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GIS and Remote Sensing -Base SCS for Runoff Estimation: Al-Zarqa Basin Jordan

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***Abstract* – Runoff is an important factor for water resources planning and infrastructure developments. This study investigates the application of Soil Conservation Services (SCS) Curve Number (CN) method of runoff depths estimation for Zarqa basin, which covers an area of about 1012.60 km2. To apply the SCS-CN model successfully, various types of hydrological information was required. Data on soil group, drainage, and land use were extracted from satellite image which used for processing of soil and land use map of the watershed, and then SCS model was applied to estimate the runoff for the monthly storm. The estimated runoff was validated with the observed runoff of 2012-2014. The calculated storm runoff was compared to the observed runoff depth of different storm events of different years and found to be close to that of observed. The difference ranged between 5.2-18.6%. It was again found that the percentage of change in runoff due to the land-use change is almost constant with different land-use and the rainfall pattern (different years) for the study area.**

***Keywords* – Runoff, SCS-CN, Hydrological, Soil, Land Use, Runoff Depth.**

I. Introduction

Jordan is located in an arid to semi-arid zone where conditions are severe. The weather variation in relation to hydrological parameters such as rainfall, runoff and evaporation is high. As the water resources in Jordan are limited, the threat of water shortages is not something that merely looms into the future. Water shortages are already a reality [5].

Depletion of non-renewable water resources due to over pumping from exploited aquifers is also a serious problem. Consequently, the degradation of water quality due to increasing salinity is taking place. Surface water resources are unevenly distributed among 15 basins; Jordan would thus fall into the category of having an absolute water shortage.

Generally, a watershed is the area covering all the land that contributes runoff water to a common point. Advances in computational power and the growing availability of spatial data have made it possible to accurately predict the runoff. The possibility of rapidly combining data of different types in a Geographic Information System (GIS) has led to significant increase in its use in hydrological applications. The curve number method (SCS, 1972), also known as the hydrologic soil cover complex method, is a versatile and widely used procedure for runoff estimation. Runoff is one of the most important hydrologic parameters used in many local water resources agendas. Reliable prediction of quantity and rate of runoff from the surface into streams and rivers is a difficult and time-consuming process to obtain for water sheds once run manually. Conventional models for the prediction of river discharge require considerable hydrological and meteorological data. Geographical Information System (GIS) however, provides efficient tools for data input into database, retrieval of selected data items for further processing and software modules, which can analyze, manipulate the retrieved data in order to generate desired information in specific formats.

Review of the related literature reveals that satellite-derived information have been used in estimated runoff applications, such as use of the land sat for runoff estimation [4,10] and use of AVHRR for runoff estimation, [1-3,9,11]. However, mostly dose not eliminate the influence of the time variability of the hydrologic processes on runoff estimation, which lead to low accuracy mapping runoff estimation, in this research we have eliminated the influence of the time variability of the hydrologic processes which is a basic property is an important parameters to runoff estimation.

Furthermore, the in-situ data have been used in the previous research for developing algorithms and validating the runoff estimation only small areas and without any seasonal measurement and validation. This resulted in low accuracy of the outputs of the models developed for mapping and runoff estimation in many regions. In addition, determination of runoff has been processed based on Rainfall stations and soil classes map which will lead to low accuracy of the produced runoff estimation models because of the time variable is one of the most effected parameter due to the different percentage of water charge during the time . So, for more accurate runoff estimation, models should take the time into account.

II. Research Methodology

A. Study Area

Figure 1 shows the location of the study area, AL Zarqa, which lies between longitudes 31°59'30.03" N and latitudes 36° 2'57.36" E. As variability in hydrologic processes on runoff estimation is relevant to this research project.

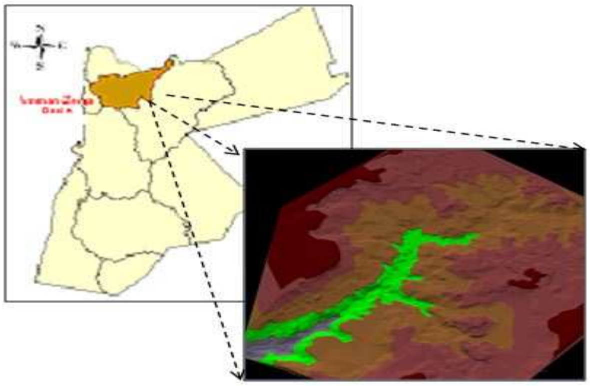

Figure 1–the location of the study area, Al Zarqa, Jordan.

B. Research Data

The data used in this research was found to be available in digital format and stored as Shape files. They were thus, easily read by Arc-GIS 0.9 software.

1. Basin Boundary
2. USDA soil classes
3. Land use/land cover map
4. Rainfall stations + Mean monthly rainfall but was generated.
5. Hydrologic soil classes

This was obtained by converting the USDA soil map into hydrologic soil map in Arc GIS.

C. Combining SCS by using Arc GIS 9.0

The SCS runoff curve number method is one of the basic and efficient models to estimate the surface runoff. The parameters that form the method are simple and the mathematics can be easily implemented. The surface runoff according to SCS model stated in equation (1) [6]:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad (1)$$

Where:

Q: Runoff (mm)

P: Rainfall (mm)

S: Potential maximum retention after runoff begins

Ia: Initial abstraction

Initial abstraction are all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation and infiltration. Among several expressions to compute initial abstraction, by the following empirical equation (2) [6].

Ia = 0.2 S

By replacing Ia, this will produce:

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

The parameter S is related to soil and cover conditions of the watershed through the curve number CN. CN has a range of 30 to 100 and the relation between S and CN is given by equation (3) [7]:

$$S = \frac{25400}{CN} - 254 \qquad (3)$$

CN is determined through several factors. The most important are the hydrologic soil group (HSG), the ground cover type, treatment, hydrologic condition, the antecedent runoff condition (ARC), and whether impervious areas are connected to drainage systems, or whether they first outlet to pervious area before entering the drainage system.

The runoff curve numbers here represents average runoff condition (describes the soil before it is saturated by a storm to the point of runoff). Soils are extremely important in determining the runoff curve number, since these values can vary widely. Soils are generally divided into four HSG's (hydrological soil groups: A, B, C, and D) and are classified according to how well the soil absorbs water after a period of prolonged wetting.

D. Calculation of Potential Maximum Retention (S) Value

The CN methods S values was computed and add it to the dialog box, a field for the S values is created using the Calculate option. (Figure 2) show the calculation for the S value.

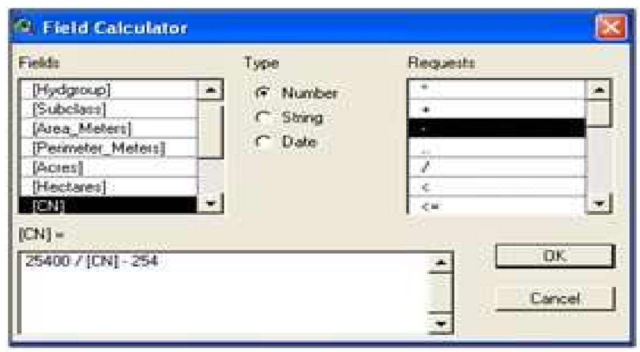

Figure 2– Calculation of potential maximum retention (S) value

E. Calculation of the Rainfall (P)

According to [8], average rainfall was calculated from points' precipitation measurement using the Thiessen Polygon (TP) method. The Extension provides two options to define boundary of resultant TP theme. They are catchment for a boundary or buffered group of rainfall stations for a boundary.

Thiessen Polygon method was used to calculate monthly rainfall average. The Thiessen Polygon method is a good alternative to the station average method. Polygons were formed about each gage (23 gauge station were used in this study) by constructing perpendicular bisectors between each pair of nearby gauges.

Procedure:

1. Locate all rainfall stations on a base map and record rainfall amount.
2. Connect each station by straight lines with the several nearest stations to form a series of triangles.
3. Erect perpendicular bisectors on each of these lines and extend them to the intersect with other bisectors, thus forming a series of irregular polygons.
4. Measure the fraction of the catchment area in each polygon (called the Thiessen constant), multiply by the rainfall catch at the station within the polygon and sum to get the catchment average.

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III. RESULT AND DISCUSSION

There are five types of land use in Zarqa basin. The land use classes were divided into bare soil, build-up area, forest, orchard and cultivated or cultivable land. The calculated monthly runoff depth at the outlet of the basin was close to the observed monthly runoff during the period of winter 2012 to 2014. The point of control of measurement was at the bridge of Jarash. The monthly average rainfall over the basin was calculated with Thiessen coefficients derived from Thiessen Polygon coverage.

The maximum rainfall area of Zarqa basin was observed to be under hydrological soil group D (84.32%) followed by C (15.78 %). The maximum curve number value CN 94 and minimum was 72 its found and used to determine the curve number of the watershed, By overlaying the land use map and soil hydrologic map, the curve number was assigned to each combination of land use and soil type. The average monthly rainfall data for 2012-2014 used to estimate the runoff. The maximum rainfall determined was 223mm in January 2014 and the minimum was 44mm in March for the same year. The calculated runoff was 193mm for January 2014. The output of the estimated runoff was compared with the observed runoff (Ministry of Water Jordan, 2012-2014) for the period 2012 to 2014 in winter season and used to validate the SCS model as show in Table 3.1 The maximum and minimum deviation was observed to be 18.2% and 5.9% respectively, which are within the permissible limit. Table I shows the comparison between estimated runoff depths with the observed runoff depth (actual data).

Table I: Comparison of estimated runoff with the observed runoff

Month	Average rainfall Calculated (mm)	Sum-average Runoff (mm) observed	Sum-average Runoff (mm) calculated	Percent Deviation	Runoff coefficient observed	Runoff coefficient calculated
January 2014	223	212	193	9.0	0.93	0.87
February 2014	57	44	36	18.2	0.72	0.63
March 2014	44	29	25	13.8	0.66	0.57
January 2013	195	184	166	9.8	0.94	0.85
February 2013	75	57	52	8.8	0.76	0.69
March 2013	155	135	127	5.9	0.87	0.82
Januaru 2012	205	189	176	6.9	0.92	0.86
February 2012	65	48	43	10.4	0.74	0.66
March 2012	125	111	99	10.8	0.89	0.79

A. Land use Map

As mentioned earlier, the SCS Runoff Model is one of the most widely used watershed hydrologic-models. The conventional land use / land cover map of the watershed was obtained from Land Sat image. Figure 3 shows the land use result that was digitized from the Land Sat image. Arc GIS was used for processing and digitizing the various polygons of land use then overlaid with the soil hydrologic group to assigned the curve number (CN) value

Figure 3 – Land use map of Al-Zarqa basin

The developed land use map is presented in figure 3.1The attributes were given five-land use/ land covers categories in the watershed area. Table II shows the land use / cover classes division in the study area for the Year 2014.

Table II: Land use classification percentage

Land use	Area (%)	CN Value	
Soil bare		60.2	94
Build up area		3.4	92
Orchard		10.4	79
Cultivated area		5.6	85
Forest		20.4	77

B. Soil Map

The soil map of the watershed was processed and registered in Arc GIS using topographic maps of scale 1:25000. Boundaries of different soil textures were digitized in Arc GIS and the polygons representing various soils classes were assigned different colors for area recognition. The hydrologic soil groups C, and D were considered for the classification of soils of the watershed as shown in figure 4.

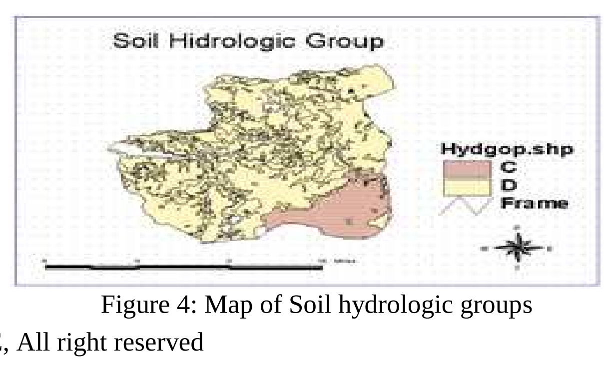

Figure 4: Map of Soil hydrologic groups

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The results of the total area for each unique CN value are shown in the figure 5 The units of area are in square meters distance and units in meters. Related curve number with land use runoff depth map is shown in the figure 6, the runoff depth was determined in association with all land uses.

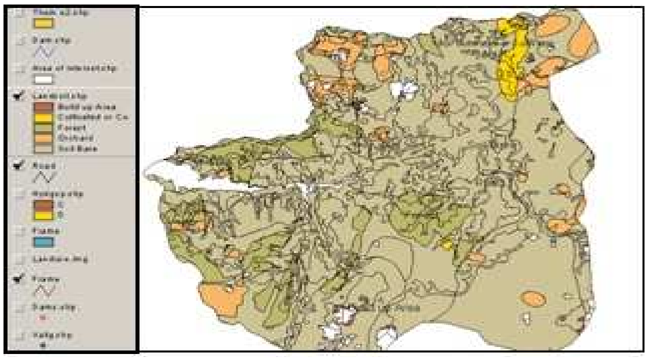

Figure 5 Total Area of Each CN Value

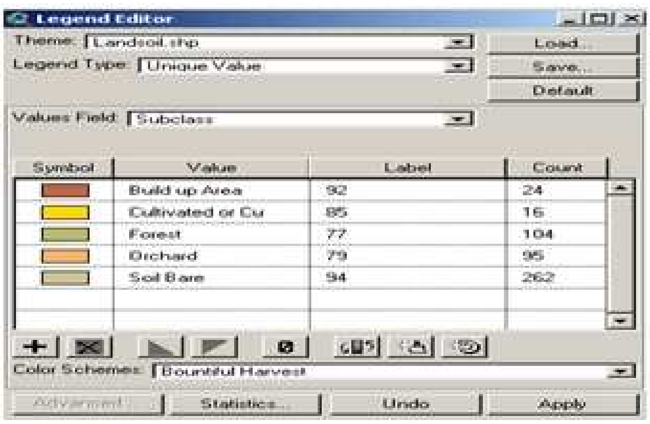

Figure 6: Curve number (CN) value

C. Rainfall Thiessen

The results of rainfall gages are shown on table III. The details on each station have been calculated to show the average rainfall. A Thiessen polygon was derived for these rain gage locations as presented in figure 7 were based on the rainfall amount recorded at each station.

Table III. Average Rainfall 2012-2014 Monthly

Month	Average rainfall (mm)
January 2014	223
February 2014	57
March 2014	44
January 2013	195
February 2013	75
March 2013	155
Januaru 2012	205
February 2012	65
March 2012	115

ArcGIS extension "Area Precipitation Calculation" was used to calculate the mean area rainfall based on Thiessen polygons. The results of the analysis showed the maximum rainfall in January 2014 to be 223mm and the minimum in March 2014 to be 44mm (Table III).

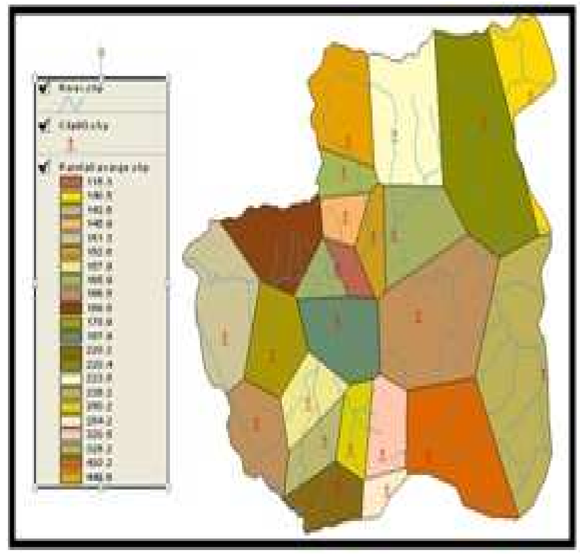

Figure 7 Calculation using Thiessen Polygons

IV. Conclusion

The calculated storm runoff of the period 2012 to 2014 has been validated with observed runoff depth. The validation results indicated that the calculated storm runoff was reliable and found to be close to that of observed with difference between 5.2 to18.6%. The percentage change in runoff due to the land-use change is almost constant with different land-use and rainfall pattern during the period between 2012 to 2014. It is again found that the average maximum monthly rainfall in January 2014 was 223mm, and the minimum was in February 2014 44mm. Generally, the runoff was found to be high in all periods during winter season specially in January due to the amount of water calculated during heavy rainfall, and it was low in march which is the last month of the winter season. The methodology of estimating the Runoff of Zarqa watershed using GIS and SCS model was found to be very effective. This model can be applied in other basin watersheds for planning of various conservation measures. The conventional hydrological data are inadequate for the purpose of designing and operating of water resources systems. Remote sensing data was used to extract land use information for the hydrological processing. Remote sensing data can also serve as a model input for the determination of river catchments characteristics, such as land use/land cover. GIS was effective in defining the spatial sub-units, in number and in descriptive detail.

REFERENCE

[1] A. Kaviani, "Estimation of agricultural water productivity in Qazvin plain using modis and Avhrr images," Pollack Periodica, vol. 6, no. 3, 2011, pp. 93–105.

[2] B. Blagojevic, "Identification Of Homogeneous Regions For Runoff Estimation In Ungauged Basins," SGEM2011 11th International Multidisciplinary Scientific GeoConference, 2011.

[3] C. Frank, K. Itten, and K. Staenz, "Improvement In NOAA-AVHRR Snowcover Determination For Runoff Prediction," International Geoscience and Remote Sensing Symposium, 'Remote Sensing: Moving Toward the 21st Century',2012.

[4] D. Tibebe and W. Bewket, "Surface runoff and soil erosion estimation using the SWAT model in the Keleta Watershed, Ethiopia," Land Degradation & Development, vol. 22, no. 6, 2010, pp. 551–564.

[5] G. Ufimtsev, "The geomorphological features of Jordan," Geography and Natural Resources, vol. 29, no. 1, 2008, pp. 88–92.

[6] N. Nagarajan and S. Poongothai, "Spatial Mapping of Runoff from a Watershed Using SCS-CN Method with Remote Sensing and GIS," Journal of Hydrologic Engineering, vol. 17, no. 11, 2012, pp. 1268–1277.

[7] R. Kabiri, "Simulation of Runoff using Modified SCS-CN Method using GIS System,Case Study: Klang Watershed in Malaysia," Research Journal of Environmental Sciences, vol. 8, no. 4, 2014, pp. 178–192.

[8] S. B. Sharma, "Assessment of the Flood Potential on a Lower Tapi Basin Tributary using SCS-CN Method integrated with Remote Sensing & GIS data," Journal of Geography & Natural Disasters, vol. 04, no. 2014, 02, pp. 232–278.

[9] S.-J. Wu, H.-C. Lien, and C.-H. Chang, "Calibration of a conceptual rainfall–runoff model using a genetic algorithm integrated with runoff estimation sensitivity to parameters," Journal of Hydroinformatics, vol. 14, no. 2, 2012, p. 497.

[10] T. Bisantino, R. Bingner, W. Chouaib, F. Gentile, and G. T. Liuzzi, "Estimation of Runoff, Peak Discharge and Sediment Load at the Event Scale in a Medium-Size Mediterranean Watershed Using the Annagnps Model," Land Degradation & Development, vol. 26, 2013. 4, pp. 340–355.

[11] Z. Şen and A. Altunkaynak, "A comparative fuzzy logic approach to runoff coefficient and runoff estimation," Hydrological Processes, vol. 20, no. 9,2006, pp. 1993–2009.

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