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OPEN SOURCE WEB GIS SOLUTIONS IN DISASTER MANAGEMENT – WITH SPECIAL EMPHASIS ON INLAND EXCESS WATER MODELING

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Abstract

In recent years, the increased frequency of inland excess water in the Carpathian Basin gets more and more attention. The authors developed a web based pilot application for disaster management, with special emphasis on inland excess water hazard management. Free and open source software was used to generate a model, and our work was based on Web GIS standards (OGC), which makes further development possible. The developed Web GIS application provides functions to support the data collection regarding channels and ditches, and on-line hydrological analysis based on OGC Web Processing Services (WPS). Hydrological analysis aims to visualize the areas potentially at risk, depending on different precipitation quantities and various values of influencing factors. In order to run the prototype a sample data set was gathered including reference maps, technical parameters and current condition of canals and ditches. The methodology of crowdsourcing can produce valuable Volunteered Geographic Information (VGI) that can fulfill the data requirements of disaster management applications. The prototype supports Crowdsourcing in the following aspects: free user access to the system's analysis functionality, stakeholders may digitize the position of ditches, modify the status of the existing ditch system according to current conditions and add or modify parameters relevant for the analysis. The application demonstrated the usability of stakeholder generated geographic information and web processing for disaster management. The idea of integrating user-generated data into the various tasks of a disaster management agency is promising. However, maintaining data quality and standards compliance remain important issues.

Keywords: crowdsourcing, volunteered geographic information, open source, web processing, disaster management

INTRODUCTION

The United Nations Office for Disaster Risk Reduction defines disaster management as the organization and management of resources and responsibilities for addressing all aspects of emergencies such as preparedness, response and initial recovery steps. Disaster management involves plans and institutional arrangements to engage and guide the efforts of governmental, non-governmental, voluntary and private agencies in comprehensive and coordinated ways to respond to the entire spectrum of emergency needs (UNISDR). A Common view is that disaster management is a continuous cycle of pre-disaster, response and post-disaster phases (Fig. 1).

The role of GIS remained more research-oriented than operational until the beginning of the 21th century (Zerger and Smith, 2003). In recent years, most of the technological barriers have been overcome and numerous operational applications and adaptations of GIS exist all over the world. Examples show the wide usage of mobile GIS as an effective, fast and cheap data collection method (Montoya, 2003; Chen et al., 2010). However, applications are not limited to data collection. Several examples can be found in literature that use complex modelling methods for disaster management (Alparslan et al., 2008). A prominent example was designed to mitigate the harms of earthquakes in Bolu Provance, Turkey by applying a complex suitability model. The lack of dynamics in early examples is obvious. Currently, Web GIS and the development of web based GIS applications are much more widespread. Standards provided by OGC (Open Geospatial Consortium) and readily available compliant software components make application development easier and faster.

Another important aspect of such application is the data being used. It is hard to disagree that decisions made during a disaster can both affect properties and lives, so data quality is an important factor. On the other hand, insufficient amounts of data can limit the success of every task in disaster management, so using alternative data sources should also be considered. Crowdsourcing is a method that uses voluntary contributors to do a specific task (Estellés-Arolas and González-Ladrón-de-Guevara, 2012). For disaster management, it is possible collect data from volunteer individuals. The spread of crowdsourcing is strongly related to the growth of the digital world. A great amount of people use the internet and many of them have smartphones as well. In 2012 68% of the Hungarian households had broadband internet connections (KSH, 2014). In the first quarter of 2013, data traffic was 20% larger than in the same period of 2012. This fact represents

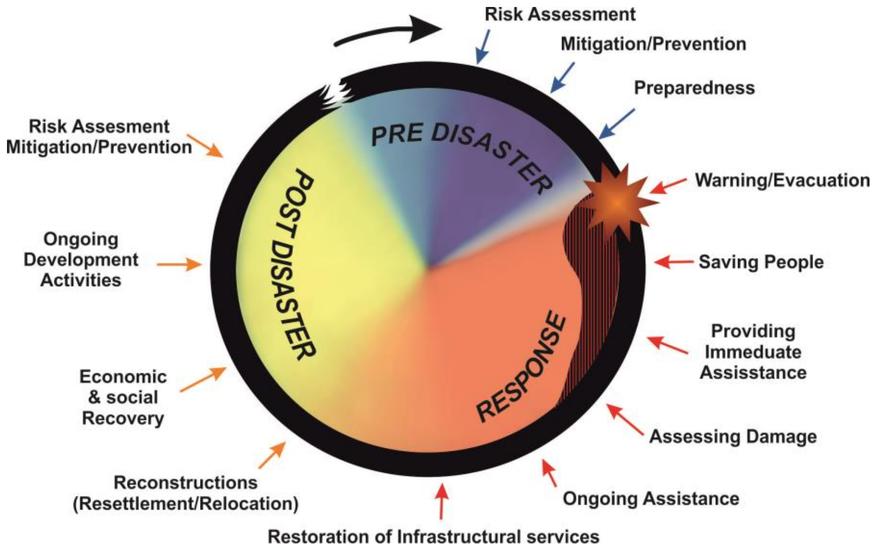

Fig. 1 Disaster management cycle (Barnier 2006)

the growing usage of smartphones in Hungary (KSH, 2014). These platforms can be the basis of a successful crowdsourcing application. However, organizing and processing crowdsourced data can be challenging. The main task is to ensure that the data produced by the "crowd" adheres to predefined standards.

This kind of data is often referred as Volunteered Geographic Information (VGI) in literature (Goodchild, 2007). All research agrees that it is highly heterogeneous and can be massive in volume. Another aspect is the lack of traditional Quality Assurance (QA) techniques in most VGI platforms (Goodchild and Li, 2012). Terminology used in scholarly literature is not standardized yet but a number of researchers suggested different classifications of VGI (Craglia et al., 2012). Geographic information is essential for emergency managers in all phases of emergency management. Data quality is a major factor since ineffective decisions caused by incorrect or imprecise data can both affect lives and properties. The possible benefits of using VGI during crises can make it a significant source of information by providing relevant data almost real-time (Goodchild and Glennon, 2010; Li and Goodchild, 2010). Previous studies have shown the importance of VGI during a crisis event. Geo-social media is ideal for emergency communications. Moreover, it can be considered as an information source for emergency managers (Vieweg et al., 2010; Lantonero and Shklovksi, 2010) since there are more than six billion human potential "sensors" in the world. Those citizen sensors can collect and share relevant crisis-related information through various platforms (Goodchild, 2007). It is important to show that a significant portion of users who share relevant information also include some kind of location information in their messages (Vieweg et al., 2010; MacEachren et al., 2011). This information therefore can be easily placed in the geographic space.

Recently, a new cooperation has been started in Hungary. The Directorate for Disaster Management and the University of Szeged teamed up to survey all the fire hydrants within Csongrád County. The Directorate asked university students to collect information of each fire hydrant, survey its position and take a picture of the surroundings. Officials of the directorate trained students what information is needed and how to collect them. The University provided the GIS equipment and the methodology. Since then, the data collected during the survey (including photos and databases) is being used by the Fire Department of the Directorate to make their operative work more effective. Operators in the center guide field teams to the appropriate fire hydrant and provide them relevant information while in the field (Huszár et al., 2013).

Properties of the rain and residual water drainage systems (spatial extent, condition, width, depth) and other anthropogenic establishments are relevant data for modelling inland excess water (Rakonczai et al., 2011; Szatmári and van Leeuwen, 2013; Leeuwen et al., 2013). As Vivacqua and Borges (2011) mentioned, knowledge of past events plays an important role in emergency situations. In the case of inland excess water, this knowledge can be gathered from local individuals.

In addition, Free and Open Source Software are now common in GIS and geography as well. All kinds of GIS software can be found depending on the needs, although their categorization is not easy (Steiniger and Hunter, 2013). Steiniger and Weibel (2009) have identified seven major types of them:

- Desktop GIS
- Spatial Database Management Systems
- Web Map Servers
- Server GIS
- Web GIS clients
- Mobile GIS
- Libraries and Extensions

Earlier, most open source and free software were developed by research institutes, universities or government agencies. In recent years, most of these projects are being developed by a new industry that develops and supports open source software. Private companies have also joined the market.

In opinion of Siki (2009), the main benefits of using free and open source software are not the low price but the direct interaction between the developers and users. They all belong to the same community resulting in shorter development periods. Using open source and free software is also financially beneficial since instead of spending money on commercial licenses, resources can be reallocated to actual development tasks.

A web-based application named VINGIS can be mentioned in Hungarian literature that uses PostgreSQL, php and MapServer as open source components (Katona and Molnár, 2005). International examples cover the wide range of disaster and emergency management such as Ushahidi (non-profit software company that develops free and open source software (LGPL) for information collection, visualization, and interactive mapping), that support resource organization and management.

Considering the above, the main goal is to develop a web Platform, which supports the crowdsourcing based local management of environmental hazards. With the platform the defenses against surface water hazards at local level can be made easier and more effective; hazards (excess or lack of surface water) may cause less damage to the local economy. The further aim for developing the web platform is to use only free and open source technologies. This would be able to reduce the financial cost of development of disaster management application drastically while making them easier to distribute and increase the user base.

METHODOLOGICAL APPROACH

Framework of Modelling

When developing a web based GIS application, the first step is usually to set up a web server that can handle incoming requests and generate corresponding responses. Common Open Source web servers are Apache, nginx and the Cherokee HTTP Server (Apache http Server project; nginx http server; Cherokee http server project). Another main component of the server side is a map server that can provide geospatial data for our application. Functionalities of map servers usually rely on OGC's (Open Geospatial Consortium) standards. The Web Map Service (WMS) provides georeferenced map images generated from spatial data (OGC, 2014). WMS is mostly used to visualize maps, but basic spatial queries can be also defined to filter data. The Web Feature Service (WFS) can add more functionality to an application since it was designed to transfer the actual geospatial features over the network. Unlike WMS, this service does not provide a simple image for clients that can be easily shown, so clients must render data to be shown on screen. Furthermore, WFS is bidirectional. Edits and modification of the database is possible via so-called transactions. This aspect of the WFS is a way to integrate crowdsourcing to an application, where users can add and modify data to a predefined dataset. This way, VGI can be generated through the application and integrated directly into the spatial database. Tasks can involve data collection (on screen digitizing) or attribute editing. The most well-known Open Source map servers are GeoServer and MapServer (GeoServer; MapServer). On the client side, different mapping frameworks can be used. OpenLayers, Leaflet and Geomajas are most common. They allow users to navigate in an interactive map, but they are also capable of editing geospatial data. A simplified scheme of a web application is shown in Fig. 2, where the server side components are marked in green. Clients can connect to a webserver, which runs on a host machine. Other software components, like a map server can be installed on the server machine.

Applications with architecture of Fig. 2 are not too sophisticated. They provide the simplest functionality possible. However, complex GIS analysis or modelling tasks requires application to use complex GIS functionality. OGC's Web Processing Service (WPS) standard can enlighten the application with all the GIS analysis functions and methods needed by running a backend software on the server machine and providing results to the client. Some map servers (such as GeoServer) have a built-in WPS implementation with a few simple algorithms. There are also standalone WPS implementations independent from map servers. An open source solution is developed by 52 North's (52NORTH) geoprocessing community. This WPS implementation can work with different backends (such as GRASS GIS or the Sextante library). Sextante and GRASS GIS are commonly used full GIS packages with large collections of spatial analysis algorithms. WPS allows the Web GIS application to use the whole functionality of such packages from a web browser. Based on these protocols, a prototype application for disaster management has been developed, with one of the stages already in operation (Podolcsák and Juhász, 2013).

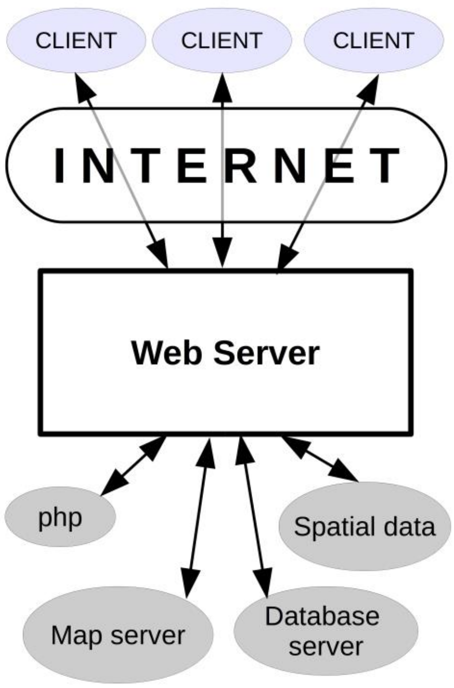

Fig. 2 Generalized architecture of a Web GIS application

The Prototype Application

As for modelling inland excess water coverage, a Web GIS application can offer support in the mitigation phase of disaster management (Fig. 1). It is of interest whether it is possible to fulfill the data requirements of such application by crowdsourced data. In theory, an engaged and well-trained community can provide relevant information in compliance with the predefined quality and technical standards. Inappropriate operation of rain diversion systems (including ditches, dams, drainage channels) highly influences the formation of inland excess water (Szatmári et al., 2011).

Local farmers know the current conditions of such systems around their land. Relevant parameters can be the width, depth of the channels, or even their existence. It is very unlikely that the individuals who work on their fields every day have no such information. On the other hand, this data is difficult to obtain from other sources, therefore it is beneficial to gather this information from them. It is a mutual benefit, because they are also affected by inland excess water formation since it can cause either profit or loss. Proactive actions, like modelling water coverage for different rain events, based on the condition of rain drainage systems can result in more effective agricultural activities as well. The prototype application enables users to add and edit ditches in agricultural lands. Furthermore, it shows the likely water cover for various fictional scenarios. These scenarios are different from each other based on rain intensity and soil humidity. The outputs from the modelling also use the current geodata of the ditch system previously provided by users, therefore it is dynamic. Users can then visually interpret the changes in water cover and the influence of the ditch system. Each individual then may or may not decide whether further actions are needed near their lands (Podolcsák and Juhász, 2013). The application is a technical demonstration, where the authors wanted to prove that it is possible to develop an Open Source, community based Web GIS application to support disaster management. Algorithms used to calculate the possible water cover may not be accurate, but this was not an objective of the research. It is also important to note that possible users of the application most likely have very limited GIS expertise, if any. In this manner, data input methods and the visual outputs have to be as easy to understand and use as possible. In addition, since non-professional users are more likely to generate inaccurate data, data quality will be a major factor. This aspect needs to be further addressed. It is likely that applying Quality Assurance techniques are necessary, such as filtering and automatic correction will improve the overall accuracy of this application.

WPS Processes

The framework was developed using solely Free and Open Source Software components. The client side is based on the OpenLayers library including some custom solutions. Server side components are the Apache web server, a MySQL relational database, GeoServer, Apache Tomcat servlet engine, a WPS implementation and GRASS GIS as the geospatial modelling engine in the background. Using the 52North WPS implementation enables our application to use almost the entire functionality of GRASS GIS. This method is able to handle any type of GIS tasks in a web environment. In other words, traditional and highly complex GIS functionality can be achieved "directly" in a web browser (Podolcsák and Juhász, 2013). Figure 3 shows the multitier architecture of our prototype application.

Users access the application via the user interface allowing them to draw new ditches and modify attributes of the drainage network. Users can view the predicted extent of water cover while browsing the User Interface. Data modifications are sent as WFS requests towards GeoServer, whereas running simulations are

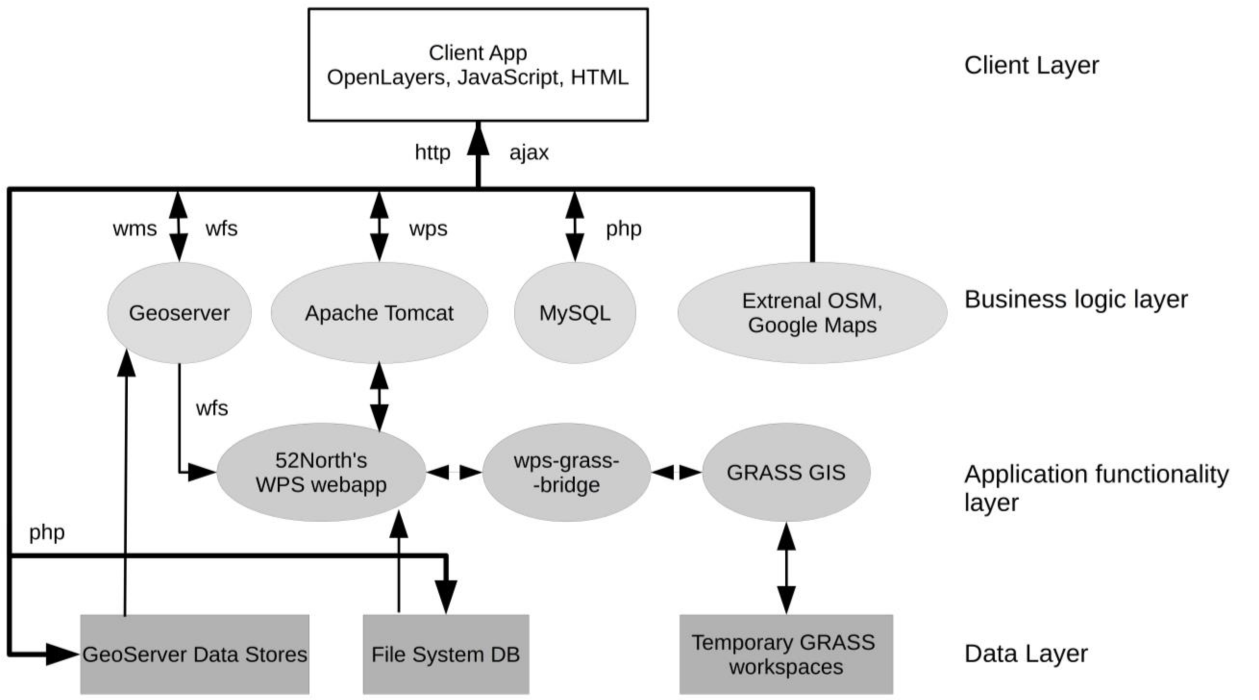

Fig.3 Multi-tier architecture of the prototype

sent as WPS requests towards GRASS GIS. These requests are defined according to the WFS and WPS specifications and they run asynchronously via AJAX (Asynchronous JavaScript and XML). Using the AJAX technique ensures the continuous operation of the application, since users do not have to wait for a process to finish, they are still able to use the application. Geospatial tasks (modelling inland excess water cover) are transferred over the network as WPS processes. A flowchart of a request-response pairs can be seen on Fig. 4**.** The model was built using the following data layers: DTM (Digital Terrain Model), runoff conditions, participation rate, infiltration rate and surplus surface water. The surface water flow direction and the area of surface water patches were determined based on the derivates of DTM. For the modelling a layer of soil types and another layer of surface cover types were also used. Based on these the infiltration rate (in mm/h) was calculated. The surplus of water values were calculated using soil types, surface covers and precipitation rate.

Although factors that have influence on the formation of inland excess waters do not change within such short time (Pálfai, 2004), it can be suspected that ditches choked with weed or artificial barriers prevent residual water from flowing away. This means that near real time analyses can also be useful. Possible users of this application can be anyone affected by inland excess water, like local farmers, local government or hydrological professionals (Podolcsák and Juhász, 2013).

MODELLING THE RESULTS

The system supports two main business processes: the creation and update of the data model and the management of the environment (mitigation of risks and utilization of surface water). In the back-end (System Administration), the developers or experts process the data, the modelling and manage the users. Firstly, the GIS model will be set up, which will make an Initial Analysis based on input data, using GRASS GIS modules (v.to.rast, r.grow, r.slope.aspect, r.buff, r.sim.water, r.math (r.mapcalc)).

The Initial Analysis will help to optimize the model for quick update to perform the Pre-processing of analysis. The Pre-processing of analysis step is linked to the Analysis/Planning part of the Front End (End Users' Functionality) process, to visualize existing probabilities of hazards. The local community members, farmers can view the other relevant maps in the platform. After visualization, the End Users can plan or analyze intervention against the hazard. Additionally, in the User Community Management the End Users can harmonize and discuss the Plan/analysis intervention phase together in order to make actions to mitigate risk in the Intervention phase.

If the users decide on mitigation actions the pre–processing of analysis can be performed again and the existing risk can be visualized in Analysis/Planning phase with the new parameters. In the Back-end system administration section, a feedback system, ensures the integration of new parameters in to the model.

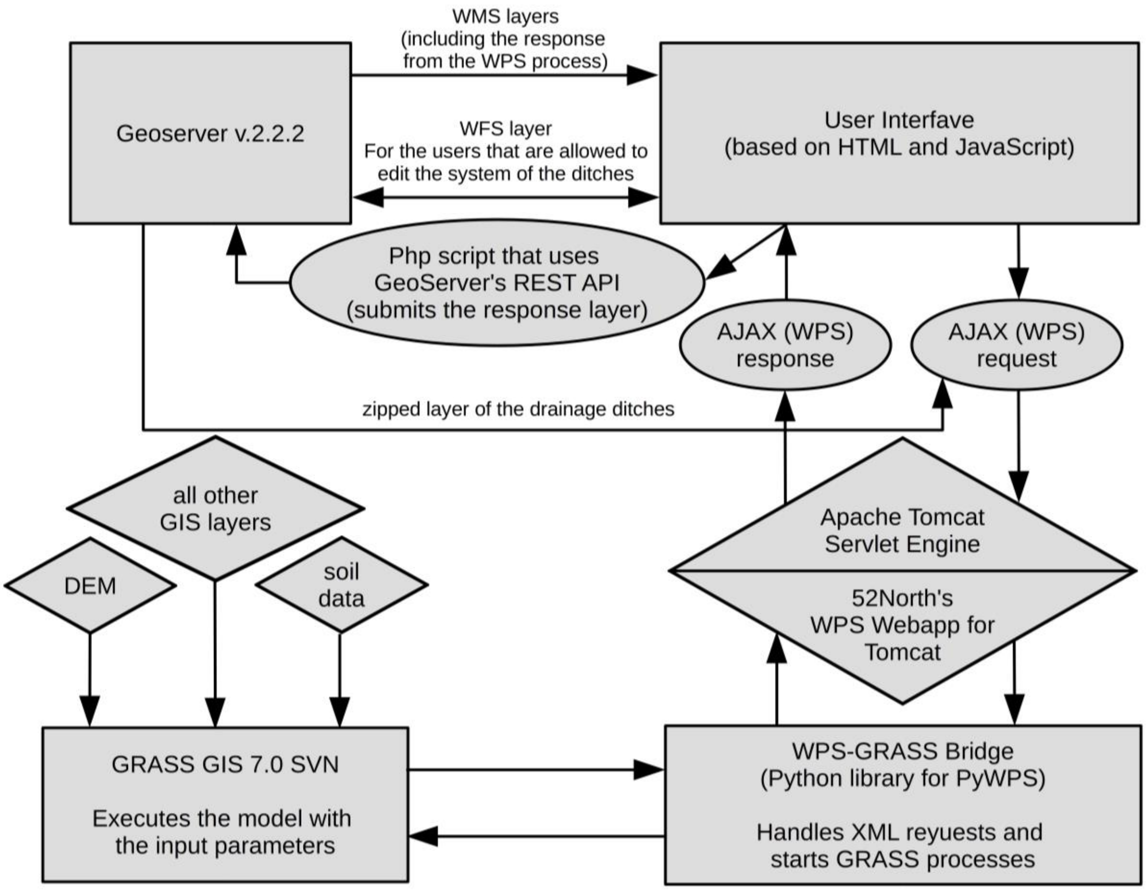

Fig. 4 Flowchart of WPS processes

Model outputs highly depend on the quality of input data. The accuracy of the input Digital Terrain Model (DTM) is crucial to determine surface flow directions. Currently, the application uses a DTM derived from elevation information in the 1:10,000 scale Hungarian topographic maps. Since the application tries to model local differences in water coverage, a more detailed terrain model would be beneficial, such as DTMs from Aerial Laser/LIDAR Scanning (ALS) or stereo photogrammetry (Szatmári et al., 2013).

Crowdsourced data is also present in the application since the properties of the ditch system can be edited by the community. They can also add or remove and modify sections. This data is used to make changes to the original DTM. This DTM modification based on the width, length and slope of the ditches will allow residual waters to "flow away". Furthermore, these ditches will lower the amount of residual waters along them.

Figures 5 and 6 show the possible water coverage in the application. Fig. 5 represents a scenario where ditches (dotted lines) have no influence on the formation of inland excess waters. Three major water patches can be identified on the picture visually regardless to the position of the ditches. This can be a real scenario in case of buried ditches when ditches are blocked by vegetation or other artificial barriers. It can also be seen that patterns and position of residual water align to the system of the point bar, and infill the lower parts. Fig. 6 illustrates a scenario where ditches along roads have influence on the formation of residual waters. It is quite visible that the extent of water cover decreased due to the influence of ditches in this area.

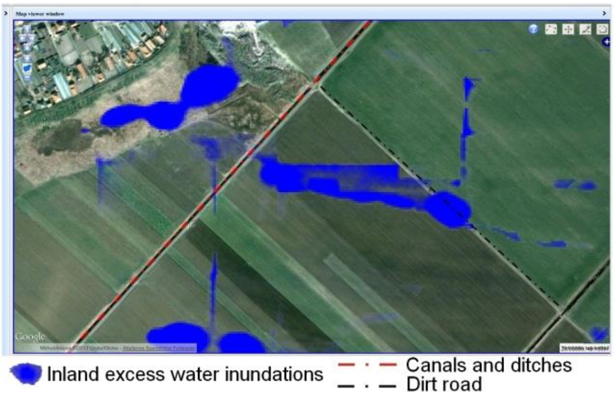

Fig. 5 Inland excess water cover seen on the application without the effect of the ditches

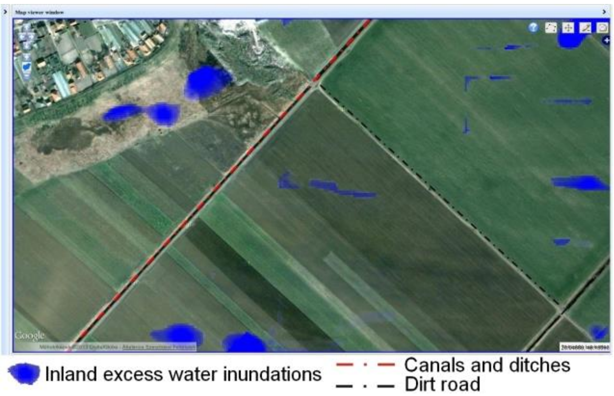

Fig. 6 Inland excess water cover seen on the application with the effect of the ditches

Users can now decide whether it is worth widening or digging ditches along their agricultural lands based on the visual results of the modelling with the new or modified ditch network. In this way, the application helps proactive decisions to be made to prevent inland excess waters. As we previously mentioned, using a more detailed DTM would be beneficial to get more accurate results. Furthermore, a vector based network analysis would be more ideal for modelling water flow in ditches.

DISCUSSION AND CONCLUSIONS

Disaster Management can describe the tasks and utilities of an organization that deals with disasters and emergency situations. Information is crucial for making effective decisions, because disasters can affect both lives and properties. Although disaster managers mostly rely on traditionally sourced, high quality data, this is not always available. Volunteered Geographic Information or crowdsourced geodata is a new trend in our field. This kind of data is the product of the so-called Web 2.0, in which non-professional users became creators and providers of spatial information. Although this data is heterogeneous and lacks traditional Quality Assurance, it can be valuable because the shortage of data also limits effective decisions of disaster/emergency managers. Therefore creating Web Applications that integrate VGI data sources into existing ones is an interesting research topic of recent years.

Using Free and Open Source Software to develop geospatial applications is beneficial for many reasons. They are valuable for companies and application developers not just because of the low financial costs, but also the shorter development cycles, as well as the often helpful and fast developing user community, that can help solve problems. Open Source software is widely used in many areas. Numerous GIS solutions exist that can compete with commercial products.

The use of Web Processing Service solutions is an interesting and promising direction for our field. It allows web applications to use complex GIS functionality over the internet. It allows Web GIS applications to move from an interactive map towards a fully functioning spatial processing framework in a web browser.

The authors have developed a prototype application, which proves that a Web GIS application can be developed to integrate the ideas of crowdsourcing and GIS, therefore can possibly create valuable VGI. The application is useful for disaster management since it can model possible extent of inland excess waters.

The application was developed using Free and Open Source software solutions. It contains an easy-to-understand user interface with interactive maps and the possibility of editing features. Users can add new features or modify existing ones. Data generated this way can be considered as VGI or crowdsourced geographic data and it is used in the modelling process. Furthermore, it uses the WPS standard to execute a complex GIS analyses. Previously this kind of functionality was unknown for Web GIS applications.

The application is a technological demonstration of integrating available software components. It clearly shows that Free and Open Source Software is capable to provide full GIS functionality and to generate valuable geographic information over the internet. Quality Assurance of the generated data and refinement of the used algorithms to create a more correct model is a challenging task for the future. It can be expected that the number of such application will arise in the near future since the technology does not limit the possibilities. Standards and software components are freely and easily available.

Considering the numerous expansion option of prototype it should be remembered that the underlying principles can be applied in the other section too, like in e.g. agriculture, environmental protection, rural development.

References

Alparslan E., Ince, F., Erkan, B., Aydöner, C., Özen, H., Dönertaş, A., Ergintav, S., Yağsan, F.S., Zateroğulları, A.,. Eroğlu, I., Değer, M., Elalmış, H., Özkan, M. 2008. A GIS model for settlement suitability regarding disaster mitigation, A case study in Bolu Turkey. *Engineering Geology* 96 (3–4), 126–140. DOI: 10.1016/j.enggeo.2007.10.006

Chen, A.Y., Peña-Mora, F., Ouzang, Y. 2011. A collaborative GIS framework to support equipment distribution for civil engineering disaster response operations. *Automation in Constructi*on 20 (5), 637–648. DOI: 10.1016/j.autcon.2010.12.007

Craglia, M., Ostermann, F., Spinsanti, L. 2012. Digital Earth from vision to practice: making sense of citizen-generated content. International. *Journal of Digital Earth* 5 (5), 398–416. DOI: 10.1080/17538947.2012.712273

Estellés Arolas, E., González Ladrón-de-Guevara, F. 2012. Towards an integrated crowdsourcing definition. *Journal of Information Science* 38 (2), 189–200. DOI: 10.1177/0165551512437638

Goodchild, M.F. 2007. Citizens as voluntary sensors: spatial data infrastructure in the world of web 2.0 (Editorial). *International Journal of Spatial Data Infrastructures Research* 2, 24–32.

Goodchild, M.F., Glennon, J. A. 2010. Crowdsourcing geographic information for disaster response: a research frontier. *International Journal of Digital Earth* 3 (3), 231–241. DOI: 10.1080/17538941003759255

Goodchild, M.F., Li, L. 2012. Assuring the Quality of Volunteered Geographic. *Information Spatial Statistics* 1, 110–120. DOI: 10.1016/j.spasta.2012.03.002

Huszár, T., Kitka, G., Mezősi, G., Szatmári, J., van Leeuwen, B., Tobak, Z.,Kovács, F., Győri, A., Okner, A., Tóth, J., Szűcs, B., Zsom, G., Juhász, L. 2013. Tűzcsapkataszter-felmérés Csongrád megyében. Katasztrófavédelem 55 (10), 5–6. (in Hungarian)

Katona, Z., Molnár, A. 2005. Magyarország térinformatikai szőlőültetvény-nyilvántartó rendszerének -VINGIS- kialakítása. Geodézia és Kartográfia 57 (10), 24–27 (in Hungarian)

Lantonero, M., Shklovski, I. 2010. "Respectfully Yours in Safety and Service": Emergency Management & Social Media Evangelism. Proceedings of the 7th International ISCRAM Conference. Seattle. USA, May 2010

van Leeuwen, B., Henits, L., Mészáros, M., Tobak, Z., Szatmári, J., Pavić, D., Savić, S., Dolinaj, D. 2013. Classification Methods for Inland Excess Water Modeling, *Journal of Environmental Geography* 6 (1–2), 1–8. DOI: 10.2478/v10326-012-0001-5

Li, L., Goodchild, M.F. 2010. The Role of Social Networks in Emergency Management: A Research Agenda. *International Journal of Information Systems for Crisis Response and Management* 2 (4), 49–59. DOI: 10.4018/jiscrm.2010100104

MacEachren, A. M., Robinson, A. C., Jaiswal, A., Pezanowski, S., Savelyev, A., Blanford, J., Mitra, P. 2011. Geo-Twitter Analytics: Applications in Crisis Management. 25th International Cartographic Conference. Paris, France. July 2011

Montoya, L. 2003. Geo-data acquisition through mobile GIS and digital video: an urban disaster management perspective. *Environmental Modeling and Software* 27, 869–876. DOI: 10.1016/s1364-8152(03)00105-1

Pálfai, I. 2004. Belvizek és aszályok Magyarországon. Hidrológiai Tanulmányok. VITUKI. Budapest, 492 p

Podolcsák, Á., Juhász, L. 2013. Crowd sourcing in disaster management at local level; incl. a demo of a prototype application supporting proactive defense against inland waters. Workshop for building V4 network researching spatial and social aspects of Disaster Management. May 22-23. Budapest

Rakonczai, J., Farsang, A., Mezősi, G., Gál, N. 2011. A belvízképződés elméleti háttere. Földrajzi Közlemények 135 (4), 339–349. (in Hungarian)

Siki, Z. 2009. Produktív környezetben használt, nyílt forráskódú komplex térinformatikai megoldások. CASCADOSS műhelymunka tanácskozás és GRASS tanfolyam. Szeged (in Hungarian)

Steiniger, S., Hunter, A. J. S. 2013. The 2012 free and open source GIS software map – A guide to facilitate research, development, and adoption. Computers, Environment and Urban Systems 39 May 2013, 136–150.

Steiniger, S., Weibel, R. 2009. GIS software – a description in 1000 words. [http://ftp.jaist.ac.jp/pub/sourceforge/j/project/ju/jump-piot/w_other_freegis_documents/articles/gissoftware_steiniger2008.pdf]

Szatmári, J., Szijj, N., Mucsi, L., Tobak, Z., Van Leeuwen, B., Lévai, Cs., Dolleschall, J. 2011. A belvízelöntések térképezését és a belvízképződés modellezését megalapozó térbeli adatgyűjtés. In: Lóki, J. (ed). Az elmélet és gyakorlat találkozása a térinformatikában II, Debrecen, 27–35. (in Hungarian)

Szatmári, J. van Leeuwen, B. (ed.) 2013. Measurement, monitoring, management and risk assessment of inland excess water in southeast Hungary and north Serbia (Using remotely sensed data and spatial data Infrastructure) University of Szeged, Department of Physical Geography and Geoinformatics, Szeged, 154p.

Vieweg, S., Hughes A. L., Starbird, K., Palen L. 2010. Microblogging During Two Natural Hazards Events: What Twitter May Contribute to Situational Awareness. Proceedings of the ACM conference on Computer Human Interaction (CHI) 2010

Vivacqua, A.S., Borges, M.R.S. 2011. Using group storytelling to recall information in emergency response. CollaborateCom'11, In: Georgakopoulos D., Joshi, J. (eds.) Proceedings of the 7th International Conference on Collaborative Computing: Networking, Applications and Worksharing, 512–515. DOI: 10.4108/icst.collaboratecom.2011.247126

Zerger, A., Smith, D. I. 2003. Impediments to using GIS for real time disaster decision support. *Urban Systems* 27 (2), 123–141. DOI: 10.1016/s0198-9715(01)00021-7

Internet references

Apache http Server project - https://httpd.apache.org/. (last visited: May 2016)

Barnier, M. 2006. For a European civil protection force: Europe aid. Report. European Commission, Brussels, http://ec.europa.eu/archives/commission_2004-2009/president/pdf/rapport_barnier_en.pdf

Cherokee http server project - http://cherokee-project.com/, (last visited: May 2016)

GeoServer - http://geoserver.org/ (last visited: may. 2016)

KSH – Központi Statisztikai Hivatal/Hungarian Central Statistical Office 2014. Proportion of households with broadband internet connection. http://www.ksh.hu/docs/hun/eurostat_tablak/tabl/tin00089.html (last visited: February 2016)

MapServer – http://mapserver.org/ (last visited: may. 2016)

Nginx http server - https://www.nginx.com. (last visited: May 2016)

OGC – Open Geospatial Consortium 2014. OGC® Standards and supporting documents http://www.opengeospatial.org/standards (last visited: February 2016)

UNISDR – UNITED NATIONS Office for Disaster Risk Reduction. 2014, http://www.unisdr.org/we/inform/terminology (last visited: February 2016)

USHAHIDI - https://www.ushahidi.com (last visited: February 2016)

52NORTH - http://52north.org/communities/geoprocessing/wps/ (last visited: February 2016)