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GIS BASED MONITORING DATABASE FOR DUBRAČINA RIVER CATCHMENT AREA AS A TOOL FOR MITIGATION AND PREVENTION OF FLASH FLOOD AND EROSION

Ivana Sušanj [1], Nevena Dragičević [2], Barbara Karleuša[3], Nevenka Ožanić[4]

Abstract

In this paper a GIS based monitoring database as a tool for mitigation and prevention of flash flood and erosion impact will be presented. The database is created for Dubračina River catchment area in Vinodol Valley (Croatia) that was chosen for its historical significance of potential hazard development. Information about built hydraulic structures (river network, river regulation..), geological (soil type, erosion and landslide affected areas), land use (types of vegetation coverage, areas used for agriculture..), anthropological (urban areas, traffic infrastructures, illegal waste disposals) and historical data (affected areas in the past, implemented structural and non-structural measures..) will be processed into an organized and correlated information database and map overview. For this purpose the software ArcGis 10.1. will be used.

Keywords

database, Dubračina river, erosion, flash flood, GIS, mitigation and prevention.

1 INTRODUCTION

Hazardous events, natural phenomena that occurs in a populated areas, with consequences such as losses of human life and/or significant material and infrastructure damages, are

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considered to be natural disasters. Same events in uninhabited areas and areas of no interest for people, are not considered to be disasters, and are rarely of any interest for detailed research and implementation of hazard mitigation strategy [1]. In populated areas, it is very hard to separate events as only natural events, in a way to exclude the impact of human activities. The occurrence of hazard phenomena cannot be prevented by humans, but its consequences can be minimized or even intensified depending on the human activities in the area prone to hazards [1]. Debris avalanches, expansive soils, landslides, rock falls, drought, erosion and sedimentation, river flooding, flash flood, mud flows and many more, are all considered to be hazardous events.

The first step in hazard mitigation and prevention strategy should be the determination of the area current condition and its comparison with historical information. The aim and objective of such monitoring database is its continuous development in order to act upon the hazard before its occurrence. In this paper, the emphasis will be given upon problems related with flash flood and erosion hazards, due to its significant impact on Dubračina River catchment area, that is already know as hazard risk area.

Flash flood and erosion can be influenced and initiated by many natural and anthropogenic factors, upon some itis possible to act and mitigate more than others. The occurrence of hazard is usually caused by a combination of different factors that could combined together potentially became triggering factors. Monitoring of changes on researched areas in order to achieve hazard mitigation and prevention is extremely important. Collected data itself is of no or little value if not used and transformed into information that is organized, presented, analysed and interpreted all in one integrated system. Only such a system can be used for different purposes: hazard risk assessment, hazard prediction, urban planning and future development of certain area, etc. [2, 3].

The research conducted on the river Dubračina catchment area within the bilateral Croatian-Japanese project "Risk identification on Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia" will be presented in this paper. The chosen research area is of great significance, withal cultural, natural, geological, hydrological, as well as an area potentially endangered with erosion, landslide and flash flood hazard. For the purpose of further analysis a GIS database was made, with the use of available data from various sources and field research. Also, the worldwide usage of similar GIS databases is presented.

2 IMPORTANCE OF GIS TECHNOLOGY IN HAZARD MONITORING, PREDICTION, PREVENTION AND MITIGATION

In order to accomplish a comprehensive review of the area, what is the subject of this analysis, it is of crucial importance to gather and evaluate all available data and sources. Such data collection can then be called "Database". Analysis and hazard risk assessments should be based upon such overall collected and organized data in order to achieve its accuracy.

The purposes of such database are future possibilities for hazard risk evaluation. For that to be able to accomplished, it is necessary to survey and analyse triggering factors that could lead to hazard event, as well as the elements at risk that could potentially be affected by the occurrence of such phenomena. There is no existing detailed regulation that consolidates these elements in one final list. To do so, it is almost impossible since these factors and elements can vary from one research area to another [2].

This type of database can also be used in the processes of planning, where it is essential that planners are familiar with the wide range of information that would often be dissipate pieces of information, if not put together and arranged properly. The Collection of data is the hardest and very complicated process [1]. Sometimes there are data that have been forgotten, or can only be obtained from older generation of inhabitants. Others are dissipated in many different profit and non-profit agencies that have done some of the research or projects on analysed area. Another very important source of information is the Local Government, but maybe the most important ones are national, regional and local archives [4, 5].

2.1. GIS database in theory

When dealing with the problem that needs to be solved, and with numerous information that as individual are of little value, techniques for managing the information have shown to be very useful in preventing planners mistakes. For such purposes, Geographic information systems (GIS), is often used. GIS is a systematic tool, used for geographic referencing of large number of "layers", that are perceived as information, in order to facilitate the overlaying, quantification, and synthesis of data with the purpose to simplify and focus each specific decision-making task and its processes (Fig. 1) [1]. A part of Geographic information system is geographical information, that is a georeferenced data, processed into a form that is meaningful to the user and as such is of great importance in the decision making process [3].

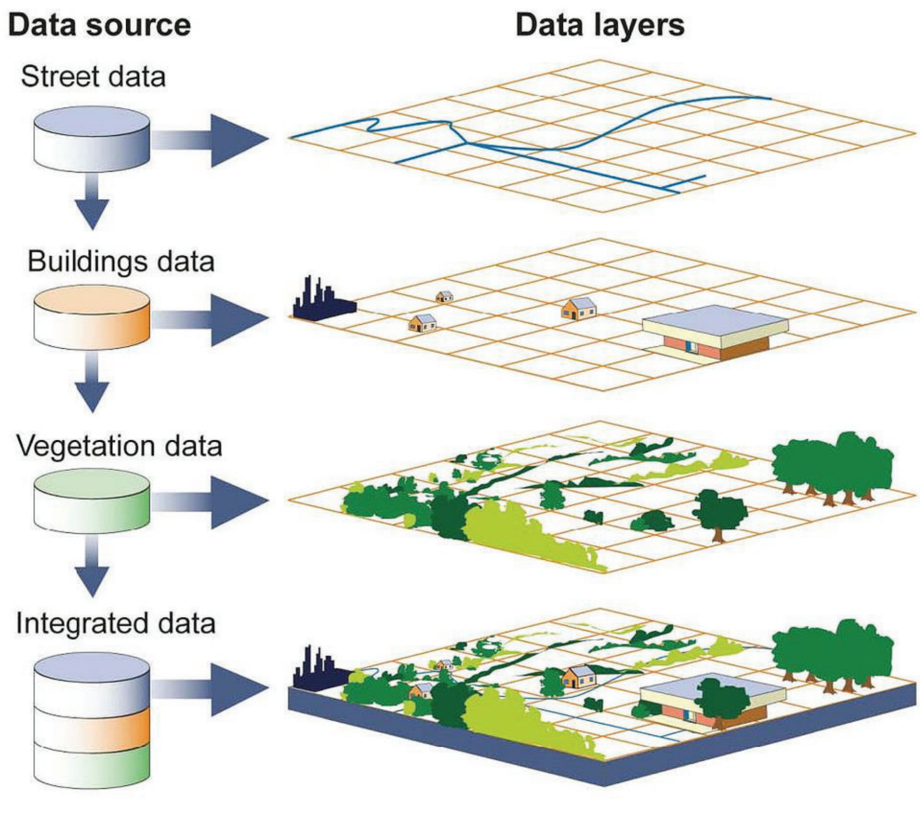


Fig. 1: Geographical information system - GIS „layers" of information [6]

Last few decades, GIS technology has attracted the interest of many disciplines, among ones is civil engineering. Infrastructure management, transportation, land use planning, water resources management, environmental engineering, are just some areas of civil engineering where GIS was found to be very useful (Fig. 2), when implemented. Advantages, like lower costs, improvement of quality, supporting multi-discipline analysis for complex projects, have contributed to its further development, and today, its use is almost obligatory in the processes of solving various civil engineering problems [7].

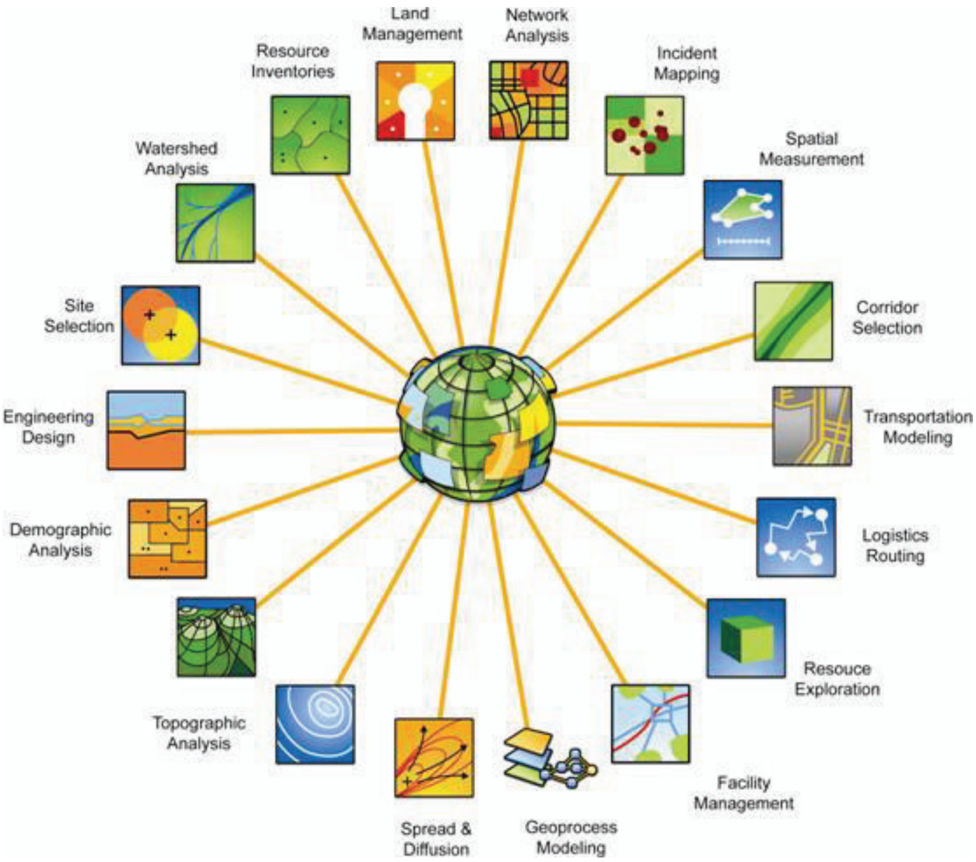
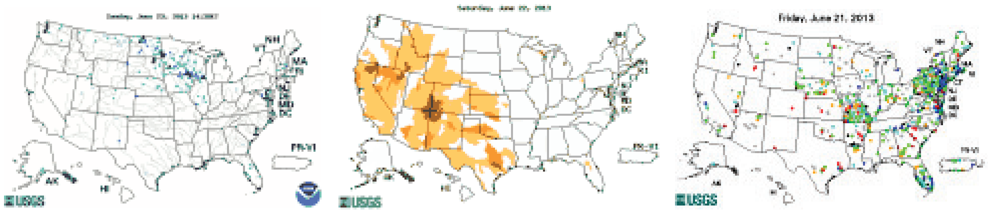


Fig. 2: Implementation of GIS [8]

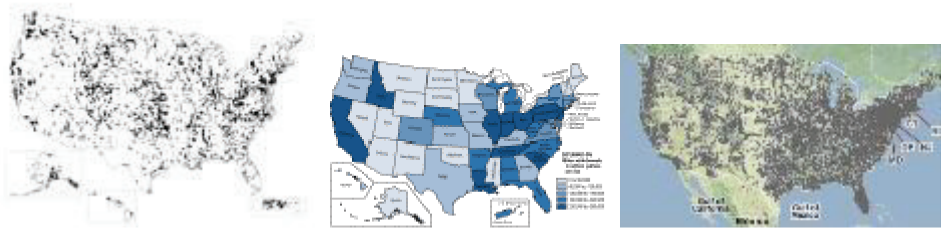
2.1. Worldwide implementation of GIS technology

There are various GIS computer software available that can be used for capturing, storing, checking, integrating, analysing and displaying spatially referenced data about the Earth. Nowadays, GIS is very much used for analyses of past hazard events and applications of disaster risk management measures [9].

An example of databases used for various analyses, projects and for one very important aim – information exchange and public information, is led by The U.S. Geological Survey (USGS) [10]. They collect and synthesize various different groups of information in several databases. For example, water spatial data, groundwater information, watershed maps and spatial data, surface water, water quality, water use, flood maps, etc. Such groups of data are later organized and presented into various forms: as real time water conditions (water level, streamflow, temperature), water alerts (high water levels), real-time streamflow (comparison with historical data), real time flood data, real time drought data, real time groundwater levels, recent groundwater levels, sediment data, National Water Quality Assessment, Water use in the United States, Annual water data reports, etc. (Fig. 3) [10]. Further use of this kind of data has no limits and it only depends upon the need of the society and the imagination of the researcher.



a) FLOOD DATA b) DROUGHT DATA c) GROUNDWATER LEVELS



d) SEDIMENT DATA e) WATER USE f) WATER ALERT

Fig. 3: Information as result of organized database by USGS [10]

Debris flow can be initiated by any factors, such as loose sediment, torrential rainfall and topographic conditions. Those data, among many others (topographic humidity index, sediment transport capacity index, elevation-relief ratio, form factor, effective basin area, slope gradient) were collected as input data for GIS database, used for identification of topographic features and conditions favourable for initiation of debris-flow. This analysis was made for the area of total 11 river catchment areas in northern and central Taiwan [11].
In Japan, the study whose aim is determination of the frequent distribution of knickzones in bedrock rivers (Fig. 4) throughout Japanese mountainous areas, was based on various topographic, climatic and geological data (topographic maps, water flow direction, drainage area, stream networks, slope angles, geological units, annual precipitation, elevation, etc.) and implemented in GIS surrounding [12].

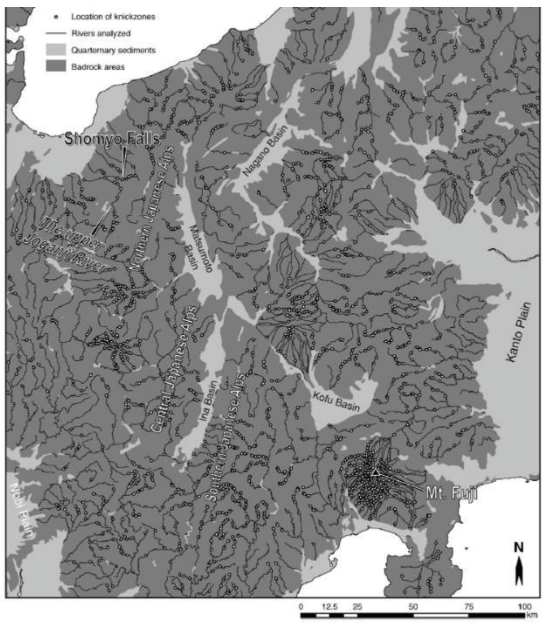


Fig. 4: Knickzone distribution in central Japan [12]

Another example of database was made for ACF Disaster Risk Reduction (DRR) and implemented in Philippines provinces: Camarines Sur and Catanduanes. Its final objective was to reduce population`s vulnerability to natural disasters. The main use of GIS in this project was based on multi-hazard mapping in two provinces that contains information like magnitude, frequency of hazard as well as affected areas [9].
Due to several severe storm flood events, that caused hundreds of people to evacuate from their homes in the Yerba Buena and Tucuman in Argentina, urban flood hazard assessment was made using GIS technology as a base for multi-criteria analysis [13].
In south-eastern Egypt, the development of mining activities and domestic infrastructures, caused the need for more precise knowledge about flash flood hazard in the area. GIS was used as a base database and latter for estimation about the amount of the surface runoff and the magnitude of flash floods [14].
There are numerous researches done around the world using GIS technology. Although, this technology exists for several decades, its full potential is jet to be discovered and implemented.

3 RESEARCH AREA: DUBRAČINA RIVER CHATCHMENT AREA

Vinodol Valley is a unique spatial entity situated between Križišće in the north-west, Novi Vinodolski in the south-east and the coast alongside the Vinodol channel (Fig. 5). It's characterized by extremely asymmetrical cross section in the most part, with a north-eastern slope that is distinctly shorter and steeper than a south-western slope. Riverbeds of its two main watercourses Dubračina and Suha Ričina Novljanska are located at the lowest elevations of Vinodol Valley, but for this research Dubračina River catchment area is chosen.

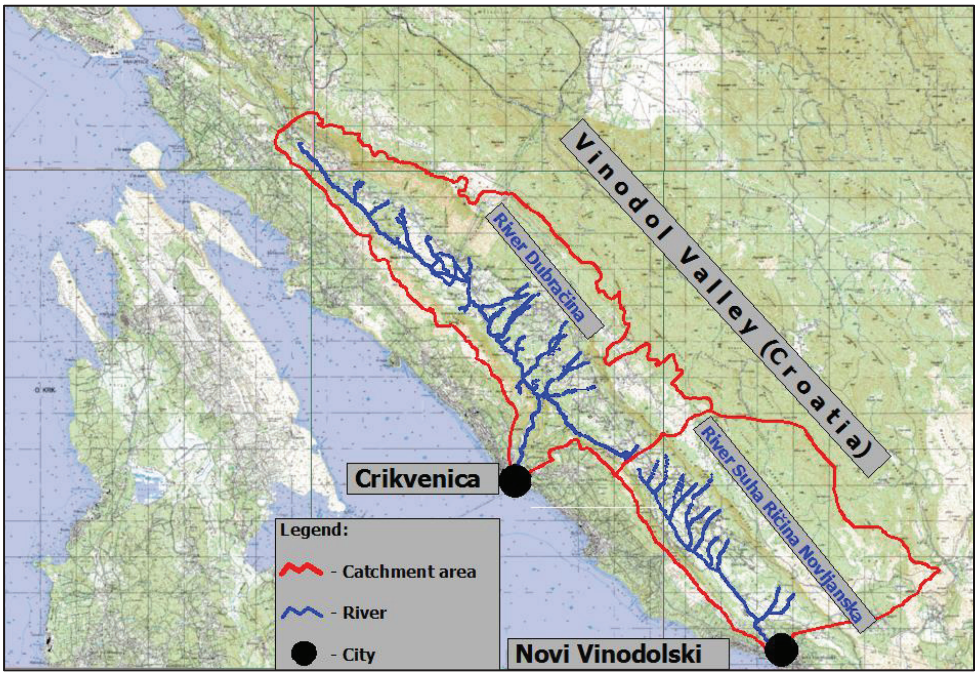


Fig. 5: Location of Dubračina and Suha Ričina Novljanska rivers catchment areas [15]

The composition of the soil in the area of the Vinodol Valley is very complex and consists of a many different lithological layers. Deposits from Cretaceous and Paleogene periods are litificated and they form carbonate sedimentary rocks of a clastic type (Fig. 6). Sediments that are partially or fully covering the older bedrocks are from younger Pliocene and Quaternary Period. Rocks from Cretaceous Period are from the Upper Cretaceous Epoch: Cenomanian-Turonian (K21, 2) and Turon-Senonian (K22, 3). The rest of the sedimentary rocks are from Paleogene Epoch: Paleocene to Lower Eocene (PCE1), Middle Eocene (E2), Middle-Upper Eocene (E2, 3) and the Upper Eocene-Lower Oligocene (E3O1) [16].

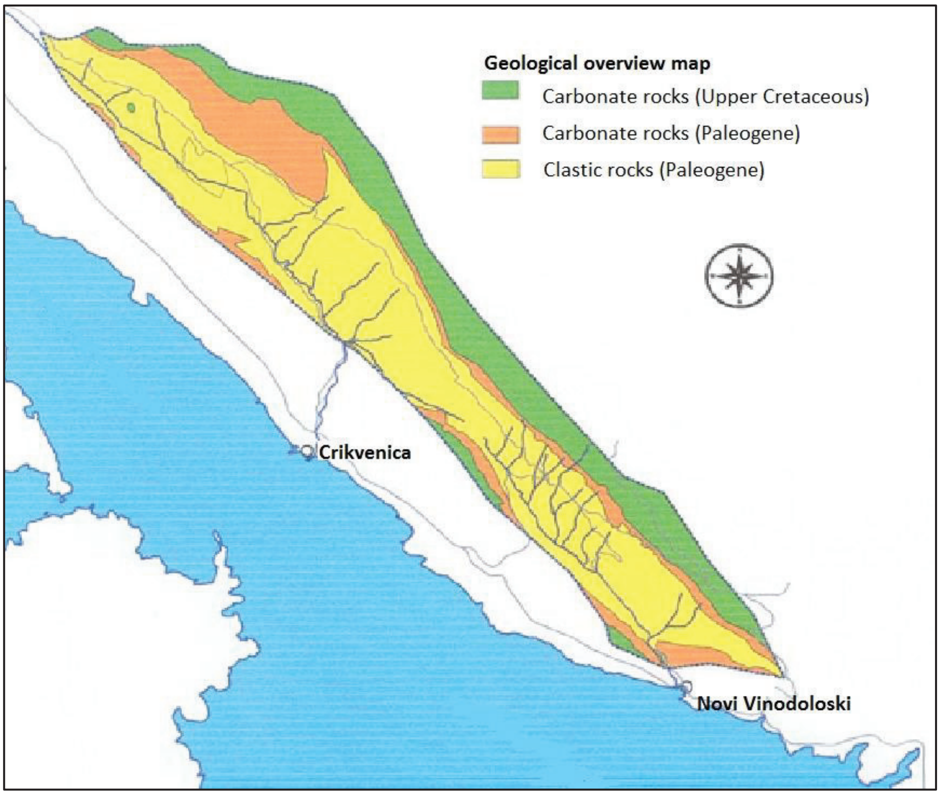


Fig. 6: Geological overview map of Vinodol Valley [17]

Because of its complex geological structure and special valley cross section with distinct steep slopes affected by erosion, local landslides and torrents this area has been known for many years as an area of potential hazard risk. Many elements in this area are considered to be of exceptional natural and cultural value, and as such, Vinodol Valley bears the title „Area of special significance for Primorsko – Goranska County".

Dubračina River main watercourse in the central part of Vinodol Valley, it gathers waters from its many tributaries (Duboki, Bronac, Cigančica, Sušik, Slani potok, Mala Dubračina, etc.) of which most have torrential characteristics, and ends in the sea at the very centre of Town Crikvenica. Dubračina River catchment area is situated in the central part of Vinodol Valley. On the catchment area many springs and river tributaries form very well distributed river network on north-eastern slopes of Vinodol Valley. Because, the most affected areas with erosion, landslides and torrential flow, within the Vinodol Valley, are located on Dubračina River catchment area, this area has been chosen as a research area. Its sub-catchment areas of tributaries Slani Potok and neighbouring Mala Dubračina stand out as most affected ones (Fig. 7). Slani Potok catchment area is, as mentioned before, an example of the combined erosion, landslides and torrential impacts. Its surface is affected by excessive erosion that covers the area of 600 m in length and 250 m in width. The side effects, alongside the erosion affected areas are landslides, formed as a result of weathering of the flysh rock complex that is specific for this area [18, 19]. The overall size of affected area is approximately 3 km² causing potential hazard risk for its surrounding settlements Belgrad, Baretići, Grižane and Kamenjak as well as roads. Similar problems can also be found on the catchment area of river tributary Mala Dubračina. Unfortunately, roads and houses affected by local landslides and erosion processes can be found along the entire area of Vinodol Valley.

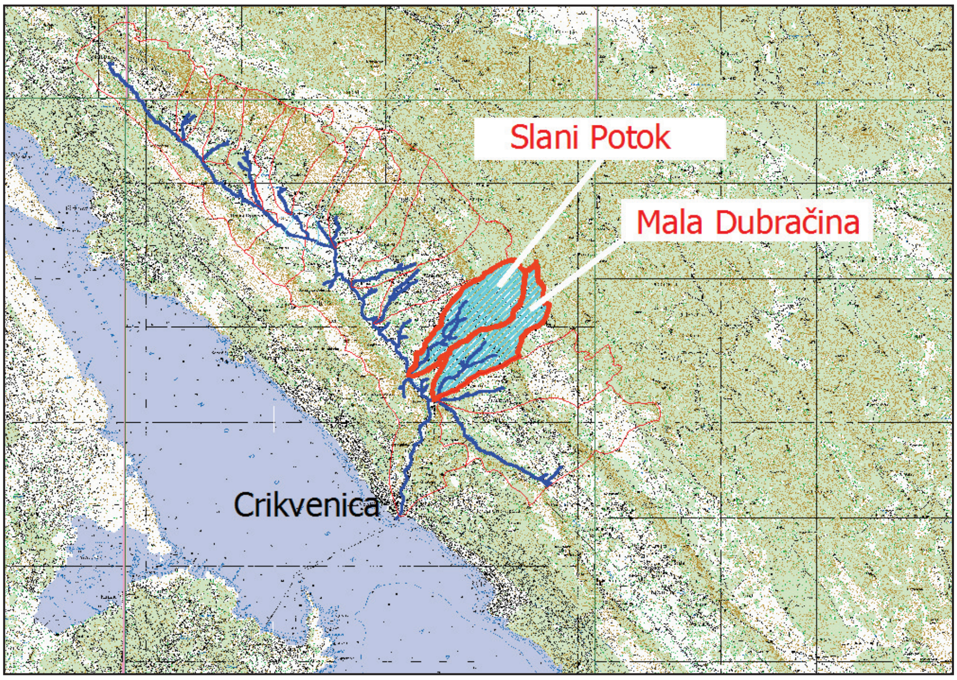


Fig. 7: Most affected areas: Catchment area of Slani Potok and Mala Dubračina [20]

For erosion affected areas, local landslides and torrents, reconstruction projects (roads, riverbed regulations, retaining walls, etc.), as well as geological and hydro-geological research have been performed many times in the last hundred years, especially the ones for the areas of Slani Potok and Mala Dubračina [21, 22]. Unfortunately, without positive outcome and with no prospect in finding the permanent solution of existing problems.

One of the main problems is the loss of some research documentations and projects along the years. Another problem is that data from existing documentation in some parts of the catchment does not correspond to existing data and state identified directly in the field. Also, maps showing roads, rivers, cities and villages are out of date and do not represent the current condition, but can be used for comparison with new data for progress of erosion, occurrence or expansion of landslides and torrent affected areas.

In this paper a GIS based monitoring database as a tool for monitoring, mitigation and prevention of flash flood and erosion impact is presented. The database is created for Dubračina River catchment area in Vinodol Valley (Croatia), which is included in the bilateral Croatian-Japanese research project "Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia" and was chosen for its historical significance of potential hazard development.

3.1. Methodology and data

The final aim of this research is to synthesize existing data and problems in the area of interest. Its first step was gathering of the available information and documentation. At the very early stage of the research, problem with data collection became obvious. Some of data from previous projects and documentation have been lost during the years, and also most of existing and available data is outdated. For this reason, as well as for dissipation of existing information sources, it was impossible to determine the current condition of the river tributaries, catchment areas and their risk of potential hazard. Base maps (Topographic maps, Digital Elevation maps, Ortophoto maps, etc.) are out of date and do not entirely present the current condition in the field (such as riverbed position, changes of road routes, spreading of cities and villages, etc.). For this reason, and in order to obtain more accurate data, the database was complemented with on-site field survey. For the purpose of determination of current area condition, steps of research were established and this paper provides the proposition of the methodology that was used for the determination of current area condition, developed on Dubračina River catchment area, that encompasses several steps of essential research work needed in order to achieve the final aim.

This most essential part of the research is divided into four main groups: collection of existing data, field research, classification and presentation of data which can be seen in Table 1.

Tab. 1: Steps of research divided into main four groups

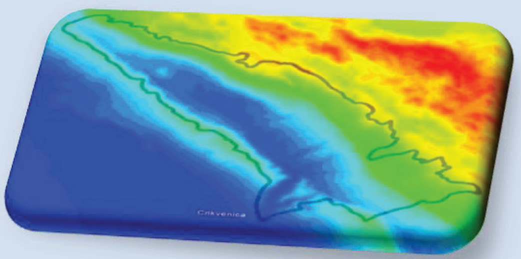
Collection of existing data
• Maps: (Scale 1:2500, Orthophoto, Regional Development Plan, Topographic, etc.) • Photography: Old photos • Reconstruction projects for damaged roads, riverbeds, culverts caused by erosion, landslides or torrents • Research studies: Geotechnical, Geological, Hydro-Geological, etc. • Interviewing people: local population involvement through interviews and public discussions • National, regional and local archives (old photos, newspapers, books, etc.)
Field research
• Filling the prepared form for descriptive evaluation for each river Dubračina tributary and its catchment area in the field. • Photo documentation: Photographing all the tributaries, hydraulic structures and catchment area conditions (April 2013.)
Classification of data
• Organizing into the groups (hydraulic, geological, land use, anthropological and historical data) • Collected data verification (comparison of the collected and existing data) • Overlapping of collected data
Presentation of data
• Database and map overview in the software ArcGis 10.1. • Map overview with photo documentation that has easy access to the all relevant information • Attribute table for every inputted object

Preparation of the database and map overview with photo documentation is a first step and probably the most important step towards the development of a detailed database, which requires constant growth and upgrade in the upcoming years.

3.2. Information GIS database for research area Dubračina river catchment area

Database with organized and correlated information is made in the software Arc Gis 10.1. Information such as hydraulic (river network, river regulation, etc.), geological (soil type, erosion and landslides affected areas), land use (types of vegetation coverage, areas used for agriculture, etc.), anthropological (urban areas, traffic infrastructures, illegal waste disposals) and historical data (affected areas in past, implemented structural and non-structural measures) are processed into a database for the purpose of the flash flood and erosion analysis.
The collected data can be divided into two main groups: existing data and new data (obtained by field overview) after which these data was classified into sub-groups (hydraulic, geological, land use, anthropological and historical data) and incorporated into the ArcGis database and map overview with photo documentation. Examples of incorporated data within layers in ArcGis are presented in tables (Tab. 2 and Tab. 3).

Tab. 2: Examples of existing data incorporated within database

	PRESENTATION OF DATA IN ArcGis	TYPE OF DATA	DESCRIPTION OF DATA
EXISTING DATA		Base map	Layer consisting of Croatian Topographic Maps with Dubračina river catchment area (orange area - research area) Scale 1:25000
		Base map	Layer consisting of Elevation raster map conducted from Digital Elevation Map with Dubračina river catchment area

Tab. 3: Examples of new data incorporated within database

	PRESENTATION OF DATA IN ArcGis	TYPE OF DATA	DESCRIPTION OF DATA
NEW DATA		Hydraulic	Layer consisting of springs (blue points), river network (blue lines) and lakes (light blue area) obtained from existing river network map that is revised to the current condition after field research (displacement of the riverbed, occurrence or disappearance of riverbeds…) with Dubračina river catchment area and tributaries catchment area
		Hydraulic	Layer consisting of river network (blue lines) and lakes (light blue area) obtained from existing river network map that is revised to the current condition and all hydraulic objects (riverbed regulations, embankments and culverts...) after field research with Dubračina river catchment area
		Geotechnical	Layer consisting of river network (blue lines) and lakes (light blue area) obtained from existing river network map that is revised to the current condition and all places where erosion or landslides caused road damage (red car symbols)

For the purpose of creating a detailed data base on which is possible to apply analyses such as assessment of current condition, hazards risks or their prediction, it was necessary to combine available data for each element, in a form of attributes arranged in multiple tables. Examples of such attributes for the group of objects are: Name, Length (m), Area (m^2), Building material, Geometrical shape, Condition of object, Photo documentation, etc. Most important attributes among mentioned ones, are Condition of the object and Photo documentation because they are showing current condition of the researched area. To provide uniform evaluation of condition for different groups of objects (for example: Culverts, Riverbed, Springs, etc.) simple descriptive attributes were assigned for each group element, along with its numeric value. An example of such ranking can be seen in Table (Tab.4).

Tab. 4: Example of descriptive evaluation with assigned number values for condition of culverts

NUMERIC VALUE	Description of the culvert condition
5	Excellent condition: no need of any reconstruction, the flow is not disturbed by any obstacles
4	Very good condition: traces of sediment transportation, the flow is not disturbed by described obstacles
3	Good condition: evident sediment transportation, the flow is potentially enabled by described obstacles
2	Poor condition: large amount of sediment transportation, vegetation inside of culvert, the flow is partially enabled by described obstacles
1	Very poor: culvert is full of sediment, the flow is fully enabled by described obstacles

Among all, during the field research, photo documentation of each structure was made and later implemented in the attribute table providing the user quick and easy insight of its condition. Example of attribute table for one culvert object is shown in Figure 8.

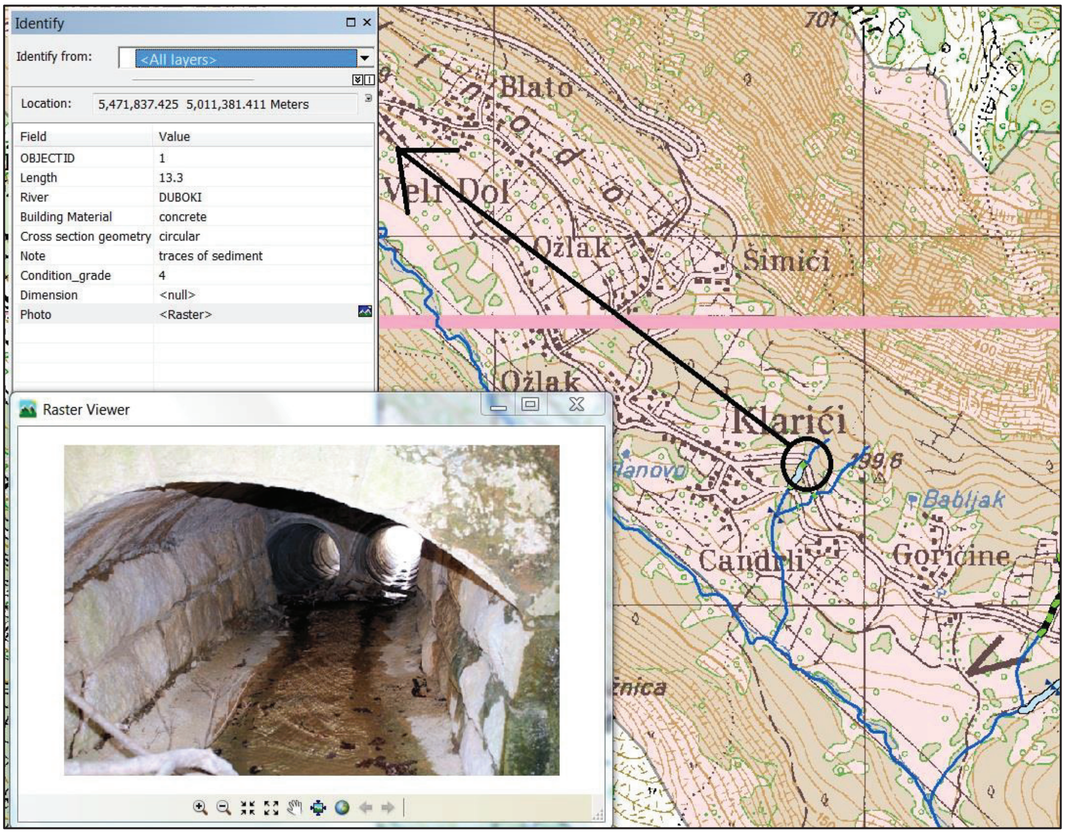


Fig. 8: Example of attribute table with photo documentation for culvert

4 DISCUSSION/CONCLUSION

Because of its complex geological structure and distinct steep slopes, significant natural and cultural values, as well as existing problems with erosion, landslides and torrential flow, Dubračina river catchment area was chosen as research area and area of potential risk hazard, upon which an integrated database was made.

In the past there were many existing data, but thought the years many of them had been scattered, forgotten or even lost, and some of remained data are not up to date, which is why all data integration was necessary. Among them, the most important ones could be divided into hydraulic, geological, land use, anthropological and historical groups of data. Preliminary research that was consisted of gathering existing information, projects from numerous sources (local government, archives, local and regional newspaper, field work and overview, information exchange and interview with local population, etc.) were all processed into an organized and correlated information database and map overview. This database as any other requires constant growth and upgrade in the upcoming years, in order for it to be up to date and available to the wider range of final users.

Long-term monitoring will lead to the improvement of hazard risk assessment, and future decision making processes regarding implementation of mitigation and prevention measures. Continuity in monitoring will enable future comparison between past, present and future on site conditions, and provide better evaluation of conducted measures and changes in the area, as well as its positive and even negative side effects. This will allow future decision makers experts and planners better evaluation and selection of planed actions for Dubračina River catchment area, whether it regards urban development (water supply system, transportation systems, city and village's growth, industrial infrastructure etc.), hazard (mitigation and prevention measures), agricultural development (selection of area that pose minimum risk of hazard, definition and recommendation of allowed actions toward sustainable agriculture and hazard prevention, selection of culture for future growth, etc.), or any other implementation depending on the final user's needs.

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