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Evaluation of Two Hydrological Processes and Soil Characteristics under Different Climatic Conditions at West Bank, Palestine

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ABSTRACT

A 2-year experiment was conducted to address the two hydrological process (runoff and sedimentation) and soil characteristics for three sites that represent different environmental conditions at the southern part of West Bank. From each study sites 3 representative soil samples were collected from 10 cm depth, chemical and physical properties were conducted. In addition, runoff and sedimentation also collected for each study sites. Soil of these sites shows a different variation in their physical and chemical properties. Results showed that higher OM, EC and clay content were in Sorif site than Dura and BaniNoem. Runoff and sedimentation amounts varied between the sites and during the rain events. Recorded runoff and sedimentation yield were 13.8, 26.6 l/m2 and 46.7, 23.7 g/m2 in Sorif site, 7.8, 19.6 l/m2 and 23.7, 10.5 g/m2 in Dura, and 13.5, 6.1 l/m2 and 8.4, 14.5 g/m2 in BaniNoem during 2004 and 2005, respectively. In addition, higher runoff coefficient was recorded in BaniNoem site compared to Sorif and Dura sites in study years. These values may be considered very low and mainly affected and controlled by the interaction of different factors that includes the rainfall characteristics, vegetation cover type and percentage, and soil conditions. Therefore, under such conditions these factors should be taken into consideration for land management and soil conservation.

Keywords: Runoff, Sedimentation, Soil Properties.

1. INTRODUCTION

Runoff and soil erosion represent an important component of land degradation and desertification in the Mediterranean region (Dunjo et al., 2004). Palestinian areas, similar to many other countries, located in the Mediterranean region, are characterized by mountainous and fragile semi-arid climate, which makes the area subject to many environmental problems, such as loss of vegetation cover, low and high rainfall intensity which causes soil erosion and overland flow (Retrenberg et al., 1947 and Zohary, 1947).

In the Mediterranean region, particularly the arid and semi-arid regions, a positive relationship was detected between annual rainfall, geomorphic processes (runoff and erosion rates) and environmental factors; water regime, soil and vegetation cover (Yair and Kossovsky, 2002; Aviad et al., 2004). Under the hilly and semi-arid areas of the eastern part of the Mediterranean, intense rain events are not unusual. According to Abu Hammad (2006), rainstorms with intensity ≥ 4 mm h^{-1} and rainfall ≥ 10 mm at the Palestinian mountainous areas are more likely to cause runoff and soil erosion. Moreover the amount of eroded soil during the study period ranged from 1769 to 5057 kg ha^{-1}, with a runoff coefficient of 20 %.

Thurow et al., (1986) reported that factors determining runoff and erosion are the effects of complex interactions of vegetation and soil characteristics. Therefore, vegetation covers play an important role in erosion control, by the direct crop canopy protection to soil from the detachment caused by raindrop impact, and on the other hand by improving of the soil chemical and physical properties due to incorporation of soil organic matter (Andreu et al., 1995, Bochet, 1998, Casermeiro et al., 2004).

Changes along the climatic gradient are integrated to alternation of surface properties and vegetation characteristics. Runoff and sediments increase positively with amount of annual rainfall up to 300 mm at which point the more extensive vegetal cover increase infiltration and surface protection, thus decreasing relative runoff and erosion rate (Yir and Kossovsky,

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2002). Similar approach was found by Sarah (2004a, and 2004b) who presented a case study conducted at southern West bank, suggesting a high correlation between mean climatic conditions and ecogeomorphic variables. The study showed that sodium: potassium adsorption ratio and overland flow increased and those of organic matter content, aggregate stability, clay content and infiltration decreasing with increasing aridity.

For more than a century, rangeland at southern part of West Bank has suffered from land degradation due to environmental conditions and human activities. Thus, the objectives of the present study were to evaluate the hydrological processes (runoff and sedimentation) and soil properties at different environmental conditions at the southern West Bank.

2. MATERIAL AND METHODS

2.1. Study Site

The study was conducted during 2004 and 2005 at three sites in Hebron District (Map 1). BaniNoem is located in semi-arid region of eastern slopes of the West Bank, 15 Km east of Hebron city. The geographical position is 35.1 East and 31.4 North. Its topography is mountainous with elevation ranges from 596 to 704 m above sea level. Its climatic conditions are characterized by Mediterranean semi-arid type. It is in the rain shadow, with an average mean precipitation of about 250-300 mm (MOA, 2004) most of it falls as high intensity rainstorms. The soil bedrock is calcareous (limestone or hard chalk) with shallow soil. According to Awadallah and Owaiwi (2005) modified after Ravikovitch (1992) soil data from Dan (1976), the soil association in this site is belong to Brown Rendzinas and Pale Rendzinas.

The site occupies an area of about 50 ha and was used for many years as a rangeland, grazing was excluded by fencing since 1995. According to Al-Jubeh (2006), the dominant plant species in natural vegetation are *Torilis tenella*, *Poa bulbosa*, *Anthemis spp*, *Vivia sp*, *Crithopsis delileana*, Medicago *sp* and *Helianthemum salicifolium*.

Sorif site is located in the western parts of the central mountain region of the West Bank, 10 km North West of Hebron city. The geographical position is 35.06 East and 31.62 North (Map 1). Its topography is mountainous with steep slopes, its elevation ranges from 568 to 727 m above sea level. The area is considered as semi-arid to semi-humid Mediterranean climate with a long, hot dry summer and short cool rainy winter. Average annual rainfall is about 350-400 mm fall during the winter season (November to April). Soil is classified as Terra rossa, Brown Rendzinas and Pale Rendizanas (Awadallah and Owaiwi, 2005).

The area was subjected to overgrazing and cutting the trees since the British occupation. The total area is about 15 ha, which was fenced and excluded from grazing in 2001. According to Al-Jubeh (2006), the dominant plant species are *Sarcopoterium spinosum*, *Avena sterilis, Lolium sp, Bromus fasciculatus, Crepis aspera* and *Aegilops binuncialis*.

Dura site is located 16 km Southwest of Hebron city. The elevation ranges from 486 to 535 m above sea level. The geographical position is 34.95 East and 31.46 North, covering an area of about 2 ha. Climate is considered as semi-arid, with 300 mm mean annual rainfall (MOA, 2004), Soil taxonomy is Brown Rendzinas and Pale Rendzinas (Awadallah and Owaiwi, 2005). The dominant plant species are *Crupina crupinastrum*, *Avena sterilis*, *Bromus spp, Asphodelus aestivus* and *Onobrychis caput-galli*. (Al-Jubeh, 2006).

2.2. Soil Properties

Three representative soil samples were collected from each site from the top 10 cm of natural vegetation area at the three sites once in August in 2004 and 2005. The bulk soil samples were air-dried, crushed with a mortar and pestle and sieved to remove coarse (>2 mm) fragments. Soil particle size distribution was determined using the pipette method (Bouwer, 1986). Soil pH was determined by using an electrode pH-meter for a saturated soil paste (1:2.5) using distilled water. The electrical conductivity (EC) was also measured in a saturated paste (1:2.5) (Skoog and West, 1976; FAO 1980). Organic matter was determined by using the Walkey and Black method (Nelson and Sommers, 1982). Extractable bases were determined following displacement with 1 M NH_4OAc (Thomas, 1982). The Olsen method was used to determine extractable phosphorus using a molybdate reaction for colorimetric detection (Olsen and sommers, 1982). The $CaCO_3$ content was determined by using the calcimeter instrument.

2.3. Runoff and Sedimentation

To evaluate the amount of runoff and sediment yield, replicated experimental runoff plots (Fig. 1) (2-micro-catchment) 50 m^2 each were constructed in natural vegetation area at the three study sites. The area generally have the same slope between the three sites, in average the slope percentage is 13 %, 14 % and 11.5 % in BaniNoem, Dura and Sorif. Respectively. Each runoff plot was bounded with cement block (20 cm height) to prevent run-on from the adjacent area. A plastic pipe was used to convey the runoff water to 0.7 m^3 tank. After each main rainstorm event, the amount of runoff was measured after allowing the sediments to settle down. In addition rainfall was measured by rain gauges which placed in the area to record the amount of rainfall. The accumulative sediments were measured one time at the end of winter season. Runoff coefficient was calculated as the amount of runoff to the amount of precipitation received.

2.4. Statistical Analysis

Completely randomized design was used to investigate the soil properties, amount of runoff and sedimentation between the study sites. The analysis of variance (ANOVA) and Fisher LSD test at $P \leq 0.05$ were used to compare between the means for each variable.

3. RESULTS AND DISCUSSION

3.1. Soil Properties

Soil particle distribution and the texture classes were different among the study sites (Table 1). Sorif had higher clay content (37.7 %) than Dura (25.8 %) and BaniNoem (29 %) (Table 1). According to Kim (1995), the soil at Sorif is classified as clay loam, whereas in both Dura and BaniNoem sites classified as loam. Sarah (2004 a) reported that clay content in the soil increases from about 10 % in the arid zone to about 50 % in the Mediterranean zone. Such differences express the change in the intensity of the chemical weathering, which mainly controlled by the long-term influence of the different amounts of precipitation along the climatic transect. Soil physical properties such as soil particle distribution are recognized for their important role in supporting plant growth because affects the supply and storage of water and nutrients, aeration, and ease of root penetration.

Soil organic matter is an important soil quality, which provides nutrients for plant growth; and it influences many soil properties (Rezaei et al., 2005a and b). Higher organic matter in soil enhances the aggregates stability, which is critical for erosion resistance, water availability and root growth (USDA, 2003). Data in Fig. (3) showed that soil organic matter significantly increased from BaniNoem (2.4 %) to Dura (3.9 %), which represent the semi-arid area, to Sorif (5.2 %) located in a semi-arid Mediterranean region. This increase was probably due to the differences between climatic zones, which affected the soil moisture, vegetation characteristics and microorganism activities. This result agreed with Sarah (2004 a) and Kutiel and Lavee. (1999) results, where they found that the OM % increased from arid zone (1.6%) to Mediterranean zone (6.3 %). The increase in OM is associated with the increase in the amount of precipitation (Fig.2). Similar results obtained by Khresat and Taimeh. (1998) where they reported that organic matter content increased as the precipitation increased, as will as the clay content and vegetation cover increased. In a study at the same sites, Mohammad (2007) and Al-Jubeh (2006) reported that higher amount of vegetation dry biomass in Sorif and Dura sites compared to BaniNoeim. Such results may indicate that in rangelands management the relationship between soil organic matter and vegetation covers plays an important role in decreasing the amount of runoff and increasing the infiltration rate.

Soil pH and electrical conductivity (EC) are important soil parameters, which affect the solubility of most elements necessary for plant growth. Soil pH values of the three sites were optimal range for plant growth. According to Marx et al. (1999) the soil is classified as neutral to moderately alkaline soil. In addition, the results indicated that the soil of the three sites was non saline, therefore, soluble salt problems were not considered in these soils.

Dura and BaniNoem sites had significantly higher soil pH than Sorif site (Table 2). In contrast, Sorif site had significantly higher electrical conductivity (0.40 dsm^{-1}) in 2005, than Dura and BaniNoem, while the difference was not significant in 2004. In general, soil pH decreased and electrical conductivity increased from BaniNoem, to Dura and Sorif sites. Rainfall decreased the pH value due the dilution of the soil solution, this reason might explain the low soil pH value in Sorif site which had high rainfall (Fig.2). Al-Seekh et al. (2007) reported higher soil moisture content in Sorif and Dura sites than BaniNoem site. In contrast to pH and EC, available nitrogen (NH_4^+, NO^-_3) and phosphorus (P) increased from BaniNoem site to Sorif site (Table 2). This could be related to high organic matter content in Sorif compared to BaniNoem and Dura sites (Fig.3). The differences of available (P, NH_4^+, NO_3^-) between the sites are not predictable and strongly influenced by climatic conditions and precipitation due to leaching and mineralization processes.

Soil concentrations of NH_4^+ and NO_3^-depend on biological activity, and therefore fluctuated with changes in conditions such as temperature and moisture. According to Marx et al. (1999), available nitrate (NO^-_3) considered low in the three sites during the study years. The reason for this result was probably due to leaching effect of high intensity rainfall. In addition, the overgrazing of the study sites for long time reduced the plant cover and disturbed soil quality. Soil available ammonium (NH_4^+) and phosphorus (P) were within the range of typical plant growth at the three sites during the study years (Marx et al., 1999). Sorif site has higher available ammonium (6.6 ppm), than to Dura (4.1 ppm) and BaniNoem (3.8 ppm) sites in 2005 (Table 2). Rezaei et al. (2005a) reported that there is significant interaction between organic carbon, EC, nitrogen and phosphorus. Therefore, it could be concluded that soil organic matter within rangeland systems provides nutrients for plant growth, resulting in a positive feedback as more plant biomass is expected to produce more soil organic matter. The interdependency of vegetation types and soil chemical properties may lead to a variety of species, vegetation types, and plant communities.

3.2. Surface Runoff

Runoff data were measured during the winter seasons of 2003/2004, and 2004/2005. Data in Fig. (4 a and b) show the total amount of surface runoff in natural vegetation at the three sites during 2004 and 2005 winter seasons.

No significant differences ($p \leq 0.05$) were found between the three sites in 2004 (Fig. 4a). In 2005, BaniNoem and Sorif sites had the highest amount of runoff 13.76, and 13.48 l/m^2 , respectively, compared to Dura site 7.83 l/m^2. On the other hand, in 2005 the total amount of runoff was significantly higher for Sorif and Dura 26.58, 19.63 l/m^2 than BaniNoem 6.04 l/m^2. In addition, there was higher amount of runoff in 2004/2005 winter season than to 2003/2004 winter season. Results showed that there were differences in the amount of runoff between the three sites during the study years, this might be caused by the interaction of different factors, that include the rainfall characteristics, vegetation cover type and percentage, land use and soil conditions (Andreu et al 1995, Bochet,1998; Casermeiro et al., 2004, Kharabsheh, 2004). Higher amount of total surface runoff in BaniNoem site in 2004 might be due to high rainfall events that occurred with short intervals during the period between December 22 and January 17 (Fig. 7a) where there was very low vegetation cover to slow down the runoff. In a study at the same sites and time Mohammad (2007) reported that BaniNoem had the lowest percent of plant cover (21%) compared to Dura (59%) and Sorif (71%) in early growing season of 2004. In addition, BaniNoem site has low soil depth (Al-Seikh, 2006) this means that the soil gets saturated when the amount of rainfall is 90 mm during a short period leading to higher runoff. In contrary, significant higher amount of runoff values were recorded in Sorif and Dura sites compared to BaniNoem site, regarding that these values not considered the amount of rainfall between the study sites. Therefore, the amount of rainfall amount was the main reason for such result, where higher amount of precipitation (Fig.1) in Sorif and Dura sites compared to BaniNoem site gave higher values of surface runoff. Runoff coefficient (Fig. 5) shows the relation between amount of runoff and the amount of precipitation in the study sites, where BaniNoem site has the highest value of runoff coefficient compared to other two sites. These results agreed with the results of Sarah (2004) who observed that the overland flow increase and infiltration rate decease from Mediterranean zone to arid and semi-arid zones which explained by low biotic activity, organic matter content and clay content in the arid zone. Soil surface properties are affected by a combination of different factors that have an important role in runoff generation. However, Sorif site has higher vegetation cover and, dominated by shrub *(Sarcopoterium spinosum)* (Mohammad 2007; Al-Jubeh 2006). In addition, it has higher organic matter than Dura and BaniNoem sites. These conditions increase the infiltration rates. Thus, reduce the runoff and soil erosion (Bochet, 1998, Yir and Kossovsky, 2002).

Soil erosion (sedimentation) was significantly different between the three sites in 2004/2005 it was 47.6, 23.7, and 8.42 g/m^2 in Sorif, Dura, and BaniNoem sites, respectively (Fig. 6 a). During 2003/2004 winter season the amount of sedimentation was significantly higher in Sorif site (23.7 g/m^2) than Dura and BaniNoem (10.5 and 14.5 g/m^2), respectively (Fig. 6 b). The significantly higher amount of sedimentation in Sorif site compared to the other two sites might be related to the high amount of runoff which was observed also by different other studies (Yir and Kossovsky, 2002; Casermeiro et al., 2004; Al-

Kharabsheh., 2004) and by soil conditions where Sorif has high amount of clay content (39 %) which leads to lower the infiltration rate and consequently higher surface runoff. In addition, clayey soils have high suitability for detachments by raindrop and erosion by surface runoff. These results reflect the importance of soil structure versus soil texture in runoff and soil erosion, therefore soil texture seems to be a good indicator for soil erosion.

3.3. Rainfall Runoff Relationship

The relationships between monthly values of rainfall and runoff at the three sites are presented in Fig. 7, 8 and 9. The first main rain event started on December 15 and November 19 in 2004 and 2005, respectively. The amount of surface runoff at each rain events was different between the study sites. According to Yir and Kossovsky (2002) the Mediterranean climate is characterized by a high year to year variability in runoff this variability mainly related to vegetation cover and type, soil characteristics, and characteristics of rainfall (intensity and amount). Rainfall distribution is another factor that plays an important role for such variability. The average intervals between the main rainfall events range from 3 to 18 days in short and long time interval, respectively. These periods affect the amount of deep percolation and soil evaporation which depend on environmental condition and soil characteristics. Based on potential evapotranspiration the aridity index was different between the study sites 0.16, 0.22 and 0.24 in BaniNoem, Dura and Sorif, respectively. As a result Sorif is classified as semiarid while Dura and BaniNoem are arid. On the other hand, soil moisture content is different between the study sites depending on rainfall amount, environmental conditions, and soil characteristics (Al-Seikh, 2007). The soil holding capacity and infiltration rate are different at these sites, which explain part of the runoff fluctuation during the study years.

These results represent two years of study under such conditions and provide primary results about the impact of environmental conditions on soil erosion and runoff. According to Imeson et al (1998) the projection of the impact of climate on erosion over a period of 30-50 years is required to understand how the resilience of the eco-geomorphological system is affected by climate. In addition, Kumwenda (1999) and Holechek et al (1989) reported that in dry land the effect of soil and water conservation managements take a long time to be appreciated.

4. CONCLUSION

From the current results it can be concluded that semi humid regions have higher nutrients content than semi-arid regions. Although, rainfall is higher in semi humid but the runoff coefficient was higher in semi-arid region. This may implies that, soil and water conservation in semi-arid area is essential practices to rehabilitate the regions.

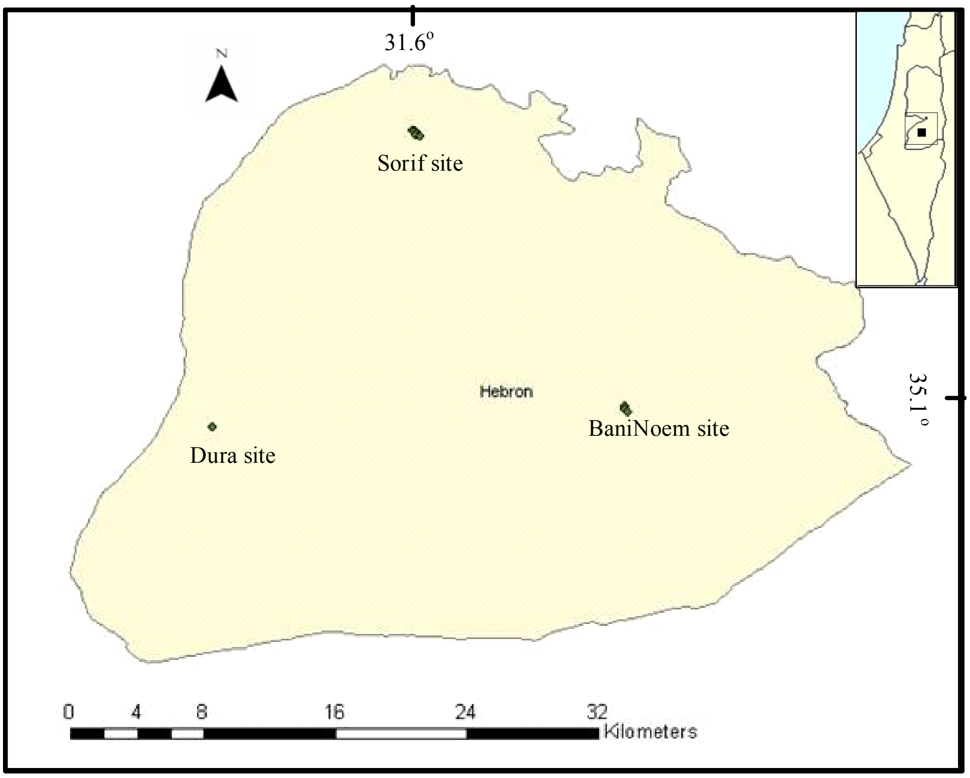
Table 1. Soil particle distribution (course sand, fine sand, silt and clay) and the texture classes at the three study sites (Sorif, Dura and BaniNoem)

Sites	Course sand	Fine sand	Silt	Clay	Texture classes
	(%)				
BaniNoem	6.1	34.2	30.7	29	loam
Dura	14.4	28.1	31.7	25.8	loam
Sorif	3.5	29.9	28. 9	37.7	clay loam

Table 2. Average soil pH and EC, Available NH_4^+, NO^-_3, and P at the study sites (Sorif, Dura and BaniNoem) in natural vegetation during 2004, and 2005.

Treatments	EC (dsm^{-1})		pH (1:2.5)		NH_4^+ (ppm)		NO_3^- (ppm)		P (ppm)	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Sorif	0.37 a	0.40 a	7.13 b	7.02 b	4.2 a	6.6 a	2.3 a	1.1 ab	3.3 a	8.1 a
Dura	0.35 a	0.32 b	7.73 a	7.54 a	3.7 a	4.1 b	2.9 a	1.6 a	6.9 a	7.4 a
BaniNoem	0.29 a	0.27 c	7.75 a	7.65 a	3.1 a	3.8 b	2.2 a	0.5 b	2.9 a	4.6 a

* Means followed by the same letter in the same column are not significantly different, according to Fisher LSD test at P ≤ 0.05.



Map 1. Location of the study sites.

Fig. 1. Micro-catchment (50 m^2) with natural vegetation to collect runoff and sedimentation

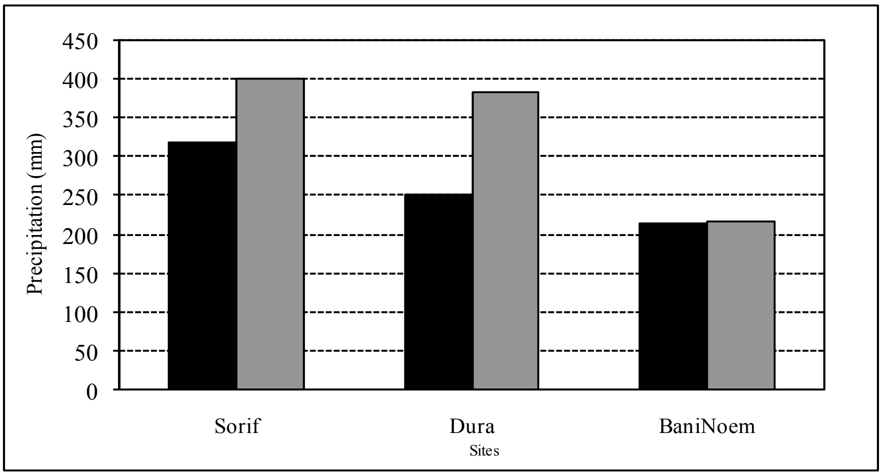


Fig. 2. Total amount of precipitation at BaniNoem, Sorif and Dura during the year 2004 and 2005.

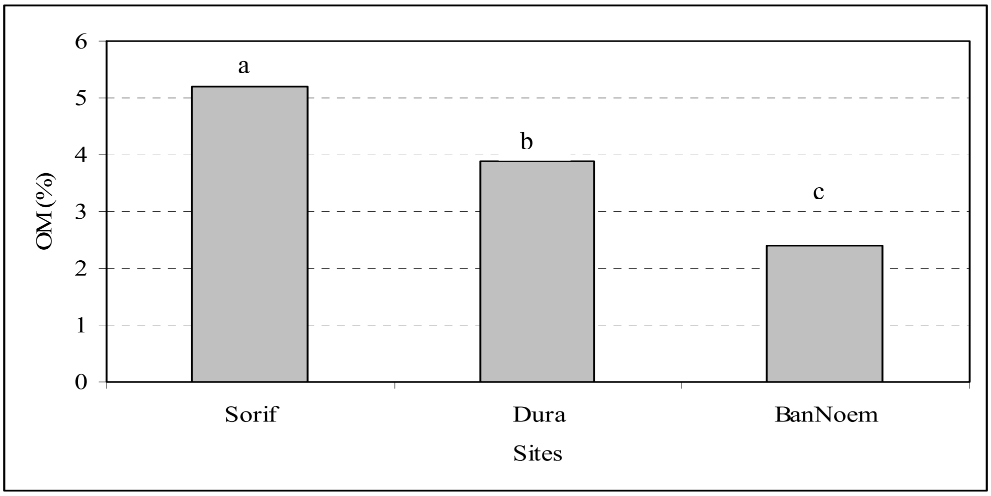


Fig 3. Average soil organic matter at the study sites (Sorif, Dura and BaniNoem). Columns with the same letter are not significantly difference. According to Fisher LSD test at P ≤ 0.05.

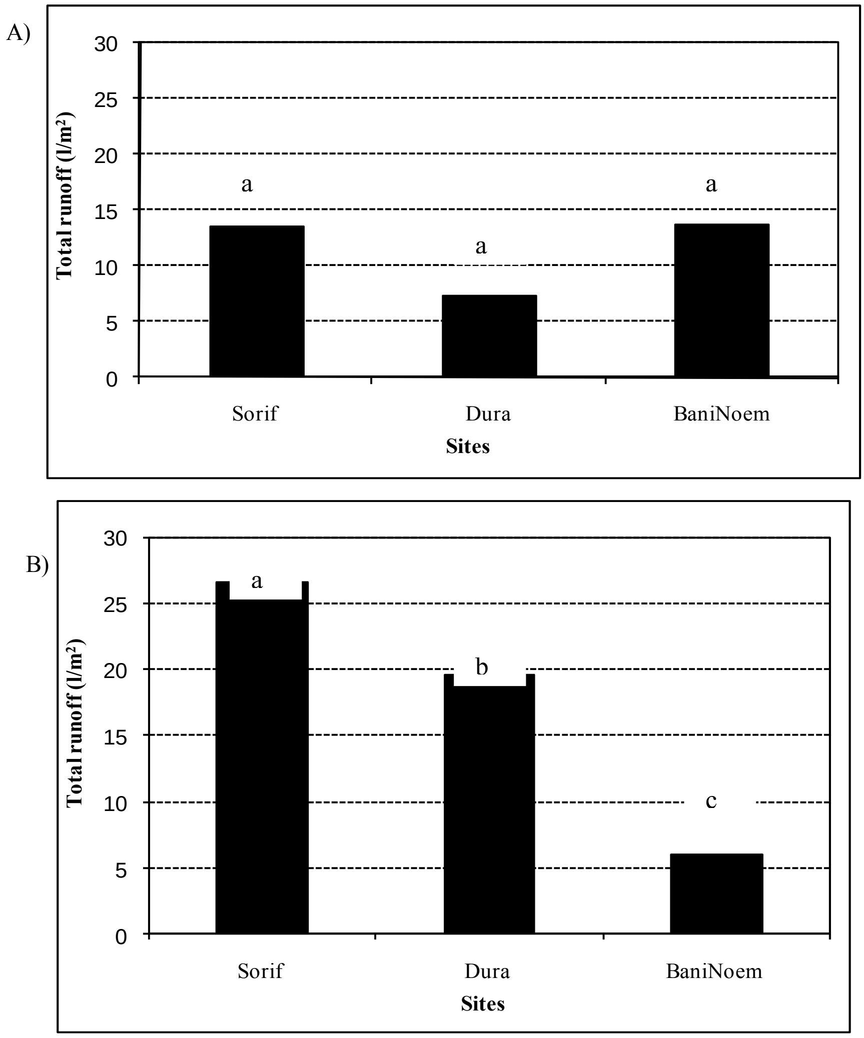


Fig. 4. Total amount of runoff in natural vegetation at the three sites in A 2003/2004 and B 2004/2005. Columns with the same letter are not significant difference according to Fisher LSD test at P ≤ 0.05.

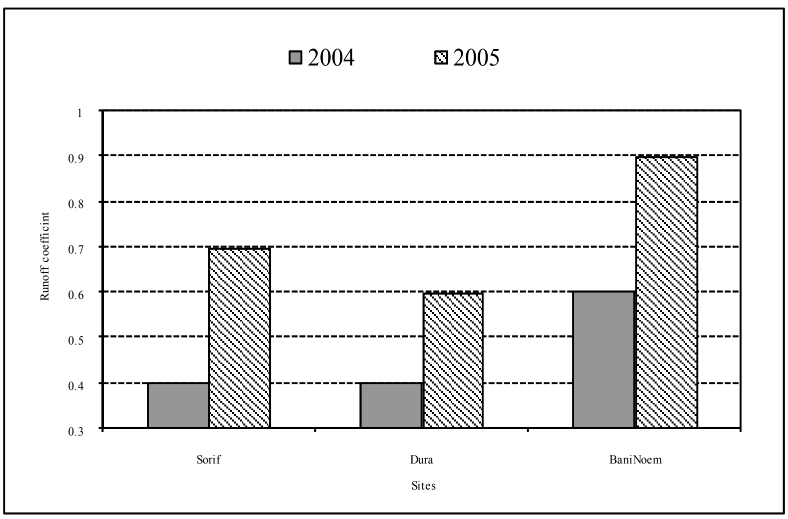


Fig. 5 Runoff coefficient at the three study sites during 2004 and 2005.

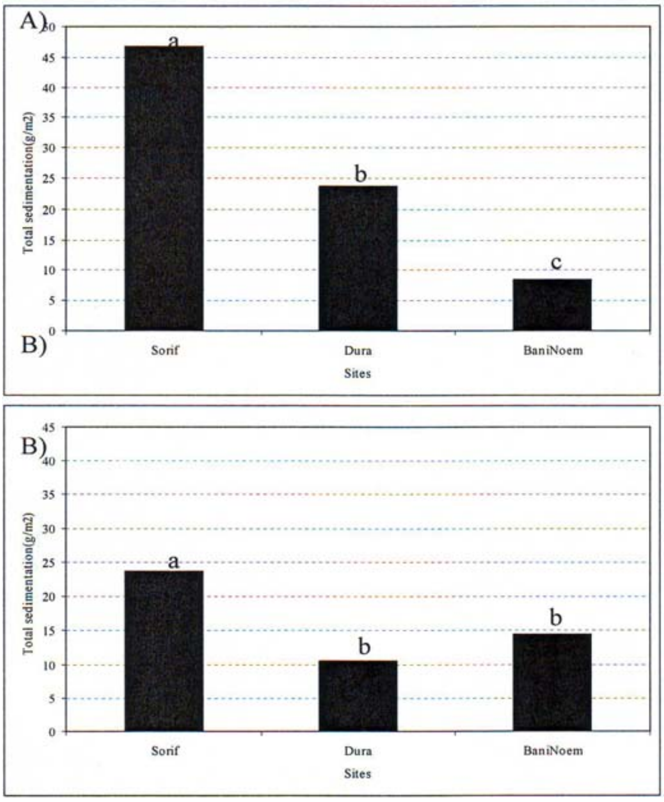


Fig 6. Total amount of sedimentation in natural vegetation at the study sites (Sorif, Dura, and BaniNoem) duing A 2004 and B 2005. Columns with the same letter are not significant difference according to Fisher LSD Test at P ≤ 0.05.

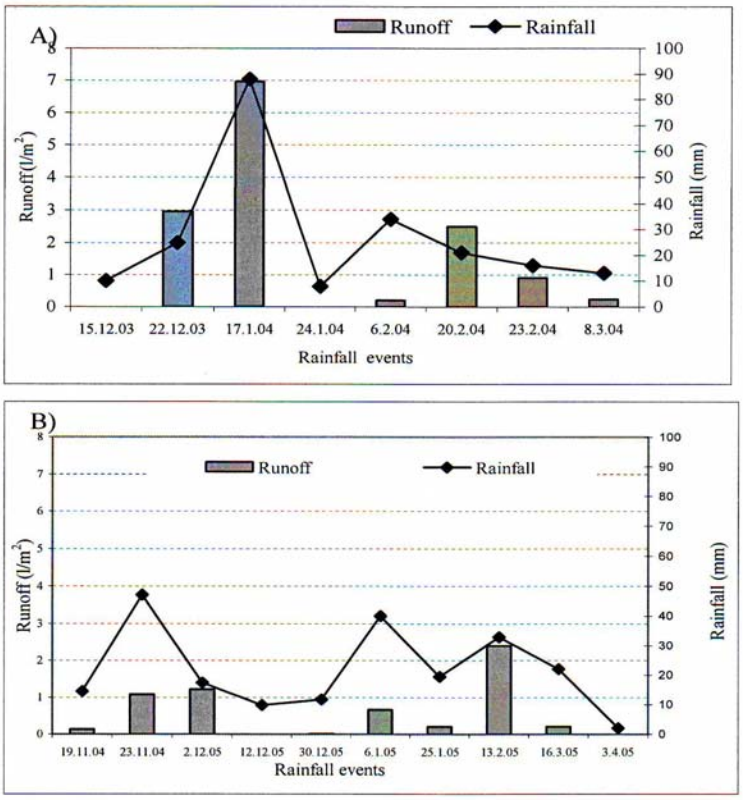


Fig 7. Rainfall and runoff in each rain events at Bani-Noem site during A 2003/2004 and B 2004/2005 winter seasons.

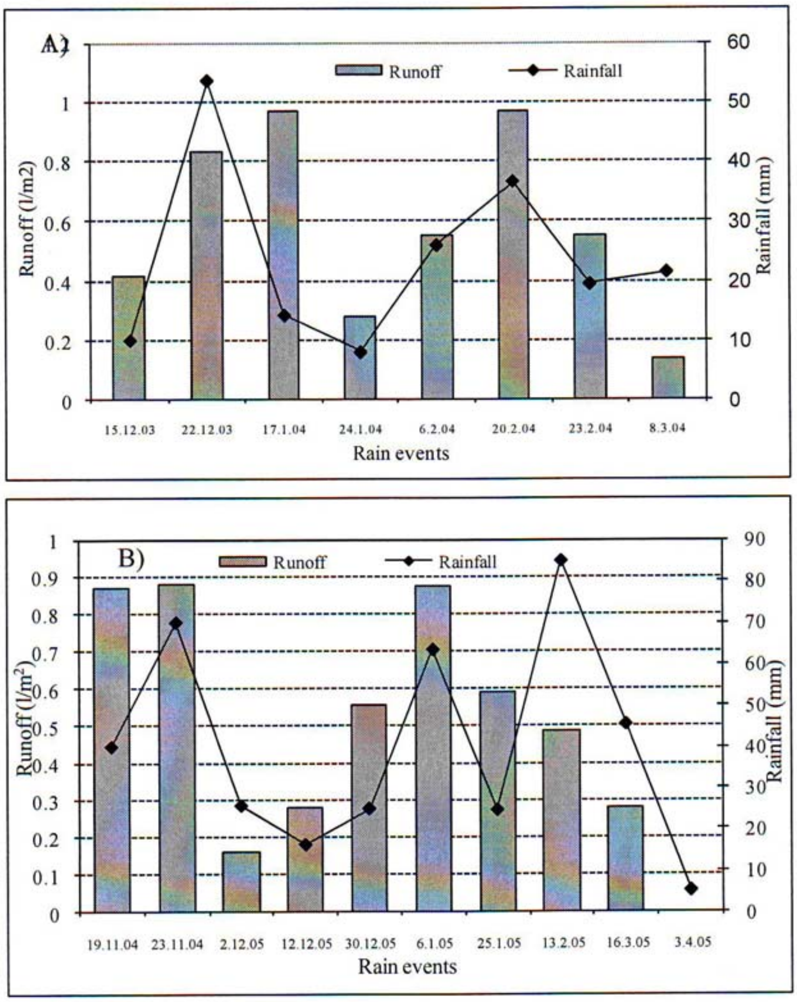
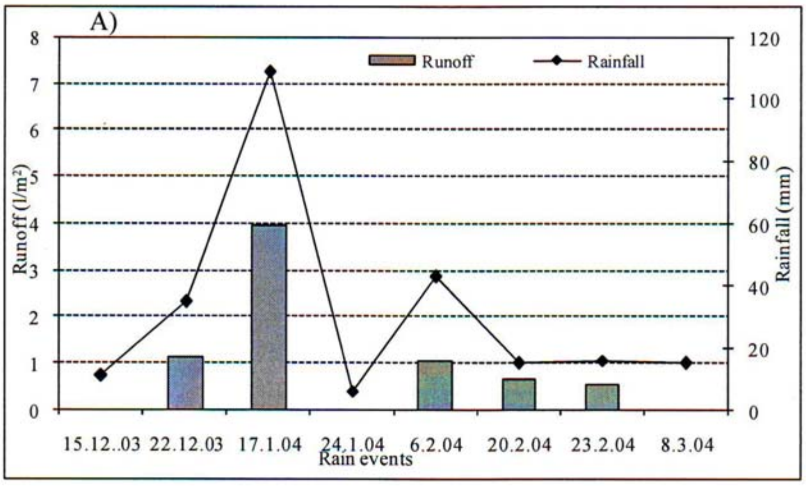


Fig 8. Rainfall and runoff in each rain events at Sorif site during A 2003/2004 and B 2004/2005 winter seasons.



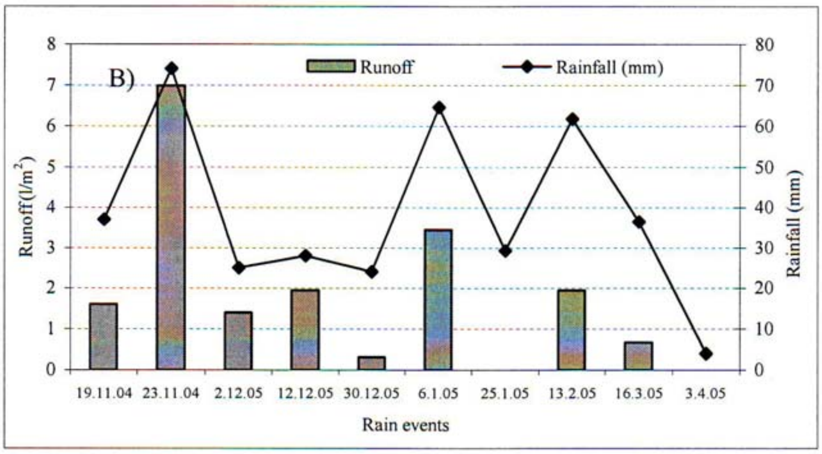


Fig 9. Rainfall and runoff in each rain events at Dura site during A 2003/2004 and B 2004/2005 winter seasons.

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تقييم العمليات الهيدرولوجية وخصائص التربة تحت ظروف مناخية مختلفة للضفة الغربية، فلسطين

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ملخـص

تتحدث الدراسة عن العمليات الهيدرولوجية التي تتمثل بالجريان السطحي وانجراف التربة بالاضافة الى خصائص التربة في ثلاث مناطق تمثل ظروفاً مناخية مختلفة تقع في الجزء الجنوبي للضفة الغربية. خلال عامين من الدراسة تم فيها جمع ثلاث عينات تربة ممثلة من كل منطقة من عمق 10 سم للتحليل الكيميائي والفيزيائي، بالاضافة لقياس الجريان السطحي والترسبات بعد كل عاصفة مطرية في الثلاث مناطق. اظهرت النتائج ان التربة في هذة المناطق تختلف في الصفات الفيزيائية والكيميائية. بينت النتائج ان المادة العضوية وEC والطين عالي في منطقة صوريف التي تمثل مناخ البحر المتوسط مقارنة مع دورا وبني نعيم التي تنتمي للمناخ شبه الجاف.

هناك تباين في الجريان السطحي والانجراف بين المناطق وكذلك بين العواصف المطرية. حيث كانت نتائج الجريان السطحي والترسبات (13.8، 26.6 لتر/م2 و46.7، 23.7 غم/م2) في صوريف (7.8، 19.6 لتر/م2 و23.7، 10.5 غم/م2) في دورا، و(13.5، 6.1 لتر/م2 و8.4، 14.5 غم/م2) في بني نعيم خلال السنوات 2004 و2005 على التوالي. بالاضافة لذلك اظهرت النتائج ان معامل الجريان السطحي في بني نعيم اعلى منه في دورا وصوريف خلال سنوات الدراسة. اعتمادا على الدراسات السابقة قد تعتبر هذه القيم قلية جدا من حيث عدة عوامل منها طبيعة الامطار ونوع ونسبة الغطاء النباتي وحالة التربة. لذلك تحت الظروف المتشابهة لهذه الظروف فان هذه الظروف يجب ان تأخذ بعين الاعتبار خلال عمليات الاستصلاح والمحافظة على الارض والتربة.

الكلمـات الدالـة: الجريان السطحي، انجراف التربة، خصائص التربة.

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