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Rainfall Floods as a Result of Land Use Alteration in a Syrian Refugee Camp in Jordan

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Abstract

The Zaatri Refugee Camp (ZRC) established summer 2012 shortly after the Syrian conflict started. Due to high flux of refugee fled the conflect south of Syria to Jordan and in a short notice, the international organizations with the Government of Jordan started to establish the camp with limited data on socio-economic and environmental impacts of the selected site. The camp is located in a nearly flat area which forms natural soil pan that used for cultivation. One of the environmental impacts for the selected site is the flooding in parts of the camp due to altering the hydrologic response of the area. This alteration is resulted in two ways: the first on is the building of earth wall around the camp which stops the runoff floods from getting into the natural water courses, the second alteration is the building of dense metal houses with compacted pathways in between.

After establishing the camp, the land use changed completely, dense metal housings are built covering around 50% of the area. Networks of compacted roads between the housing blocks are built using imported crushed limestone aggregates. The change in land cover increased the Curve Number (CN) from 84 for the natural agricultural land to 92.5 for the built up area. The increase in CN due to altering the hydrologic parameters within the camp area increased the runoff depth by 82% to 614%, this resulting in more flood water trapped inside the boundaries of the camp. The flood volumes that accumulated can cover more than 10% of the camp area with average water depth 25 centimeters (cm) for 25-years return period storms. In other hand, the storms event that most probably occurs every other year (2-years return period) could result in flood that covers about 1.5% of the camp area with water depth that reaches 25 cm.

Keywords: Rainfall floods, Land use alteration, Zaatari Refugee Camp, Jordan

1. Introduction

Flood risk analysis for an area requires modeling the runoff resulting from up normal rainfall storm (Apel et al. 2006). In order to model the flood risk, the rainfall-runoff modeling requires good delineation of watersheds and estimation of physical and hydrological parameters of these watersheds as well as metrological data (Monte et al. 2016). The flood risk could be in a regional scale where large areas are at risk of flooding or it could be in local scale where small lower areas can be flooded due to limited amounts of rainfall. The flood modeling at a regional scale has limited accuracy due to variation of modeling input such as rainfall depth at a regional scale (Knebl et al. 2005). The backbone of flood risk analysis is the rainfall-runoff hydrological modeling, there are several techniques for runoff modeling. The useful technique for flood analysis is the use of distributed modeling in a raster based modeling environment (Khan et al. 2011, Gharagozlou et al. 2011, Horritt & Bates 2001).

The SCS-CN method is widely used to model runoff using rainfall events (Zaharia et al. 2015). In ungagged watersheds, there are limited data to use complex models, the SCS-CN method needs simple input data that can be derived from physio-geographic data such as Digital Elevation Model (DEM), soil type and land use/cover for the targeted area. (Miller & Clancy 2017, Cronshey 1986). In the SCS-CN method the runoff depth (R) is calculated for a given storm that has a rainfall depth (P) using one parameters, the potential storage (S) which is calculated using the Curve Number (CN). The CN for a given watershed is derived using the characteristics of the watershed such as soil type, land use and man-made practices if any (Cronshey. 1986). The S value (in millimeters) is calculated as:

$$S = \frac{25400}{CN} - 254 \tag{1}$$

The SCS-CN method suggests that the runoff occurs when the rainfall depth exceeded the initial abstraction (Ia) which is in average equal 0.2 the potential storage (S) (Cronshey. 1986). The runoff for storms more than 0.2S is calculated as:

$$R = \frac{(P-0.2S)^2}{(P+0.8S)} \qquad (2)$$

The Digital Elevation Models (DEM) are spatial grids with the value of each cell represents its elevation. There are several algorithms in the Geographic Information System (GIS) software to extract geographic data from the DEM, these data are defined and extracted based on the purpose of analysis (Troolin & Clancy 2016). For hydrologic analysis, the DEM are used to delineate watershed boundaries, stream lines, watershed slope and with other data such are land use and soil, other parameters of the watershed can be extracted such as runoff soil retention potentials and hydrologic response (Martínez-López et al. 2014, Zhang et al 2014). All GIS software use what is called D8 flow routing algorithm where each cell is surrounded by 8 cells and it routs its flood to the neighboring cell of most gradient. In watershed delineation, each cell is given a flow direction to the highest gradient of the surrounding cells and from these direction an accumulated values are for each cell to represent how many cells rout its flood to that cell. In some cases, a cell with an elevation is lower that all surrounding cells cannot rout its flood to any cell and form what is called in GIS a sink where flood routed from surrounding cells end into the sink cell forming an error in flow direction and accumulation, in this case, the value of the sink cell is corrected to be equal the lowest value in the surrounding 8 cells (Troolin & Clancy 2016). The literature suggested that there is no significant difference between different watershed delineation algorithms used GIS software (Castronova & Goodall 2014). The accuracy of the watershed delineation depends mainly on the resolution of the DEM which is the area size of each cell (Liu et al. 2016, Reddy & Reddy 2015).

2. Study Area

The Zaatri Refugee Camp (ZRC) established summer 2012 shortly after the Syrian conflict started (UNHCR 2017). At that time a flux of refugee fled the conflict area in south Syria to Jordan. In a short notice, the international organizations with the Government of Jordan started to establish the camp with limited studies on socio-economic and environmental impacts of the selected location. One of the environmental concerns for the selected site that it is located in a nearly flat area which forms natural soil pan that used for cultivation. The site low slope limits the draining of the runoff to a close by water course, most of these rainfall infiltrates into the top soil. The works in the camp altered the natural hydrologic response of the area in two ways: the first on is the building of earth wall around the camp which stops the runoff floods from getting into the natural water courses, the second alteration is the building of dense metal houses with compacted pathways in between. The dense houses and compacted pathways increase the runoff and reduce the soil capacity to store water. As a result of these effects, after each heavy rainfall events, several areas in the camp are flooded and affect the life of the residents of these areas. This study will evaluate the hydrologic response of the area before and after building the ZRC and estimate the runoff volumes based on most probable storms for different return periods and recommend solutions to reduce flood effect on these areas.

3. Methodology

To analyze the hydrologic response of the study area, the hydrologic parameters are established. The ASTM-DEM is used to delineate the major watersheds around the ZRC and the flow accumulation inside the camp area. The CN for the area before establishing the camp and after changing the land cover within the camp is calculated. The watershed geographic parameters along with the average CN are used to calculate the runoff volume resulting from daily rainfall events. The rainfall values are found using Intensity-Duration-Frequency (IDF) for the area (CEC 2011).

The ASTM 30-m resolution DEM from the USGS site can be downloaded for the study area. this DEM then is used within the ArcGIS to find the geographic parameters for the watershed in the study area. The functions used in ArcGIS are the "Arc Hydro" tools which involve filling the sinks in the DEM, defining flow direction and accumulation and extracting stream lines and watershed divides.

The IDF data for Jordan are developed by Consulting Engineering Center (CEC 2011) for the whole country using historical rainfall records at stations covering the country. The IDF data are presented in the form of isohyet lines on the Jordan map for various rainfall durations and return periods. For the purpose of this study, the daily rainfall for the return periods 2, 5, 10, and 25 years are used.

The soil type in the study area is identified using the soil maps developed by the Jordanian Ministry of Agriculture (MoA 1995). The soil type with the land use/cover the camp are used to find the CNs for the camp area before and after establishing the camp (Cronshey, R. 1986). The CN then used to calculate the potential storage of soil (S) using Equation (1). The S values with the rainfall depths for the different returned periods are used in Equation (2) to calculate the runoff depths, which are used to calculate the flood volumes resulting in each sub-basin inside the camp for a given return period.

4. Analysis and Results

The ASTM 30-m resolution DEM that is downloaded from the USGS site for the area is used to delineate the watersheds upstream of the ZRC and the sub-basins within the camp area. The watersheds in the study area and the sub-basins within the ZRC area are delineated as shown in Figures 1 and 2 respectively. The area for each sub-basin within the ZRC is calculated from the map data and tabulated in Table 1.

Using the IDF data for Jordan that is presented as isohyet lines, the daily rainfall for the return periods 2, 5, 10, and 25 years are found and tabulated in Table 2 in the form of depths.

Table 1, Areas of the sub-basins within the ZRC boundaries

Sub-basin	Z-1	Z-2	Z-3	Z-4	Z-5	Z-6	Z-7	Z-8	Z-9
Area (km^2)	0.540	1.349	0.163	1.066	0.130	0.336	0.336	0.197	0.917

Table 2, Rainfall depths in the study area for different return periods

Return period	2	5	10	25
Daily rainfall (mm)	15	27	35	45

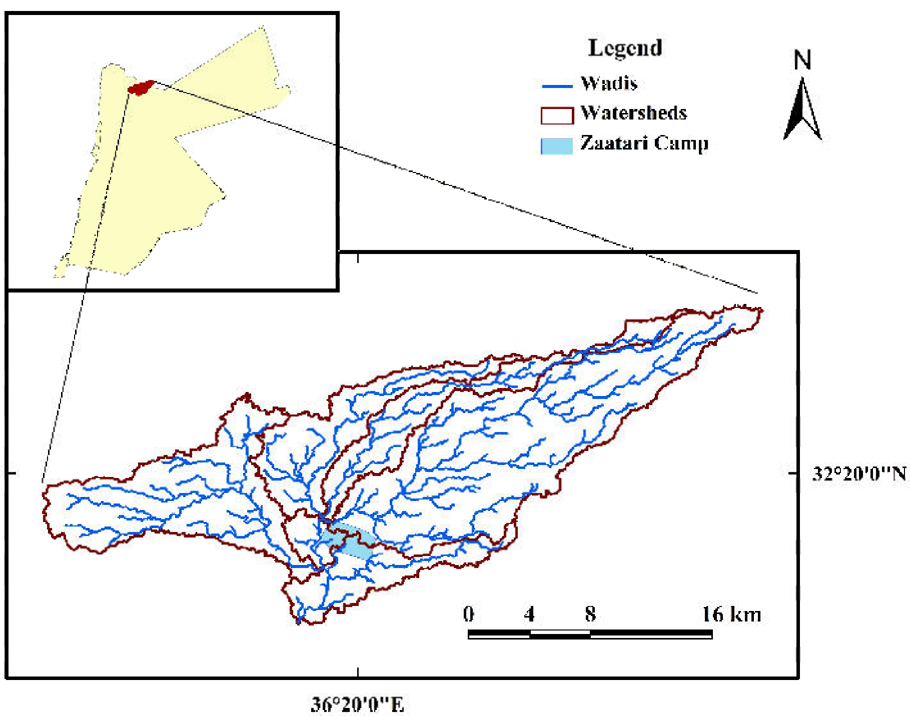

Figure 1. Watersheds Upstream of the ZRC

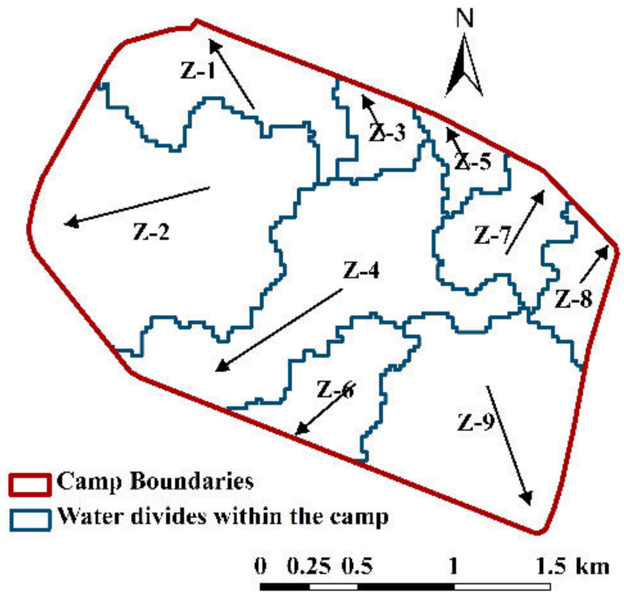

Figure 2. Sub-basins within the ZRC boundaries

The soil on the site is mostly silty clay loam which is group C for the SCS-CN method (Cronshey, R. 1986). The land use before establishing the camp is rain-fed cultivation which gives a curve number as 84. Using equation (1) with CN = 84, the potential storage, S will be 48.4 mm. With this value for S, the Runoff, R for each return period is calculated, given the daily rainfall depth using equation (2) and the results are shown in Table 3.

On the other hand, after establishing the camp, the land use changed completely, dense metal housings are built covering around 50% of the area. Networks of compacted roads between the housing blocks are built using imported crushed limestone aggregates (Figure 3). The curve number for the area between housings becomes as 87 while for the impervious area of the housings tops is 98, this results in an average curve number of the area after building the housings as 92.5. Using equation (1) with CN = 92.5, the potential storage, S will be 20.6 mm. With this value for S, the Runoff, R for each return period is calculated, given the daily rainfall depth using equation (2) and the results are shown in Table 3. The runoff volumes resulting from each sub-basin after hydrological alteration of the area within the camp are calculated as shown in Table 4,

Table 3. Runoff depths before and after area altiration for different return period

Return period	Daily rainfall (mm)	Runoff before alteration (mm)	Runoff after alteration (mm)	Percentage increase (%)
2	15	0.53	3.76	614
5	27	4.56	12.04	164
10	35	8.70	18.52	113
25	45	14.90	27.18	82

Table 4. Runoff volumes in the sub-basins for different return periods

Sub-basin	Area (km^2)	Runoff Volume (m^3) for a return period:			
		2	5	10	25
Z-1	0.54	2030	6502	10001	14677
Z-2	1.349	5072	16242	24983	36666
Z-3	0.163	613	1963	3019	4430
Z-4	1.066	4008	12835	19742	28974
Z-5	0.13	489	1565	2408	3533
Z-6	0.336	1263	4045	6223	9132
Z-7	0.336	1263	4045	6223	9132
Z-8	0.197	741	2372	3648	5354
Z-9	0.917	3448	11041	16983	24924

Figure 3, Google earth images for parts of the ZRC (source: Google Earth)

5. Conclusions and Recommendation

Altering the hydrologic parameters within the camp area increased the runoff depth by 82% to 614%, this resulting in more flood water trapped inside the boundaries of the camp and if average water depth is 25 centimeters (cm), the percentage of area covered will reach more that 10% of the camp area for 25-years return period storms. In other hand, the storms event that most probably occurs every other year (2-years return period) could result in flood that covers about 1.5% of the camp area with water depth that reaches 25 cm.

To attenuate the floods resulting from rainfall events it is suggested that drainage channels are constructed along the natural water courses before alteration. Then the drainage channels are connected to the major water courses next to the camp through culvers under the earth wall. Figure 4 shows the suggested solution based on the water flowing paths before establishing the camp.

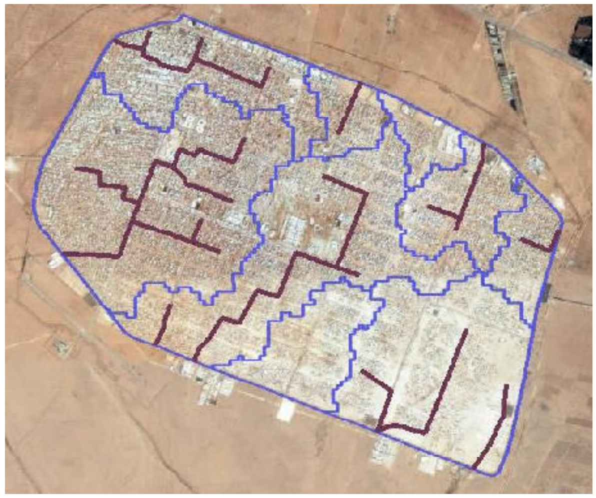

Figure 4. Proposed drainage channels inside the ZRC

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