MANAGEMENT OF AGRICULTURAL WATERSHED USING GIS IN PALASTINE

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ABSTRACT

Palestine suffers from a chronic water shortage, preventing sustained economic growth and damaging the environment and health of Palestinians. The shortage of water exists due limited quantities of water received from the source, and due to the rapid growth of the population. This prevailing condition has necessitated proper planning and management of the available resources. This needs detailed data to make predictions of water availability such that of watersheds data.

For any hydrological studies on an ungaged watershed, a methodology has to be selected for the determination of watershed characteristics and runoff at its outlet. Many methods are used to determine the morphological parameters and estimate the runoff from a watershed. The Soil Conservation Service (SCS) curve number method and Watershed Modeling System (WMS) are versatile and widely used procedure for watershed hydrological studies. These methods include several important properties of watershed namely, soils permeability, land use and antecedent soil water conditions which are taken into consideration.

In Palestine Polytechnic University (PPU) several studies -incorporating graduation projects students- were carried out to study the hydrological characteristics of different wadi's or watersheds in southern Palestine. SCS and WMS models were used with Geographical Information System (GIS) to estimate the runoff from a small agricultural watershed as well as the morphological features of these watersheds.

The work findings revealed that large quantity of water can be stored behind constructed dams in these small agricultural watersheds from runoff which represent in some areas more than 10% of the total annual rainfall. The approach of these studies could be applied in other Palestinian watersheds for planning of various conservations measures.

Keywords: Rainfall, Runoff, Watershed, SCS Curve Number, GIS, WMS.

1. INTRODUCTION

It is well known that Palestine suffers from severe water shortage problem due to natural and political reasons, and there is a necessity of searching for substantial water resources. There is consensus in most studies conducted that water harvesting is the most appropriate option for future in addition to other options. This is due to the fact that it is a considerably cheap option and there is a necessity to benefit from the water flowing into the sea during the winter season. It is also very important to state that the water harvesting projects correlate with the economic and social situation for the nations of the area.

Land degradation by soil erosion, runoff, and sedimentation, are the serious problems facing the arid and semi-arid regions in the West Bank. As a result of these problems soil tend to degraded, causing low soil fertility, in addition of the over exploitation of natural resources for agricultural production. Soil and water conservation management by different water harvesting techniques, is an effective to reduce the high intensity of runoff, and subsequently increasing soil moisture storage from rainfall, while maintaining low level of soil erosion and sedimentation.

Watershed is the area covering all the land that contributes runoff water to a common point. The problem most often encountered in hydrological studies is the need for estimating runoff from a watershed for which there is records of precipitation and no records of runoff. In Palestine, the watershed data and runoff information are scarcely available in most sites. However, quickening of watershed management programmed for conservation and development of natural resources management has necessitated the runoff information. 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 GIS has led to significant increase in its use in hydrological applications.

An approach to solution of this problem is to compare runoff characteristics with those of watershed characteristics. Watershed characteristics which may be mostly readily compared to estimating the volume of runoff that will result from a given amount of rainfall are soil type and cover, which includes land use. As mentioned earlier, many methods are used to estimate the runoff from a watershed through the study of the characteristics of watershed.

Hydrologists of the Soil Conservation Services constantly encounter the problem of estimating direct runoff where no records are available for the specific watershed. Soil Conservation Service (USDA,1985) curve number method is a well accepted tool in hydrology, which uses a land conditions factor called "the curve number". It is reliance an only one parameter and its responsiveness to four important catchment properties, i.e. soil type, land use, surface condition, and antecedent moisture condition, increased its popularity. The Watershed Modeling System (WMS) is also a comprehensive hydrologic modeling environment that provides tools for all phases of watershed modeling including automated watershed and sub-basin delineation, geometric parameter computation, hydrologic parameter computation (CN, time of concentration, rainfall depth, etc.) and result visualization.

At the same time, the possibility of rapidly combining data of different types in a Geographical Information System (GIS) has led to significant increase in its use in hydrological application. In the studies of PPU, the characteristics (morphological parameters) of different watershed were determined and the surface off from the same watersheds in southern Palestine was estimated using SCS method and WMS with the help of GIS. It considered as a case studies for small agricultural watershed.

2.PREVIOUS STUDIES

In Palestine, the hydrological studies are limited. Some investigators have studies the hydrology of different wadis and watersheds in the West Bank and Gaza strip in order to develop additional usable water resources to help in solving future hydrological problems. Applied Research Institute of Jerusalem (ARIJ) published six articles on environmental profiles of West Bank cities. The Hebron district environmental profile shows in such area, most land is sloppy (2%-20%) and the infiltration rate is low. Consequently, low cost water harvesting could be introduced in this area. This method depends on collecting runoff water using construction such as soil dam or concrete dam.

Lange, J. et al (2000) have studies the runoff on a steep 180 m^2 Mediterranean Karts environment. To provide quantitative information, measurements are under taking on experimental hill slope plot applying artificial rainfall of predefined intensities. The results show that on a dry plot about 16 mm of rainfall was needed before terrain other bar rock generated runoff. Overall 16% of rainfall turn into runoff, while in the following day 73% of the applied rainfall arrived at the outlet of the wet plot.

The geomorphological study of Wadi Al Arroub carried out by Qannam (2000) in his master thesis shows that the topography has more effect on the drainage pattern than the structure. The relatively high relief ratio of Wadi Al Aroub drainage basin and high elongation ratio (0.78) indicate that the study area is among the sub-basins that contribute strongly to the flooding in the Dead Sea-Jordan River Basin

In the study of Mohammadin, A. et al (2003), the mount of runoff for east Bani Naim watershed in the Hebron area using soil conservation service method were calculated and estimated to be about 12% of the total annual rainfall. The study of the hydrological characteristics of different wadi's and watersheds in West Bank and Gaza Strip were carried out by different researchers. Most of them are concentrated on the study of the morphological and geological characteristics of the wadi's and the hydrochemistry of springs water available in these watersheds.

3. MATERIALS AND METHODS

3.1 Watershed Boundary, Grid Setup and Land Use

The watershed boundary was restricted and the grid to conduct the experiments in suitable sites was setup by land surveying using Navigation GPS (Magellan). The conventional land use\land cover map of the watershed was obtained by the land survey technique using (GPS), and digitized map from a rectified aerial photo for the watershed. Boundaries of different land use class were digitized in the (ArcGIS.9), and the attribute where linked to them.

3.2 Soil and Infiltration Tests

The Unified Soil Classification System (USCS) was adopted in this work to classify soils at different points. Sieve analysis and moisture content experiments were carried out to classify the soil samples of the project. The infiltration rate which is helped to classify the soil was measured using Double Ring Infiltrometer manufactured for this purpose.

3.3 Morphological Parameters

The study of the characteristics of the project area was carried out by using WSM. After determined the boundary of the catchments, sub catchments, a flow direction and accumulation, the morphological parameters of the Wadi Hasca were computed following the procedures given in WSM for this purpose.

3.4 Estimation of Surface Runoff

The rainfall-runoff equation used by the SCS for estimating depth of direct runoff from storm rainfall is:

$$Q = \frac{(P-0.2S)^2}{P+0.8S} \qquad (p > 0.2S) \tag{1}$$

Where, S is the watershed storage mm; Q is the actual direct runoff mm; and P is the total rainfall mm.

The equation has one variable P and one parameter S . S is related to curve number (CN) by

$$S = \frac{25400}{CN} - 254 \tag{2}$$

Where CN is a dimensionless parameter and its value range from 1 (minimum runoff) to 100 (maximum runoff). It is determined based on hydrologic soil group, land use, land treatment, and hydrologic conditions.

The Rational Method was also used in some studies to calculate the surface runoff depth by applying the following equation:

$$Q = \frac{C * i * A}{360} \tag{3}$$

Where Q is the flood flow in cubic meter, C is the runoff coefficient, i is the rainfall intensity in mm per hour, and A is the drainage area contributing to runoff in hectare.

In this method, the drainage area is divided into a number of sub areas and the time of concentration of different sub areas, were calculated using equation (4) below:

$$tc = 0.00032 * L^{0.77} * S^{-0.385} \tag{4}$$

Where tc is the time of concentration in hours, L is the maximum length of travel of water in meter, and S is the slope equal to H/L, where H is the difference in elevation between the remotest point on the basin and the outlet (m)

After that the value of rainfall intensity was determined from Multy Curve Intensity figure for the Hebron District , the value surface runoff (Q) were estimated using equation (3)

4. CASE STUDY: WADI SU'D WATERSHED

4.1 Study Area

The study area, named Wadi Su'd, is located in the Hebron area of West Bank, southern Palestine which will known later as Wadi Su'd watershed. The watershed having a geographical area of 1.87 square kilometer, Figure (1) shows the study area and its location. Physiographically, the watershed is divided into hills, pediments. Elevation in the watershed ranges from 550 to 820 m above mean sea level. The average annual precipitation at Dura area for the last five years is approximately 500 mm. About 90% of this rainfall is received from November to April, and the major land use/land cover categories in the watershed are: pasture, agricultural area, and stony waste land (Data Obtained from Dura Municipality).

4.2 Land Use and Land Cover

Three land use and land cover classes were categorized in the watershed as given in Table (1). The land use and land cover map for Wadi Su'd watershed is shown in Figure (2).

Table 1 Classes of Land Use/Cover of the Study Area

Land Use	Area (m^2)	Percentage of Area (%)
Agricultural	1304954.00	69.82
Pasture	531652.10	28.45
Residential	32269.60	1.73
SUM	**1868876**	**100**

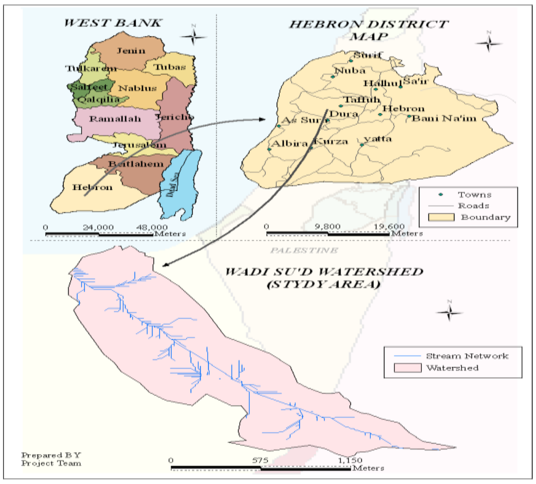

Fig. 1 Location of the Study Area (Wadi Su'd Watershed)

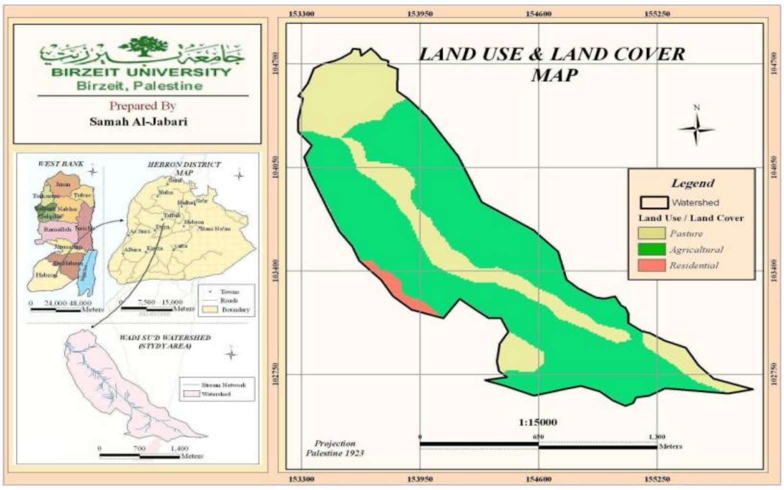

Fig.2 Land Use and Land Cover Map for Wadi Su'd Watershe

4.2 Soil Classification

According to laboratory soil testing result, the soil of Wadi Su'd watershed can be classified into four types; well-graded sand, poorly-graded sand poor-clay and silt clay, distributed at the watershed as shown in Table (2) and Figure (3).

Table 2 Classification of Soil in the Study Are

Soil classification	Area (m^2)	Percentage of Area %
Silt-clay	195960.9	10.1
Poor-Clay	302170.4	16.6
Well-Sand	312363.7	16.7
Poor-Sand	1058381	56.6
SUM	**1868876**	**100**

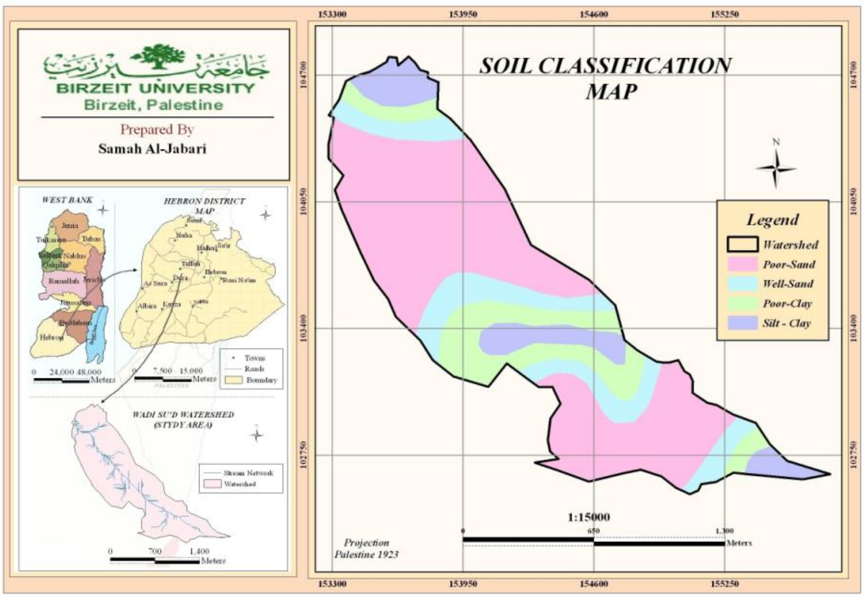

Fig.3 Soil Classification Map for Wadi Su'd Watershed

4.3 Infiltration Rate

The measured values of infiltration rates, using a Double Ring Infiltrometer (DRI) at 23 sites covering different land use types, are interpolated in ArcGIS.9 and the infiltration rate for Wadi Su'd watershed is shown in Figure (4).

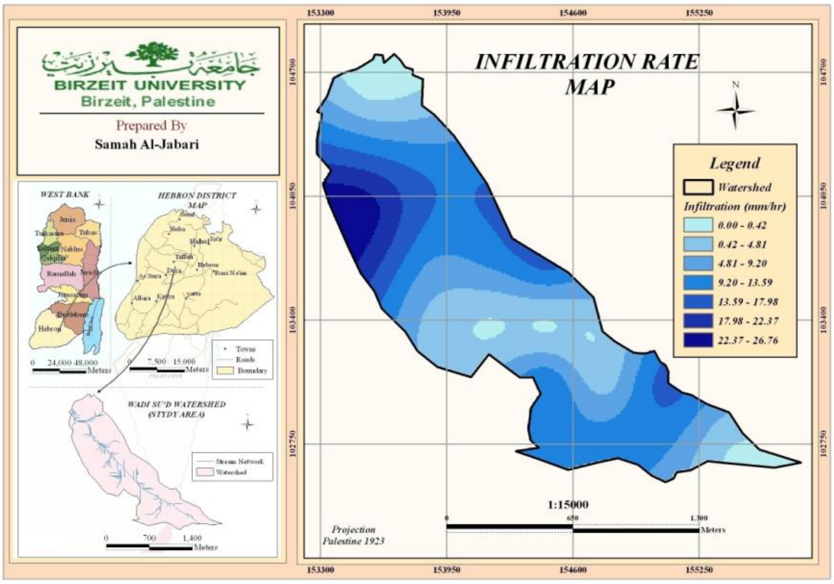

Fig.4 Infiltration Rate Map for Wadi Su'd Watershed

4.4 Estimation of Surface Runoff

By using the data of soil classification and infiltration rates, Wadi Su'd watershed was classified into four hydrological soil groups: Group D with infiltration rate (0-1) mm/hr, Group C (1-4) mm/hr, Group B (4-8) mm/hr and Group A (8-12) mm/hr based on grade condition of the soil (poorly or well graded). The hydrologic soil group classification are displayed in Figure (5).

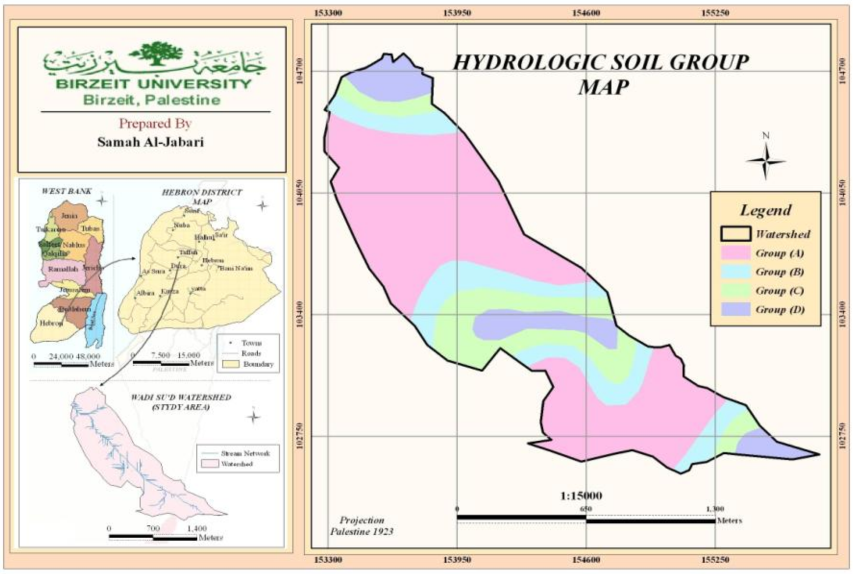

Fig.5 Hydrological Soil Group Map for Wadi Su'd Watershed

The hydrological soil group and the land use and land cover results were used to create and detect the curve number values for each classified area. After that the Rainfall data and the result of surface runoff depth for the last five rainfall seasons in the study area were obtained, and the result of season 2005/2006 as an example is presented in Table (3).

Table 3 Runoff Depth in the Study Area for Season (2005/2006)

Year	Months	Day	Storm Rainfall (mm)	Antec.Rainfall (mm)	AMC	(CN)	(S)	Runoff by Day (mm)
2005/2006	**10**	29	10	0	I	41	365.512	0
	11	17	31	0	I	41	365.512	0
		19	10	31	III	79	67.519	0
		22	27.5	41	III	79	67.519	2.4
		23	87.8	37.5	III	79	67.519	38.92
		27	49.7	115.3	III	79	67.519	12.63
	12	7	9	0	I	41	365.512	0
		8	6	9	I	41	365.512	0
		16	15.5	0	I	41	365.512	0
		25	28	0	I	41	365.512	0
	1	3	36.6	0	I	41	365.512	0
		4	29	36.6	III	79	67.519	2.89
		6	47	65.6	III	79	67.519	11.11
		24	45	0	I	41	365.512	0
	2	5	4	0	I	41	365.512	0
		7	20	4	I	41	365.512	0
		8	24	24	II	62	155.677	0
		9	23.6	48	III	79	67.519	1.31
		11	13	67.6	III	79	67.519	0
		12	11	80.6	III	79	67.519	0
	3	8	12.1	0	I	41	365.512	0
		9	26	12.1	I	41	365.512	0
		10	8	38.1	II	62	155.677	0
		11	4	46.1	II	62	155.677	0
	4	3	8	0	I	41	365.512	0
		4	4	8	I	41	365.512	0
SUM		**62**	**589.800**					**66.86**

As a result of the calculations, based on the SCS method, it was found that the average annual surface runoff rate (depth) for the last five years in Wadi Su'd watershed is equal to 36.3 mm multiple by the area of the watershed (A=1868876m^2) gives the total average volume of runoff as (67840.2 m^3), which represents 7.3 % of the total annual rainfall. The annual rainfall and runoff during (2000-2006) in the study area are shown in Table (4).

Table 4 The Average Annual Runoff Depth and Volume in the Study Area

Years	Total Rainfall (mm)	Total Runoff (mm)	Runoff Percentage	Volume (m^3) Runoff × Area
2000/2001	610.4	95.86	15.7	179150.45
2001/2002	492.6	10.456	2.12	19540.96
2002/2003	645.3	27.69	4.3	51749.17
2003/2004	374.7	15.93	4.25	29771.19
2004/2005	589.8	66.86	11.34	124953.0
2005/2006	287.8	0.799	0.28	1493.23
Average	**500**	**36.3**	**7.3**	**67840.2**

The final result in this study determine the water balance parameters of Wadi Su'd watershed in Dura area whereas the precipitation (500 mm/year) is the main input parameter in the water balance and the average monthly evaporation of the Dura whether station is around 60 mm/ month in the winter season (60 X 6 = 360 mm), estimated run off (36.3 mm), and calculated infiltration 103.7 mm (500 – 360 – 36.3 = 103.7) are the major output parameters. The results of water budget in the study area are shown in Figure (6).

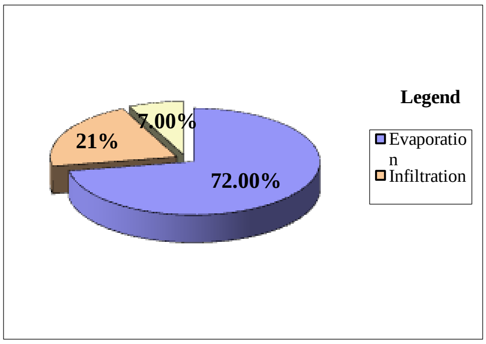

Fig.6 Water Balance of Wadi Su'd Watershed

5. CONCLUSIONS

Since there were no runoff observations available from any watershed in the Palestine, the results could not be compared with the measured values.

Large quantity of water can be stored behind constructed dams in these small agricultural watersheds from runoff which represent in some areas more than 10% of the total annual rainfall.

The approach of these studies could be could be applied in other Palestinian watersheds for planning of various conservations measures

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