

Slovenian National Landslide DataBase – A promising approach to slope mass movement prevention plan

Nacionalna podatkovna baza zemeljskih plazov – Obetaven začetek načrta preventivnih ukrepov na področju pobočnih masnih premikov

Marko KOMAC¹, Dušan FAJFAR², Damijan RAVNIK² & Mihael RIBIČIČ³

¹Geological Survey of Slovenia, Dimičeva ul. 14, Ljubljana, Slovenija, marko.komac@geo-zs.si

²IGEA, Ljubljana, Slovenija,

³NTE, University of Ljubljana, Ljubljana, Slovenija

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Abstract

The Slovenian territory is, geologically speaking, very diverse and mainly composed of sediments or sedimentary rocks. Slope mass movements occur almost in all parts of the country. In the Alpine carbonate areas of the northern part of Slovenia rock falls, rock slides and even debris flows can be triggered. In the mountainous regions of central Slovenia composed from different clastic rocks, large soil landslides are quite usual, and in the young soil sediments of eastern part of Slovenia there is a large density of small soil landslides. The damage caused by slope mass movements is high, but still no common strategy and regulations to tackle this unwanted event, especially from the aspect of prevention, have been developed. One of the first steps towards an effective strategy of struggling against landslides and other slope mass movements is a central landslide database, where (ideally) all known landslide occurrences would be reported, and described in as much detail as possible. At the end of the project of National Landslide Database construction which ended in May 2005 there were more than 6600 registered landslides, of which almost half occurred at a known location and were accompanied with the main characteristic descriptions. The erected database is a chance for Slovenia to once and for all start a solid slope mass movement prevention plan. The only part which is missing and which is the most important one is adopting a legal act that will legalise the obligation of reporting slope mass movement events to the database.

Izvelek

Kljub dejstvu, da slovensko ozemlje v večjem delu sestavljajo sedimenti in sedimentne kamnine, je z geološkega vidika zelo raznoliko in slikovito. Ena od posledic te mnogoterosti so procesi pobočnih masnih premikov, ki so v Sloveniji pogost pojav. Skalni podori, usadi, zdrsi in drobirski tokovi so značilnejši v območju Alp, ki jih povečini tvorijo karbonatne kamnine. Zemeljski plazovi se pojavljajo domala po celotnem ozemlju Slovenije, večji na območjih klastičnih kamnin v hribovitih predelih, manjši, a številnejši pa v sedimentih vzhodne Slovenije. Škoda, povzročena zaradi pojavov pobočnih masnih premikov, je velika a strategije na državnem nivoju, ki bi se uspešno spopadla s to problematiko, predvsem v preventivnem smislu, v Sloveniji še nimamo. Prvi korak k tej strategiji je izdelava nacionalne baze plazov v Sloveniji, katere izdelava je predstavljena v tem prispevku. Namen baze je vsebovati vse znane pojave pobočnih masnih premikov na ozemlju Slovenije, podatki v njej pa bi morali biti redno vzdrževani, dopolnjevani in čim bolj popolni. Ob koncu projekta izgradnje nacionalne baze plazov, ki se je končal meseca maja 2005, je bilo v bazi zabeleženih preko 6600 plazov, od katerih jih je bila okoli polovica umeščena v prostor, vsak od teh zapisov pa je vseboval vsaj osnovni opis plazu. Izdelana podatkovna baza plazov predstavlja odlično priložnost za izdelavo kakovostnega načrta preventivnih ukrepov na področju pobočnih masnih premikov. Manjka le pravni akt, ki bi zavezal deležnike, da sproti sporočajo v podatkovno bazo pojave pobočnih masnih premikov in njihove opise.

Introduction

Based on the research made in the early nineties, Ribičič et al. (1994) estimated that there could be between 7,000 and 10,000 active landslides in Slovenia. The damage caused by landslides in the year 1993 summed to 4.8 % of the GDP (Petkovšek & Marolt, 1994). In the years 1994 to 2003, the damage caused by landslides (and avalanches) summed to 84.8 million € (SORS, 2005), excluding the remediation costs. In the last decade global climate changes probably caused several extremely large landslide events on the Slovenian territory, which were not observed before. The latter represent an additional, much higher burden to the state and municipality budgets. In rare, but extreme situations, the landslides resulted in human casualties.

Landslide databases in other countries

Worldwide there are numerous landslide databases all of them with a common prerogative – landslide databases are constructed to study the evolution of landscapes, and are mandatory to ascertain landslide susceptibility, hazard and risk. To better understand the motive for the creation of a National landslide data base in Slovenia it is necessary to overview the status of similar projects in the region and European Union.

In Austrian province Burgenland the government has funded a project the main objective of which is a systematic collection of data on historic and recent landslide events, as well as a comprehensive cause analysis (Klingseisen et al., 2006). Based on recorded landslides and their triggering factors, the probability for future landslides was calculated with spatial statistical methods over the extent of the study area. The purpose of the resulting hazard map was the delineation of landslide risk zones to support decision makers in local and regional land-use planning.

In Italy an Italian Agency for environmental protection and technical services, Department of soil protection and land resources – Italian Geological Survey has constructed the Italian Landslides Inventory (IFFI Project), which aims at identifying and mapping slope instabilities over the whole Italian territory, based on standardized criteria (APAT, 2007). At present there

are about 460,000 landslides included in the inventory. The IFFI inventory represents an important tool for hazard and risk assessment and land use planning. Through the project's website users can explore the geographical data and obtain detailed information on the most important parameters of landslides in Italy. The database is in Italian language.

In the early nineties in Italy a project called National Research Council's AVI (Damaged Urban Areas) Project archive was undertaken to collect historical information of landslide events and floods in Italy and was aimed at helping the regional assessment of landslide and flood risk in Italy (Guzzetti & Tonelli, 2003). The project was designed as a very broad data and information collection campaign and at the end it included 32,000 landslide events from the period between 1900 and 2002. Based on the data from this landslide database Guzzetti and Salvati (2003) made an analysis of the casualties in Italy in the period between 1900 and 2002 as a consequence of landslide events. The analysis of the landslide database indicated that 5,813 people have died in a total of 1882 landslide events.

In France the national landslide (BDMvt) has been in operation since 1994 and is maintained by the French Geological Survey (BRGM) with the financial support of governmental institutions (BRGM, 2007).

The Swiss Federal Research Institute WSL has been collecting information on flood and landslide damage in Switzerland since 1972 (Hegg & Fraefel, 2005) and has since then collected over 15,000 events including the damage aspect. It is not clear how many of them are landslide events and how many flood events.

British landslide database currently holds over 14,000 records and it is updated every year with around 2000 records as new landslides are logged and ancient, degraded landslides are identified (BGS, 2007). The sources of information are numerous, the majority of them are derived from published British Geological Survey geological maps. Other sources include commissioned and research studies, including the Department of the Environment National Landslide Database compiled in the 1990s, and a number of regional databases compiled by the BGS since the 1970s. The information is stored in

a digital format and is among other things used also as ground control for developing and improving the GeoSure national landslide susceptibility dataset.

In the past there weren't many landslide events in Ireland. Recent events indicate that the landslide hazard is increasing due to the development, land-use expansion into potentially hazardous areas, and due to climate changes. The Irish Landslides Working Group has undertaken the task to erect the National Database of Past Landslide Events. This database will serve as a foundation upon which a better understanding and mapping of these hazards will be built to better cope with future landslide hazards in a form of mitigation and managing (GSI, 2007). The project is in the starting phase.

In late 1980s a UNESCO Working Party on World Landslide Inventory (abbreviated WP/WLI) was initiated to assist the establishment of a detailed list of the world's landslides. There have been some results on thesaurus and definitions of slope mass movements (WP/WLI, 1990 & 1991; Brown et al., 1992).

Based on the "2006 Tokyo Action Plan – Strengthening Research and Learning on Landslides and Related Earth System Disasters for Global Risk Preparedness", the International Programme on Landslides (IPL) Global Promotion Committee was established by International Consortium on Landslide (ICL) members and ICL supporting organizations (UNESCO, WMO, FAO, UN/ISDR, UNEP, UNU at the United Nations University and Government of Japan) (ICL, 2007). One of the Consortium's main goals is to maintain a database of the world's landslides. (ICL, 2006).

National Landslide DataBase

With all the above stated, several Slovenian Ministries expressed the will to finance the construction of the National Landslide DataBase (Fajfar et al., 2005; Ribičič et al., 2006) which is in fact a Slope Mass Movements DataBase since it comprises events of landslides, rockfalls and debris flows. In the following text it will be referred to as landslide database and the word "landslide" in the text should be considered as slope mass movements in general. Some of the work, such as gathering a part of the slope mass movement data and transforming these into

the digital format and later into the GIS was done in the 1990's with pilot projects (Ribičič et al., 1994). The stamina of the researchers (and financing) unfortunately diminished and until now not much was made to gather the landslide data into a common database.

Nowadays, an up-to-date landslide database is vital for the activity of the Ministry of the Environment and Spatial planning for gathering the data on imminent danger (geohazard maps), and for coping with the issues of prevention and remediation due to slope mass movement events. Practically every day new slope mass movements are created, either as a consequence of natural or human activity. Related to the removal of consequences due to the slope mass movement occurrence, usually there are huge costs, which are partly compensated by the state. Additionally, the Administration of the RS for Civil Protection and Disaster Relief that deals with the implications of disasters on people and property is interested in the use of landslide database with the aim to organise a prompt response to slope mass movement threatening events (equipment and local community shifts). Hence the urgent necessity for an up-to-date landslide database creation.

To sum up, the project goals were: (1) to establish an up-to-date central landslide database which could also be used for other natural phenomena, (2) the construction of an information system that would allow different users to use the internet application for registering and reporting new slope mass movement occurrences, and making additional changes or correcting the data already stored. The database would represent (3) the basis for spatial analysis of slope mass movement distribution and (4) the slope mass movement data could be distributed very fast to different users in accordance with their privileges/rights. Also the database would serve as a foundation for the modelling and production of geohazard and georisk maps of different scales (5).

Collecting the data

The existing slope mass movement data were acquired from different sources, from the Administration of the RS for Civil Protection and Disaster Relief (URSZR), from The Directorate of the Republic of Slovenia for Roads (DRSC), from the Ministry of the

Environment, Spatial planning and Energy (ARSO), from the Geological Survey of Slovenia (GeoZS), and from other dispersed sources (municipalities). The data, acquired in different formats, were first analyzed, the duplicates removed and merged into the

centralized database. The quality is questionable to a certain degree, since the separate databases were rarely maintained. The dominating problems were different database attributes, and missing or multiplied data (Komac et al., 2005).

Table 1. Number of slope mass movements (No. SMM), acquired from different sources and included in the National Landslide DataBase.

Source	No. SMM	No. SMM with known location	% SMM with known location
URSZR	1459	1459	100.0 %
DRSC	432	5	1.2 %
ARSO	2575	491	19.1 %
GeoZS	464	392	84.5 %
Together (11. 1. 2005)	4930	2003	40.6 %
Additional by municipalities (30. 6. 2005)	1672	1581	94.5 %
Together (30. 6. 2005)	6602	3257	49.3 %

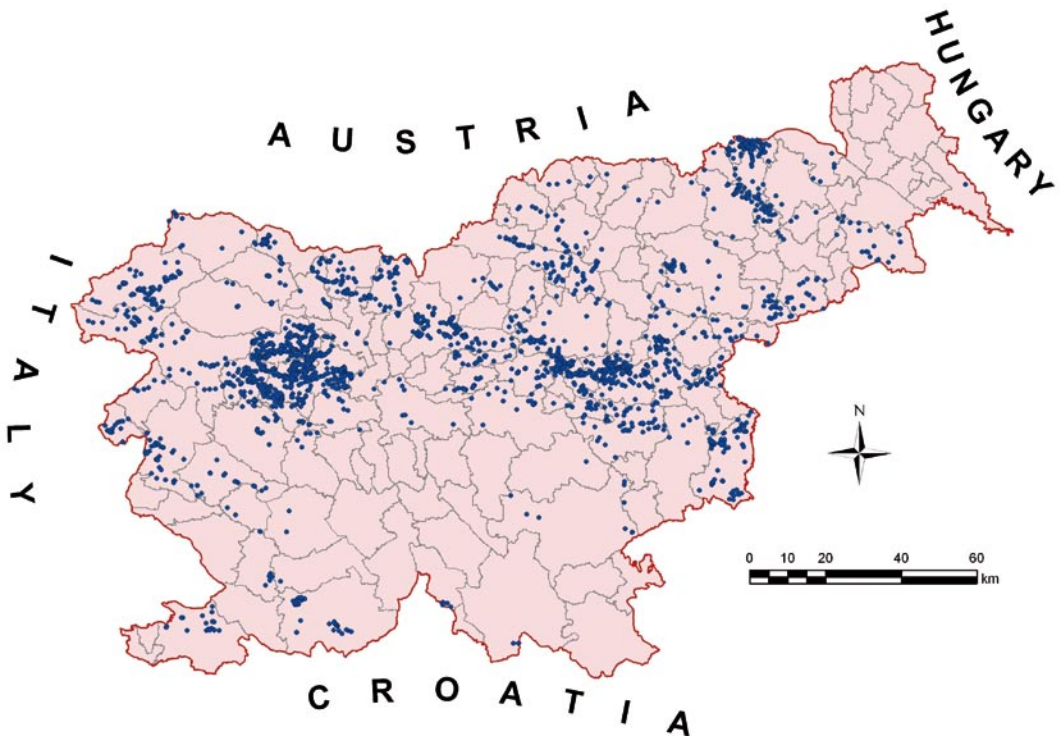


Fig. 1. Overview of slope mass movements, registered in the database.

Slika 1. Pregled vseh pobočnih masnih premikov, zajetih v podatkovni bazi.

At the end of the project there were 6602 slope mass movements in the database (Fig. 1). 3257 of them are geolocated, meaning that their location is known. The final goal was to build a living database, which means that slope mass movement events would be periodically updated.

The Landslide DataBase is made up of the following types of data:

- A) Basic data
 - Code
 - Name
 - Location
 - Date of occurrence
- B) Register of spatial data
 - Municipality
 - Settlement
- C) Coordinates
 - Gauss-Krueger
- D) Landslide condition
 - Status
 - Speed
 - Dimension
 - Geology
- E) Remediation of Landslide
- F) Costs of remediation
- G) Priority
- H) Documentation
- I) Activity on Landslide
- J) Landslide occurrence consequences
 - Damaged and threatened objects
 - Roads
 - Buildings
 - Public infrastructure
 - Land

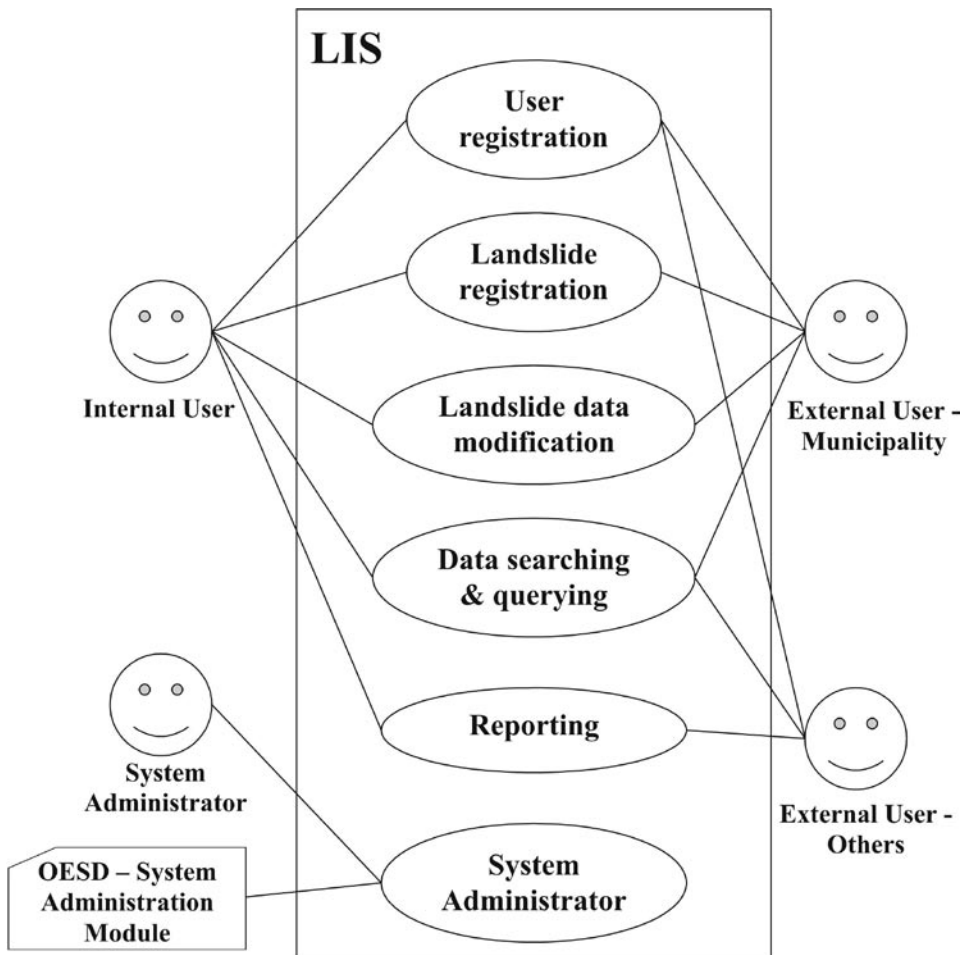


Fig. 2. Flowchart of the Landslide Information System.

Slika 2. Shema konceptualnega modela informacijskega sistema zemeljskih plazov.

The Landslide Information System consists of two different types of data; attributes and spatial data. The attributes are stored in Oracle database 9i2R (data were imported from different sources; dbf, excel, access) and Oracle Spatial is used for storing the location of slope mass movements. Other spatial data used in the system are stored on the file server (raster data – background maps, digital orthophoto, etc), or in Oracle Spatial (vector data – land and building cadastre, infrastructure, etc).

Landslide Information System

Landslide Information System (LIS) consists of three different modules, the Authorization module, the Attribute module, and the Spatial module. The users of the system can be divided into three segments: the administrator, internal users and external users (Fig. 2).

The authorization module enables:

- Managing the users and their rights (username and password)
- Access to application
- Controlling the digital certificates

At the moment access is possible only with the SIGEN-CA digital certificate, since the data are stored within the government network. Special authorization module is used, developed by the Government Centre for Informatics that manages users and their access to the application. The use of this module ensures data safety. The system administrator manages the registry of new users and authorizes system access.

The attribute module enables:

- Landslide registration (Fig. 3)
- Changing data of landslides
- Managing events on landslide

Basic landslide data

Šifra dogodka: 2788 Vrsta dogodka: Prijava plazu Datum vnosa: 13.09.2004

PODATKI O PLAZU

osnovni podatki

* Šifra plazu: 920

* Ime plazu: Plaz pri Kobaridu

* Ime lokacije: Kobarid - Bovec

Datum evidentiranja: 12.07.2004
Datum mora biti oblike DD.MM.LLLL - npr. 15.02.2004

občina in naselje

* Občina: 11026958 KOBARID

* Naselje: 10140455 BREGINJ

gauss krügerjeve koordinate

X: 379139.16561 Y: 125692.05144 Z: 2

vzroki nastanka

Št.	Procent	Vzrok	Razlog	Opomba

1 - 2 - 3 - 4 - 5 Nazaj Naprej >> 1 - 2 - 3 - 4 - 5

Zapri okno

Fig. 3. Landslide registration form – basic data on the landslide.
Slika 3. Obrazec za registracijo zemeljskega plazu – osnovni podatki.

Landslide query form

Landslide list

Sifra plazu	Ime plazu	Obcina	Naselje	Datum aktivnega vnosa
920	Plaz pri Kobaridu	KOBARID	BREGINJ	13.09.2004
1000	PLAZ			17.09.2004
1001	PLAZ			17.09.2004
1002	PLAZ			17.09.2004
1003	PLAZ			17.09.2004
1004	PLAZ			17.09.2004
1005	PLAZ			17.09.2004
1006	PLAZ			17.09.2004
1007	PLAZ			17.09.2004
1008	PLAZ			17.09.2004

Fig. 4. Searching landslides and querying the data.
Slika 4. Iskanje in poizvedovanje po bazi zemeljskih plazov.

- Searching landslides and date querying (Fig. 4)
- Managing attribute data

The system allows slope mass movement registration from the web application for all the users with the right of access (municipalities, URSZR, DRSC, etc). The slope mass movement registration is possible through the valid form in the application. In the landslide registration form the user enters basic data about slope mass movements, more detailed data about the movements if they are known, and defines the location of the slope mass movements. The latter can be defined by using the attribute module of the application (entering the coordinates) or by using the GIS WEB browser, where one can define the location directly on the map.

Each change of the data can be carried out only in the frame of a certain event (procedure), and is stored into the log files. The user himself can define the name of the event using the List of Values. Prior to modifying the data, the user must define the type of the event, the reason of the change and the date of the change. Every event is managed

as an independent entity and it can be recalled in the same form as it was entered. All changes, entered by the external user, have to be confirmed or denied by the responsible person from ARSO. The user can change the data only for the slope mass movements, which he/she registered or are under his/her supervision.

All the events on the slope mass movements are stored in the History of Events files. In this way the system enables the administrator to follow all the events on every slope mass movement entered by users in the slope mass movement registry until today (Fig. 5).

Spatial module enables:

- Viewing different graphical layers
- Checking of different graphical layers
- Magnification
- Identification
- Measuring distance
- Selecting different objects on the graphical layer and their transfer to the attribute module

Fig. 6 shows the Spatial module layout with the landslide visualization frame, tool-

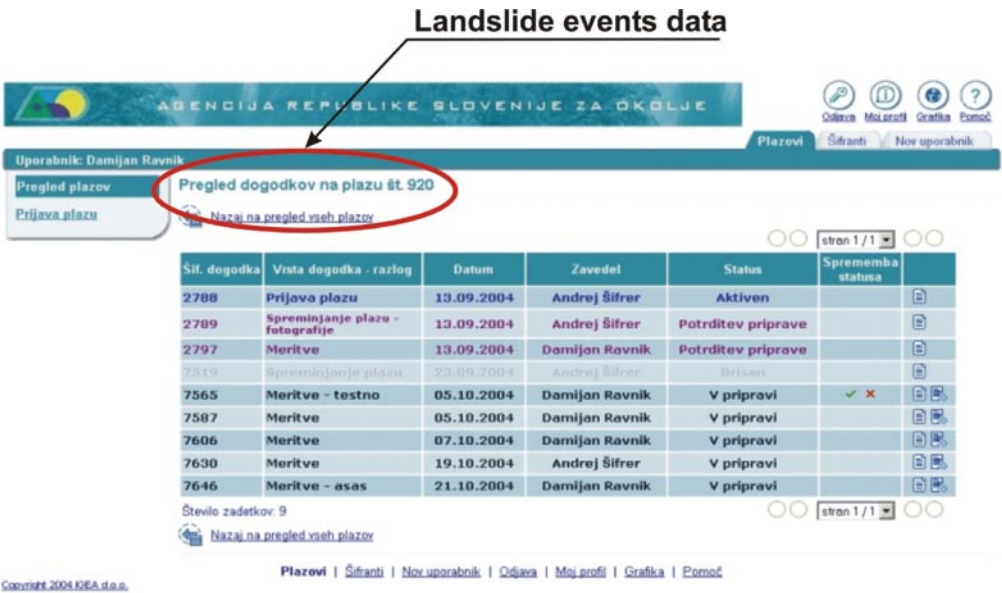


Fig. 5. Overview of the events, related to a given landslide.
Slika 5. Pregled dogodkov, vezanih na posamezen zemeljski plaz.

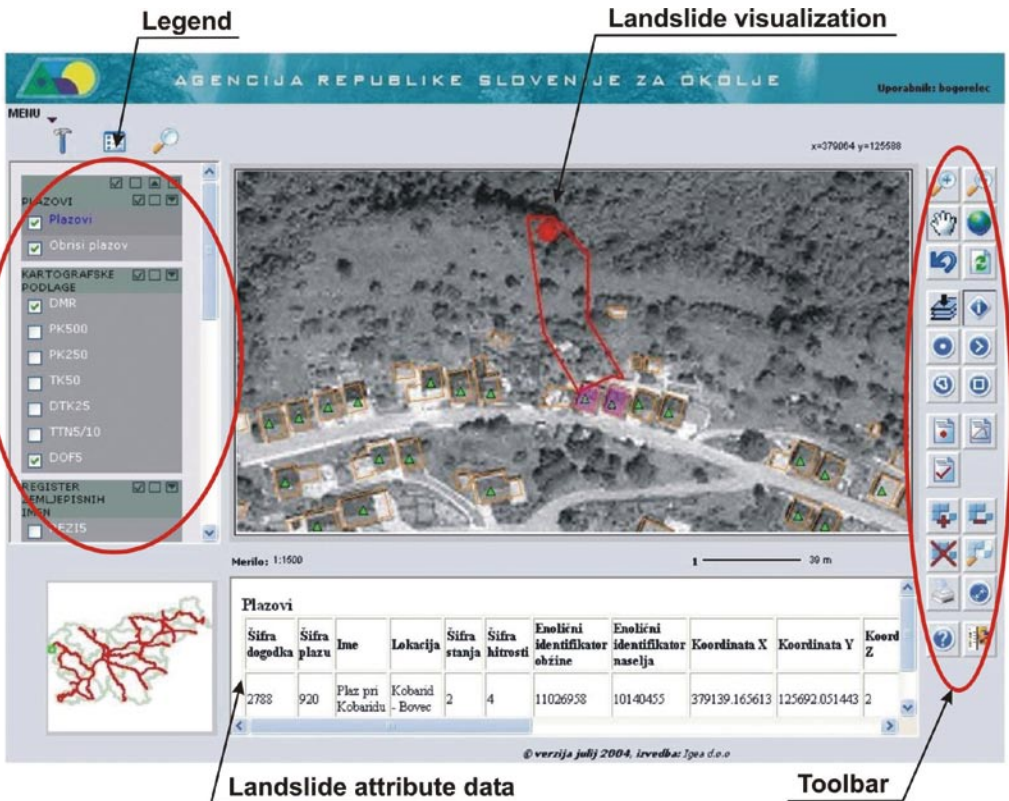


Fig. 6. Spatial module layout.
Slika 6. Izgled grafičnega prikaza podatkov, vezanih na zemeljske plazove.

bar, legend and landslide data (attribute) frame.

The spatial module of the application uses the following graphical layers:

- A) Landslide
 - Landslide – polygon
 - Landslide – point
- B) Cartographic bases
 - Digital terrain model
 - Topographic maps at different scales and orthophoto
- C) Locality names register
- D) Real-estate register
- E) Municipality names register
- F) Infrastructure
- G) Data on URSZR centres and regions

An additional module for surveying landslide occurrence consequences by the users is also available (Fig. 7). It enables the overview and tracking of the damaged objects or objects at risk with detailed description of damage.

Applications supporting the users' work consist of attribute and GIS modules connected to one system. Both modules are based on the multitier internet technology. The attribute module is created with the JSP (Java Server Pages) and runs on the Apache application server with installed Oracle Container for JAVA (OC4J). The GIS WEB module is developed inside of the Delphi environment with the ESRI MapObjects components for GIS. Also the Internet Map

Event ID

Damaged/endangered objects' form

Sifra dogodka: 2788 Vrsta dogodka: Prijava plazu Datum vnosa: 13.09.2004

PODATKI O PLAZU


Poškodovani in ogroženi objekti

ceste stavbe javna infrastruktura zemljišča

	Sifra (SID)	Mesto	Ulica	Opis
	Krajina RO	Občina	Hišna št.	Vrsta
1.	22438733	BREGINJ	BREGINJ	Stanovanjska hiša
	2214	KOBARID	48	
2.	22438734	BREGINJ	BREGINJ	Stanovanjska hiša
	2214	KOBARID	49	

Damaged/endangered objects' list

Poškodbe in ogroženosti na stavbi 22438733

	Opis	Stopnja (%)	Stopnja	Opomba
1.	 Razbita kletna okna	100	Visoka	

Damage

ceste stavbe javna infrastruktura zemljišča

1 - 2 - 3 - 4 - 5 << Nazaj Naprej >> 1 - 2 - 3 - 4 - 5

Zapri okno

Fig. 7. Form for damage or endangered object's description due to landslide occurrence.
Slika 7. Obrazec za opis škode ali ogroženih objektov zaradi pojave zemeljskega plazua.

Server was implemented to support communication between the users and the GIS WEB module. At the user level the thin client in Java supports the GIS functionality.

The system was initially installed at the IGEA company but it was transferred to the Government Centre for Informatics in 2005. It uses the spatial data distribution environment of the Surveying and Mapping Authority of the Republic of Slovenia. The application can only be used with the SIGEN-CA digital certificate.

The initial testing was successful, but it is expected that some modifications and corrections would be necessary to optimise the database.

Conclusion remarks

It is believed that the use of the Slovenian National Landslide DataBase will bring great progress in the quick response to slope mass movement threats and in the field of slope mass movement prevention. Also, many useful scientific results can be achieved on the base of analysis of slope mass movement data. The data, stored in the Landslide DataBase, will serve as the basis for a better understanding of slope mass movements and will help the experts to build better models (simulations) of these natural phenomena. The data, and the results based on these data, will further serve for the production of the geohazard and georisk maps, which will gradually improve towards better prediction levels, with regular updating of the database.

References

APAT, 2007: Italian Landslides Inventory. – APAT – Italian Agency for environmental protection and technical services, Department of soil protection and land resources – Italian Geological Survey. (www.sinanet.apat.it/progettoiffi, 4.11.2007)

BGS, 2007: National Landslide Database. – British Geological Survey. (http://www.bgs.ac.uk/science/physical_hazards/landslides/landslides_database.html, 4.11.2007)

BRGM, 2007: Base de Données Nationales sur les Mouvements de Terrain (BDMvt). – BRGM. (<http://www.bdmvt.net/presentation.asp>, 4.11.2007)

Brown, W. M., Cruden, D. M., & Denison, J. S., 1992. The Directory of the World Landslide Inventory. United States Geological Survey, Open-File Report 92-427, 216 p.

Fajfar, D., Ravnik, D., Ribičič, M., Komac, M. 2005: Slovenian National Landslide DataBase as a solid foundation for the landslide hazard analysis. – V: Abstracts of the Contributions of the EGU General Assembly 2005: Vienna,

Austria, 24–29 April 2005, (Geophysical Research Abstracts, Vol. 7). Katlenburg-Lindau: EGU, 4 str.

GSI, 2007: National Landslide database. – Geological Survey of Ireland. (<http://www.gsi.ie/Programmes/Quaternary+Geotechnical/Landslides/National+Landslide+Database.htm>, 4. 11. 2007).

Guzzetti, F. & Salvati, P. 2003: Flood and landslide fatalities and evaluation of geo-hydrological risk in Italy. – Geophysical Research Abstracts, 5, 03067, European Geophysical Society, 1 p.

Guzzetti, F. & Tonelli, G. 2003: A database of historical information on landslides and floods in Italy. – Geophysical Research Abstracts, 5, 03069, European Geophysical Society, 1 p.

Hegg, Ch. & Fraefel, M. 2005: Flood and landslide damage in Switzerland – distribution, causes and evolution. – Geophysical Research Abstracts, Vol. 7, 04299, European Geosciences Union, 2 p.

ICL, 2006: Database of Landslides of the World. – International Consortium on Landslides. (<http://www2.co-conv.jp/landslide/v2/landslide/simple.php>, 4.11.2007)

ICL, 2007: International Consortium on Landslides. – International Consortium on Landslides. (<http://www.iclhq.org/>, 4.11.2007)

Klingseisen, B., Leopold, P. Tschach, M., 2006: Mapping Landslide Hazards in Austria. – ARC News, Fall 2006, ESRI, pp. 22.

Komac, M., Šinigoj, J., Krivic, M., Kumelj, S., Hribnik, K. 2005: Novelacija in nadgradnja informacijskega sistema o zemeljskih plazovih in vključitev v bazo GIS_UJME : fazno poročilo za leto 2004. Ljubljana: Geološki zavod Slovenije, 50 str.

Petkovič, B. & Marolt, P. 1994: Rezultati študije ogroženosti Republike Slovenije za zemeljskimi plazovi. V: Režun, B. (ur.), Janež, J. (ur.), Trauner, L. (ur.), Špacapan, I. (ur.). Prvo slovensko posvetovanje o zemeljskih plazovih, Idrija, 17. in 18. november 1994. Idrija: Rudnik živega srebra, 21–29.

Ribičič, M., Buser, I., Hobljaj, R. 1994: Digitalno atributna / tabelarična baza zemeljskih plazov Slovenije za terenski zajem podatkov. V: Režun, Bojan (ur.), Janež, Jože (ur.), Trauner, Ludvik (ur.), Špacapan, Igor (ur.). Prvo slovensko posvetovanje o zemeljskih plazovih, Idrija, 17. in 18. november 1994. Idrija: Rudnik živega srebra, 139–153.

Ribičič, M., Komac, M., Mikoš, M., Fajfar, D., Ravnik, D., Gvozdanovič, T., Komel, P., Miklavčič, L., Kosmatin Fras, M. 2006: Novelacija in nadgradnja informacijskega sistema o zemeljskih plazovih in vključitev v bazo GIS_UJME: končno poročilo. Ljubljana: Fakulteta za gradbeništvo in geodezijo, 1 zv. (loč. pag.), ilustr. (http://www.sos112.si/slo/tdocs/zem_plaz_gis_ujme.pdf)

SORS, 2005: Statistične informacije št. 2 – Okolje št. 1. = Statistical Information No. 2 – Environment No. 1. – Statistični urad R Slovenije (Statistical Office of the Republic of Slovenia), Ljubljana.

WP/WLI (International Geotechnical Societies = UNESCO Working Party on World Landslide Inventory), 1990: A suggested method for reporting a landslide. – Bulletin International Association for Engineering Geology, 41, 5–12.

WP/WLI (International Geotechnical Societies=UNESCO Working Party on World Landslide Inventory), 1991: A suggested method for a landslide summary. – Bulletin International Association for Engineering Geology, 43, 101–110.