FLOOD VULNERABILITY ASSESSMENT IN TEHRAN CITY (IRAN)

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ABSTRACT: Vulnerability assessment of urban areas against flooding, as a complicated hazard, in Tehran City has been conducted in this research. The flooding has temporal and spatial variability and also increasing trend with enormous financial and life damages. Occurrence of the flood hazard is greatly dependent upon natural conditions, characteristics of urban areas, and also the culture of society. The objective of this research is to find a pattern for the differences of the vulnerability in the urban areas. Variables of old texture blocks, population concentration, land use, and distance to bridges as physical agents and variables of slope and drainage network density as intensifying agents have been included for the analysis. The variables have been prioritized and the relations between these and the vulnerability determined by Analytical Hierarchy Process (AHP). The agents of population concentration and drainage network density have been revealed to have the highest and the lowest weights, respectively. The results have indicated that the regions of 10, 17, 8, and 11 are the most vulnerable and the regions of 22, 21, 18, and 5 are the least vulnerable. The vulnerability map indicates that 138 square kilometers of Tehran area is categorized as very high and high vulnerable. Based on the results from zonal statistic, regions of 10 and 22 have the highest and the lowest vulnerability, respectively. Greatly vulnerable areas are coincident with highly populated regions of old textures.

Key Words: Flooding, vulnerability, Tehran City, Analytical Hierarchy Process

1. INTRODUCTION

Flooding is a common catastrophe that the world today is faced with. This is more devastating than any other hydro-climatic phenomena [1]. The flood events have enormous damages in human lives and financial assets. For comparison with other natural hazards, about 20 % of mortality and more than 33 % of losses in global economy is caused by this hazard [2]. With rapid urban growth and development of infrastructures, this hazard is more intensified in urban areas [3]. Urban areas reduce infiltration, increase runoff with great discharges, decrease recharge of groundwater by expansion of impermeable surfaces. Urbanization increases the possibility of floods due to an increase in peak flow and volume of discharge and a decrease in time of the peak discharge [4,5,6]. Human interference in environment with poor regulations for conservation results in vulnerability of human society against urban flooding. The vulnerability is very complicated and depends greatly upon precipitation, runoff and its time of concentration, and also the areas subjected to inundation downstream. The vulnerability of urban areas against flooding is various in time to time and in different regions. This is because of certain natural conditions, human activities, and the culture of community about the hazards.

As the city of Tehran is very diverse in socio-economic circumstances and quality of life in different regions as well as has structural differences in physical texture, it can be vulnerable to flood events and be subject to financial and health damages. It was reported that the huge flood of 1954 and the event of 1987 in Darband left about 2150 people and 300 people dead, respectively. From 1954 to 1968 about

2226 people was died by 10 flood events. From 1969 to 1982, up to 21 events occurred that killed 25 citizens. Finally, from 1983 to 1995, up to 305 people were killed by 12 flood events in Tehran. [7]

Management of vulnerability due to floods is an important issue to cope with flood hazard. a comprehensive management require to employ qualitative and quantitative models and Geographical Information System (GIS). Many attempts have been conducted for comprehensive management of the hazard and reduction of vulnerabilities. Some of these attempts are including investigation about geomorphologic properties of watersheds and their potential for flood generation, application of quantitative analyses and measurements of variables, modeling and flood management in channels, flood zonation, geomorphologic assessment for urban development, and effects of upstream basins on flooding in residential areas urban integrated flood models [8,9,10,11].

In this study, variability of the vulnerability of urban areas by floods investigated on 22 regions of Tehran City using Analytic Hierarchy Process (AHP) and zonal statistic. This investigation is based on the variables vulnerable in front of flood in order to find the patterns that can explain structural differences of the vulnerability among these regions.

City of Tehran has an area of 730 square kilometers. The city has Alborz Mountains in the north, Lavasanat in the east, Karaj City in the west, and Varamin in the south. The abrupt elevation difference between the urban area (1300 m above sea level) and Tochal mountain summit (3933 m) in 10 km horizontal distance is the main topographic characteristic of the city [12]. In administrative divisions the city has 22 regions, 119 districts, and 362 quarters. The city has a complicated climatic condition due to its location in an elevated area, elevation differences, population growth, development of industries in suburbs, and mountains in the north and desert areas in the south [13]. It is warm and arid in the south and cold in mountainous areas.

2. METHODOLOGY

In this research, the variables effective in vulnerability assessment of physical infrastructures including element at risk and intensifying elements have been selected. The elements at risk are the old structures can be easily inundated by flooding and are occupied by many people. The parameters of population concentration and land use type can be effective in the vulnerability. The water courses, drainage network, and slope are effective in flood assessment as intensifying variables.

Variable of landuse: in Tehran, there are 9 landuse types including residential, green space, urban facilities, industrial, commercial, transportation and warehouse, military, bare lands, and mining. The residential has the most proportion of urban area (35.09%), then the green space (20.28%), and lowest proportion is for mining (1.7%). (Figure 2)

Variable of old urban texture based on legislated indices of supreme council of civil and urban planning is defined by instability, impermeability, and micrograins standards. About 3268 hectares of the urban area is old according to the concluded indices. The increased area of the texture with high population concentration is the main challenge of the city to natural hazards, particularly in from region 7 to 18 and parts of regions 1 and 20.

Variable of population concentration is gathered from population census data in 2009 in regions units. The most concentration of population is in regions 8, 10, 14, 15, 17, 20, and some parts of region 1. The regions of 21 and 22 have the least population concentration. This is ranged from 268 to 59685 people per square kilometers.

As the obstruction of watercourses in bridges is a widespread challenge in runoff management. Distance to the bridges is considered as a variable. There are 127 bridges reported in Tehran by technical council of Tehran Municipality.

Slope can be considered as a flooding pattern in Tehran City. The rapid flow of runoff in the north of the area due to steep slope and the slow flow in the south due to somewhat flat slope can explain the role of slope in flood behavior. The slope variable has been derived from ASTER elevation data.

River and channels in the urban area have a plenty of problems. They are just flowing in main watercourses and not tributaries and also restricted by urban structures. The decrease in the capacity of runoff flow augments the risk of flooding. Human activities have considerable influence on rivers. The hydrolic system determined the geometry of the rivers is now transformed to create flow with frequently higher intensity.

Getting a comprehensive pattern from the variability and vulnerability of flood behavior for an appropriate management requires knowledge of different parts of the city relative to flooding. Analytical Hierarchy Process (AHP) is employed for converting continuous and discrete data of pairwise comparison into ratio scales and for getting weights of relative preferences [14]. AHP is a flexible, powerful, and simple method for decision making in conflict criteria and in a multidimensional space on matrices. With a hierarchy and step by step process this is possible to make comparison matrices in different levels of the hierarchy and to calculate the weights of options by combination of vectors [16]. For this analysis, we make a direct or inverse linear relation between the vulnerability and each of the parameters. As the vulnerability increase relative to the values of each variable, the relation is direct and vice versa. Definition of the relations needs to specify the values if each variable, i.e., it must be possible to make relation between the vulnerability and the change in the values of the variable. Based on the importance of the variables in vulnerability and linear or non-linear relation, their prioritization has been compared and weighted for execution of the model (Table 2).

Table 2: weighting and variable classes and their prioritization in AHP based on the vulnerability

Weight of variable	1	2	3	4	5	6	7	8	9	10
Land use (CN)	82	70	85	98	90	97	88	93	92	95
Old texture	-	Micro-grain	-	Impermeable	-	Instable	-	-	Instable – impermeable	Instable – impermeable – micro grain
Distance to bridge (m)	8828-104116	7404-8828	6021-7404	4841-6021	3865-4841	3010-3865	2237-3010	1505-2237	813-1505	0-813
Population concentration	268-2821	2821-5606	5606-7927	7927-10712	10712-13729	13729-17443	17443-22781	22781-28584	28584-40885	40885-59685
Slope (degree)	0-1.28	1.86-3.5	3.5-5.5	5.5-8.06	8.06-11.17	11.17-15.3	15.3-20.4	20.4-26.4	26.4-34.3	34.3-53
Concentration of stream network (km/km^2)	0-1.3	1.3-4	4-6.6	6.6-9.5	9.5-12.6	12.6-16.1	16.1-20.5	20.5-26.2	26.2-33.5	33.5-43

3. RESULTS

The variables effective in vulnerability including landuse, old texture blocks, distance to bridge, population concentration, slope, and concentration of stream network have been entered a 6*6 matrix to determine their weights and prioritization.

To calculate the eigenvectors and eigenvalues, the relative weights have been obtained after normalization of the matrix. The relative weights have been used as the magnitude of influence of each variable in the vulnerability. The vulnerability in front of flood is defined as a function of these coefficients in equation 1.

Equation 1:

$$V = (0.3825\mathrm{P}) + (0.2504\mathrm{T}) + (0.1596\mathrm{T}) + (0.1006\mathrm{B}) + *0.641\mathrm{S}) + (0.0428\mathrm{D})$$

Where, V is vulnerability, P is population concentration, T is old texture blocks, B is distance to bridges, S is slope, and D is drainage network concentration. Figure 1 indicate the vulnerability map of Tehran in front of flood. Values of 0 represent the classes with least vulnerability and the values of 1 the classes with the highest vulnerability. The area is categorized into five classes of very high, high, moderate, low, and very low vulnerable.

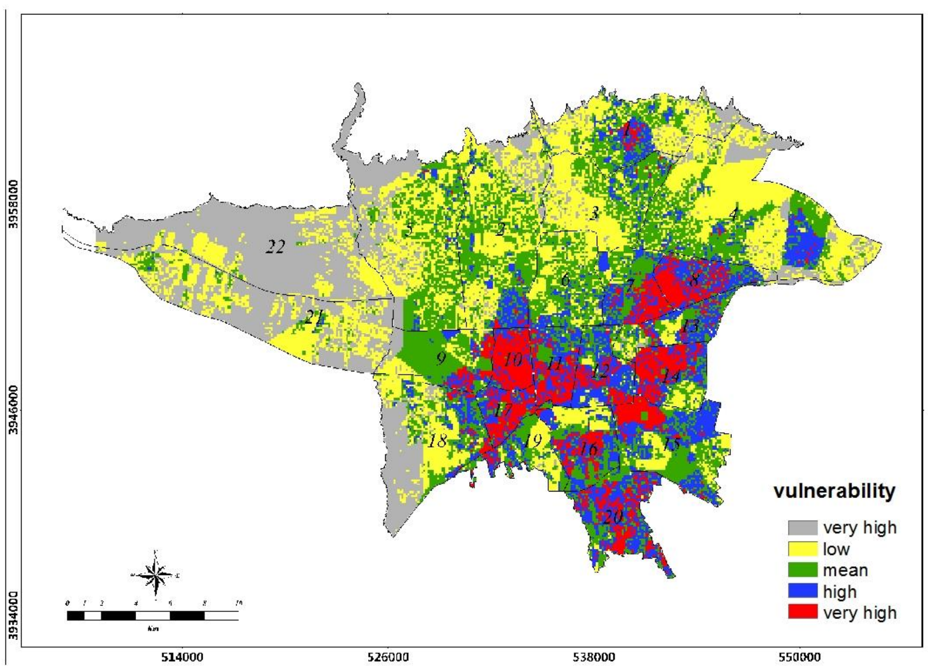

Figure 1: potential risk areas of flood in Tehran megalopolis

4. DISCUSSION AND CONCLUSION

The potential flood risk map cannot solely provide the information for urban flood management. The information about the amount of damage and magnitude of destruction may not just be predicted by estimation of the intensity of the hazard, but it depends greatly to the construction conditions. Prediction of hazard risk requires a scrutiny on causes of the damage by considering both risk potential and vulnerability. Thus, it is necessary to have a set of flood hazard and other parameters for a proper flood management. To achieve this goal, analysis of the vulnerability is essential to grasp the effects of the flood upon human properties and lives. The possibility and the intensity of hazard is not the only effective factor in risk potential, but the potential is dependent upon the dangers to which the constructions are exposed and upon how much they are vulnerable.

The vulnerability values of the 22 regions of Tehran Municipality based on the weights from AHP have been obtained using zonal statistic (Figure 2). The regions of 10, 17, 8, and 11 are the most vulnerable and the regions of 22, 21, 18, and 5 are the least vulnerable in case of flooding. The later is approximately devoid of urban old texture and also less populated than other regions. Particularly the region 22 has very low vulnerability because it has no old texture, very low population concentration, and good drainage of runoff.

The vulnerability map can indicate social and economic circumstances of different regions of Tehran. The most vulnerable areas are coincident with old textures and high populated regions. Instable micrograin textures next to the main watercourses of Tehran in south, center, and east of the city can be the reason for vulnerability of these regions. As the most of the city area is belonging to residential land uses in regions 7 and 18 with old blocks, the regions are mostly vulnerable to flooding.

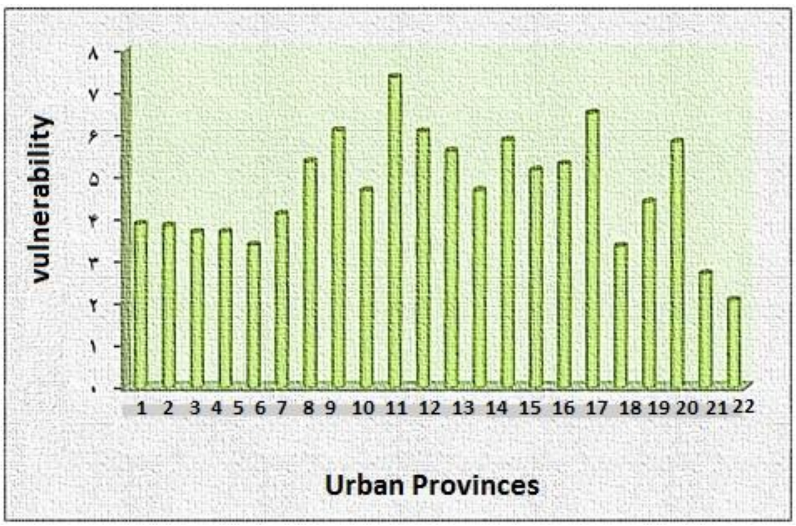

Figure 2: The vulnerability in different regions of Tehran

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