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DETERMINING OF DIFFERENT INUNDATED LAND USE IN SALYAN PLAIN DURING 2010 THE KURA RIVER FLOOD THROUGH GIS AND REMOTE SENSING TOOLS

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ABSTRACT: People are struggling with floods, which are types of natural disasters. Floods are in the first place among natural disasters in terms of damage to the community and the number of victims. Acquisition data from reliable sources is one of the central issues in the assessment of the condition in areas with high probability of flooding and operative decision making in extreme situations. As the source of this kind of data Remote Sensing data is widely used which is interpreted by Geographical Information Systems technologies in a short time. In addition, accurate geographical linking is possible through modern satellite navigation technology, which makes it possible to spread information quickly and deliver obtained results to customers. Since the Kura River is the source of fresh water in Azerbaijan, most important and strategic importance, there are many settlements, industrial and economic facilities along the riverbed. That is why, as a result of the floods in the downstream of the Kura River, the environment, economic infrastructure, individual spatial areas and the population living in these areas are damaged. As an example of flood damage assesment, the recent flood in 2010 was analyzed. Different archival, field survey and digital materials were used. Maps of flooded areas and the potential infrastructure in flooded areas were determined through ArcGis 10.2.1 software. Among all flooded areas, settlements and pastures had the highest share. The study proved that integration of various spatial data could greatly support flood damage assessment.

Keywords: *Natural Disasters, Flood Hazard, The Salyan Plain, Inundated Areas, Damage Assessment, Remote Sensing (RS), Geographical Information Systems (GIS)*

1. INTRODUCTION

Disaster is a natural or human-induced event that adversely affects the individual or the society (Şentürk, E. and Erener, A., 2017). Among natural disasters, floods are more hazardous and large-scaled. Floods are mainly caused by heavy rainfall, cyclone effects, and melting of snow and glaciers in the mountains.

Floods are among one and main natural disasters that occur frequently in Azerbaijan and damage to local people, agriculture and infrastructure, generally to the whole economy of the country (Ağayev A.T., 2016, Musayeva M.R., 2014). Especially, devastating floods occur in the Kura river basin, downstream of the Kura River where Shirvan, Mughan and Salyan plains situates. The most recent devastating flood in the Kura river occured in 2010. The flood differed from previous flood events significantly by its scope. Due to the large extent of the flood, I conducted the study only within the Salyan plain. The aim of the study was to test the possibility of determination flooded land use categories through the mapping of inundated areas using archival materials, aerial and satellite images.

Early property damage assessment and accurate modelling of flood events require that private-owned objects, agricultural land use and infrastructure are identified on a land cover map. Different application fields, such as earth sciences, natural resource management, environmental protection, urban and regional planning, defense, transport, tourism, statistics and education need geographic data, because they require regional or countrywide analyses (Yılmaz, A. and Canıberk, M., 2017). Earth observation techniques may contribute significantly to improve our efforts to model flood events, to develop proper mitigation strategies and to assess damage to residential properties, infrastructure and agricultural crops (C.J. van der Sande et al., 2003).

A lot of studies were conducted on the integration of GIS technology and RS data in worldwide practise and the analysis of natural and anthropogenic factors affecting the development of hydrologically hazardous situations has widely covered (Dano U.L. et al., 2011, Mateeul H. et al., 2012, Audisio C., 2011). Basically satelitte data from different period of time were used in those studies which allowed to assess the dynamics of flood accidents.

Large-scale investigations have been carried out in many privately owned and public institutions around the RS data and GIS technology assessment of Kura river floods. In the conducted studies the application of GIS technologies were achieved on the investigation of floods in the mountains of the southern slopes of Greater (Müttəlibova Ş.F. avtoref. 2007, Süleymanov T.İ. and Müttəlibova Ş.F., 2006, Сулейманов Т.И. and Мутталибова Ш.Ф., 2005, Süleymanov T.İ. and Müttəlibova Ş.F., 2004). In other studies, investigations have been carried out around real estate electronic cadastre issues and the method of operative determination of flooded areas and damaged property during the Kur River flood has been proposed (Alıyev E.M. avtoref. 2016, Süleymanov T.İ. and Alıyev E.M., 2009, Сулейманов Т. И. and Алыев Э.М., 2012, Aliyev E.M., 2013). Therefore, utilizing of results of the studies, suggestions and methods have been considered appropriate.

Thereby, it is necessary to determine the extent to which the different purpose lands are flooded and the operational assessment of the damage caused by the flood events on the basis of high-definition cosmic drawings and GIS technologies.

2. STUDY AREA DESCRIPTION

The Salyan plain, west of the Caspian Sea and situated downsteam the Kura river, was selected as a study area (Fig. 1). The primary reason to select this area for the study is a regular occurrence of floods.

The Salyan plain embraces the area from the right side of Kura river between the Kura and the Akusha rivers to the Caspian Sea (Aslanov, 2013). The plain is totally below the sea level (maximum -12.2 m and minimum -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.

Figure.1 Study area

2.1 History of floods

Historically, floods in the downstream of the Kura river were observed regularly, but written records cover the period after 1858. As can be seen from this information, devastating floods that caused damage to the agriculture and threaten the local population occurred in this part of the Kura river basin in the nineteenth century. For example, in 1896 the stream that depleted the soil barrier on the right bank of the Aras river in 1896 near the Saatli settlement created New Aras tributary, as people called it, and not only the Mughan plain, but also southeastern parts of the Salyan plain including the 160000 hectares were under floodwaters. The Kura river flood that occurred in May, 1915 was one of the most hazardous floods over 150 year. A large territory in the Shirvan plain within Aghdash, Goychay, Kurdamir districts were inundated by floodwaters which destroyed coastal barriers in Garadeyin (Aghdash), Gakhay (now Khinakhli village, Aghdash), Zardab (Zardab city), Mollakand (Kurdamir) and other riverside villages. The flood that occupied more than 200000 hectares area flew through left bank of the Kura river and run into the river near Shirvan settlement again (Aslanov, 2013). Besides these two historical facts, a lot of large-scale floods occurred in these lowland areas so far.

Figure.2 A part of the railroad damaged as a result of flood waters in 1915 (Pashayev and Hasanov, 2010)

The next flood event was in 2003 in the area where Kura River floods occur regularly. During the flood, Kurgaragashli, Garachala, Karabakh (Tazakand), Arabgardashbayli, Khojaly and Jangan in Salyan district, including the town with the same name were mostly suffered settlements from the Kura River flood (Aslanov, 2013).

2.2 2010 flood

The most recent flood event occured in 2010 May and differed in extent from the previous flood events, significantly impacting the state budget. During the flood, 11 districts and approximately 150 settlements were damaged either completely or partly (Fig. 3).

Figure.3 Images from the 2010 flood (http://www.fhn.gov.az/index.php?aze/pages/33)

Figure.3 Continued

Imishli, Saatli and Sabirabad districts were most affected areas in 2010 flood. In total 110929 ha were flooded (Ağayev A.T., 2017). Although Salyan and Neftchala districts have a high flood risk, but during 2010 flood, the impact of flood water in those areas was relatively low. However, the Kura river flood affected these areas too. Totally 3415 ha area in Salyan and Neftchala districts were inundated.

After some flood mitigation measures for reducing flood impact, the consequences of that natural phenomena were mostly eliminated. Approximately 30 million AZN (equal to 15 mln EUR) was allocated from the state budget with the purpose to aid suffered families financially, to recontruct and rebuild destructed and damaged houses, replacing them with new ones. 26.5 million AZN was spent for financial aid and construction and restoration of houses (Table 1).

Table 1 A number of damaged houses, families and amount of funding allowance due to the flooding

№	Names of the districts	Planned reconstruction of private houses. Handed over houses	Number of families supported with financial aid	Paid amount, Total, AZN
1	Salyan	145	615	1156700
2	Neftchala	42	112	234300
3	Other districts	4078	13530	17867500
4	Additional aid, other districts	-	14344	7205969
	Total:	4265	28601	26484469

3. MATERIALS AND METHODS

To determine of flood extent, and delineate infrastructure and land use categories affected by flood various materials are needed, e.g., data from responsible agencies of government or freely available spatial data from internet archives. In this study I used official 1:100000 (published in 1991) and 1:10000 (published in 1989) topographic maps, orthophoto images in 1:5 000 scale compiled from aerial images (acquired in 2009)

(Fig. 4) and Landsat satellite data.

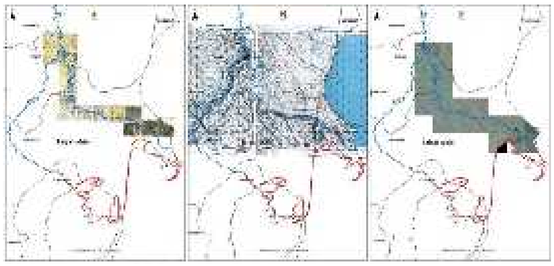

Figure.4 Data sources used in the study: a) 1:10000 topographic maps, b) 1:100000 topographic maps, c) 1:5000 orthophotos (Archival materials)

Recently, remote sensing data has increasingly been used in order to generate land use/land cover classifications (Tina Gerl et al., 2014). Maps and orthophoto images at high spatial resolution enabled the identification of urban and sub-urban objects (C.J. van der Sande et al., 2003, Ağayev A.T., 2015). Landsat satellite images are freely available satellite data with 30 m resolution and relatively high temporal frequency of acquisition, therefore they could help to capture the 2010 flood extent. To investigate flooded areas in Salyan plain during 2010 flood two acquisition dates were selected for the US Geological Survey Earth Explorer archive (http://earthexplorer.usgs.gov): 26 September 2009 and 24 May 2010, that is one pre-flood and one flood acquisition. Two standard scenes for each date were used, in total four images were analysed (Fig. 5, Table 2).

Table 2 Metadata of the satellite images

Data Set Attribute	Attribute Value			
	1	2	3	4
Spacecraft Identifier	LANDSAT_5			
WRS Path	167			
WRS Row	032	033	032	033
Date Acquired	2009/09/26		2010/05/24	
Quality Band 1-7	9			
Output Format	GEOTIFF			
Grid Cell Size Reflective	30			
Grid Cell Size Thermal	30			

Geographic Information Systems (GIS) and the remote sensing technology present the most powerful tools emerged in the hydrological field, which allow for the collection and analysis of environmental data as well as provide a platform for integrating space and ground-based data for flood monitoring and modelling (Galina Merkuryeva et al., 2014). I used several methods for the determination of 2010 flood extent and flooded land use categories. In the first stage, obtained satellite images were processed using on-screen manual vectorisation with ArcGIS software. Then, water courses in the study area within the scope of satellite image were delineated with the appropriate tools of the software. This procedure was implemented on the satellite image captured before the flood (in 2009). Riverbed and small water bodies along the river were included. Next the procedure was implemented on the satellite images taken during the 2010 flood. Delineated boundaries show the condition of the area before and after flood.

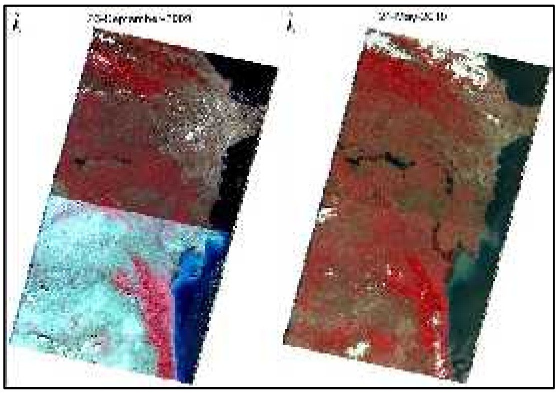

Figure.5 LANDSAT 5 satellite images before and during the 2010 flood (http://earthexplorer.usgs.gov)

After delineation of the 2010 flood extent it was possible to interpret infrastructure and land use in those areas (within the flooded area boundary). The scale and resolution of satellite images were not sufficient, and for that reason, I utilized archival topographic maps in the scale 1:100000 and 1:10000, and orthophoto images in the scale of 1:5000.

4. RESULT

Flooded areas obtained through the interpretation of satellite images, are clearly visible if two satellite maps are compared (Fig. 6). For the study area, the flooded area was estimated for 1336 ha.

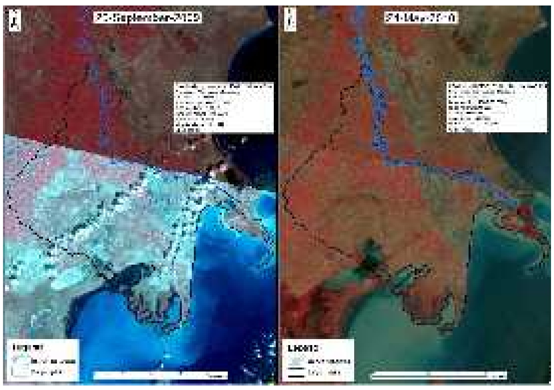

Figure 6. LANDSAT 5 satellite images before and after flood. Even in this scale inundated areas during 2010 flooding are clearly visible

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Figure 7. Flood extent areas

By overlaying the boundaries of the settlements to the map, the partly inundated settlements can be visible.

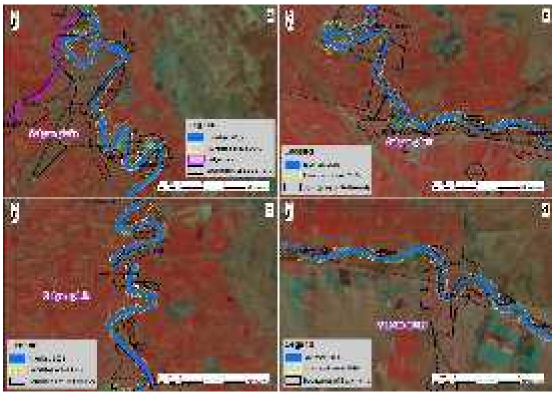

Figure 8. Settlements affected by floodwaters

For the flooded areas, various land use types were identified (Fig. 9, Table 3). Among them, pastures and settlements were the major categories occupying around 60% of the flooded land.

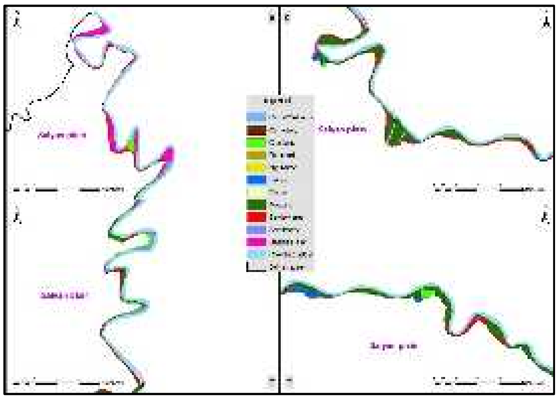

Figure 9. Land use categories under floodwaters

Table 3 Quantity of land use categories under floodwaters

№	Land use category	Area, ha
1	Pasture	617,73
2	Settlements	217,57
3	Useless land	192,13
4	Cropland	118,45
5	Shrubbery	65,67
6	Lakes	64,55
7	Dirt roads	37,3
8	Canal/Collector	16,41
9	Highways	3,28
10	Cemetery	2,47
11	Parks	0,72
Total:		1336,28 ha

One of the mostly inundated land use types were settlements. For settlements, high resolution orthophotos allowed to identify buildings that were flooded in 2010 (Fig. 10, Table 4). In total, more than 800 buildings were identified as flooded in the settlements of Salyan and Neftchala districts within the boundary of the Salyan plain.

Figure 10. Houses under floodwaters

Table 4 The number of flooded buildings over settlements

№	Districts	Settlements	Houses	Total
1	Salyan	Arabqardashbayli	47	316
2		Beshdali	25	
3		Jangan	18	
4		Khojali	14	
5		Kurgaragashli	52	
6		Salyan city	160	
7	Neftchala	1 Garali	5	498
8		2 Mayak	4	
9		Ashagi Garamanli	22	
10		Ashagi Surra	93	
11		Astanli	20	
12		Dordlar	23	
13		Gadimkand	19	
14		Khilli	141	
15		Kurgarabujag	35	
16		Mirzagurbanli	6	
17		Neftchala city	25	
18		Novovasilyevka	105	

5. DISCUSSION

Flood damage in the selected area was determined through GIS tools. Various spatial data within flood extent were integrated and processed through GIS tools, however, the methodology could be further improved, e.g., using automated flood delineation with satellite data.

Integration of various spatial data may lead to several problems, e.g., orthophoto was acquired in 2009, hence not at the same time as the flood and one year difference between the flood occurence and captured orthophotos dates reveals that there is not exception in the changes of infrastructure of the area. Another issue was that due to low resolution of satellite data, the flood extent boundaries had a certain error margin, which might impact the accuracy of flooded buildings delineation.

6. CONCLUSIONS

Integration of various types of spatial data allowed quick mapping of flooded areas that could establish a spatial database for subsequent flood damage assessment. Landsat satellite data were found useful in delineation of flood extent, although it should be noted that 2010 flood was a dynamic event, and flood extent varied in late May and early June, for example, to reduce the flood extent and eliminate consequences of the flood, new tributary of the river was opened by the government decision. In consequence, floodwaters decreased in some areas, but in other areas flood showed different pattern (Aghayev, 2017).

My study showed significant damage during the 2010 flood, which in particular affected pastures, settlements, useless land and cropland. For settlements, data and methodology allowed to identify flooded buildings and indicate the most flood-prone areas.

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