Spatial Assessment of Flood vulnerability in Lattakia Governorate Area Using GIS and Remote sensing

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Abstract

This study aimed at spatial assessment of flood vulnerability in Lattakia Governorate. In carrying out this work, Remote Sensing (RS) and Geographic Information System (GIS) were employed. Results indicated that the agriculture sector and built-up areas along Al Kabeer Al Shemaly River in Lattakia is very high vulnerable which implies that the along Al Kabeer Al Shemaly River in Lattakia is at risk to floods. Most of the buildings in the industrial zone are at high risk of the different flood periods which were assumed. Flood frequency analysis shows that Gumbel's distribution is suitable for predicting expected flow in the river. Such results may assist decision makers during planning to take appropriate adaptive measures for reducing the vulnerability along Al Kabeer Al Shemaly River in Lattakia, as well as increasing the resilience to future inundations. For future studies, the inclusion of socio-economic parameters is foreseen by this study, as an enhancement to the vulnerability presented here.

Keywords: flood, GIS, vulnerability, land use planning, topography

1 INTRODUCTION

In recent years, the global impacts of floods are rising because of their high pressure on the environment, exposed people and correlated losses of life and economic damage (Jongman *et al*., 2014). Flooding alone accounted for 43% of all weather-related disasters (1995-2015), affecting 2.3 billion people, (95%) of them live in Asia. The number of floods per year rose to an average of 171 in the period 2005-2014, up from an annual average of 127 in the previous decade (Guha-Sapir & Wahlstrom, 2015).

1.1 PROBLEM STATEMEN

Syria is subjected to a range of natural hazards. In addition to drought and desertification, floods still do occur (the collapse of part of the massive Zeyzoun dam in northwest Syria in 2002, a flood occurred in Al Hasakeh City in the northeastern region in 2006), causing the blocking of different highways and roads in different areas of the country; flooding various irrigated areas in several governorates; and damaging a number of historical places (UNDP, 2009). According to INFORM country risk profile for Syria (2016), across Syria, the annual expected exposed people to floods is 48875, and the physical exposure to flood ranks 4.8. Another report by INFORM (2016) showed that combined economic losses between 1990 and 2014 were 5.8% and mortality due to floods was 5.1 %.

When it comes to risk prevention and risk reduction, the challenges within the disaster risk management (DRM) plan in Syria which have been reported by the World Bank (2014) are the lack of safety rules in designing buildings and infrastructure, public awareness, need for laws and legislation and coordination mechanisms that organize the work of disasters and emergency management plans are still reactive. Nationally there are capabilities for disaster response evident in several areas such as fire service, civil defense, the branches of the Red Crescent and the women's union but there is no risk assessment available.

There might be many causes of flood vulnerability in Syria. The first is due to uncontrolled urbanization within the flood plains that generates large concentrations of vulnerable populations. The second factor is that Syria is one of the countries that totally lacks disaster insurance programs, in addition to Syria's economic vulnerabilities, because of the already vulnerable agricultural sector (McEntire, 2008).

In February 2015 a drowning incident of a family of four people occurred after the flooding of Al Kabeer Al Shemali River in Lattakia. This flood led to some citrus groves and greenhouses inundation on both sides of the river course, as well as the sinking of some areas that are low and adjacent to the river which led to the sinking of some properties and a number of cars in addition to the big area of the industrial zone in Lattakia (Figure1).

The implications for flood vulnerability in the study area will be magnified as a result of natural and manmade causes. The natural causes are due to heavy rainfall which continues for many hours, in addition to the surface conditions such as slope and elevation of the receiving basin. The manmade causes include unsuitable building structure, mismanagement of the river banks and poor flood plains planning and absence of emergency readiness. It is therefore considered important for a vulnerability assessment to be conducted to categorize the degree of vulnerability along Al Kabeer Al Shemaly River in Lattakia as to understand the subsequent risk associated with it.

Figure 1: Effects of flooding in the study area. Source: (http://www.sy-weather.net/vb/showthread.php?t=38290)

1.2 OBJECTIVES

The aim of this study is to assess the vulnerability along Al Kabeer Al Shemaly River in Lattakia considering land use with constructions such as buildings. The specific objectives of the study are:

- To analyze the extent of flood prone areas (exposure) within the study area.
- To assess the vulnerability of the land use within the study area.
- To recommend some aspects of future vulnerability mitigation within the study area.

This research is designed to investigate and to find solutions for the following research questions:

- What kind of elements are the exposed to floods in the study area?
- What types of vulnerability do these elements have?

2 STUDY AREA

The coastal zone in Syria covers an area of 4200 km^2 distributed over two governments: Lattakia in the north (2300 km2; 9981311 inhabitants) and Tartous in the south (1900 km^2; 333188 inhabitants). While the coastal region is only about 2 % of the total country's area, it is inhabited by more than 11 % of the total population (total population is about 21.4 million) (MOLA, 2007).

Al Kabeer Al Shemaly River (Figure 2) is one of the most important water resources in the coastal basin in Syria. A 16 Tishreen Dam was constructed with a storage capacity in average 210 Mm^3 to irrigate the agricultural fields near to it with a height 100m or less. It is 96 Km long in the Syrian Terrain, and its peak flow is 40 m^3/sec. It might be dried in the hot seasons to 1 m^3/sec or less as happened in 1985. The river flow system relates to the amounts of rainfall, so the average flow in the rainy seasons (early November up to the end of February) is 17.1 m^3/sec and the average flow in the hot seasons (June and lasts up to early September) is 2.3 m^3/sec.

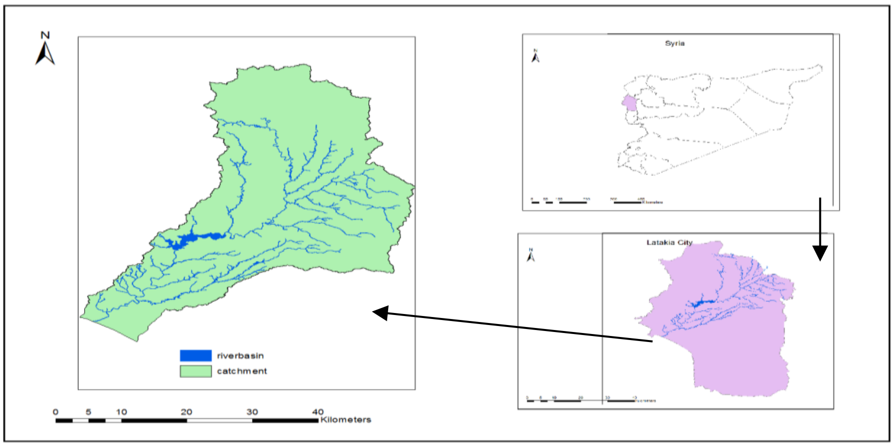

Figure 2: Location map of Al Kabeer Al Shemali Watershed

The average of annual rainfall is 950 mm for the entire basin, but in the upper basin, the average of annual rainfall is 1113 mm. The annual average temperature reaches a maximum of 35.6 °C and a minimum of 5.4 °C. To have an idea about the rainfall in the area, figure 12 shows the annual rainfall at 16 Tishreen Dam Station for 37 years of data recorded (Water Resources Directorate, 2015). The general trend in rainfall in 16 Tishreen Dam Station shows that since the beginning of 2005, the rainfall has decreased, which affect directly the stream flows of Al Kabeer Al Shemaly River.

The topography of the river watershed varies from the upper basin which starts in the mountains near to the Turkish Borders in the north with average height of 1700m, to the mid-basin where a transitional area of hill between the mountains and the plains with average height of 450m to 50m, to the lower basin in the coastal plain with heights vary from 50m to 0 m. Its course descends rapidly to the 16 Tishreen Dam, after which, it becomes slightly descended until it reaches its mouth and pour in the Mediterranean Sea (Figure 3).

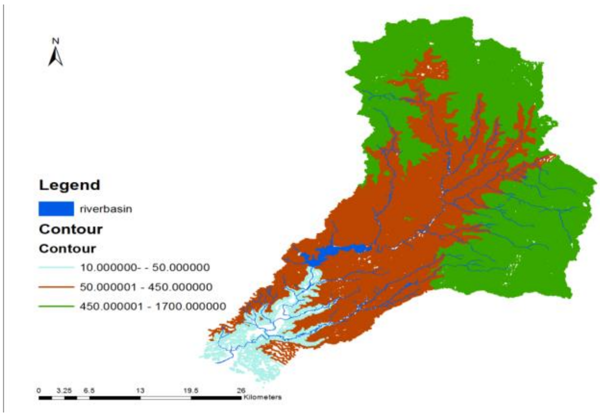

Figure 3:Topography map in the watershed

3 METHODOLOGY

The contour map obtained from General Organization of Remote Sensing (GORS) in Lattakia was used to extract the digital elevation model (DEM) from the interpolation of the elevation data by the triangular irregular network (TIN). The collected LANDSAT L7 ETM^{+} Satellite image (2014) was georeferenced according to the geographic coordinate system (GCS_ WGS_ 1984). Projected coordinate system used for this study is WGS_ 1984_ UTM _Zone_37N which is suitable for Syria. By applying a supervised analysis on the LANDSAT L7 ETM^{+} Satellite image, we developed land use map.

Point interpolation technique at GIS system has been applied using water level in order to generate interpolated water level surface. Flood inundation map was prepared using the DEM and the interpolated water level surface for different return periods. All the above operations were done by using ArcGIS 10.1.

According to Water Resources Directorate (2015), the average of water depth in the lake is 1.49 m for the years 1976-2010. The minimum depth recorded is 0.64 m and the maximum reached 2.71m. Applied flood risk analysis, very often poses the question how detailed the analysis needs to be in order to give a realistic figure of the expected risk (Apel *et al*., 2009). Although floods can be modeled using GIS, they request highly detailed data and complex procedures (Peduzzi, 2005). The resolution of the hydrologic and meteorological data available dictates the most appropriate model to be used (Elhassan, 2014). Therefore, one of these study limitations is the need for hydrologic and hydraulic modeling so that flood hazard in the catchment can be best investigated.

Due to the lack of data, the assumption in the current study is that water level can reach 5m, 10m, 15m knowing that the maximum water level recorded in 35 years is 2.71m in a normal situation. Thus, 15 m water depth was considered as 500 years return period; 10 m water depth was considered as 100 years return period and 5 m water depth was considered as 50 years return period.

Four physical variables were incorporated in the study namely; slope, elevation, frequency of occurrence and water inundation; which aimed to highlight the areas where the impacts of floods are most likely greatest (Table 1) (Balica *et al.,* 2010).

Table 1. Exposure indicators and their relevance to flood vulnerability

Name	Definition of indicator	Functional relationship with vulnerability
Topography	Average slope of river basin	The steeper the slope, higher vulnerability
Frequency of occurrence	Years between floods	Bigger # of years, high vulnerability
Topography	Elevation difference of river basin	The lower the elevation, the higher vulnerability
water inundation	Water depth of river basin	The higher the water depth rate, the more vulnerable an area to inundation hazard is

The variables were ranked based on their value (Table 2). Exposure values between 1 (lowest) to 3 (greatest) were assigned to each specific data variable.

Table 2: exposure ranking for variables

variables	Low 1	Medium 2	High 3
Slope (%)	0-32	32-57	57-84
Elevation (m)	450-1700	50-450	0-50
water inundation (m)	5	10	15
Frequency of occurrence (yr.)	50	100	500

Land use or land cover dataset has been generated from the digital image classification of LANDSAT ETM satellite images applying supervised image classification method. The supervised classification process is divided into two phases: a training phase, where the computer is 'trained', by assigning a limited number of pixels to what classes they belong to in this particular image, followed by the decision-making phase, where the classification algorithm assigns a class label to all (other) image pixels, by looking for each pixel to which of the trained classes this pixel is most similar (Bhuiyan,2014). Then it was reassigned by categorizing the land use into five general classes (Anderson *et al*, 1976) and converted to a raster layer.

The study of the physical vulnerability of land use was reclassified into five groups in order of their capacity to increase or decrease the rate of flooding. While buildings vulnerability in this study focused on measurement of building size. The variables were ranked between 1 (lowest) to 5 (greatest) based on their specific data variable (Table 3).

Table 3: Land use and building vulnerability ranking

Ranking	Classification	Land use
1	Very low	Forest
2	Low	Agricultural area
3	Medium	Water bodies
4	High	Barren land
5	Very high	Built-up areas

The land use map was overlaid with the flood zone map of various return periods in ArcGIS, for each and every return period, a separate overlay was created. The flood vulnerability map of the land use in the study area was generated.

4 RESULTS

This section presents the choice of variables used in the exposure analysis and their classification into classes. The factors considered are water depth, elevation and slope and water accumulation.

Displaying flood exposure maps for the various return periods is shown in figure (4). It outlines the flood exposure color adopted for this study based on the assumption of the three water levels. It has to be considered the vulnerability areas (villages, city center, and industrial zone) to evaluate exposure according to the three water levels.

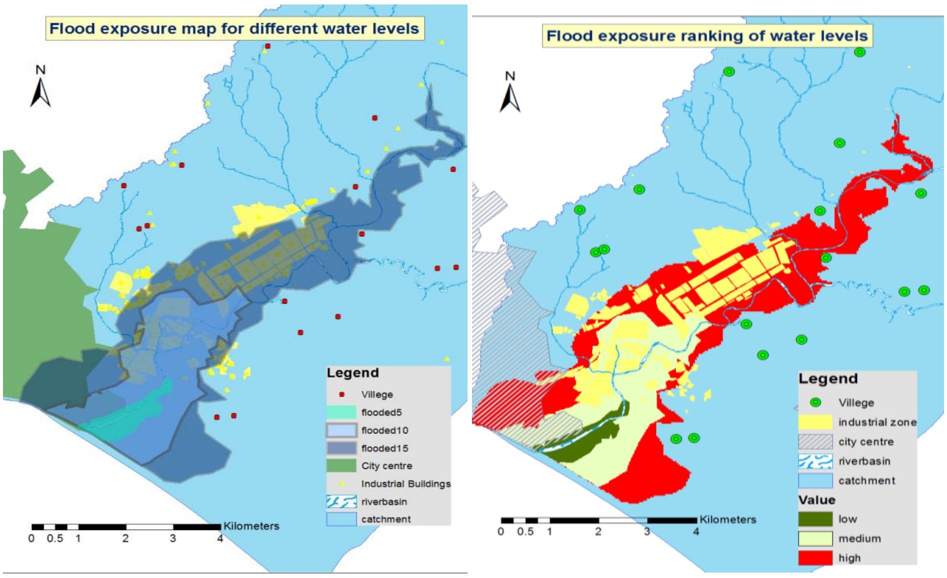

Figure 4 : Flood inundation maps

On the map, parts of the city center and the industrial zone are treated by a flood event. The event of 5m depth can occur in 50 years but still has a low impact on the city center, but no impact on the industrial zone; although it has a high flooding hazard. The city of Lattakia starts to be flooded, and the first areas of the industrial zone are inundated by the event of 10m depth_ flood. The 15m depth flood is likely the one which will cause a lot of damage if ever occurs. Some settlements will be inundated and a big part of the industrial zone will be affected. Table (4) shows the areas that will be affected in the city center, industrial zone, and the entire catchment because according to the water depth.

Table 4. Flood inundated area according to water depth

Water depth (m)	Area (m^2)		
	City center	Industrial zone	All catchment
5	87435	-	1104507
10	805949	1369385	7641773
15	2397162	5517997	21378761

It is important to highlight that this study only considers the assumption of water depth and therefore a detail hydraulic and hydrologic analysis on the flooding in the whole area will be better to have a holistic view.

Table 5 depicts the flood inundation area and percentage in different return periods. It shows that flood inundation of the study area increases with the increase of return period. In 50 years flood period, the inundation area is 0.1 percent. The flooded area under 100 and 500 years return period are 0.75, 1.93 percent, respectively. Most of the inundation areas are located in the plains.

Table 5: flood inundation map of the terrain in the study area

NO.	Return period (years)	Area (m^2)	Percentage, %
1	50	1104507	0.1
2	100	7641773	0.75
3	500	21378761	1.93

Samuels *et al.* (2009) revealed that flood inundation maps indicate the geographical areas that could be covered by a flood according to one or several probabilities. These can range from floods with a very low probability (extreme events with a return period of 100 years); floods with a medium probability (a return period of 1000 years); floods with a high probability (a return period of 5 years). In this case, the return period is based on 500 years for the low probability, 100 for a medium probability and 50 years for a high probability of flood occurrence. Figure 4 contains a map of the floodplain of different periods.

The most exposed areas to flood events are flat areas within the catchment because it allows the water to flow quickly. Steeper slopes are more susceptible to surface runoff, while flat terrains are susceptible to water logging. According to figures (5 - 6), most of the area lies in a high slope and low to moderate elevation. This implies that slope may be a predominant factor in ranking exposure to the hazard.

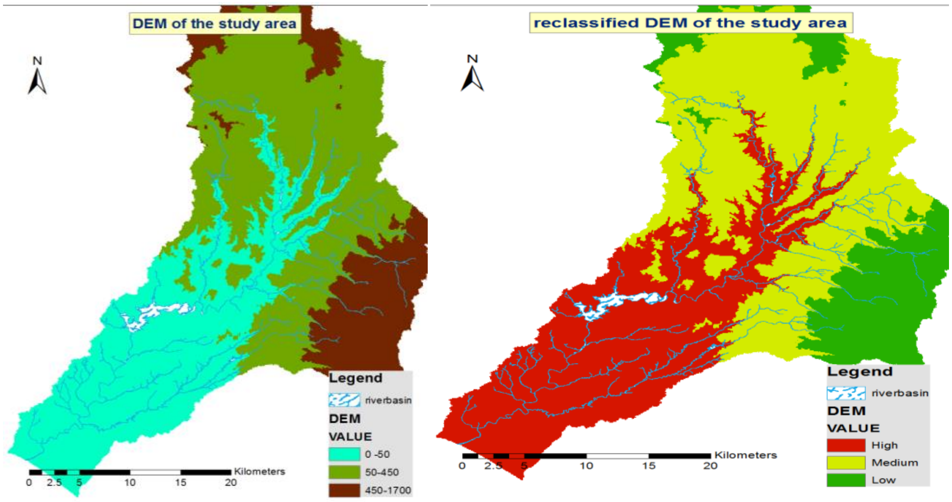

Figure 5: Elevation maps

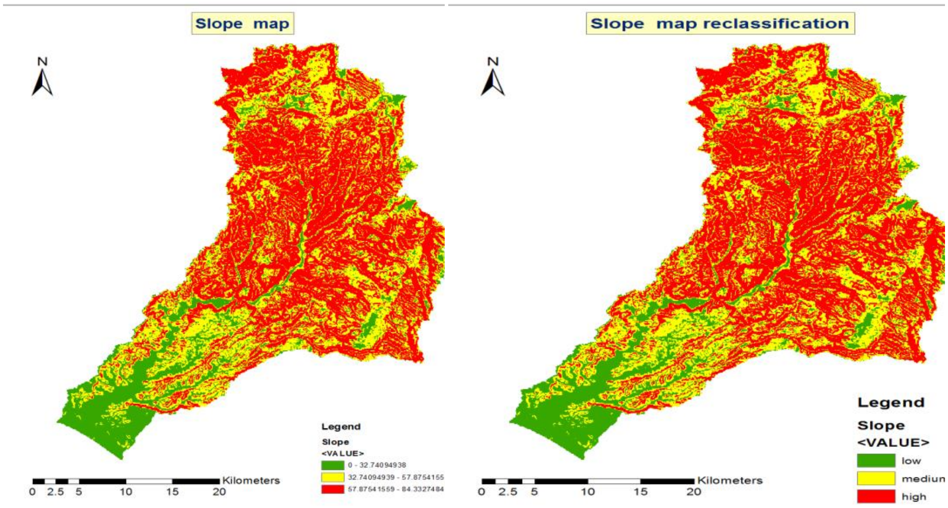

Figure 6: Slope maps

Figure 7 shows the land use map and land use vulnerability map to floods in the study area. The land use of the area comprises agriculture, water bodies, bare soils, rural settlements and forest.

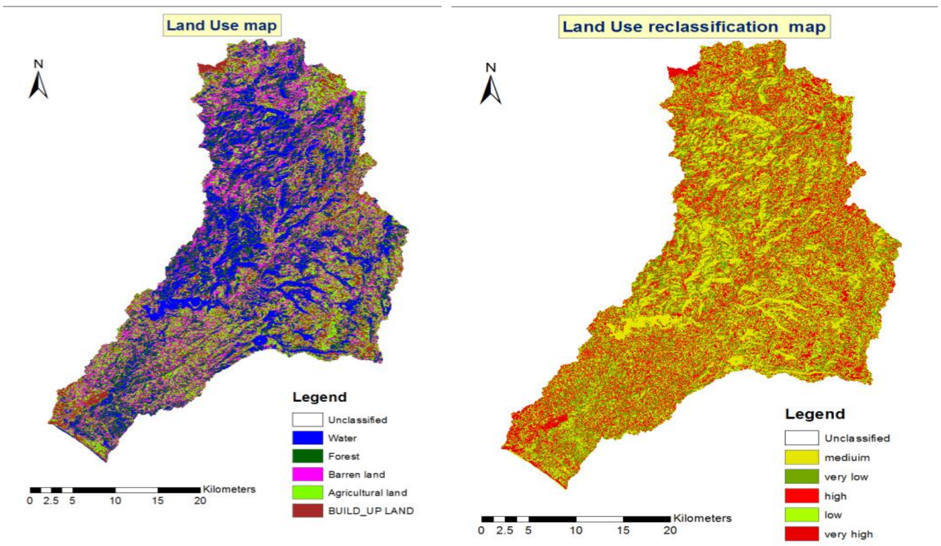

Figure 7: Land use maps

Most of the area lies in the medium to very high vulnerable zone according to the type of land use coverage. The statistics of the major land coverage has been given in Table 6.

Table 6: areas of the major land use coverage in the study area

Land use component	Area (km^2)
Barren land	515.562199
Forest	434.806015
Agriculture	107.194446
built up area	27.113297
Water	19.036133

Figure 8 shows the land use which is vulnerable and at high risk to different return periods. The results show that agriculture system is much vulnerable. The assessment of the flood areas indicates that a large percentage of agriculture land lies under high hazard. In the 50 years flood map (252200) m^2 area lies under high hazard zone while in 100 years flood map (1448100) m^2 area lies under high hazard zone and in 500 years flood map (2287800) m^2 area lies under high hazard zone. This show impact of flooding is in increasing trend. Similarly, urban areas are also in a vulnerable condition where (187200)m^2 of urban areas will be under higher hazard zone in 50 years flooding and increased this area in 100 years flooding by (1890000)m^2. Similarly, high hazard zone of barren lands and forests will also increase.

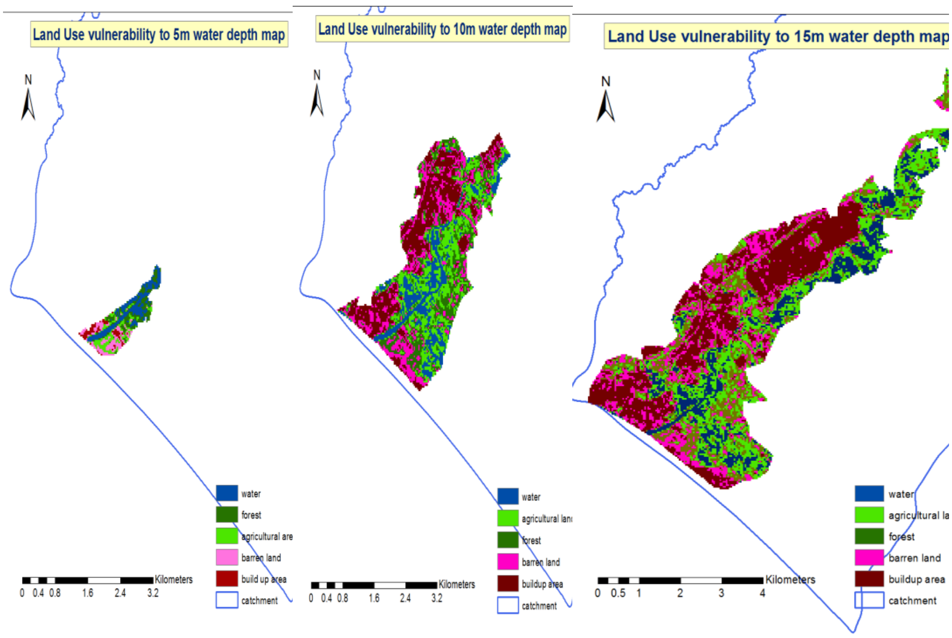

Figure 8: Land use maps

Table 7 shows the statistics of the area of land use coverage which is vulnerable to different water depths.

Table 7: Areas of the major land use coverage vulnerable to flood event

Land use type	Area (m^2)		
	5m water depth	10m water depth	15m water depth
Water	327600	1059300	1897200
forest	190800	1743300	3162600
Agriculture	252200	1448100	2287800
Built up area	187200	1890000	2274300
Barren land	89100	1522800	3708000

Al Kabeer Al Shemaly River plains were found to be vulnerable (high-very high) to flood hazards. A relatively moderate trend in water depth reflected very high vulnerability to agriculture and industrial zone infrastructure; therefore, this has great implications for the communities, infrastructure and natural resources along this river. It can be recommended to implement water depth measures for the whole river course and also to increase the resilience of the river plains to future inundations by the installation of protective structures where suitable so as to decrease the vulnerability along the studied river.

Based on the experiences made in the framework of this case study the following recommendations can be drawn for the management of river flood zones in general:

- Integrate this assessment into river zone's management plans as a tool for categorizing the degree of vulnerability of river flood plains in Syria which will aid in prioritizing decisions.
- Provide hydrographic networks measuring equipment.
- Setup flood defense in risk zones.
- A strong policy for urban planning.
- Continuous improvement of information on risks, hazards and vulnerability by the establishments of an early warning system.
- For future studies, this assessment can be improved by incorporating more variables such as socio-economic parameters (e.g. Population, infrastructures) and adaptive (coping) capacity. Additionally, a more complete dataset of water depth in the gauges can give a better description of the risks to riverine communities and infrastructure.

Improve the system of data collection and availability which will allow the assessment to be replicated to other areas in Syria and can, therefore, support the identification of priority locations for adaptation or mitigation measures.

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References

APEL, H., ARONICA, G. T., KREIBICH, H., THIEKEN, A. H. (2009): *FLOOD RISK ANALYSES - HOW DETAILED DO WE NEED TO BE?*. NATURAL HAZARDS, 49(1), 79- 98.

Balica, S.F. & Wright, N.G. (2010*). Reducing the Complexity of Flood Vulnerability Index.* Environ Hazard J (EHJ). 9(4):321–339

Bhuiyan, S.R. (2014): *Flood Hazard and Vulnerability Assessment in a Riverine Flood Prone Area: A Case Study.* A thesis by in partial fulfillment of the requirements for the Master of Science in water resources development. Institute of Water and Flood Management, Bangladesh University of Engineering and Technology, p.121

El Hassan, I. M., Algarni, D. A. and Dalbouh, F.M. (2014*): Flood Risk Prediction Using DEM and GIS as Applied to Wijj Valley, Taif, Saudi Arabia*. Journal of Geomatics. 8(1), 86-89

Guha-Sapir, D.; Wahlstrom, M. (2015): *The Human Cost of Weather Related Disaster (1995-2015).* Centre for Research on the Epidemiology of Disasters (CRED), the United Nation Office for Disaster Risk Reduction (UNISDR), P.13.

INFORM. (2016*). Measuring the Risk of Humanitarian Crises and Disasters in 191 Countries; Syria country profile*. P.19. http://www.inform-index.org/

Jongman, B., Hochrainer-Stigler, S., Feyen, L. (2014) :*Increasing stress on disaster risk finance due to large floods*. Nature 4,P. 1–5.

McEntire, D. A. (2008). *Comparative Emergency Management: understanding disaster policies, organizations, and initiatives from around the world.* Emergency Administration and Planning, Department of Public Administration, College of Public Affairs and Community Service, University of North Texas. P.13.

Ministry of Local Administration and Environment (MOLA). (2007): Records of the Ministry of Local Administration and Environment, Damascus-Syria.

Peduzzi, P., Dao, H., and Herold, C. (2005): *Mapping Disastrous Natural Hazards Using Global Datasets,* Nat. Hazards, 35(2), 265–289.

Samuels, P. and al. (2009). *The language of Risk: Project Definitions*. Retrieved from floodsite.net, PP.61

UNDP. (2009*): Strengthening Capacity development for disaster risk management in Syria.* Project document. SYR/09/002, P. 39.

Water Resources Directorate. (2015). Records of the Ministry of Water Resources, Lattakia, Syria.

World Bank. (2014): *Natural Disasters in the Middle East and North Africa: A Regional Overview*.81658, P114.