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Integrated application of HEC-RAS and GIS and RS for flood risk assessment in Lighvan Chai River

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ABSTRACT: *One of the newest methods of flood zoning maps is using GIS and combining with hydraulic and hydrological models. Flood events in Lighvan basin damage to garden, agriculture and residential areas. Also the main causes of these damages are land use changes in last few years. In this study, flood prone area with different return periods was determined in 16 km length of the Lighvan Chai River using GIS and HEC-RAS model and land use changes of 10 years (2000-2010) was extracted using satellite images. The results of flood zoning show that the ratio of flooded area by 25-year to the flooded area by 200-year return period is equivalent to 67%. This issue indicates that approximately 67% of the total area of flooding is caused by 25-year or less. The land use change analysis shows decreasing in dense pasture, barren land and irrigated farming and increasing in residential area, weak pasture, and rain fed farming. The analysis of water surface profiles shows that flooded areas of residential area, rainfed farming and garden have increased in different return periods and from 2000 to 2010.*

***KEYWORDS*:** *Flood, GIS, HEC-RAS, Land use, Lighvan Chai River*

1. INTRODUCTION

The population in hazardous areas and the vulnerability of human settlements has grown dramatically over the past half century. The growth of disaster losses is to a large part due to human decisions and human investments [1,2].One of the most common hazards among all environmental hazards is flooding that endanger the lives of millions people around the world each year. Throughout history people have been attracted to the fertile land of the flood plains where their lives have been made easier by virtue of close proximity to sources of food and water. Ironically, the same river or stream that provides sustenance to the surrounding population also renders these populations vulnerable to disaster by periodic flooding. Floods are of many types including flash flooding [3], flooding due to rising ground water [4], coastal flooding [5] and flooding due to the opening or breaking of a dam or reservoir [6]. Of course nowadays excessive human interference has caused flooding in many places that previously was not flood. So that in addition to excessive rainfall and snowfall, some human activities increases the risk of flooding such as the construction in the floodplain of the river that reduces the natural capacity of the river. So the management of flood plains will be very important. First step to the management of floods and flood plains is preparation of flood zoning maps. The application of these maps can be used to determine the river bed, study of economic development projects, flood forecasting and warning, rescue operations and flood insurance. There are different methods used to create the flood zoning map such as observation method, comparison of aerial photographs, mathematical models. One of the newest methods is using GIS and integrated with hydraulic and hydrological models [7,8].

Regarding to zoning and identification of flood prone areas, many studies has been done in the world; Qummi Oil et al (2010) simulated flood zoning of Karun River between Bandeghir to Ahwaz using HEC-RAS model. Flood risk zoning were estimated using DEM of the river vicinity and maximum water level elevation at any given sections for the period of 5, 10, 20, 25, 50 and 100 years using HEC-RAS software capabilities. Alao area of agricultural lands and residential areas that will fall at risk in the event of flood risk were identified for the floods with different return periods [9]. Roushan et al. (2013) simulated hydraulic behavior of the Bashar River using HEC-RAS and GIS. The purpose of this study was to combination the HEC-RAS hydraulic model and Arc View GIS software using HEC-GeoRAS extension for simulating the hydraulic parameters of Basher River located in the Kohgiloyeh and Boyerahmad province. The results of this study indicate that the HEC-RAS model can provide the appropriate numerical values for investigating the hydraulic characteristics of flow in rivers and used for flood hazard mapping with more accuracy and low cost [10]. Timbadiya et al. (2011) has predicted flood for Lower Tapi River in India using HEC-RAS for 1998 and 2003 years. The calibrated model, in terms of channel roughness, has been used to simulate the flood for 2006 year in the river. The performance of the calibrated HEC-RAS based model has been accessed by capturing the flood peaks of observed and simulated floods; and computation of root mean squared error (RMSE) for the inter-mediated gauging stations on the lower Tapi River [11]. Prata et al. (2011) analyzed flooding using HEC-RAS modeling for Taquaraçu River, in the Ibiraçu city of Brazil. They simulated different levels of water and water flow for different return periods [12]. ShahiriParsa et al.(2013) simulated flood zoning by HEC-RAS model in the Kota Tinggi district in Johor state. Implementation processes of the zoning on basin for return periods of 2, 25, 50 and 100 years were applied with different roughness coefficients. The volume and upstream surface runoff area and stream or flood conditions and physical characteristics of the area (surface morphology, etc.) were the most significant factors that can affect the severity and recurrence of floods in every region [13]. Kute et al. (2014) modeled flood of Godavari River using HEC-RAS software. The flood released for Gangapur dam, which was constructed on upstream of Nashik city at 14 km distance is considered for the modeling. The flood discharge was based on the worst discharge of 1969 flood. The river, 14 bridges across the river and the flood plain were modeled. The model facilitated to locate the flood plain and its extent for effective flood mitigation measures [14]. Mohaghegh et al. (2015) investigated the effect of flood zones of Maroon River on the environment and around the river using HEC-RAS and GIS. Results show that difference in flooding area expansion is mostly resulted from topographic traits of the valley path. Wherever the waterway width increased, flood area also was increased and wherever the valley was narrow, the width of flooding area decreased proportionally, and depth of flooding area increased. By increasing return period also, the flood zone increased but, it was obvious that, 25 years old and older flood zones were hazardous for the region and may cause some risks for the environment, consequently, preservative and management measures were needed. Damages of flood were investigable in various economic, social and environmental sectors [15]. So many of studies have confirm that software HEC-RAS using GIS and satellite images has a high capacity to determine the flood zone and the water level in natural or artificial channels and also the effect of river structures can to simulate useing different return periods and also it is possible to simulated flood zoning in three dimensions [16,17,18]. According to the Regional Water Authority of East Azarbaijan province, flood damages have increased in the Lighvan basin during the last 10 years. The main causes of damage are ignorance of the law and technical issues, also basin problems, including severe erosion in the basin and increased runoff, grazing and land use change, climate change and drainage problems such as non-technical structures, occupied bed and natural factors are involved in causing the damage. So flood zoning and respect to river privacy and avoid non-essential structures and land use optimization to address the threat of flooding in the area seems necessary.

II. MATERIAL AND METHODS

2.1. Study area

The Lighvan basin is located in the northern slope of Sahand Mountain (north western Iran) with the geographical coordinates 37º 55' to 37º 43'30"of north latitude and 46º 22'25" to 46º 29' 15" of east longitude (Fig. 1). According to topographical characteristics, the study area can be divided into two unites: high mountain and high plateau. Igneous rocks, Quaternary in age, and alluvium tuff with the relatively large thickness outcrop in the basin. Soils are young and relatively undeveloped and consist of two categories, entisol and inceptisol. There are two hydrological stations within the basin. The average annual precipitation in the period 1991-2012 was 333 mm and 250 mm respectively at Lighvan and Hervi station. Average annual temperature of the Lighvan basin is 6.4 ° C. The climate, according to classification categories of Ball (1991) and available statistical data, is cold semi-arid, shifting to cold semi-humid in the highest portions of the basin [19]. The length of the Lighvan River is 28.5 km. The regime of river is snowy and therefore its drainage basin density is low. The average annual discharge is 6.6 m3/s at the outlet of the basin (Hervi station). Lighvan valley has U-form in the upper part of the basin where the river is mainly confined. Gradually the valley bottom becomes wider and the Lighvan Chai River flows in semi-confined and unconfined conditions [20]. Also in this valley, there are four villages within the study area (Hervi, Beiragh, Lighvan and Sefideh Khan). By increasing population of these villages in Lighvan Chai floodplain, land use changes have increased. The length of study reach in this area is 15.8 km, from Lighvan village to Hervi village. Lighvan basin has an area of 142 km2. Since human activity and demographic changes lead to changes in the land use pattern of the area and Lighvan basin as a semi-arid region is influenced by natural and human factors that are sensitive to environmental changes and is always at the risk of flooding.

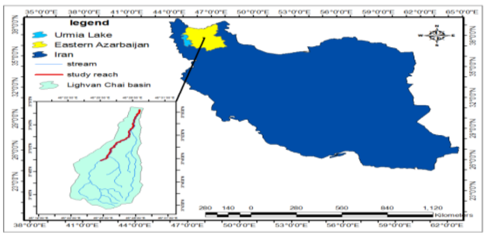

Figure 1: The Geographical location of the study area

2.2 Extracting land use map using satellite imagery

Remote sensing can provide measurements of many of the hydrologic variables such as land use. Since the multitemporal Landsat data, among others, represent a useful approach to map and analyze changes in land cover over time: changes in Land use/Land Cover due to natural and human activities can be observed using current and archived remotely sensed data [21,22,23,24], and they can provide information to be used as inputs to land management and policy decisions [25]. The pixel format of digital remote sensing data makes it suitable to merge it with geographic information system (GIS) [26]. In this paper, after preparing the remote sensing data (ETM + of 2000 and 2010) for the study area and processing them, land use map were extracted. In this method, first, after the corrections of images, image processing was done. The ENVI 4.7 software was used for preparing land use map of Lighvan Chai basin based on supervised classification in which automatic classification of all pixels in the image is according to the type of ground cover or similar cases. For classification, multi-spectral image data are used, in fact spectral pattern of data for each pixel is used as numeric base for the classification [27]. Training samples was determined by referring to images, maps and Google Earth and then after specified the training samples, classification defined by the maximum likelihood algorithm that showed the best results so that the pixels of image were evaluated and classified based on defined algorithms in land cover classes in proportion to the numerical of the training samples.

The classes include garden, irrigated farming, rainfed farming, pastures, residential areas, barren land, which were based digital interpretation. Since the classification is completed when its accuracy is evaluated. When the sampling of pixels were performed as a pattern of spectral classes, evaluation spectral reflectance of classes and their resolution can be performed simultaneously .Therefore, evaluation of the classification accuracy is performed to ensure the classification accuracy. Classification accuracy will be indicated a trust level of extracted map. Then for assessing the accuracy of statistical parameters such as the error matrices, kappa coefficient, overall accuracy of classification for each classification is obtained. In the final process, the methods used to improve the classified images that are known usually as post classification. At this stage we can use the various techniques such as GIS and involving the use of non-spectral information to improve the classification quality or carried out the operating such as merging classes or evaluation of the output maps accuracy by calculating kappa and overall accuracy classification.

2.3 HEC-RAS model

The 1:1000 topographic maps of 16 km of Lighvan Chai River (prepared by the Azarpeymayesh Consulting Engineers of East Azarbaijan) were used for Lighvan Chai River flood zoning. So that after georeferencing of maps in ArcGIS software and converted to UTM and local height above MSL (mean sea level height) and then the digitizing the maps using ArcGIS software and Auto Cad, geometric data of the river cross section profiles were extracted from these maps. Then Lighvan basin was divided into 7 sub basins base on the data of maximum discharge of Lighvan and Hervi stations and connecting tributaries. And then the maximum flood discharge at different return periods was obtained using Smada software and Fuller empirical formula (equations 1 and 2):

$$Q_{max} = Q_{PT}(1 + 2.66A^{-0.3}) \quad (1)$$

$$Q_{PT} = CA^{0.8}(1 + 0.3474 \ln T) \quad (2)$$

Where T is flood return period (years), C is a constant coefficient that amount of which depends on the slope and basin land cover that is between 0.03 to 2.8, A is area (km2) and Qmax is maximum flood discharge (m3/s)

In this method, the maximum flood discharge of the region has been linked with its area [28]. It is noteworthy that at the study area, Fuller formula has been approved for estimation of maximum flood. After obtaining the discharge with different return periods, these data with cross-sections were inputted the HEC-RAS software. HEC-RAS software was developed by America's military engineers and it calculates water surface profile by the geometric and hydrometric data [29]. HEC-RAS was chosen for this research because it is an open source application and its geometric data input and simulation can be done in GIS environment. The simulation in HEC-RAS has fallowing steps:

- Create a schematic project of Lighvan Chai river system
- Import geometric data of cross sections extracted from topographic maps
- Entering the river and reach information, the right and the left banks of the cross sections, distance of the main channel and the left and the right bank from the downstream section, roughness coefficient in the main channel and the left and the right banks (roughness coefficient was obtained based on maps, photos and field observations and using the table of Chow roughness coefficients [30]).
- Entering the steady flow data and discharge with different return periods calculated by the Fuller formula.
- Determine the boundary conditions (there are four boundary conditions such as rating curve, normal depth, critical depth and water surface level. Here, boundary conditions of normal depth were chosen. For this type of

boundary conditions, it should be calculate energy grade-line that will be used in the calculating of normal depth. A normal depth will be calculated based on the slope. If the information of energy grade-line is not available, the approximate value of energy grade-line should be defined by entering the water surface slope or channel slope. Thus, the mixed flow regime was considered and the average of energy grade-line in the downstream and the upstream were calculated and were introduced to the model). Finally, after entering all of the data, the simulation was carried out and the water surface profiles were extracted.

- In the next step, after modeling in HEC-RAS, results were interred into Arc View and by using HEC-geoRAS and Xtools extensions, flood zones and its areas was extracted. HEC-GeoRAS was used to extract water surface profile data from HEC-RAS and incorporate it into a floodplain map in GIS. The flooded area was delineated using the water surface data and the DEM created for the basin.

After preparing flood zoning maps and land use maps, these maps were overlaid in Arc GIS and the area of different land uses that can be flooded in different return periods was calculated.

III. RESULTS AND DISCUSSION

After entering all of the 120 cross sections of Lighvan Chai River (Fig. 2) and the maximum flood discharge with different return periods in seven reaches (Table 1), and other information such as the coefficient of roughness of the main channel and floodplain, modeling was performed.

Figure 2: Location of cross sections on the Lighvan Chai River

Table 1: Maximum flood discharge at different reaches

Reach	Discharge(m3/s) with different return periods						
	2	5	10	25	50	100	200
1	4.58	9.07	13.37	20.74	27.92	36.84	47.87
2	4.73	9.36	13.79	21.40	28.81	38.02	49.40
3	4.66	11.19	16.50	25.60	34.47	45.49	59.10
4	5.88	11.62	17.13	26.58	35.79	47.22	61.36
5	6.08	12.03	17.74	27.52	37.05	48.90	63.53
6	7.95	15.73	23.19	35.97	48.43	63.91	83.04
7	8.29	16.39	24.16	37.49	50.47	66.60	86.54

The simulation results were shown the flood levels in cross sections (Fig. 3) and three-dimensional view of flood levels in a part of the study reaches (Fig. 4) also calculation of flood zoning and the its area was performed in GIS.

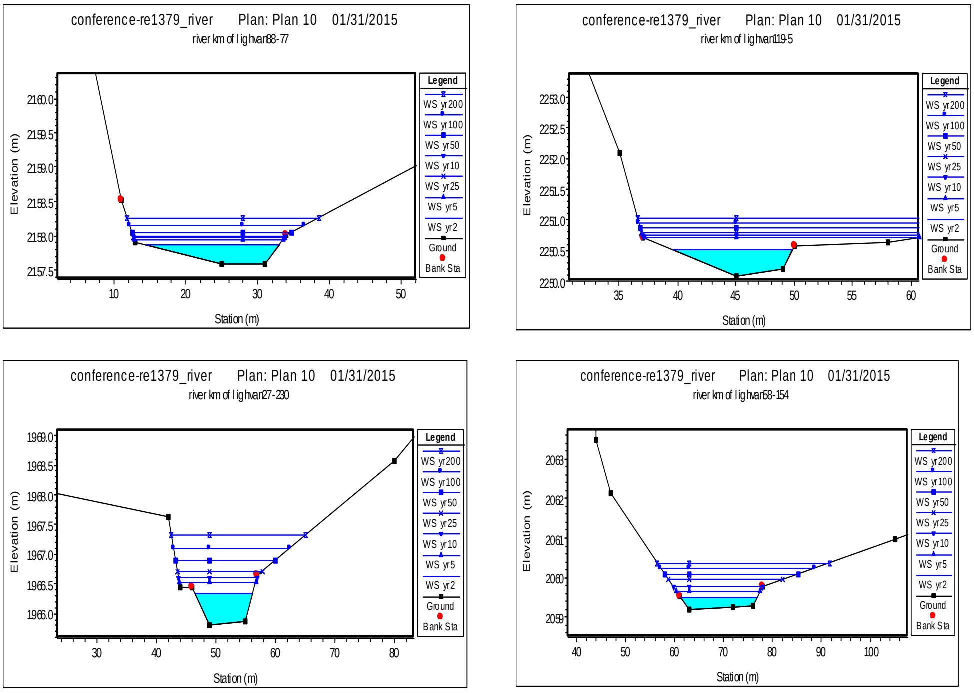

Figure 3: Flood levels with different return period in four cross sections

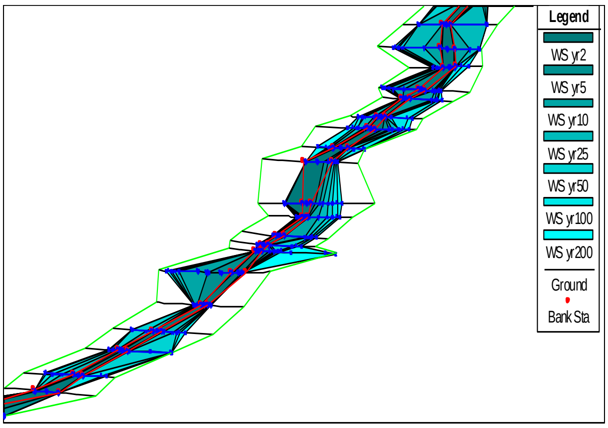

Figure 4: Three-dimensional view of flood levels on the part of study reach

Flood levels area in Table 2 and Fig. 5 show that by increasing the discharge of longer return periods, flood covers more surface flooding. Expansion of flood zoning affected by topographical features of the Lighvan Chai River valleys, human intervention in river channel and river banks such as construction, agricultural, and channel narrowing. Anywhere the valley width and the channel have increased, the width of the flood area has increased and water has expanded in wider area. Conversely, anywhere the valleys and channel width have been narrow, the width of flood area has reduced in the same proportion and also the depth of flood levels has increased.

Table 2: Area of flood zoning at the different return periods

Return Period (Year)	2	5	10	25	50	100	200
Area (km2)	0.21	0.31	0.40	0.51	0.60	0.69	0.76

Figure 5: Flood zoning with different return periods in the part of the study area

According to Suriya and Mudgal (2012) integrated flood management and land use change along with HEC-RAS hydraulic model simulations is required for flood risk mitigation [31]. So land use change of Lighvan basin were analyzed in two time periods (2000 and 2010). The land use classes of Lighvan basin were defined: garden, irrigated farming, rain fed farming, bare land, residential areas, dense pasture and weak pasture (Fig. 6). Overall accuracy was assessed 96% and 95% for 2000 and 2012 also Kappa coefficient was 0.95 and 0.94 for 2000 and 2012 respectively. Land use changes from 2000-2010 (Table 3) shows decreasing of dense pasture (-44), barren land (-54.3) and Irrigated farming (-0.5); increasing of residential area (88.9), weak pasture (45.5) and rain fed farming (38.6). These land use changes in Lighvan basin are related to population changes, management and knowledge level of the rural residents in the area [32].

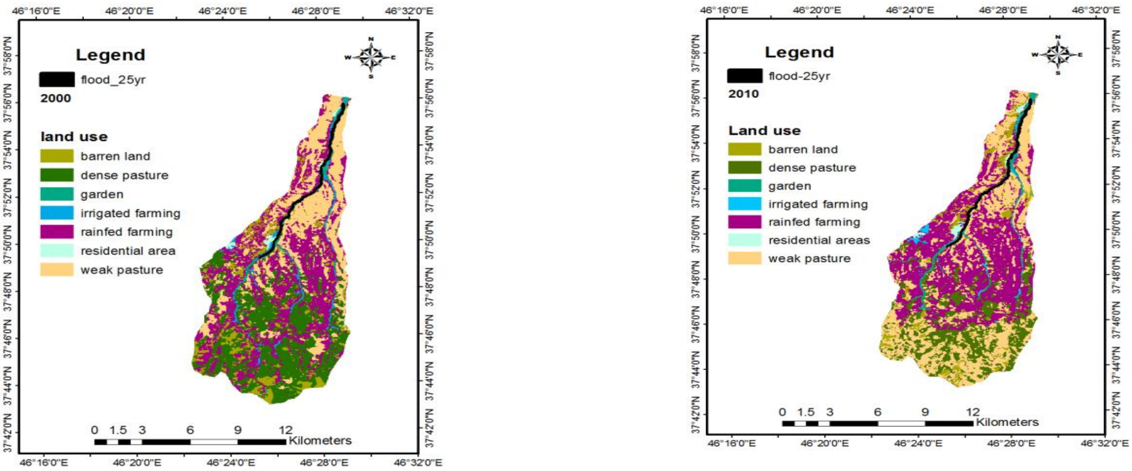

Figure 6: Land use maps of 2000 and 2010 with floodplain area (black color) for return period of 25-yr in Lighvan basin

Table 3: Land use changes in 2000 and 2010

Land use	2000	2010	Change%
	Area(km2)	Area(km2)	
Residential area	0.9	1.7	88.9
Weak pasture	33.2	48.3	45.5
Rainfed farming	37.5	52	38.6
Garden	3.9	5	28.2
Irrigated farming	3.2	1.5	-0.5
Dense pasture	44.7	25	-44
Barren land	18.6	8.5	-54.3
Sum	142	142	

Land use along the study-reach flood plain is predominately by trees, vegetation, residential area and agricultural farming. Overlaying land use maps (Fig. 6) and flood zoning map (Fig. 5) in different return period shows that flooded area in rainfed farming, residential area and garden has increased but flooded area in barren land and irrigated farming has decreased (Table 4).

Table 4: Flooded areas (m^2)in different return periods

Return period	Baren land		garden		Irrigated farming		Rain fed farming		Residential area	
	2000	2010	2000	2010	2000	2010	2000	2010	2000	2010
2	19332.19	14323.17	207800.79	206416.87	58401.27	8323.17	29793.44	18268.25	13662.89	13834.28
5	31233.44	21653.36	313102.84	310634.61	112263.24	13054.48	46721.55	41065.24	20776.65	20793.77
10	47960.86	36889.16	411227.24	408628.07	185003.11	46039.38	168354.95	88428.85	29799.45	29816.57
25	73854.46	46482.44	528564.25	526184.41	556838.74	55211.79	455202.23	313394.86	38256.25	38290.48
50	164297.34	53834.57	620557.95	618391.72	981097.21	65116.93	761533.86	594345.28	45121.97	45139.09
100	387300.62	153049.17	709782.34	706705.58	2705161.27	74912.65	1579214.09	1035038.56	53189.40	53206.51
200	819982.72	377276.04	789166.54	787901.30	3957228.87	133934.58	2139200.87	1644715.26	156019.81	156036.93

IV. CONCLUSIONS

Geographical information system and remote sensing is the useful tool in recognizing environmental hazards especially flood. Also with integrating remote sensing data, field study and softwares such as HEC-RAS it is possible to determine the flood area and allowable limit of construction and the criteria for zoning flood and flood insurances The main advantage of using GIS for flood management is that, it does not only generate a visualization of flooding but also creates potential to further analyze, this product to estimate probable damage due to flood. These advances will provide for a more efficient and a more accurate alternative to traditional methods for studying basins. Findings of this research show that with use of the satellite images and flood simulations it is possible to show flood zoning maps, return periods and the effects of flood on land use of flood plains. The results of Lighvan Chai flood zoning show that the ratio of flooded area by 25-year to the flooded area by 200-year return period is equivalent to 67%. This issue indicates that approximately 67% of the total area of flooding is caused by 25-year or less. So much of the flood plain areas to be flooded. The Land use change of lighvan basin analysis shows 44%, 54.3% and 0.5% decrease in dense pasture, barren land and Irrigated farming respectively. However, residential area, weak pasture, and rainfed farming have increased by 88.9%, 45.5% and 38.6% respectively. The analysis of water surface profiles shows that flooded areas of residential area, rain fed farming and garden have increased in different return periods and also from 2000 to 2010. Therefore, flood damages to valuable agricultural lands and residential area in the study area. Therefore, strategic programming by using the maps of land use changes and flood hazard zoning in different return periods can prevent from large cost.

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