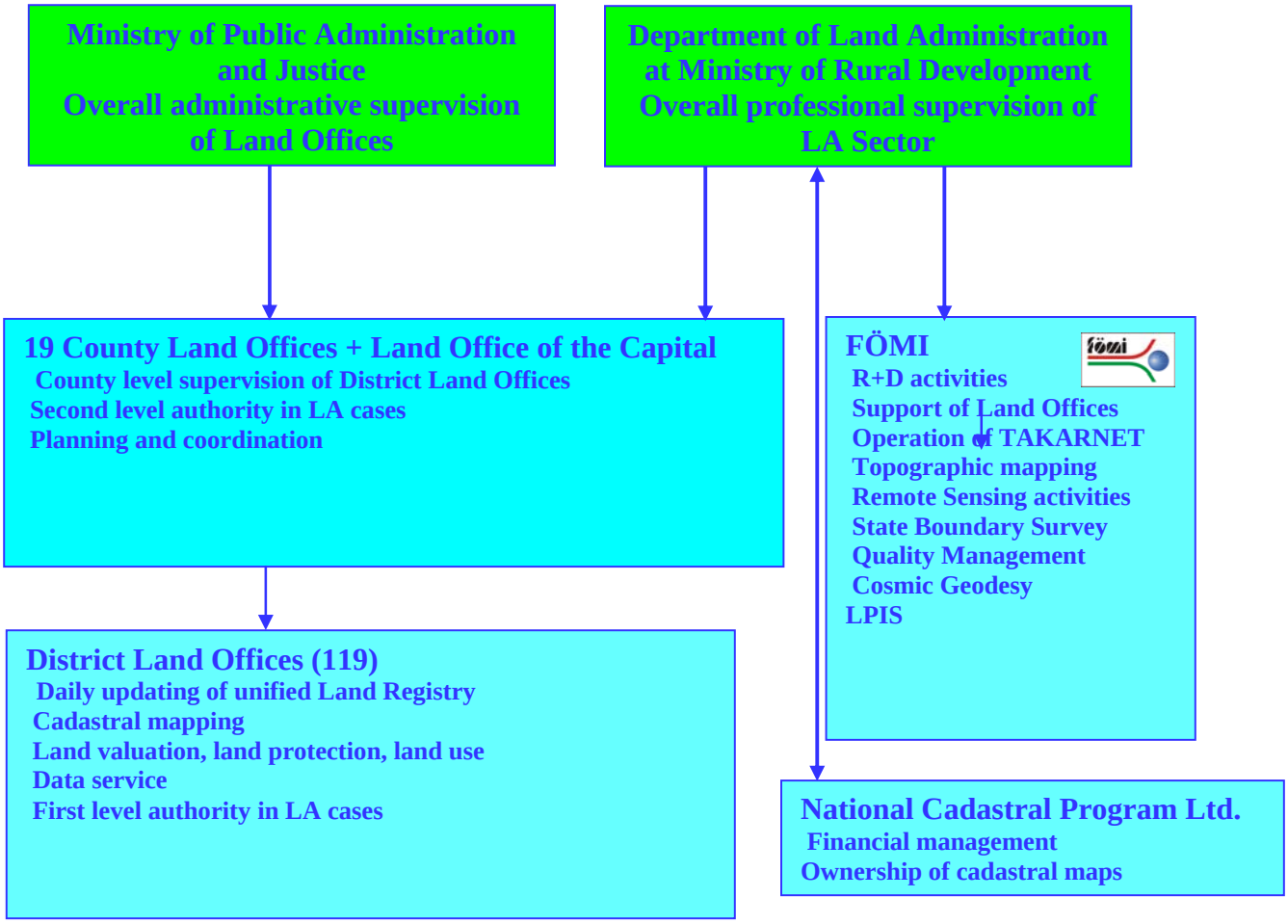

Figure 1.: Structure of the Hungarian Land Administration

Land Administration Sector in Hungary is operating within the Ministry of Rural Development. Department of Land Administration at the Ministry, which is responsible for the overall professional supervision of Land Administration Sector and the Ministry of Public Administration and Justice, responsible for administrative supervision of Land Offices.
Hungarian Land Administration operates a Unified Land Registry. Unified Land Registry means that the registration of land records and cadastral mapping belongs to the same institutions, Land Offices. This Unified Land Registry has been operating since 1972. The Unified Land Registry is an authentic, title registry, so the Hungarian State guarantees all the rights and facts registered in it. The Unified Land Registry is operated by the Land Office network, which contains 19 County Land Offices and the Land Office of the Capital (Budapest) and 119 District Land Offices.

County Land Offices are responsible for the supervision of District Land Offices, planning and coordination of their work, and act as a second level authority in Land Administration cases.
District Land Offices update the Unified Land Registry both land record and cadastral map parts, valuate protect the lands, register, control and maintain land use data, service land registry data for clients and professionals and act as a first level authority in Land Administration cases.

FÖMI is a national-level public administration organization responsible for:

- R+D project in the fields of land administration, remote sensing, satellite geodesy, cadastral and topographic mapping etc.
- Management and Maintenance of Ground Controls
- Official, National GNSS Services
- Regional and Country-wide data services, including cadastral maps, land records, orthophotos, aerial photos, topographic maps, land cover data and other value added products
- Operating of Geoportal of the Land Management Sector (GEOSHOP),
- Management of national, large scale (1:10 000) topographic mapping,
- Continuous support and development of Land Offices' IT systems,
- Operating of TAKARNET network, network of the Land Administration sector,
- Land Registry services via TAKARNET,
- Official Gazetteer of Hungary,
- Agricultural Remote Sensing activities, including operating of Land Parcel Identification System (LPIS) of IACS, Vineyard Cadastre etc.
- Environmental Remote Sensing activities, including CORINE Land Cover database management.

As it seems above, FÖMI has a wide-range of activities both in cadastre and SDI implementation in Hungary. The two activities SDI implementation and Cadastre meet institutionally at FÖMI.

3. FÖMI's ACTIVITIES IN NATIONAL SDI

INSPIRE Directive of the European Union and its Annexes summarize well the different themes of any SDI. Showing the important rule of FÖMI in Hungarian SDI we have used INSPIRE themes in the following table:

INSPIRE theme	**FÖMI's activity**
Annex I	
Coordinate reference systems	**Overall Ground Control Point management (including 3D)** **GNSS Services**
Geographical Names	**Management of the Official Gazetteer of Hungary**
Administrative Units	**Management of the Administrative Boundary Database of Hungary, derived from Central Unified Land Registry Database**
Addresses	**Management of Central Unified Land Registry Database**

Cadastral parcels	**Management of Central Unified Land Registry Database**
Annex II	
Elevation	**Management of HUNDEM-5, 5m resolution GRID DEM database**
Land Cover	**Management of CORINE 1:100 000 scale, and National 1:50 000 scale Land Cover Databases**
Orthoimagery	**Management of Official Orthophoto Database of Hungary, resolution 0,5m, 5 years period updating**
Annex III	
Buildings	**Management of Central Unified Land Registry Database**
Land use	**Management of Central Unified Land Registry Database**

Table 1.: SDI and FÖMI's activities

In Table 1. only the direct theme connections are highlighted, but there are other activities which related to other INSPIRE themes, for example management of LPIS can be related to environmental monitoring facilities, or Area management.

In TAKARNET24 project a new Central Unified Land Registry Database will be established by the end of this year, which provides a central management and query system for many Annex themes as shown in Table 1. The Central Unified Land Registry Database contains:

- Cadastral Parcels,
- Cadastral Subparcels,
- Land Use,
- Buildings,
- Land Values (only for cultivated lands),
- Administrative Units and Subunits (e.g. built-up and rural areas)
- Land records (descriptive data, ownership data, mortgages, easements, usufruct)
- Land user data (including the owner and the user of land).

Other important, nation-wide databases handled by FÖMI:

- Raster and vector format databases of 1:10 000 scale topographic maps,
- Orthophoto databases with 0,5m resolution to the whole country from 2000 and 2005, and to the 1/3 of the territory from 2007, 2008, 2009 and 2010.
- LPIS database for agricultural parcels, covers the whole territory of the country including non-subsidizable areas, updating yearly,
- VINGIS database for the GIS support of wine-growing regions and vineyards of the Country,
- CORINE 1:100 000 scale and National 1:50 000 scale land cover database,
- HUNDEM-5, high-resolution (5m) Digital Elevation Model of Hungary, updated yearly from orthophoto production,
- National Ragweed Monitoring Database, updated yearly by the using of satellite imagery.

FÖMI has and had a lot of national, international projects, which strengthen knowledge and experiences in SDI field. Some main national projects in SDI field (international projects will be described later):

- TAKARNET24 project: “Land Registry Data Services via Client Gate” (2008-2010), EU funded project
- Establishment a Geoportal for Land Administration Data Services (2009-2010), EU funded project
- Establishment of Permanent GPS Network , National funded project,
- New dimensions of zone-planning by the usage of satellite imagery, funded by the National Space Research Bureau
- National Ragweed Monitoring System, National funded project
- Establishment of LPIS for Hungary, National funded project,
- Control of area-based subsidies by remote sensing, National funded project,
- VINGIS GIS support of wine-growing regions and vineyards,
- CORINE Land Cover project, national and European level,
- Drought-damage detection by remote sensing,
- Forest-fire detection by remote sensing,
- Maize-insect injury detection by remote sensing.

Using the acquired knowledge and data assets FÖMI has great opportunity to act as a leader institution in the establishment, maintenance and management in the Hungarian SDI.

4. INTERNATIONAL ACTIVITIES

FÖMI always has been very active in international cooperation and projects. From the on-going and ended projects we would like to mention:

- GIS4EU project: The project's main objective is to increase communication and networking relationships among the project partners to ensure it addresses cross scale, cross language and cross border interoperability and accessibility issues. This is to create a common knowledge base and make spatial information more accessible according to standards and requirements of the INSPIRE Directive (20007/2/EC).
- HUMBOLDT project: The main goal of the HUMBOLDT project is to enable organisations to document, publish and harmonise their spatial information. The software tools and processes created will demonstrate the feasibility and benefits of an Infrastructure for Spatial Information in Europe as planned by the INSPIRE initiative , meeting the goals of Global Monitoring for Environment and Security. The technical goal of HUMBOLDT is to support Spatial Data Infrastructure (SDI) enablement by providing the functionalities for covering the data hamonisation process as a whole. TheHUMBOLDT Tools and Services are built on current state of the art and standards, designed to provide solutions to all types of users, data custodians as well as private end-users.HUMBOLDT enables the use of single functionalities as part of your own infrastructure.

- EURADIN project: The general objective of EURADIN is to significantly contribute to harmonizing the European Addresses, proposing a solution to achieve their interoperability, and thus facilitating the effective access, reuse and exploitation of that content, which will promote the creation of new added value products and services across Europe.
- ESDIN project: The goal of ESDIN to become a bridge over the troubled geospatial data. Help Member States to prepare the data, improve the access to them. Harmonised and maintained pan-European data for some of the INSPIRE Annex I themes already exists at small scales but it is not fully 'interoperable', it is not maintained in the most efficient manner and does not meet the increasingly demanding requirements of users. Through organisational development and better implementation of existing technology it would be possible to improve the interoperability of, and cost efficiency with which, the existing datasets are maintained and to increasingly improve access to other reference themes at different levels of detail**.** Get together experts from different geospatial oriented communities, share the achievements in different projects and initiatives and create an open discussion forum for wide user's community Stimulate the development, use and re-use of European digital content in global network.

FÖMI has contributions to all goals, and acts as an active and important participant in these projects.

5. INTEGRATION OF SDI, LAND ADMINISTRATION IN DISASTER MANAGEMENT, A REAL EXAMPLE

As it was mentioned in introduction on 4th October 2010. a red-mud accident happened at a sludge reservoir of alumina factory Ajka-Hungary. The red-mud broke through at the corner of the dum of a sludge reservoir at 12:10 o'clock. The watered red-mud flooded about 800 hectare plough-land and pasture and about 3,5 hectare built-up area (Devecser, Kolontár). 96-98 % of the red-mud settled remained in the sludge reservoir (first estimation). The watered red-mud is alkaline, therefore it is dangerious for the nature and it causes a corrodent injury on the skin surface. It is expected that the heavy metals had settled in the red-mud during the years therefore not too much run out from the sludge reservoir together with the watered red-mud. At the area of Alumina Factory Ajka there are ten sludge reservoir. About 50 million m^3 grey-mud and 30 million m^3 red-mud are storaged in that. There is no any information about similar accident in the history of the Hungarian alumina production. 9 people died and 123 injured by the alkaline watered red-mud (pH value was 13!) in the catastrophe.

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5.1. Study area

The study area is a rectangular area flooded by red mud near Ajka
Soil environment of mud flooded area[1]:
The sludge flood disaster was in the valley of the Torna stream, having alluvial soils with silty sand loess, fluvial and runoff residual. The soils here have light mechanic composition: gravely coarse sand, loamy sand. Typical soil types of the mud flooded territory are: calcaric fluvisol - down in the valley, cambisols - on higher position.

Land use of the study area based CORINE Land Cover map (CLC100): forest (7.2%), arable land (44%), settlement (7.7%), orchard (0.1%), wine (0.5%), water body (0.5%), meadow (40/%).

Figure 2.: The damaged dam of the reservoir

[1] source: Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences (RISSAC HAS); webpage: http://www.mta-taki.hu/

Figure 3.: Cleaning on the street (look at the level of flood on the wall!)

In TAKARNET24 project the replication of District Land Offices' databases has already done, so we could use the capabilities of the Central Unified Land Registry Database. The first figure shows the results of analysis on flooding the cultivated lands on the area (Figure 4.):

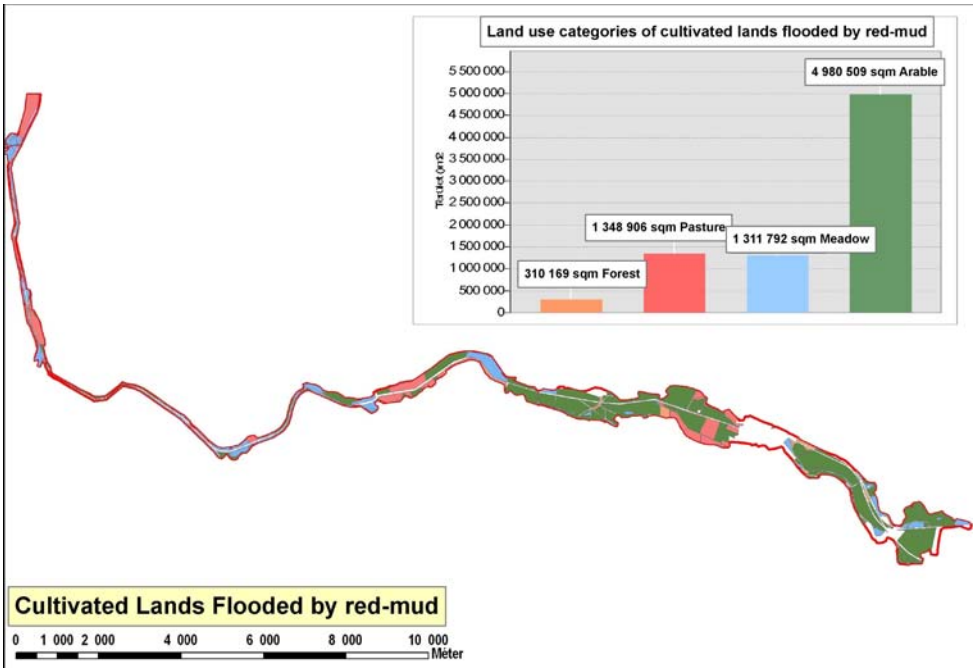

Figure 4.: Cultivated Lands flooded by red-mud

This analysis showed that approximately 800 hectares of cultivated lands affected directly by the flood of red-mud. These are mainly arable lands, but meadows and pastures also influenced. All these areas the change of soil is required.

The next analysis pointed to the building categories, affected by the flood. The Central Unified Land Registry Database strongly helped this task, because the buildings and their categories are also included in it (Figure 5).

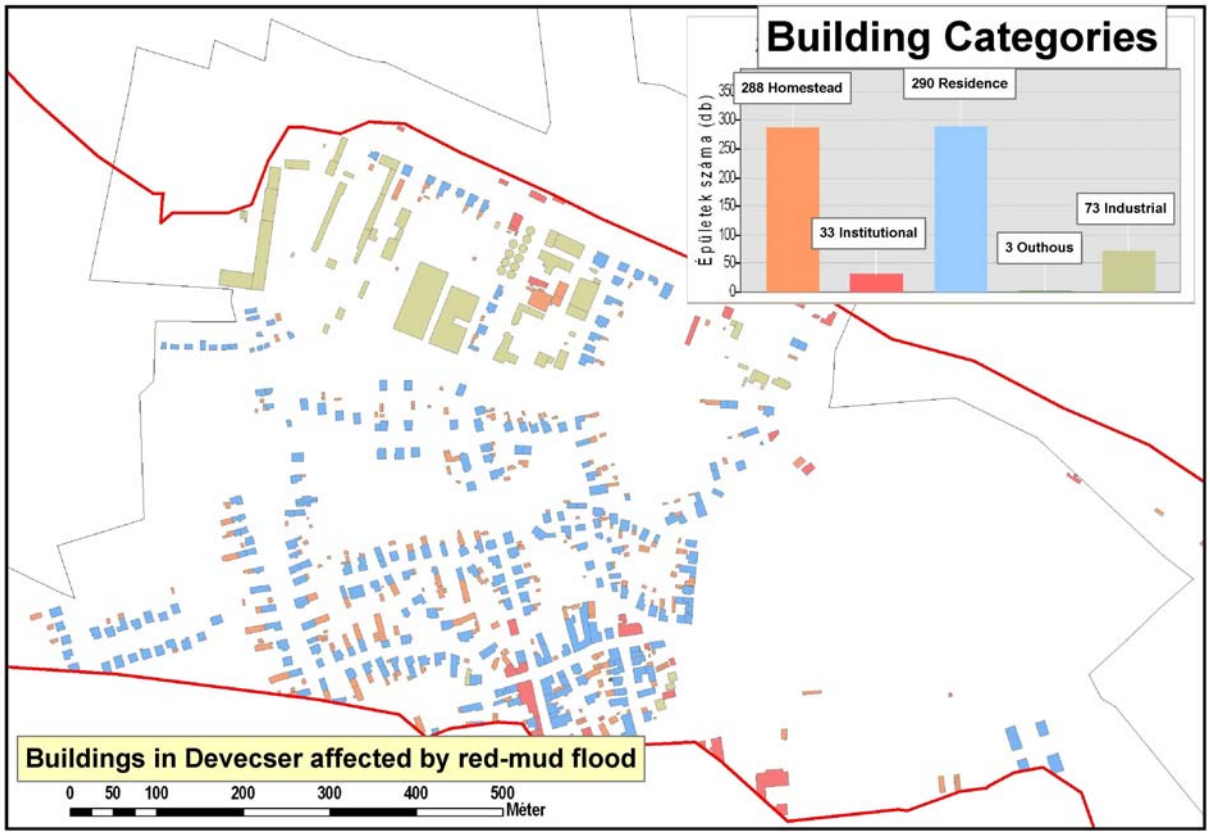

Figure 5.: Buildings affected by the flood in Devecser

Devecser, a small town close to the factory, also received a part of the flood. This analysis showed that mainly homestead and residence buildings are damaged in the flood.

Of course, red-mud flood causes pollution on natural conservation areas too. The next figure shows the NATURA2000 areas polluted by the red-mud (Figure 6.):

Figure 6.: NATURA2000 areas polluted by red-mud

Based on the Central Unified Land Registry Database FÖMI also identified the owners, mortgages and/or users of land on the polluted areas for the distribution of aids, planning of reconstruction and for other goals.

5.2. Utilization of radar-interferometry in movement monitoring

The industrial disaster occurred is highlighting the use of the possibilities given by remote sensing on the field of prevention of spread and damage surveying as well. As monitoring continuously the spatial ground objects we can derive important information. With the use of

radar interferometry a time-back monitoring of the movement of reservoir's broken damp, going back to many years could be accomplished, following the moving of the damp in mm precision. Such kind of survey and publication was done by the research team of the Satellite Geodesic Observatory of FÖMI (Grenerczy et. al. 2010).

5.2.1. Hypothesis to be tested and methodology

Although the on the spot checks and aerial photos attempted to measure flood area, an estimation based on satellite images would be also desired. As neither the toxic waste (consisting liquid and solid matter) nor the absorbing soil types (clay, aleurite, sand) were homogeneous, the flood area show manifold color tones. Therefore we needed satellite image with high spectral resolution especially to detect the slightly affected zones. The 8 spectral bands of WorldView-2 satellite image provided us an important help. We evaluated it quantitatively by different image processing methods (cluster analysis, classification). As the spatial resolution of WorldView-2 is significantly higher compared to other available satellites images from disaster (RapidEye, SPOT5), we managed to detect the pollution of narrow temporal streams which spread the red mud.

The relief is rather diverse, the reservoir which had been hurt is on 200 m high, which has a gradual decrease to western direction. The red mud was flowed over the areas lower then the reservoir. The highest point of the territory is the Somló hill, which is an individual historical wine region as itself.

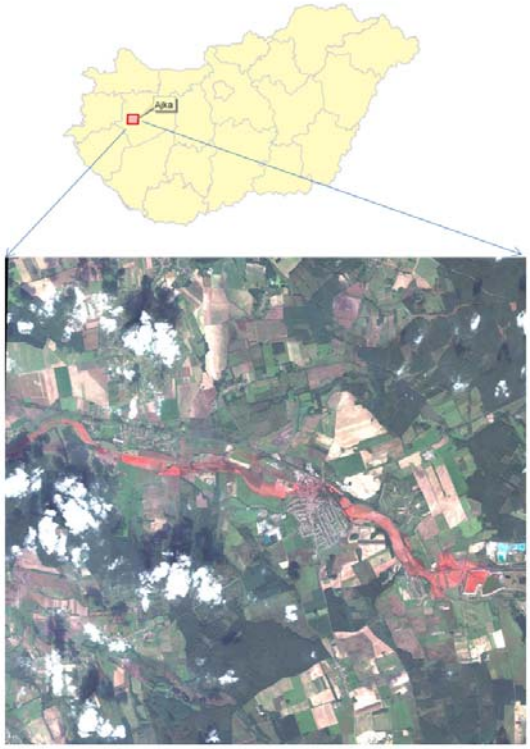

Fig. 7.

Red mud flooded study area near Ajka in WorldView-2 satellite image (09/10/2010) composite (R: red, G: green, B: blue)

5.2.2. Examinations

The aim of our study was the monitoring of red sludge spill with remote sensing using WorldView-2 and Rapideye satellite images. The study was done in 3 steps, which are the followings:

1. Delineating the spill of red mud (4.1)
2. Studying the stream waters of the contaminated area (4.2.)
3. Analysing the spectral features of the contaminated soils (4.3)

The applied methods and results used in the above mentioned analyses are the following:

5.2.3. Red mud flood map generation

We analysed the following two satellite images out of the very high and high resolution images made after the catastrophe:

- RapidEye made on 7 October 2010.
- WorldView-2 – two days later: 9 October 2010

Beside these we had results of GPS measurements from the flooded area.

Methodology applied on processing of WorldView-2 satellite image

The classification was done based on segmentation, both on the WorldView-2 and RapidEye images, with the aim of the possible most precise delineation of the flooded area.

Spectral indexes:
Three indexes were used: NDVI, red - green and red edge – red indexes. These were chosen based on the main characteristics of spectral curves of target classes.

Segmentation:
By defining the segments the main intention was that the boundary of the segments must strictly follow the boundary of the land cover elements and the boundary of the flooded area.

Classification:
The classification was done with sampling using maximum likelihood (ML) method. There are 3 target classes:

1. open surface of red mud cover
2. soil spilled by the red mud
3. vegetation spilled by the red mud

Accuracy assessment:

We can state that both the accuracy of the segmentation and the classification is deteriorating as going further from the position of the dam was broken as the representatives of the surface has stronger effect to the swamp.

Comparison of red mud flood map derived from WorldView-2 and RapidEye satellite images

Differences in spatial resolution of WorldView-2 and RapidEye satellite images are apparent in the results. Classification by WorldView-2 follows the delimitation of the spill more accurately. While one pixel of the WorldView-2 image is 4 m^2, it is 25 m^2 in the RapidEye image, that is, spectral values of each pixels from the border of the spilled surface are from a much larger area. This is the main reason for the inaccuracies of the RapidEye classification. Differences in spectral richness are less obvious and their main consequence was the higher number of incorrect hits.

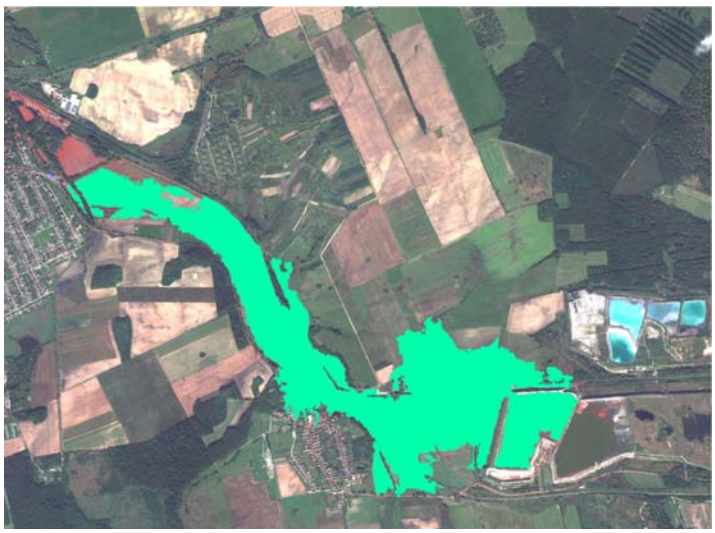

Fig. 8.
Red mud flood map derived from WorldView-2 satellite image composite (acquired in 09.10.2010)

5.2.4. Studying the watercourses of the red mud flooded area

The aim of our study was to demonstrate how the spatial resolution of satellite images the WorldView-2 allows of the categorization of narrow watercourses with respect to the spill. First we digitalized watercourses accurately using the WorldView-2 satellite image and 1:10 000 topographic maps of the area. On the digitalized map of the watercourses, we created a 2-m-wide buffer zone in which we point-wise categorized the contamination. Flooded watercourse areas match the delimitation of other types of flooded areas (soil, vegetation).

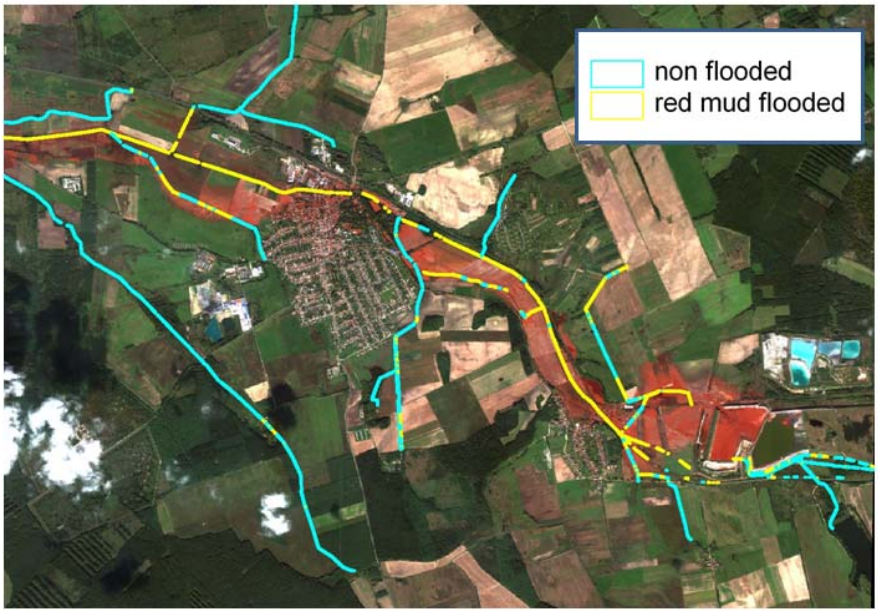

Fig. 9.
Red flood map of streams near Ajka

6. CONCLUSIONS

In the last chapters we would like to introduce the Hungarian solution for the implementation of Land Administration and SDI. The structure of the Hungarian Land Administration Sector, and its activities provides a flexible, well-operating infrastructure to achieve a real SDI together with legal data included in Land Registry.

Red-mud catastrophe showed that integrating Land Administration and SDI results a good solution in the way for establishing a real e-Governance.

FÖMI's researches on movement monitoring by radar-interferometry in the case of red-mud disaster showed that we should continue broader implication of this technique. We are interested in tracking the long-term consequences of the disaster on the directly affected zone and in a larger buffer zone as well. We expect complete destruction of some trees and herbaceous plants on the main flood track and serious anomalies in vegetation development around it.

REFERENCES

1. Gyula IVÁN — Gábor SZABÓ — Zoltán WENINGER: Object Oriented Unified Real Estate Registry for a Good Spatial Data Management. FIG Workshop on e-Governance, Knowledge Management and e-Learning, 27-29 April, 2006., Budapest, Hungary

2. Gyula IVÁN — Szabolcs MIHÁLY — Gábor SZABÓ — Zoltán WENINGER: Standards and new IT developments in Hungarian Cadastre. "Standardization in the Cadastral Domain". Joint workshop of "FIG Commission 7" and "COST Action G9", 9-10 December, 2004., Bamberg, Germany.
3. Gyula IVÁN — Gábor SZABÓ — Zoltán WENINGER: Expansion of Land Information Services in Hungarian Land Administration. Proceedings of "Shaping the Change" XXIII FIG Congress, Munich, Germany, October 8-13, 2006.
4. Gyula IVÁN — Gábor SZABÓ — Zoltán WENINGER: Integrated Land Information Services in Hungarian Land Administration. Proceeding of "Strategic Integration of Surveying Services", FIG Working Week, Hong Kong SAR, China, 13-17 May, 2007.
5. Gyula IVÁN — Gábor SZABÓ — Zoltán WENINGER: A Complete, Free Solution for Cadastral Map Management. Proceedings of "Integrating the Generations", FIG Working Week, Stockholm, Sweden, 14-19 June, 2008.
6. Szabolcs MIHÁLY-Gyula IVÁN-Gábor Szabó-Zoltán WENINGER: Land Administration Standards and their implementation in practice. Proceedings of Surveyors Key Role in Accelerated Development, FIG Working Week, Eilat, Israel, 3-8 May, 2009.
7. Gyula IVÁN-Tamás DOROSZLAI-Gábor SZABÓ-Zoltán WENINGER: TAKARNET24 project, towards e-Land Administration in Hungary. Open Symposium on "Progressing towards u-Cadastre", Kuala Lumpur, Malaysia, 15 October 2009.
8. Gyula IVÁN-Gábor SZABÓ-Zoltán WENINGER-Piroska ZALABA: DATR-Towards e-Land Administration in Hungary. Proceedings of "Facing the Challenges-Building the Capacity" FIG Congress 2010, Sydney, Australia, 11-16 April 2010.
9. Gyula Grenerczy, Urs Wegmüller (2010): The embankment failure of the mud reservoir of the alumina plant near Ajka, Hungary: implications from ENVISAT ASAR Persistent Scatterer Interferometry analysis
10. Kreybig Digital Soil Information System: http://www.mta-taki.hu/hu/osztalyok/gis-labor/dktir
11. WorldView-2; Catalog ID: 1030050008F99F00, Sensor: WV02, Acquisition date: Oct 9, 2010, Centre point is the following: Lat: 47.10 long: 17.42°
12. Rapid Eye; Acquisition date: Oct 7, 2010, ID No. 2010-10-07T104547_RE5_3A-NAC_4476381_96112, 2010-10-07T104547_RE5_3A-NAC_4476383_96112, 2010-10-07T104548_RE5_3A-NAC_4476638_96112

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