Remote Sensing and Geographic Information System/Geodatabase in River Flood Mapping

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***Abstract*-Natural disasters drastically affect the Earth's inhabitants, causes loss of life, injuries, and damage or loss of valuable goods, such as buildings, communication systems, agricultural lands, forests, and natural environments. The economic losses resulting from natural disasters have shown an increase of scale as society undergoes globalization.**

There is no doubt that natural disasters need to minimize any possible risks. This makes it necessary to collect appropriate data through the monitoring process. In conformity with selected method and methodology, one must determine what kind of information is required for vital success in managing natural disasters and their consequences.

Satellite data accessed by Remote Sensing is an excellent tool for natural disaster management purposes. Up to date technology achievements in space science and technology are making it possible to use a large number of multi-temporal spatial data for prevent, preparedness, and forecasting of natural disasters after appropriate data processing stages. During the last decades, the Remote Sensing method has become the best operational instrument for disaster preparedness and warning phases, including the disaster of floods. Using data from the Remote Sensing method is not possible without a proper tool to handle the large amount of data and combine it with data from different sources, such as maps, measurement stations, or field data. Therefore, Remote Sensing applications integrated into Geographic Information Systems (GIS) have become increasingly important for disaster management processes.

This paper is dedicated to build up a geodatabase for natural disaster management, mainly focusing on river flood impact, using Remote Sensing data and GIS. For this reason, a digital map of the selected Salyan plain area has been developed. The map development was very important due to the lack of such information before the study. This circumstance eliminates further implementations concerning the assessment of ecological, environmental, and other related aspects.

For this purpose, the current stage has provided vectorisation of the boundaries of the area. The paper describes of method of approach in boundary definition and identification. This was achieved with the use of ArcGIS software within the data processing of space images, with further development of GIS technology. The use of indicated data processing has made possible to classify bounders with high accuracy.

In conformity with methods for space image processing with GIS performance, maps have been developed that are integrated into classes of flood, hydrological points, 3D, and the Digital Elevation Model of the area.

Keywords- Natural Disasters; Data Source; Features; Space Image Processing; River Flood; Digital Elevation Model (DEM); 3D; Remote Sensing (RS); Geographic Information System (GIS); Global Positioning System (GPS); ArcGIS; Geodatabase

I. INTRODUCTION

An assessment of environmental consequences makes it necessary to integrate multidisciplinary knowledge from environmental science, ecology, geography, biology, and Earth studies. It is the field of study for evaluating the risks associated with a possible eco-environmental hazard under any existing uncertainties. Modern technologies for risk assessment include Remote Sensing and Geographic Information System; they allow scientists to predict, analyse, and evaluate the damage from disasters or accidents and may help protect the ecosystem. Ecological risk assessment aims to provide risk management in a large scale [1, 2], which is very important for appropriate state authors in decision-making process.

There are a number of typical natural disasters occurring in Azerbaijan: landslide, river flood, earthquake, and mud volcanoes. Obviously, these cause huge economic and social infrastructure damages. They demand the development of a system of timely natural disaster monitoring and assessment. By developing and successfully executing a well-planned disaster mitigation strategy, economic losses and other casualties can be create a best bases for reducing natural disaster consequences.

There is no doubt that Remote Sensing and Geographic Information System are integral instruments of disaster management strategy and implementation plan development. It is computer-based system makes available to store and manage information through developed Geographic Information System depends of task needed to be undertaken during problem solving. Remote Sensing collects large scale of information (geographic and environmental) based on space-borne and airborne facilities. An integration of Remote Sensing data into the Geographic Information System is an effective tool for monitoring, assessment, and development for further natural disaster forecasting.

Natural disasters can be successfully mitigated if detailed information is accessed that is relevant to the expected frequency, character, and magnitude of hazardous events [3-5].

Much of the information that is needed in natural disaster management has an important spatial component. Spatial data is the data with a geographic component, such as maps, aerial photography, satellite imagery, Geographic Positioning System (GPS) data, rainfall data, borehole data, etc. Nowadays, people can access information with gathering and organising technologies like Remote Sensing and GIS:

- Remote Sensing and GIS provide a database that can interpret and combine evidence from previous disasters to arrive at hazard maps that consider potentially dangerous areas;
- Many types of disasters, such as floods, drought, volcanic, etc., will have certain precursors. Satellites can detect the early stages of these events as anomalies in a time series. Images are available at regular short time intervals and can be used to predict both rapid and slow disasters;
- In case disaster occurs, the speed of information collection from air and space-borne platforms and the possibility of information dissemination with a matching swiftness make it possible to monitor the occurrence of the disaster;
- In the disaster relief phase, GIS is extremely useful in combination with GPS in search and rescue operations in areas that have been devastated and where it is difficult to orientate. Remote sensing can assist in damage assessment and aftermath monitoring, providing a quantitative base for relief operations.

In the disaster rehabilitation phase, GIS is used to organize the damage information and the post-disaster census information, so sites for reconstruction can be evaluated. Remote Sensing is used to map the new situation and update the databases used for are reconstruction and can help to prevent such a disaster from occurring again.

II. CREATION OF GEODATABASE AND GIS SPATIAL DATA DIGITALIZATION

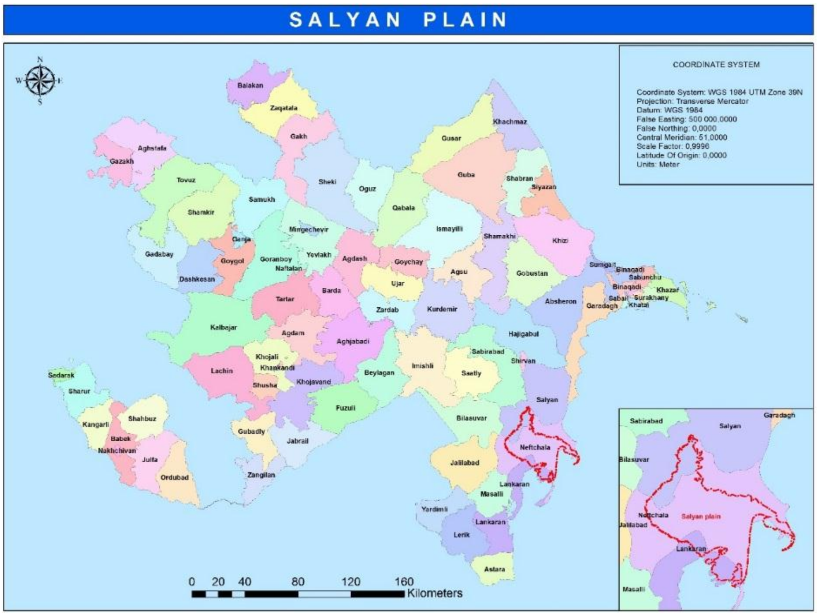
A geodatabase is a store of spatial and attributive data. A geodatabase supports all kinds of data, including attribute data, features (geographical layers), satellite and aerial imagery (as raster and vector data), land surface modelling or 3D data, network systems, and field measurements; it can also be used by ArcGIS in data processing. Storing GIS data in the geodatabase improves database management. The geodatabase is implemented as either a collection of files in a file system or as a collection of tables stored within a relational database management system.

The following are some advantages to creating a geodatabase:

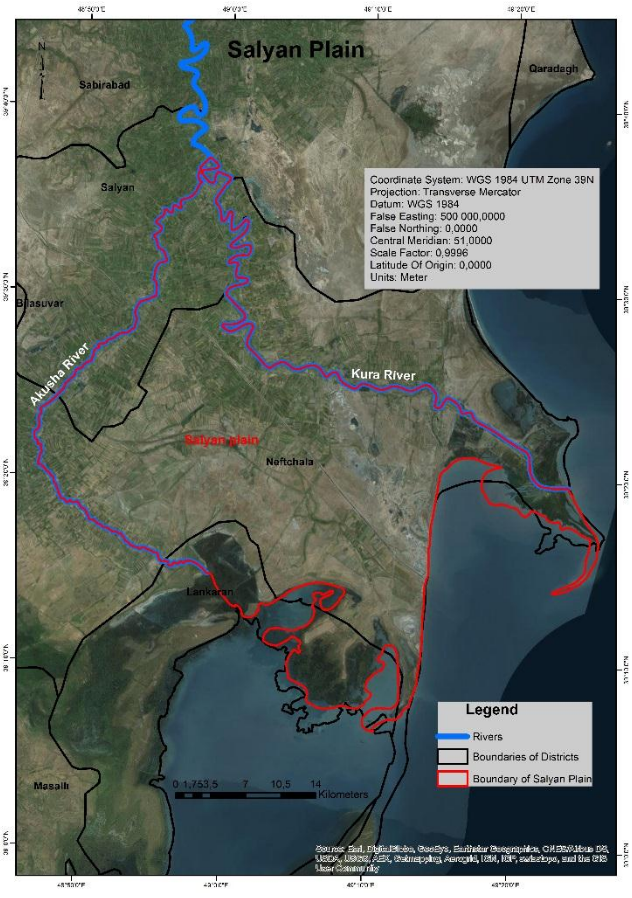
- ➢ The geodatabase is integrated into the spatial system;
- ➢ All geographical data can be stored and managed centrally by a one database;
- ➢ Data input and edition are accurate and errors can be prevented, defined, and changed during the edition by use of an appropriate operation;
- ➢ Data stores in the database can be defined links with other data;
- ➢ The use of large numbers of data allows the development of good quality maps;
- ➢ Data collection can continuously be done;
- ➢ Several users can edit, input, and transfer data at the same time;
- ➢ Dynamic changes of the process can be defined.

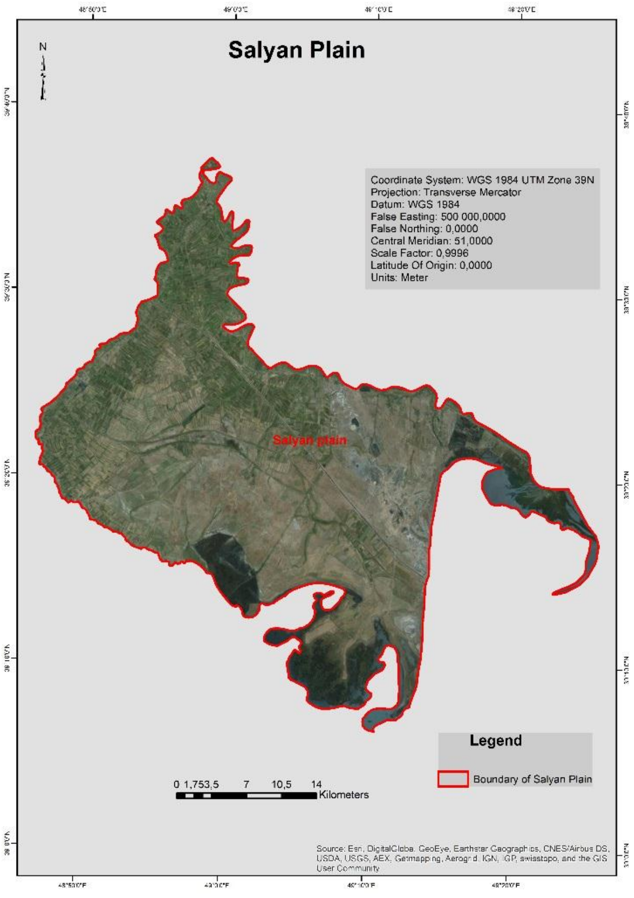
One of Azerbaijan's plains, the Salyan plain, has been selected as the study area. It is situated on the downstream of the Kura River and is constantly exposed to flooding. The Salyan plain is located on the right side of the Kura River and occupies the area from the converging of the Kura and Akusha rivers to the Caspian Sea [6]. The plain is below the World ocean level (the maximum -12.2 m and minimum of -30.59 m). The Salyan plain is surrounded by the South-East Shirvan plain and the North Mughan plain from the north-west, the West Lankaran lowland from the south, and the Caspian Sea from the east.

As the precise boundaries of the plains in Azerbaijan have never been developed, the selected area for study is variously illustrated in different data sources. But the location of the Salyan plain with the particular existing boundary (e.g. one side with the Akusha River, the other side with the Kura River and Caspian Sea) facilitates to vectorize the boundary of the plain. Therefore, the boundary of the Salyan plain has been vectorized more accurately through the ArcGIS software application with the use of high-resolution aerial imagery (Fig. 1 a, b and c). As a result, at present the plain area has been determined more accurately than previously. This is very important segment in future investigations.



a





b c

Fig. 1 Delineation of neighbouring areas and vectorization of Salyan plain

III. GEODATABASE DEVELOPMENT

A geographical area where the Kura River flows in the central part of the Salyan district within the Salyan plain boundary has been selected for development of the geodatabase (Fig. 2). The area comprises approximately 24 km^2. The Kura watershed is one of Azerbaijan's most important agricultural production areas. During the last 10 years, it was affected by 5 excessive floods, causing a lot of damage to people and goods. One of the major sources of Azerbaijan freshwater is the Kura River [7].

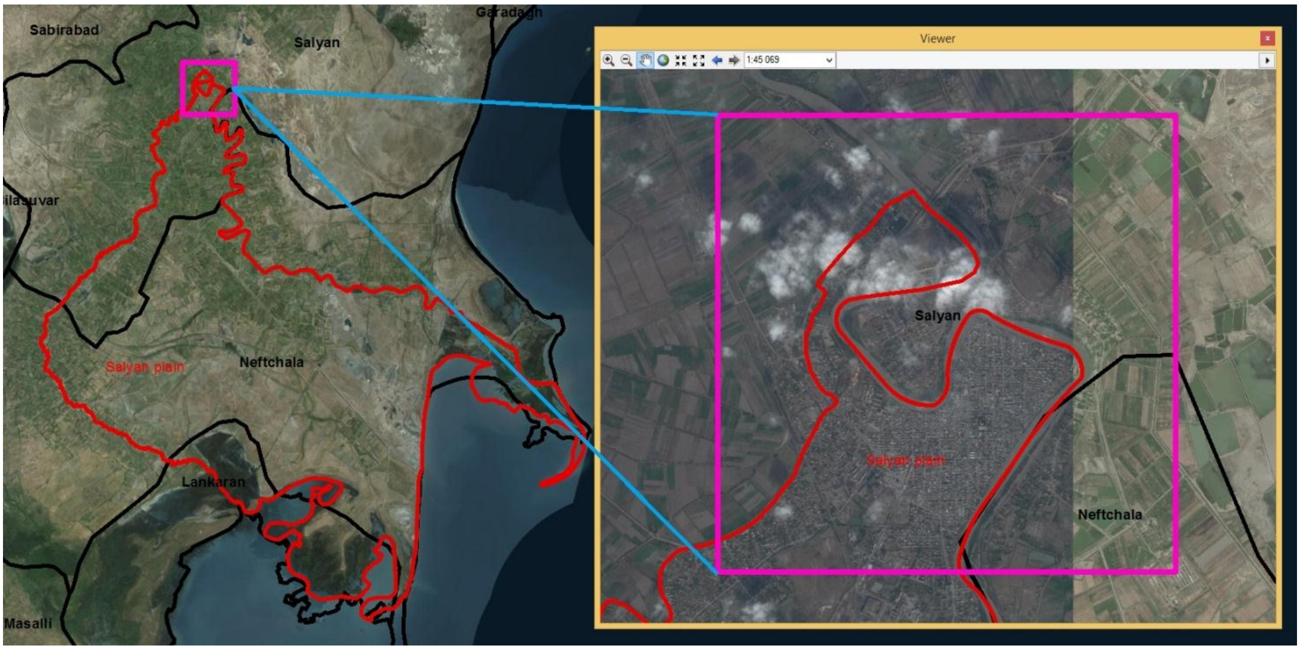


Fig. 2 Geographical point of interest in the centre of Salyan district

IV. METHOD OF APPLICATION

ALOS imagery was acquired 10 June 2007. The image was georeferenced to UTM zone 39 North, WGS84, using a first degree polynomial rectification algorithm with 30 ground control points (GCPs) extracted from a digitized topographic map at the scale of 1:100 000. The root mean square (RMS) error was equal to 0.5 pixels (5 m).

The image was classified between follow general classes (Fig. 3):

- Urban or Built-up Land
- Agricultural Land
- Garden
- Scrub
- Open area
- River
- Stream
- Canal
- Road
- Railroad

One Landsat Enhanced Thematic Mapper (ETM) satellite image from June 2000 (path 167, row 32) was selected for analysing. This image was also georeferenced to UTM zone 39 North, WGS84, using a first degree polynomial rectification algorithm with 25 ground control points (GCPs), extracted from a digitized topographic map at the scale of 1:100 000. The image pixels were resampled to 28.5 x 28.5 m using the nearest-neighbour interpolation method to preserve radiometric integrity. The root mean square (RMS) error obtained in the rectification process was less than 1 pixel (28.5 m).

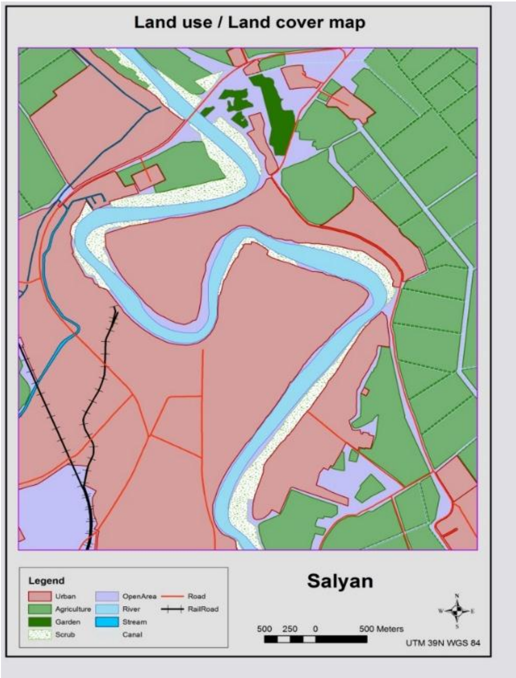


Fig. 3 Land use/Land cover map

A. Tasseled Cap Transformation

A tasseled cap transformation was applied to this image to optimize data viewing (Fig. 4). The tasseled cap transformation offers three types of data structure axes that can be used to define vegetation content information:

Brightness: a weighted sum of all bands defined in the direction of the principal; variation in soil reflectance.

Greenness: orthogonal to brightness, a contrast between the near-infrared and visible bands that strongly related to the amount of green vegetation in the scene.

Wetness: relates to canopy and soil moisture and effective to discriminate wet areas.

The tasseled cap algorithm, using coefficients for ETM imagery, are:

The first Landsat-7 image was converted to at-satellite radiance using Eq. (1),

$$L_{sat} = \frac{L_{\max sat} - L_{\min sat}}{DN_{\max} - DN_{\min}} \cdot \left(DN - DN_{\min} \right) + L_{\min sat} \tag{1}$$

where,

$L_{\max sat}$ – is the band-specific spectral radiance scaled to $DN_{\max}$ (W/(m2*ster*μm),

$L_{\min sat}$ – is the band-specific spectral radiance scaled to $DN_{\min}$ (W/(m2*ster*μm),

$DN_{\max}$ – is the maximum quantized calibrated digital number (255), and

$DN_{\min}$ – is the minimum-quantized calibrated digital number (0 for LPGS data, 1 for NLAPS data).

Eq. (1) accounts for the gain state (i.e., high/low setting) by using respective published LMIN/LMAX values (Landsat 7 Science Data User's Handbook).

After conversion to at-satellite radiance, the image was exposed to Tasseled Cap transformation. The Tasseled Cap operation (also known as Kauth's Tasseled Cap) computes the three Kauth biophysical indices (greenness, brightness, and wetness) from raster objects that contain the six spectral bands of ETM imagery: ETM1, ETM2, ETM3, ETM4, ETM5, and ETM7. This spectral information is translated into values that represent a site's biophysical properties. The process produces three output raster objects that represent greenness, brightness, and wetness using a set of linear combinations of Landsat ETM spectral bands. Output is generated according to the following formulas:

Brightness = 0.3561(ETM1) + 0.3972(ETM2) + 0.3904 (ETM3) + 0.6966 (ETM4) + 0.2286 (ETM5) + 0.1596 (ETM7)

Greenness = -0.3344 (ETM1) - 0.3544 (ETM2) - 0.4556 (ETM3) + 0.6966 (ETM4) - 0.0242 (ETM5) - 0.2630 (ETM7)

Wetness = 0.2626 (ETM1) + 0.2141 (ETM2) + 0.0926 (ETM3) + 0.0656 (ETM4) - 0.7629 (ETM5) - 0.5388 (ETM7)

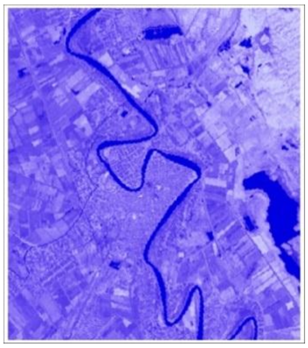
		
RGB COMPOSITE WITH BANDS 5,4,3	**RGB COMPOSITE WITH LAYERS BRIGHTNESS, GREENNESS, AND WETNESS**	**PSEUDO COLOR COMPOSITE WITH WETNESS INDEX**

Fig. 4 The original ETM image, the image applied the tasseled cap transformation, and the derived wetness layer

Fig. 5 Potential flood inundation areas are determined by the wetness index of the tasseled cap transformation.

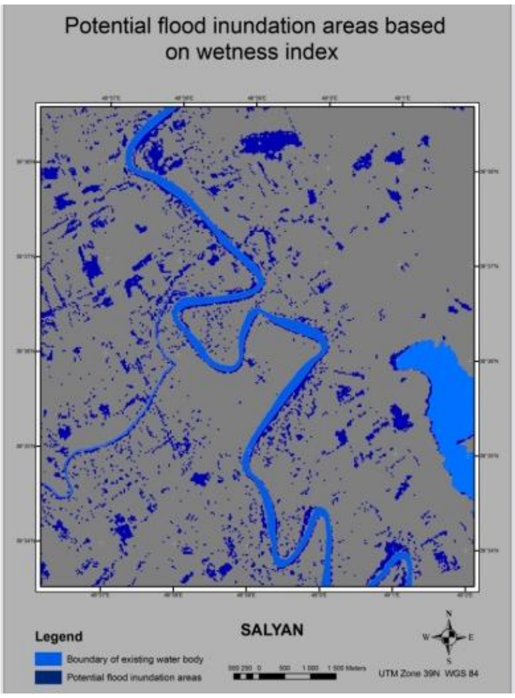


Fig. 5 Potential flood inundation areas based on wetness index

B. Digital Elevation Model Development

It is obvious that developing the Digital Elevation Model of the area opens an environment for the assessment number of the consequences of the river flood. One of the significant advantages of DEM its Environmental Impact Assessment (EIA). The EIA mainly analyses impacts on physical resources, such as Earth surface features, land cover marine lives-fauna and flora, people’s economic development, infrastructure, transportation, quality of life, aesthetics, population and ethnic patterns, perceptions, religion, preferences, public health, the local economy, employment, income, and host of other socio-cultural attributes of the inhabitants [6]. It integrates or separately interfaces the indicated segments affecting the environmental condition of the investigated area.

The following components are relevant to the implementation and achievement of expected results in Environmental Impact Assessment [8]:

- Current existing environment assessment

- Possible impact areas and impact assessment
- Selection of environmental parameters
- Collection of information and field surveys/integration of collected data
- Description and evaluation of environmental systems
- Description of proposed project and design and alternatives
- Prediction and evaluation of direct, indirect and cumulative impacts

Processing all of the above information is required to collect all possible and available information related to the studied area in order to assess and achieve the environmental aspects of the investigation. It is necessary to merge the data into any additional components during integration in the processing stages.

The Digital Elevation Model (DEM) was developed using the common method of digitizing the contour lines and elevation points from the topographic map (Fig. 6). The digitized lines in shapefile format were converted to points by the ArcGIS software application using the "Feature to Point" transformation tools. The points were interpolated using the IDW - inverse distance weighting method.

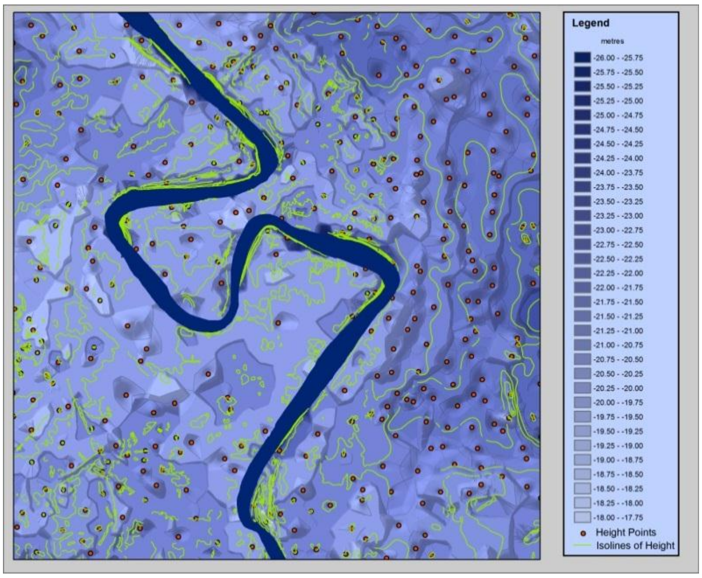


Fig. 6 Digital Elevation Model of the selected area with high points and isolines

GIS neighbourhood operations allow for the calculation of the mean DEM. The selected potential flooding areas were convex and fell at an elevation range between -26 m and -21 m, which is approximately the elevation range corresponding to the lower alluvial plain. It is the one generally affected during severe flooding.

The main target is to assist the local authorities to create useful databases for disaster risk reduction, particularly for the selected area with more sensitively to river flooding.

In the meantime, the advantages of remote sensing methods and GIS technology based on space image data collection and data processing for similarity problem solving have been demonstrated.

The developed database using the remote sensing methods and GIS technology creates resources and opportunities for the prediction and reduction of natural risk due to the timely implementation of appropriate engineering and technological activities. Based on those results as well as the existing database for the river level change, there is approach of study and identification of the dynamic change of the Kura River level.

The above results have been correlated with data-reflected climate circumstances for the appropriate period of investigations to find relationships between river flood natural disasters and the climatic parameters for the selected area. The findings are indicated below:

- Space technologies are advanced tools for monitoring, data collection, data processing, reviews, and reports on the progress and challenges in implementing disaster risk reduction and recovery actions at the national level;
- Further steps in wide scale of river monitoring are required for successful and effective forecasting, preparedness and reduction of the natural disaster impact;
- Awareness information programs of this hazard need to be developed and implemented to save human life and properties, as well as to reduce disaster damage impacts;
- Potential flood inundation areas can by identified by satellite imagery and ground-based measurements;

- Mapping potential flood areas can help further settlement planning in this region;
- These finding must be undertaken for further successful management to reduce the effects of natural disasters on river flooding.

An appropriate and sufficient high accuracy database has to be developed for local authorities to make decisions.

In this research work, ArcGIS software was used to develop a geodatabase of Salyan plain's spatial data.

Satellite images, aerial imagery, archive materials, and various kinds of maps are necessary for developing digital maps, depending on the requirements of the scale or the nature of the problem. Therefore, it is necessary to collect and develop geodatabases using indicated or other relevant sources in processing stage. The existence of these materials in the pre-designing phase is vital to identify the structure of the geodatabase. But this is not an exception there is an opportunity to modify the structure by adding any new data into existing source for the best satisfaction of data-processing demands (Fig. 7).

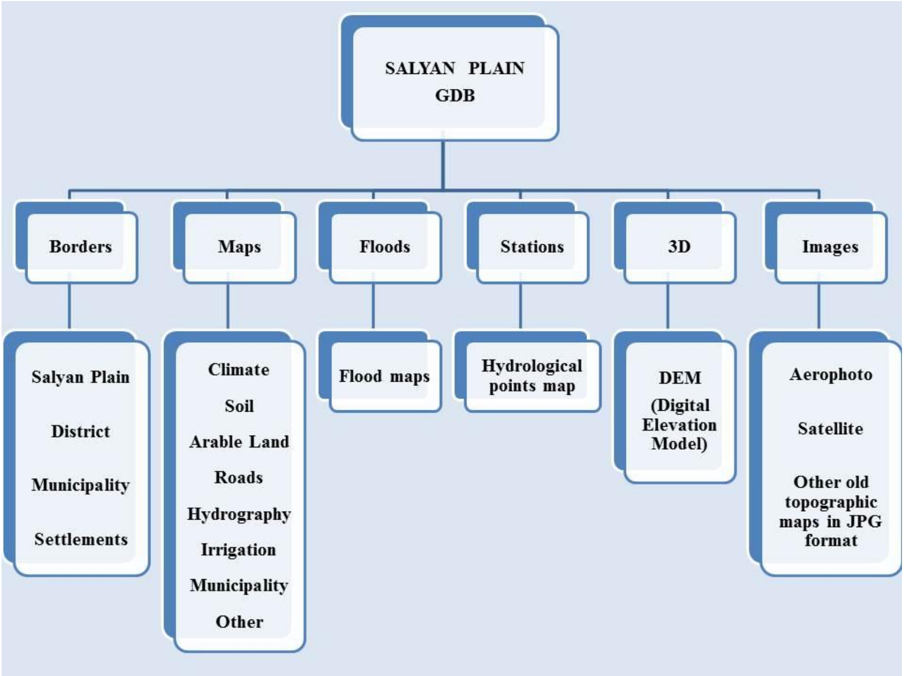


Fig. 7 The structure of geodatabase development

A developed structure consists of layers within the geodatabase (GDB). The first phase development of GDB is the structure determination of the boundary of the study area. The content of this stage contains the classification of settlements and the administrative features-territorial boundaries of municipalities. Using ArcGIS software, indicated sections have been vectorised under relevant layers within GDB (Fig. 8).

For the next stage as a necessary segment of data spatial data and materials undertaken for processing can be stored within the developed geodatabase by creating layers according to the structure (Fig. 9).

It is highly necessary to form an attributive database of the layers after creating and vectorising the above layers, because vectorization does not reflect all the information of the selected area. For instance, contouring of the Salyan plain illustrates only location and which regions it comprises. It does not show the area's size, soil content, Earth features coordination, or the length of the boundary of Salyan plain, which are all very important and useful features of GIS development. These can be implemented by collecting, creating, and recording attribute data.

Formation of attribute data of layers within the developed geodatabase indicated above sets for each layer separately. The table below shows the structure of attribute data formation of layers within the geodatabase.

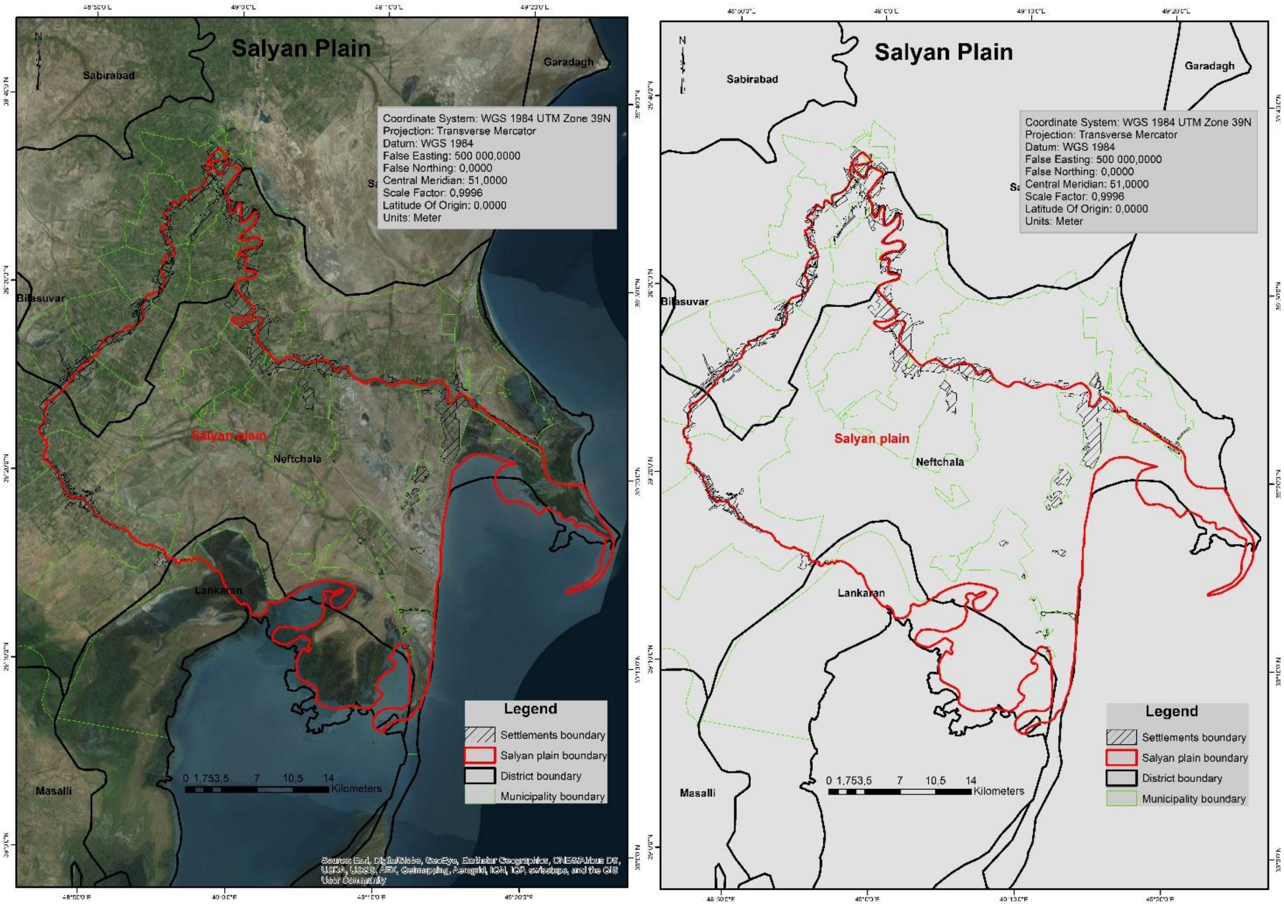


Fig. 8 Boundaries within Salyan plain and neighbouring areas

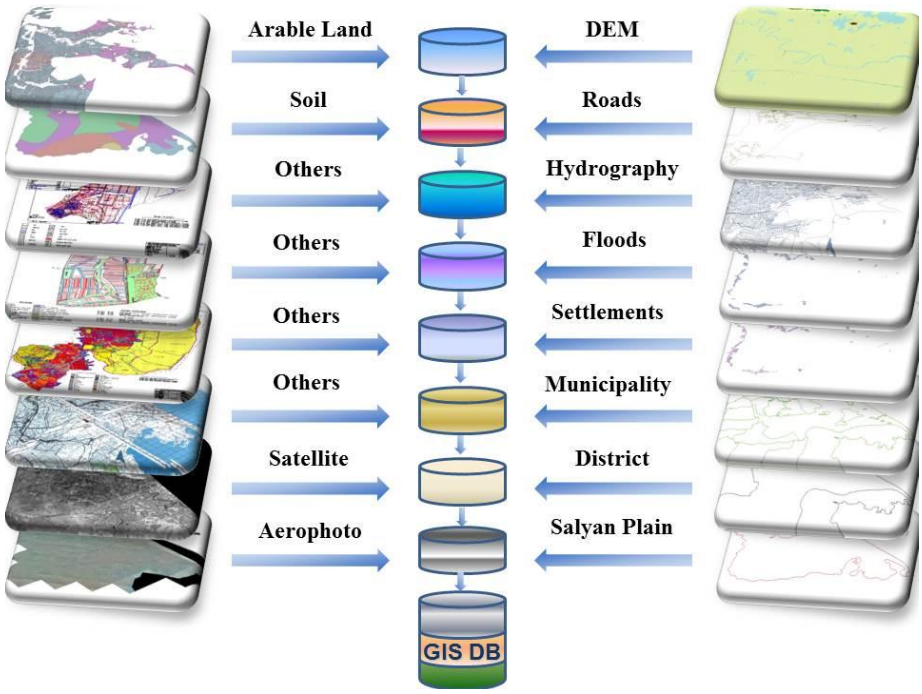


Fig. 9 The sequence of data collection into GDB

Table 1 illustrates the four layers of the minimum structure of the attribute table. At the end of each layer, "Other" describes the possibility of adding additional data to the table without any exceptions. For instance, it is possible to collect unconsidered data to appropriate layers by creating proper columns in the structure. The attribute of each layer forms the columns and rows in the program table.

TABLE 1 CREATING TABLES and RECORDING ATTRIBUTE DATA

Name of Layer	Column	Type	Note
Salyan_Plain	OBJECT ID		
	Shape		
	Shape_Length	Double	
	Shape_Area	Double	
	Name	Text	
	Temperature	Text	Average annual temperature
	Rainfall	Text	Average annual precipitation
	Other	-	
District_Boundary	OBJECT ID	Object ID	
	Shape	Geometry	
	Shape_Length	Double	
	Shape_Area	Double	
	Name	Text	
	Establishment_Date	Date	
	Population	Short integer	
	ID_District	Short integer	
	Type	Text	City or region
	Other	-	
Flood	OBJECT ID	Object ID	
	Shape	Geometry	
	Shape_Length	Double	
	Shape_Area	Double	
	Flood_Date	Date	
	Photo	Raster	
	Other	-	
Hydrological points	OBJECT ID	Object ID	
	Shape	Geometry	
	Name	Text	
	Level	Short integer	River Level
	Discharge	Short integer	River Discharge
	Building_ Date	Date	
	Current_Condition	Text	
	X	Double	X Coordinates
	Y	Double	Y Coordinates
	Photo	Raster	
	Other	-	

After structure development, each existing material can be added into the rows appropriately (Fig. 10).

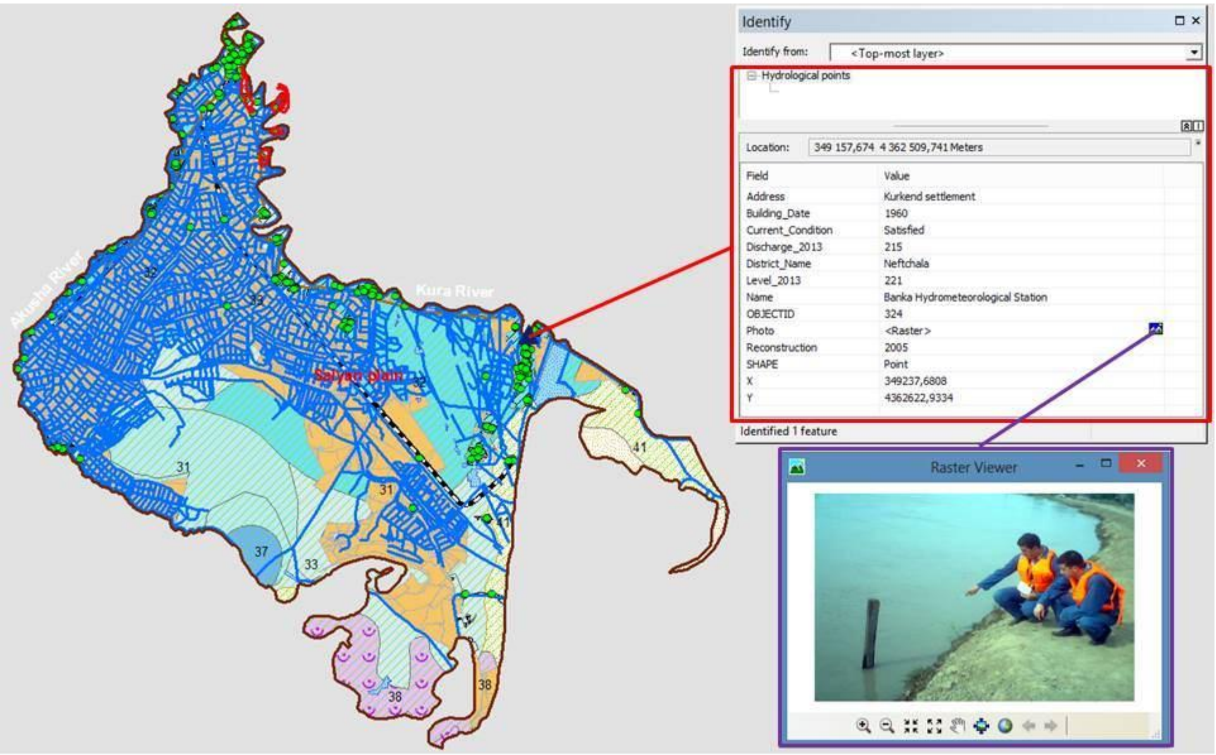


Fig. 10 Attribute data of hydrological point

The developed database allows all data related to the study area to be collected in one database, forming different types of data at any time. It also allows scientists to query, extract reports, analyse, build up diagrams to assess and predict risk, create 3D maps, and assess actual and future natural disasters.

V. CONCLUSIONS

The subject of the paper is river flood mapping of the study area. It focused developing a geodatabase based on space image data processing. ArcGIS software showed high accuracy in boundary definition for selected area of Salyan plain. The advantages of this method and its implementation have made it possible to integrate appropriate data for a number of purposes.

In the meantime, the purpose of geodatabase development for large-scale integration of GDB into GIS has been demonstrated. The approach as focused on river flood studies as a common natural disaster in the region. For this reason, this paper has used 3D map developments.

The next stage of 3D geodatabase performance is the Digital Elevation Model. Accessing such information is an excellent tool in assessing environmental impact as well as considering other consequences of natural phenomena and disasters.

This paper has provided data for the selected study area based on building up and enhancing the geodatabase through the Remote Sensing method and GIS technology. The advantages of managing of the study area through a single database have been demonstrated; this is a vital source for state authorities in decision-making stage. 3D modelling of the study area helps the prognosis of flood risk areas, while geodatabase creation based on the existing infrastructure of the area helps to prevent flood inundation. Moreover, building up the geodatabase allows for a rapid comprehensive assessment of river flood damage.

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