Catena 81 (2010) 97–103

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

The impact of vegetative cover type on runoff and soil erosion under different land uses

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ARTICLE INFO

Article history:
Received 28 March 2009
Received in revised form 6 January 2010
Accepted 26 January 2010

Keywords:
Runoff
Soil erosion
Vegetative cover
Land use
Forest
S. spinosum

ABSTRACT

The effects of different vegetation types on runoff generation and soil erosion were investigated. The study was conducted at the Southern part of West Bank, about 10 Km north-west of Hebron city, during 2005, 2006 and 2007. Five treatments were implemented; forests planted with *P. halepensis* (F), natural vegetation dominated by *S. spinosum* (W.S), natural vegetation where *S. spinosum* was removed (W/o.S), cultivated land (C), and deforestation (Df). Three types of data were estimated in each plot: runoff after each rainfall event, sedimentation at the end of the rainy season, and chemical and physical soil properties. The obtained results indicate that there are significant and important differences in runoff generation and sediment production with respect to the different types of vegetative cover. Forest and natural vegetation dominated by *S. spinosum* treatments exhibited the lowest amounts of runoff, with averages of 2.02 and 1.08 mm, respectively, in comparison to other treatments. The removal of *S. spinosum* significantly increased the total amount of runoff and sedimentation compared to the forest and *S. spinosum* treatments. In addition, runoff significantly increased (4.03 mm) for the Df treatment compared to that of the forest site. The greatest amount of sedimentation was observed in cultivated land and with deforestation.

The forest and *S. spinosum* treatments exhibited the highest percentages of organic matter of the five investigated treatments.

The results indicate that forests and natural vegetation dominated by *S. spinosum* prevent or decrease the risk of runoff and soil erosion. In conclusion, the removal of *S. spinosum* and forest trees as a means to improve rangeland productivity increases runoff and sediment fluxes if not accompanied by careful grazing management. In addition, interchangeably using arid and semi-arid lands as rangeland and for cultivation may have significant negative impacts on the production potential of these lands.

1. Introduction

Most rainwater falls on the soil, either directly or indirectly through stem flow or leaf drainage. A small portion remains on the leaves (interception) and eventually evaporates; however, water that reaches the soil surface is stored (infiltrated) in the soil profile or travels downhill as surface runoff or may percolate to a groundwater body. The amount of water that infiltrates into the soil profile or leaves as runoff depends on many factors, such as soil characteristics (Oztas et al., 2003), the type of vegetative cover (Chirino et al., 2006), and the root system (Gyssels et al., 2005). Several studies under different environmental conditions have demonstrated the positive effect of vegetative cover in reducing water erosion. A common method for decreasing water runoff and soil erosion is via stable and suitable vegetative cover (Dunjo et al., 2004; Chaplot and Bissonnais, 2003; Reid et al., 1999; Kothyari et al., 2004; Zhong et al., 2004; Tromble, 1976; Mohammed, 2005).

Vegetation controls soil erosion by means of its canopy, roots, and litter components; erosion also influences vegetation in terms of the composition, structure, and growth pattern of the plant community (Gyssels et al., 2005). Loss of vegetative cover may lead to the formation of soil seals that increase runoff and erosion during the early stages of seal development (Singer and Bissonnais, 1998).

Vacca et al. (2000) studied runoff and soil erosion in three areas under different land uses (abandoned grazing land, burned machia, and *Eucalyptus sp*), and found that different amounts of runoff and soil erosion result from different land uses. The highest runoff was found under *Eucalyptus sp* (135 mm), followed by abandoned grazing land (45.25 mm) and burned machia (30.45 mm). Reid et al. (1999) noted that the total runoff was significantly different between three types of land patches, the highest being from bare intercanopy patches, the intermediate being vegetated intercanopy patches, and lowest being canopy patches. In another study, the decrease in canopy cover density as a result of overgrazing led to rapid water erosion in

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doi:10.1016/j.catena.2010.01.008

rangelands (Oztas et al., 2003). Loss of vegetative cover as a result of human activities such as overgrazing and deforestation leads to the formation of soil seals (Singer and Bissonnais, 1998) that increase the risk of runoff and soil erosion (Singer and Bissonnais, 1998; Snyman and duPreez, 2005; Al-Seikh, 2006). Snyman and duPreez (2005) and Al-Seikh (2006) observed that rangeland degradation usually leads to increased surface water runoff and soil compaction due to decreased plant cover, reduced aggregate stability, reduced soil fertility, and decreases in the soil water content in all soil layers. In another study, Merzer (2007) reported that bare plots produced significantly more runoff than did a variety of vegetative plots.

FAO (1988) reported that one of the most common methods for rehabilitating degraded land and reducing the risk of soil erosion is to use forest cover. In Mediterranean areas, the establishment of *Pinus halepensis* (Allepo pine) tree cover has traditionally been encouraged in both natural and degraded ecosystems in order to reduce soil erosion and increase the growth of different vegetation forms. Xin et al. (2004) reported that increases in the number of native plant species could significantly reduce soil erosion and increase soil antiscourability by enhancing rootlets with and the diversity of root system characteristics that comes with the presence of a greater number of different species.

Since the beginning of the last century, *P. halepensis* has frequently been used in reforestation because of its role in succession after degradation of the soil. Ariza (2004) observed that *P. halepensis* primarily improves the soil by doubling the organic matter content contained therein, which increases aggregate stability and prevents erosion. Alternatively, the same positive effects can be achieved through the recovery of the natural vegetation.

Due to a lack of natural resource management, most forests in the West Bank have been deforested, especially over the last few decades. The rangelands have also been overgrazed, leading to an increased risk of soil erosion and a loss of vegetative cover (Mohammed, 2005). Most of the rangeland in the West Bank, especially in the Central Highland and eastern slope, is dominated by the dwarf shrub *S. spinosum* (Al-Joaba, 2006; Mohammad, 2000), which, although unpalatable, seems to be important for soil conservation and decreasing the risk of erosion (Mohammad, 2000).

Information about the relationship between vegetative cover and surface water runoff and soil erosion in the Palestinian environment is very limited; therefore, the main objective of this study is to study the impact of different vegetation types on water runoff and soil erosion.

2. Materials and methods

2.1. Site description

This study was carried out near Soreif, a town about 10 Km to the north-west of Hebron city in the western slopes of the West Bank/ Palestine, Central Highland; the exact geographical position is 35.06° East and 31.63° North, with an elevation 670 m above sea level. Plots covered an area of about 40 ha each. The site topography is characterized by high mountains and steep slopes, with grades ranging between 10 and 13%. The climate is Mediterranean, with rainy winters and long, hot, and dry summers. Most precipitation typically occurs between October and April, wherein the annual rainfall ranges from 400 to 500 mm according to Awadallah and Owaiwi (2005).

The same authors have characterized the soil located at this site as Brown Rendzinas and Pale Rendzinas.

2.2. Experimental field design

2.2.1. Treatments under investigation

This study was carried out during the winter seasons (October–April) of the years 2005, 2006, and 2007.

Two plots (replicates) were randomly assigned to undergo each treatment at the study site. These treatments include:

- Natural vegetation dominated by *Sarcopoterium spinosum* species (W.S) with percent cover ranges between 49% and 56%. Other herbaceous dominant species include *Avena sterilis*, *Bromus* species *Lactuca virosa*, and *Lotus corniculatus*.
- Natural vegetation, where the *S. spinosum* was removed repeatedly during the fall of each study period (W/o.S). The dominant species include *Trifolium stellatum*, *Crupina crupinastrum*, *A. sterilis*, and *Brachypodium distachyon.*
- Cultivation practices wherein all vegetative cover was removed and cleared (C). The land was plowed before the start of the rainy season without planting anything inside the microcatchment that builds. The dominant species after regrowth include *B. distachyon, Avena sterilis*, *Hedypnois cretica*, and *Rhagadiolus stellatus.*
- Afforestation (*P. halepensis)* planted in 1960, (F).
- Deforestation areas (Df). Cutting has been practiced on *P. halepensis* over the last 20 years, and at this time, the land is open to continue over grazing. The dominant species include *Piptatherum holciforme, Asphodelus aestivus, Cichorium intybus,* and *S. spinosum*.

2.2.2. Physical and chemical soil properties

Soil particle size distribution was determined using the pipette method (Bouwer, 1986). Soil pH was determined using an electrode pH-meter on saturated soil paste (1:2.5) using distilled water. Electrical conductivity (EC) was also measured in a saturated paste (1:2.5) (Skoog and West, 1976; FAO, 1980). Organic matter was evaluated using the Walkey and Black method (Nelson and Sommers, 1982). Extractable bases (Na^+, K^+, NH_4^+, NO_3^-) were evaluated following displacement with 1 M NH_4OAc (Thomas, 1982). Extractable P was evaluated using a molybdate reaction for colorimetric detection (Olsen and Sommers, 1982). The $CaCO_3$ content was determined using a calcimeter instrument (William, 1949). A completely randomized design was used, with three replicates, to enable comparison among treatments.

2.2.3. Runoff and erosion measurements

Two replicated microcatchments of 50 m^2 (5 m × 10 m) area were constructed for each vegetation type in order to measure surface water runoff and sedimentation.

Cement blocks (20 cm tall) surrounded each runoff plot to prevent run-on from the adjacent area. Plastic pipe was used to convey the runoff water to a 0.7 m^3 tank (Fig. 1).

The amount of runoff was measured after each main rainstorm event after allowing the sediment to settle. A rain gauge was used to measure the amount of rainfall in the study site during the study period (Fig. 2). The sediments accumulated at the bottom of each tank were also measured at the end of the winter after being air-dried (Fig. 2).

2.2.4. Ground cover

A permanent Line-Intercept Transect method was used to evaluate the ground cover percentage in each treatment, in accordance with (Bonham, 1989). In each microcatchment, two 10 m lines were established across each experimental plot. Whatever was present under the line, whether it was a plant species, rock, or bare soil, was recorded.

2.2.5. Statistical analysis

Completely Randomized Design with two replicates was used to compare between the treatments. One way ANOVA was used to compare treatment means for soil properties, runoff, and sedimentation. The Fisher LSD (Least Significant Difference) test at $p \leq 0.05$ was used for mean separation utilizing Sigmastat® program. Correlation analysis between runoff as dependent variable with clay content and % vegetation cover as independent variables was done.

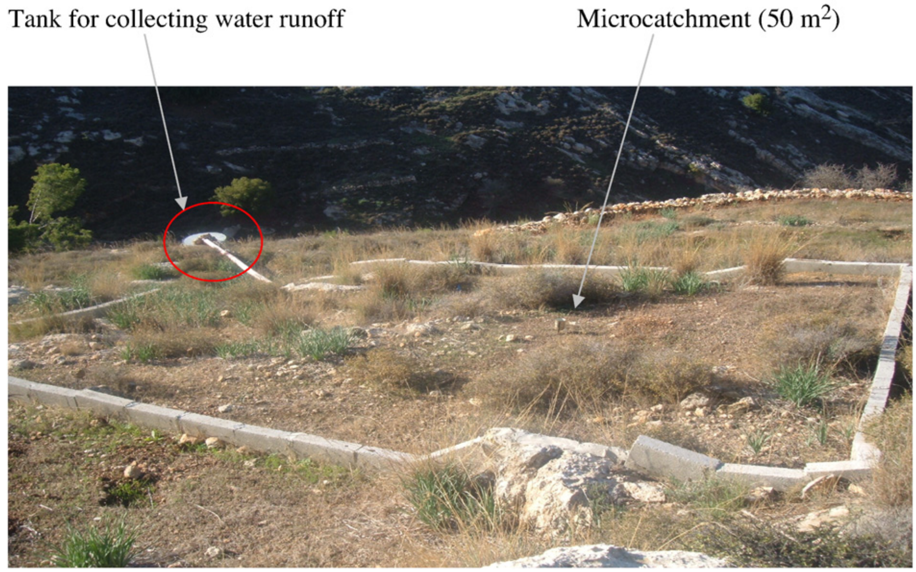

Fig. 1. Microcatchment used to measure runoff and sedimentation.

Also the correlation between runoff as independent variable with sedimentation and EC as dependent variables was tested.

3. Results

3.1. Soil properties

Although the amount of organic matter measured was relatively high in all treatments, the levels were significantly higher in treatments with *S. spinosum* (WS) and forest (F) compared to the others (Fig. 3). No significant differences were found between treatments without *S. spinosum* (W/0.S), cultivation (C), and deforestation (Df).

Deforested land has a significantly higher pH (7.29) compared to all of the other treatments, except the cultivation treatment (Table 1). The highest EC values were found in the forest and *S. spinosum* treatments, which were both significantly different from others. The EC was significantly lower in deforested plots (0.44 ds m^{-1}) and in those with removed *S. Spinosum* (0.47 ds m^{-1}). In addition, the correlation analysis between runoff and EC show a strong negative relationship with an r value of −0.89 that might be explained by the leaching of nutrient with runoff. On the other hand, no significant differences were found in NH_4^+, K^+, or available P among the various treatments. The highest Na^+ (39.68 ppm) level was found in the forest site, although there were no statistically significant differences among the treatments. A significant difference was found in the NO_3^- concentration in the forest site compared to the deforestation site (13.8 ppm vs. 8.9 ppm, respectively); however, no significant differences were shown between the NO_3^- concentration of sites with and without *S. Spinosum*, (10.8 ppm vs., 5.8 ppm, respectively). The highest percent of $CaCO_3$ (22.3%) was found in the cultivated treatments, and the lowest (13%) in the deforestation treatments. Results showed that there was no significant difference in clay and silt particles between the treatments (Table 2). Cultivation has the highest amount of sand particles (39%) compared to other treatments.

3.2. Ground cover

There was a difference in the percentage of ground cover (plant, bare soil, and rock) among the different treatments over the three years studied (2005, 2006, and 2007), as seen in Table 3. There was also a difference in plant cover, which was higher in 2006 than in 2005. In 2005, the sites with removed *S. spinosum* had a higher percentage of plant cover compared to the cultivated land; however, cultivation showed a higher percentage of bare soil during that year compared to other treatments. Also, in 2006, the cultivation-treated sites had higher percentages of bare soil cover compared to treatments without *S. spinosum* and with deforestation (Table 3).

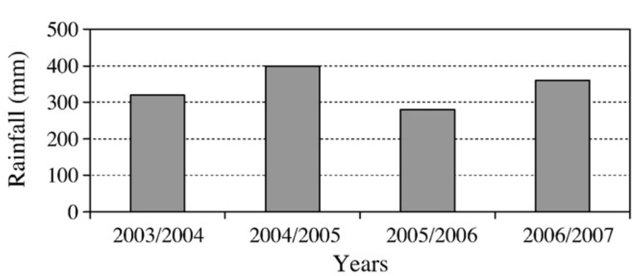

Fig. 2. Annual rainfall (mm) at the study site over four years 2003/2004, 2004/2005, 2005/2006, and 2006/2007.

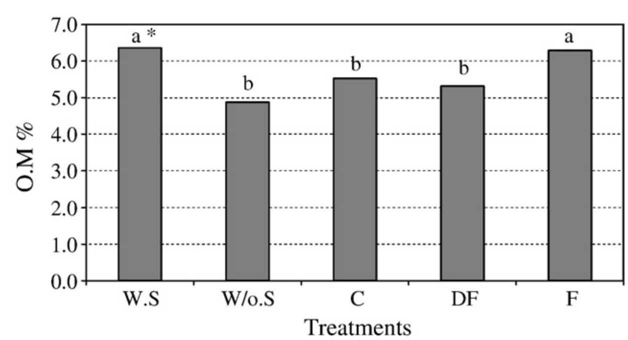

Fig. 3. Organic matter percentage in the treatments: With *S. spinosum* (W.S), without *S. spinosum* (W/o.S), cultivation land (C), deforestation (Df), and forest (F). *Columns with the same letter are not significantly different, according to the Fisher LSD test at $P \leq 0.05$.

Table 1
Soil chemical properties in the upper 10 cm of soil for all treatments during 2005: With *S. spinosum* (W.S), without *S. spinosum* (W/o.S), cultivation land (C), deforestation (Df), and forest (F).

Treatments	pH (1:2.5)	EC (ds m^{-1})	NH_4^+ (ppm)	P (ppm)	$CaCO_3$ (%)	Na^+ (ppm)	K^+ (ppm)	NO_3^- (ppm)
F	7.05 b*	0.71 a	5.94 a	12.3 a	16.7	39.68 a	379.98 a	13.8 a
Df	7.29 a	0.44 d	7.47 a	12.2 a	13	38.66 a	407.64 a	8.9 b
W.S	7.06 b	0.61 ab	8.5 a	10.2 a	18.6	33.56 a	407.89 a	10.8 ab
W/o.S	7.06 b	0.47 cd	5.86 a	7.7 a	15.4	35.57 a	373.64 a	5.8 b
C	7.21 ab	0.55 bc	6.26 a	9 a	22.3	38.12 a	313.5 a	6.8 a

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

3.3. Surface runoff

There were significant differences among the treatments in the amount of surface runoff during the rainy season study periods (Fig. 4). Forest (*P. halepensis*) and natural vegetation dominated by *S. spinosum* had the lowest amount of total runoff by far (2, 1.7 mm during 2005; 1.7, 2.5 mm during 2006; and 3.8, 3.2 mm during 2007, respectively,) compared to other treatments. The deforestation treatments had the highest total runoff (4.1, 4.4, and 8 mm during 2005, 2006, and 2007, respectively) (Fig. 4). In addition, during the second season, the deforested sites as well as those without *S. spinosum* had the highest amount of runoff (Fig. 4). The correlation between runoff and percent vegetation cover during the study periods 2005, 2006 and 2007 shows a negative *r* values of −0.35, −0.35, and −0.45, respectively. Also correlation analysis between runoff and clay particles shows a week positive relationship during the study period 2005, 2006, and 2007 with an *r* value 0.29, 0.14, and 0.06, respectively.

Generally, there is a close relationship between the amount of runoff and soil erosion (sedimentation).

The results in Fig. 5 show significant differences among treatments in the total amount of accumulated sedimentation during the winters of 2005, 2006 and 2007. From Fig. 5, it can be seen that forests and natural vegetation dominated by *S. spinosum* had the lowest amount of sediments compared to other treatments. This result could be related to the low amount of water runoff. On the other hand, it might be related to significant root systems and a high organic matter content, both of which improve the soil structure (Al-Seikh, 2006).

3.4. Soil erosion

Our results demonstrated that soil erosion (sedimentation) was significantly different among the treatments during the three seasons. Treatments with *S. spinosum* and forest had significantly lower amounts of accumulated sedimentation compared to the others (Fig. 5); however, in the winter of 2005, there was no significant difference in the accumulative sedimentation found between the other three treatments of cultivated land, land without *S. spinosum*, and deforestation. On the other hand, in 2005, the cultivated land had the highest amount of sediment compared to all of the other treatments, except deforestation.

3.5. Relationship between total surface runoff and sedimentation

A close relationship appeared between the amount of water runoff and sedimentation in most treatments (Figs. 6). The correlation

Table 2
Percentage of clay, silt, and sand in the upper 10 cm of soil for all treatments with *S. spinosum* (W.S), without *S. spinosum* (W/o.S), cultivation land (C), deforestation (Df), and forest (F) during the three study periods.

Treatments	%Clay	%Silt	%Sand
F	55 a	18 a	27 bc
Df	58 a *	16 a	26 c
W.S	54 a	15 a	31 bc
W/o.S	55 a	12 a	34 ab
C	45 a	16 a	39 a

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

Table 3
Percentage of ground cover types (plant, soil and rock) for all treatments: Without *S. spinosum* (W/o.S), with *S. spinosum* (W.S), Cultivation (C), deforestation (Df), and forest (F) during the three study periods.

Ground cover	Plant cover (%)			Soil cover (%)			Rock cover (%)		
Treatments	2005	2006	2007	2005	2006	2007	2005	2006	2007
W/o.S	71.4	90.5	93.7	16.4	3.4	2.9	12.2	6.2	3.5
W.S	64.1	82.8	90.8	23.8	6.6	3.8	12.1	10.6	5.4
C	49.3	86.4	90.2	34.6	8.2	5.6	16.1	5.4	4.1
Df	55.1	70.6	69.2	14.4	4.9	4.2	30.6	24.5	26.5
F*	70.2	72.6	74.5	9.5	7.1	8.4	24.5	11.7	10.5

* Canopy cover was measured for the forest.

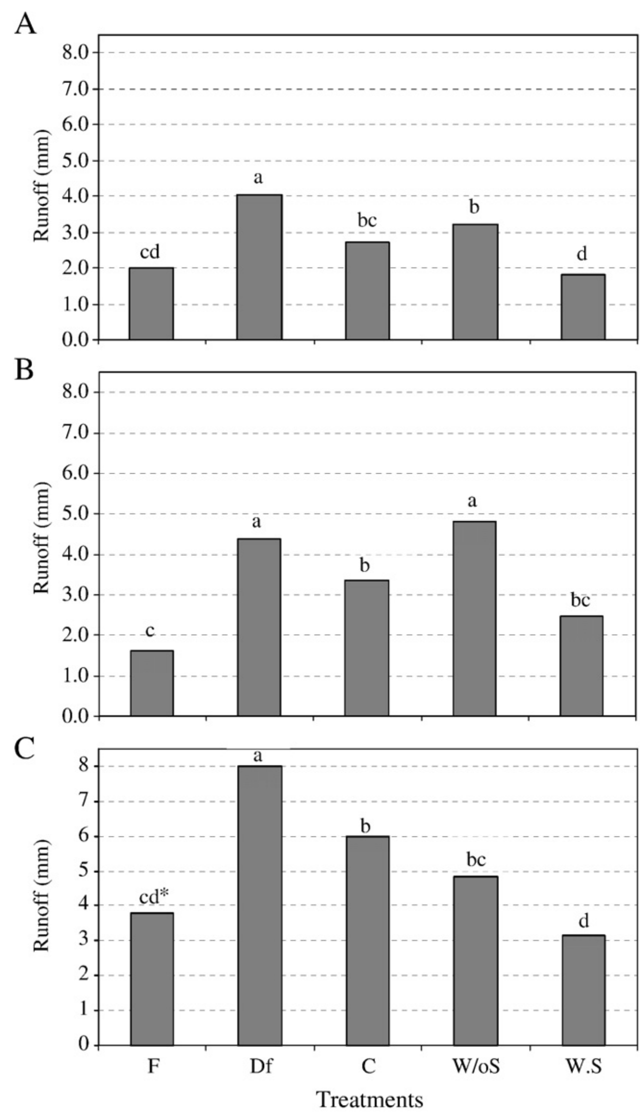

Fig. 4. Total amount of runoff (mm) in all treatments: With *S. spinosum* (W.S), without *S. spinosum* (W/o.S), cultivation land (C), deforestation (Df), and forest (F) during 2005 (A), 2006(B), 2007(C). *Columns with the same letter are not significantly different, according to the Fisher LSD test at $P \leq 0.05$.

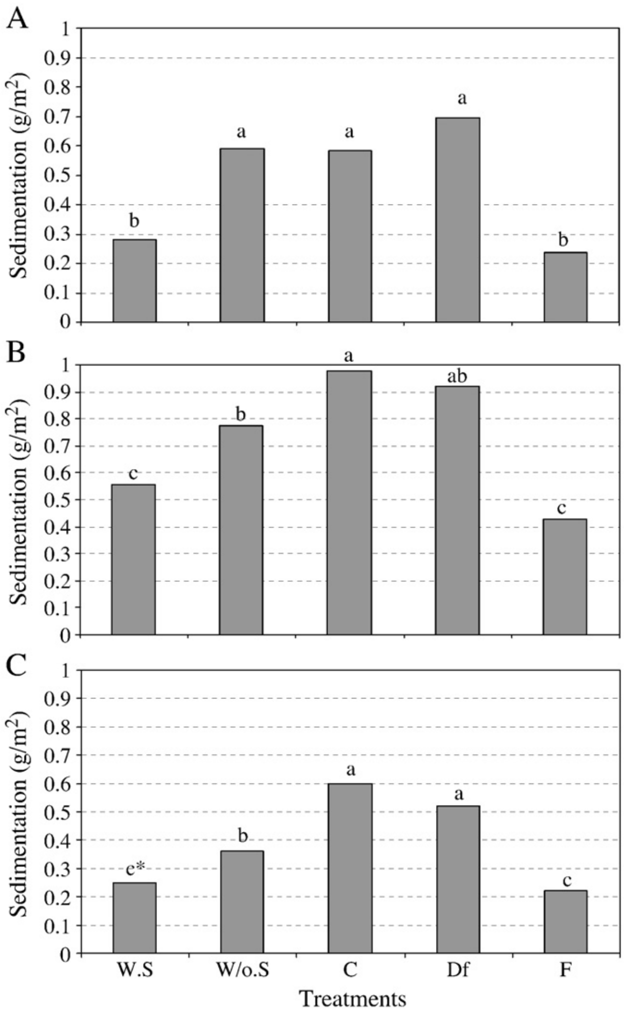

Fig. 5. Total amount of sedimentation (g/m^2) in all treatments: With *S. spinosum* (W.S), without *S. spinosum* (W/o.S), cultivation land (C), deforestation (Df), and forest (F) during 2005(A), 2006(B), 2007(C). *Columns with the same letter are not significantly different, according to the Fisher LSD test at $P \leq 0.05$.

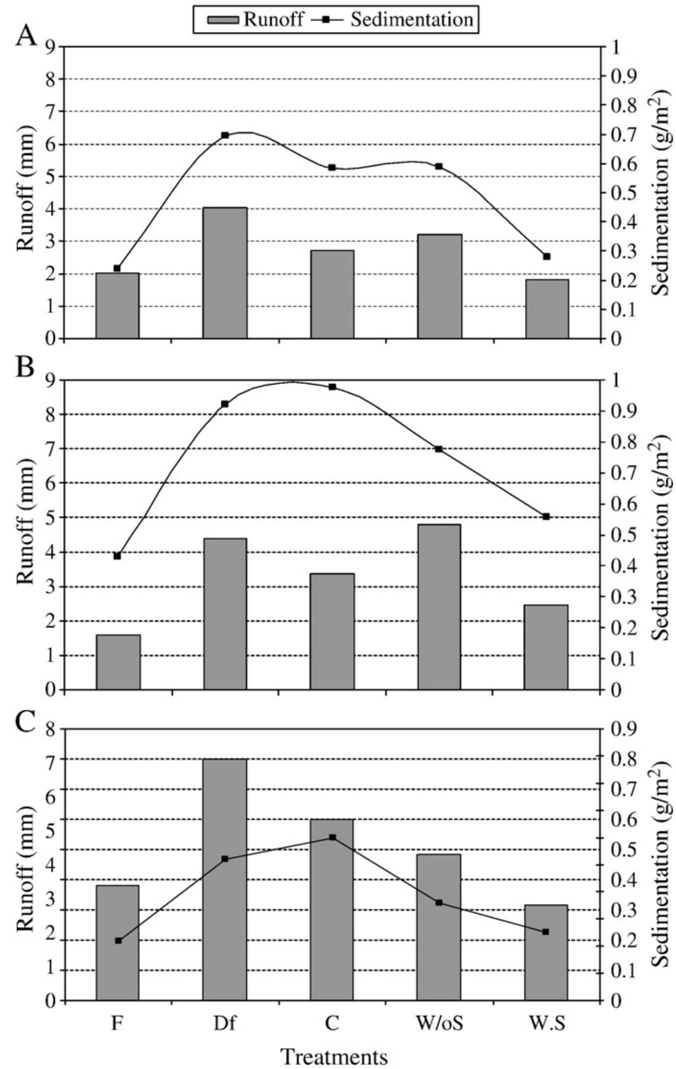

Fig. 6. Relationship between the total amount of runoff (mm) and accumulative sedimentation (g/m^2), during winter season of 2005(A), 2006(B), and 2007(C) in treatments with *S. spinosum* (W.S), without *S. spinosum* (W/o.S), cultivation land (C), deforestation (Df), and forest (F).

analysis between runoff and soil erosion during the study periods 2005, 2006, and 2007 shows strong positive relationships with an r values of 0.93, 0.76, and 0.84, respectively. Increases in the amount of surface runoff lead to an increase in soil erosion for most treatments, especially during the main storm events of each winter; however, these relationships are inconsistent in all treatments, which reflect the influence of other factors, such as vegetative cover type. In the cultivation treatment, the amount of runoff is less than in treatments without *S. spinosum* (W/o.S) or deforestation (Df) during 2005, despite the fact that accumulated sediment is higher for cultivation in comparison to these treatments.

4. Discussion

4.1. Soil properties

The amount of organic matter reflects the percentage of plant residues and soil organisms that have lived and died in the soils. The basic functions of organic matter are the development and maintenance of soil structure, water holding capacity, nutrient and organic carbon storage, and the maintenance of biological activity (Fu, et al, 2003).

The data in Fig. 3 show that soil organic matter is significantly higher in forests and with *S. spinosum* treatments compared to other treatments; these results are probably related to the fact that the needles of the *P. halepensis* fall and decomposed underneath the trees, adding high amounts of organic matter. This result agrees with a study conducted by Ariza (2004), who concluded that forests with Aleppo pine (*P. halepensis*) improved the soil by doubling its organic matter content. In addition, in natural vegetation dominated by *S. spinosum*, the organic matter was probably high due to the dominance of shrubs (mainly *S. spinosum*), which increases the amount of organic matter by adding and decomposing plant litter. Similar results were obtained by Al-seikh (2006), who found that organic matter content in shrub lands dominated by *S. spinosum* was the highest compared to other treatments; however, in other treatments, the amounts of organic matter were lower due to different causes. Cultivated land had lower quantities of organic matter due to the removal of most of the vegetative cover, which is the source of organic matter. Similar results were also observed by (Al-seikh, 2006; Fu et al, 2004); wherein the amount of organic matter was found to be lower in cultivated land than that in land with natural vegetation. The tillage practices used in cultivation have also been found to increase and enhance the biological activity, and thus, increase the decomposition rate of organic matter (Dunjo et al., 2003).

Soil pH is considered one of the most important soil parameters because it directly affects the growth of plants and influences other soil parameters. In all of the treatments, the pH values were within the range for optimal plant growth conditions (6–7.5) (Marx et al, 1999). The higher soil pH values found in deforestation and cultivated treatments might be related to low soil moisture and a low amount of organic matter (Rezaei and Gilkes, 2005). In treatments with *S. spinosum* (W.S), forest (F), and without *S. spinosum* (W/o.S), no significant difference was found in soil pH (Table 1).

The EC was significantly higher in the forest treatment compared to the others, which might be related to the higher content of organic matter and low amount of runoff. Results showed that strong negative relationship with an *r* value of −0.89 was found between runoff and EC values. Zhang, et al (1997) found that EC decrease exponentially with time during the initial stages of wet and water table runs. On the other hand, decreases of EC on other treatment may relate to raindrop impact and confined to mixing zone, causes an exponential depletion of chemicals (Zhang, et al, 1997).

4.2. Surface runoff

There is a close relationship between each rainfall event and the amount of runoff, which depends directly on the type of vegetative cover. In addition to the current season's growth, the presence of sparse dead vegetation from the previous season is sufficient to decrease runoff generation during the early stages of the rainy season (Merzer, 2007). Data from Fig. 4 show that there is variation in the total runoff under different types of vegetative cover.

Removing the *S. spinosum* increased the surface runoff during the study period; these results can be explained by the fact that the differences between treatments in the percentages of plant cover, bare soil, rock cover, type of vegetative cover, and organic matter directly affect the amount of runoff (Table 3). Data in Fig. 4 show that the deforestation treatment had the highest total amount of runoff compared to all other treatments for all three years, except for the treatment without *S. spinosum* in 2006. This might be related to the disturbance of the land when the forest was removed, which decreased the impact of canopy interception of raindrops. In addition, this land was exposed to overgrazing for a long period of time after the trees were cleared. In addition, the high rock cover in the deforestation compared to the other treatments explains the high runoff (Adam, 2007). Fig. 4 shows that the forest and *S. spinosum* treatments had a significantly lower amount of total runoff (mm) compared to other treatments during the three seasons. These results might be due to the interception phenomenon, which decreases the velocity of raindrops and prevents them from directly impacting the soil surface in a way that splashes the soil particles. In addition, some raindrops that are intercepted by plants might evaporate directly to the atmosphere and never reach the soil. Further, high vegetative cover slows the overland flow, and the root systems of trees and shrubs play an important role in decreasing runoff by improving soil characteristics, such as soil porosity and organic matter content, thus increasing the infiltration rate and decreasing the runoff. Furthermore, our results show that the forest and *S. spinosum* treatments have higher organic matter contents compared to the other treatments, which contributed to better soil properties, such as porosity and aggregate stability, again increasing the infiltration rate and decreasing water runoff and sedimentation. Ultimately this lead to higher soil moisture levels in these treatments. These results agree with Chirino et al. (2006), who mentioned that forestation with Aleppo pine (*P. halepensis*) and natural vegetation without trees result in the same (no significant difference) amount of runoff. Also, Merzer (2007) reported that the interaction between trees and the annual understory reduces the runoff to almost nothing. In addition, Al-Seikh (2006) concluded that reforestation (of shrub land) exhibited significantly lower amounts of runoff due to the high amount of organic matter and clay particles, which improve the soil structure and increase the infiltration rate. Also, Casermeeiro et al. (2004) noted that runoff and soil erosion are significantly lower under shrub land as a result of the high infiltration rate afforded by the addition of organic matter to the soil.

After removing the *S. spinosum*, which occurs in both treatments without *S. spinosum* and in cultivation, the amount of runoff is significantly higher than with other treatments (Fig. 4). This is probably due to low raindrop interception, which means that the drops fall with high speed and high kinetic energy. This increases the amount of runoff and change in root systems after removing *S. spinosum* and cultivating the land, which in turn directly affects the soil physical properties as well as the porosity of the soil, and thus, the amount of runoff and the infiltration rate. In addition, after removing the *S. spinosum*, the annual plants that become the dominant species (grasses and forbs) do not have extensive root systems like the shrub roots. These results agree with Gyssels et al. (2005), who reported that plant roots penetrating the soil layer macrospores improve the soil infiltration capacity, which reduces the volume of surface runoff. In addition, the land disturbances caused by removing the *S. spinosum* and cultivation increase the amount of runoff.

4.3. Soil erosion

The soil losses generated from cultivated treatment were equal to 0.58 g/m^2, 0.9 g/m^2, and 0.6 in 2005, 2006, and 2007, respectively. These were higher than other treatments, except for deforestation. Soil loss is high in cultivated treatments, despite the low amount of runoff compared to other treatments. These results might be related to the fact that cultivating the land leads to breakdowns of aggregate stability, loss of vegetative cover, exposure of the soil particles to direct impact of rain drops and the resulting detachment; these factors enable the soil particles to be easily moved by overland flow. In addition, most of the prevailing erosion events were transport-limited or detachment-limited; in the case of cultivation, the erosion occurred by transport-limited factors (Abu Hammad, 2004). In addition, Al-Seikh (2006) reported that the amount of sedimentation was higher in cultivated land in comparison to natural vegetation due to the loss of vegetative cover and the detachment of soil particles. In the conditions under which the research was carried out, the forest with *P. halepensis* did not significantly reduce the runoff or sedimentation in comparison to natural vegetation dominated by *S. spinosum*. Therefore, the risk of runoff and soil erosion after removing *S. Spinosum* can be decreased by increasing the growth of shrubs or trees in the cleared site to maintain a stable and suitable plant cover.

The variation in total runoff and soil erosion under different vegetation states reflects the great importance of vegetative cover type.

5. Conclusions

The results of this research can be summarized as follows:

- The runoff and soil erosion measured in the five vegetation systems show significant differences, wherein the lowest runoff and soil erosion rates are associated with the forest and with natural vegetation dominated by *S. spinosum*.
- Deforestation and the removal of *S. spinosum* have a directly increasing effect on runoff and soil erosion losses.
- Land cultivation and deforestation create conditions that are much more favorable for surface runoff and soil erosion, and therefore have a negative impact in terms of increased runoff, and soil erosion.

– Runoff and soil erosion were found to be more reduced based on the type of vegetative cover rather than the percent of vegetative cover.

6. Recommendation

Human activities such as deforestation, the removal *S. spinosum* for firewood and other purpose, and interchangeably using arid- and semi-arid lands between cultivation and grazing significantly increase runoff generation and sedimentation production, which in turn increases the potential for land degradation. Consequently, the removal of *S. spinosum* as a means to improve rangeland productivity must be accompanied by careful grazing management.

Therefore, keeping suitable vegetative cover should be considered for soil and water conservation in forests and rangeland, and any cultivation or brush control should be carefully practiced to avoid retrogressive trends in these lands.

Acknowledgement

Finally we extend our thanks and appreciation for the funding agencies: USDA Forest Service, USAID Middle East Regional Cooperation (MERC), the US State Department and to those who support this study as part of a large project (Monitoring and Evaluation of Watersheds in the Middle East Region). Also we extend our appreciation for Saleh Al-Seikh and Osama Al-Joaba for their help in data collection.

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