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The impact of land reclamation on natural vegetation

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ABSTRACT:

This study evaluated the effects of different land reclamation practices (treatments) on vegetation characteristics in semi-arid to semi-humid conditions of the southern part of the West Bank, Palestine. For each treatment, the study evaluated the vegetation above ground dry biomass and plant density.

Results showed that above ground biomass increased significantly ($P \leq 0.05$) by 80 % and 45 % and plant density by 15% and 52 % in stone terrace plots and semi-circle bund plots, respectively, compared to the natural vegetation (excluded grazing) plot. In addition, grazing significantly reduced ($P \leq 0.05$) the amount of dry biomass by 36% and plant density by 37 %. Our results indicated that the use of afforestation as a management option should be planned carefully for restoring the provision of ecosystem services of rangelands and that the type of trees should be considered when it is practiced. Pinus halepensis is not recommended for conservation of natural vegetation diversity.

It was concluded that management decisions can have substantial influences upon vegetation diversity and production. Therefore, using simple water harvesting techniques and excluding grazing, for a period of time, may be key to increasing vegetation dry biomass and plant density, while at the same time conserving natural vegetation.

Key words: Water harvesting, above ground dry biomass, plant density, afforestation.

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الملخص:

تتناول هذه الدراسة آثار الممارسات المختلفة لاستصلاح الأراضي على بعض الخصائص الطبيعية للنباتات البرية تحت الظروف شبه الجافة وشبه الرطبة. تم تنفيذ الدراسة في موقع صوريف جنوبي الضفة الغربية. في كل معاملة تم دراسة وتقييم كثافة النباتات وكمية المادة الجافة.

تبين النتائج أن كمية المادة الجافة زادت معنويا بنسبة 80 ٪ و 45 ٪ وازدادت كثافة النباتات بنسبة 15 ٪ و 52 ٪ في معاملة المصاطب الحجرية ومعاملة الأحواض نصف الدائرية، على التوالي ، مقارنة مع معاملة منع الرعي. اضافة إلى ذلك فإن الرعي قد قلل معنويا من المادة الجافة بنسبة 36 ٪ وكثافة النباتات بنسبة 37% لغاية شهر نيسان. تشير النتائج إلى أن استخدام التحريج لاستعادة خدمات النظم الإيكولوجية للمراعي ينبغي أن يخطط بعناية، و كذلك يجب الأخذ بعين الأعتبار نوع الأشجار. لا يوصى باعادة زرع أشجارالصنوبر ((Pinus halepensis لإعادة تأهيل المراعي لأنها خفضت من كثافة النباتات الرعوية عريضة الأوراق.

تشير النتائج إلى أن القرارات الإدارية لها تأثير كبير على تنوع وإنتاجية النباتات الطبيعية. لذلك فان استخدام تقنيات بسيطة لجمع المياه ومنع الرعي لفترة من الزمن قد تكون العامل الرئيسي لزيادة المادة الجافة وكثافة النباتات في الأراضي شبه الجافة، وفي نفس الوقت المحافظة على النباتات الطبيعية.

الكلمات الدالة : الحصاد المائي ، كتلة المادة الجافة ، كثافة النباتات ، تحريج المراعي.

INTRODUCTION:

Water is one of the key factors in the conservation of natural vegetation in arid and semi-arid regions. Water harvesting can be defined as the process of concentrating rainfall as runoff from a large catchment area to be used in a smaller target area (Oweis et al., 1999). Water harvesting techniques can be used in rangeland to reduce soil erosion and sedimentation and to increase soil water storage and fertility (Prinz et al, 1996; Schiettecatte et al., 2005). Traditionally, water harvesting techniques have been implemented and developed by local farmers in arid and semi-arid areas of the world. In Palestine, people built water harvesting cisterns and established old stone terraces in the central mountains of the West Bank that were used for soil and water conservation by reducing the negative effect of intense rainfall resulting in a lower amount of runoff and soil erosion (Abu Hammad, 2004; Al-Seekh and Mohammed, 2008, Al-seekh et al., 2009). In addition, runoff agriculture in the Negev desert can be traced back as far as the 10th century B.C (Oweis et al., 2004).

With widespread droughts in semi-arid and arid areas, a growing awareness of the potential of water harvesting techniques arose in the 1970’s and 1980’s (Critchley and Siegert, 1991). Although various forms of water harvesting techniques for soil and water conservation are used, the effectiveness of these techniques depends on several factors, including climate, topography, soil, and socio-economic factors. Schreiber and

Frasier (1978) found that water harvesting increased the average productivity five times for an area receiving less than 130 mm of precipitation during the growing season. Abu- Zanat et al., (2003) observed that harvesting rainfall increased the coverage of both total vegetation (36%), forage plants (48%) as well as mean biomass production in West Asia.

Replanted trees are used now as a method for rehabilitating degraded land and reducing the risk of soil erosion (FAO, 1988). In Mediterranean areas, the establishment of P. halepensis (Aleppo 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. The effect of forest trees on vegetation was studied by several researchers (Penuelas et al., 1998; Cahill, 2002; Fernandez et al., 2006; Ahmed et al., 2008; Navarro-Cano et al., 2009). Mohammad and Al-Adam (2010) found that forest plot dominated by P. halepensis significantly decreased the amount of runoff compared with deforestation plot. Many studies have been conducted to evaluate the efficiency of different water harvesting techniques in controlling rainfall runoff and soil erosion for cultivated lands (Singth et al., 1990; Abu-Zanat et al., 2003; Abu Hammad, 2004; Al-Seikh, 2006). However in arid and semi-arid areas the use of water harvesting techniques might have a different consideration from the economic point of view and its suitability as a tool for conserving the degraded ecosystem, mainly vegetation.

In the southern part of the West Bank, the rangeland was found to suffer from severe deterioration due to overgrazing and utilization of marginal land (Mohammad 2005), which lead to damaged vegetation cover, low productivity, increased poisonous and unpalatable plant species, low vegetation cover, and the presence of a large percentage of weeds such as Sarcopotrium sp. (Alishtayeh and Salahat 2010; Mohammad 2008).

Recently in the West Bank, due to land limitation and scarcity of water, many projects have been implemented in the area for water harvesting, aiming at soil and water conservation and increasing the yield of crops. However, using water harvesting structures in rangeland ecosystem to improve natural vegetation condition is very limited in West Bank, since most of the rangelands are not privately owned and the returns from these projects are of a long- term nature.

Therefore, the objective of this study was to evaluate the use of water harvesting techniques (stone terraces and semi-circle bunds), afforestration and excluding grazing as a tool to conserve natural vegetation diversity and productivity.

2. MATERIALS AND METHODS

2.1. STUDY SITE

The study was implemented at Sorife town in the Hebron District / Palestinian Authority during the years 2006 and 2007. The geographical position of the site is 35.06 East and 31.62 North and is located in the western part of the central mountain region of the West Bank, 10 Kms north west of Hebron city (Map 1). Its topography is mountainous with steep slopes with elevation ranging from 568 to 727 m above sea level (GIS, 2008). The area is considered as semi-arid to semi-humid Mediterranean climate with rainy winters and long, hot, and dry summers. Average annual rainfall is about 350-400 mm during the winter season (November to April). Soil is classified as Terra rossa, non saline clay loam, that has medium amount of clay (37.7 %) and a high amount of organic matter (5.2 %) (Awadallah and Owaiwi, 2005; Al-Seekh and Mohammad, 2008).

The area was subjected to overgrazing and cutting the trees for more than sixty years. The total area is about 15 hectares, which was fenced and excluded from grazing in 2001. According to Aljoaba (2006), the dominant plant species at this area are Sarcopoterium spinosum, Avena sterilis, Lolium sp, Bromus fasciculatus, Crepis aspera and Aegilops binuncialis.

2.2. TREATMENTS

After 5 years of excluded grazing and land managements by building different water harvesting structures, vegetation attributes (biomass, and density) were evaluated in the following treatments: natural vegetation (excluding grazing), stone terraces, soil semi-circle bunds, afforestration by P. halepensis, and grazing area.

For water harvesting techniques, stone terraces were constructed along the slope using small stones in order to slow down runoff, increase the infiltration and capture the sediment. The technique is widely used in the mountainous areas, which have an adequate supply of stones that can be used quickly and cheaply. Semi-circle bunds are earth embankments constructed by excavating the soil and placing it down slope to form semi-circle shape; this technique used in a staggered orientation and is mainly used for rangeland rehabilitation and fodder production. The afforestration treatment was planted by P. halepensis in the year 2002. The grazing site was exposed to severe over-grazing by sheep and goats for over 60 years.

2.3. VEGETATION SAMPLING

Vegetation characteristics were evaluated in April, during the peak of primary production (Mohammad, 2008). The vegetation attributes were evaluated according to Bonham (1989) as the following:

2.3.1. Vegetation biomass

At each treatment, each year (2006 and 2007), fifteen 1 m2 quadrate (square plots) were randomly allocated (used as replicates), and all the current year growth of each plant species inside the quadrate was clipped to the soil surface, and placed in labeled paper bags. The plant samples were taken to the lab and the fresh and dry weights (dried at 65 C°) were recorded.
The species relative biomass was estimated as follows:

$$S.R.B = \frac{\text{Biomass б species in all quardrate}}{\text{Biomass б all species in all quardate}} \times 100$$

2.3.2. PLANT DENSITY

At each treatment, each year (2006 and 2007), fifteen 0.25 m2 square quadrates were allocated randomly (used as replicates). The number of all species, and the number of individuals of each species was recorded for each quadrate.
The species relative density was estimated as follows:

$$S.R.\mathrm{D} = \frac{\text{Density б species in all quardrate}}{\text{Density б all species in all quardate}} \times 100$$

2.4. STATISTICAL ANALYSIS

A completely randomized design was used, and the data of vegetation attributes between the different treatments were analyzed in a one way ANOVA. The Fisher LSD (Least Significant Difference) test at $P \leq 0.05$ was used for mean separation utilizing Sigmastat® program.

The data were collected during the years 2006 and 2007, then the average of the two years was calculated.

3. RESULTS

3.1. DRY BIOMASS

The results showed that total dry biomass was significantly ($P < 0.05$) higher in the stone terraces (3099 kg/ha) compared to other treatments (Table1), followed by semi-circle bunds (2488 kg/ha). Moreover, forbs total dry biomass in the stone terraces and semi-circle bunds (1732 kg/ha and 1143 kg/ha, respectively) was higher than in the other treatments (Table 1). Data showed that grazing plot had the least dry biomass (1101 kg/ha). Moreover, the data showed that there was no difference in herbaceous dry biomass between the natural vegetation (exclude grazing) plot and the afforestration by Pinus halepensis. Based on their relative dry biomass the dominant species at the stone terraces plot were: Avena sterilis and Crepis aspera, in the semi-circle bunds plot were: Avena sterilis and Sarcopoterium spinosum, in replanted trees were: Sarcopoterium spinosum and Asphodelus aestivus, in the grazing plots were: Asphodelus aestivus and Sarcopoterium spinosum and in the natural vegetation plots were Sarcopoterium spinosum and Avena sterilis (Table 2).

3.2. PLANT DENSITY

Results showed that plant density was significantly ($P \leq 0.05$) higher in the semi-circle bunds (408.7 individual / m2) compared to other treatments. Additionally, stone terraces had significantly higher plant density (314 individual /m2) compared to the afforestration plot, the natural vegetation plot and the grazing plot (Table 3).

Our results showed that there was no significant difference ($P \geq 0.05$) between the plant density in stone terraces and the natural vegetation. However, natural vegetation had significantly ($P \leq 0.05$) higher plant density than the afforestration plot (Table 3).

Concerning the total density for grasses, forbs and shrubs, data showed that forbs had the highest plant density in semi-circle bunds and in stone terraces (286.5 individual / m2 and 244.3 individual / m2, respectively) (Table 3). Based on relative plant density, the dominant species at the stone terraces plot were; Crepis aspera, Avena sterilis, Rhagadiolus stellatus and Bromus sp. Dominant species in the semi-circle bund plots were: Trifolium stellatum, Avena sterilis, Crupina crupinastrum and Brachypodium distachyon. However in the afforestration the dominant species are: Brachypodium distachyon, Evax contracta, and Avena sterilis. The dominant plant species in the grazing plot are: Evax contracta, Stipa capensis and Asphodelus aestivus and in the natural vegetation are: Avena sterilis, Brachypodium distachyon and Bromus sp (Table 4).

4. DISCUSSION

Effect of semi-circle bunds and stone terraces The statistical analysis demonstrated that there were significant differences ($P < 0.05$) in plant dry biomass and plant density among the treatments (Tables 1 and 3). Plant biomass and plant density increased in water harvesting plots compared to other treatments. Thus, it appeared that water harvesting structures (semi-circle bunds and stone terraces) slowed down the rate of runoff, allowing more time for water to infiltrate into the soil, and become available for use by vegetation. Moreover, this has a selective effect on biomass, increasing the proportion of some plant species at the expense of others. According to Al-Seekh and Mohammad (2009) in a study at the same site, the runoff was reduced by 65 %, 85 % and sedimentation was reduced by 58 %, 69 % in stone terraces and semi-circle bunds compared to control plots, respectively. At the same time, soil moisture significantly increased in such water harvesting structures. Increased soil water storage in dry land areas generally results in significant yield increases (Singth, 1990). Singh et al., (2010) reported that water harvesting structures significantly increased the plant density, species number, richness and productivity compared to control. Abu-Zanat et al., (2003) found that dry biomass was increased from 533 kg/ha in control plots to 651 kg/ha in the plots where rainfall was harvested. However, rangeland water harvesting structures aim to improve performance, within constraints, and to ensure the survival of the plants from season to season (Critchey and Siegert 1991).

These results highlighted the view that severe over-grazing of rangeland in the West Bank for many years (more than 60 years) resulted in a drastic vegetation disappearance which caused an increase in rain water runoff and soil erosion; therefore water and soil conservation should be considered as a priority management for rangeland rehabilitation under such condition.

The results showed that forbs percentage was higher in water harvesting plots than in the other treatments. It seems that increased water input to the soil due to water harvesting increased the difference in water depth, and allowed forbs with their deep roots to absorb water from much greater soil depth than grasses, thus reducing the competition with grasses and increasing forbs growth and consequently increasing forbs seeds. Our results indicated that using simple methods such as semi-circle bunds can be an effective tool for conservation of natural vegetation

EFFECT OF PINUS HALEPENSIS

Our results indicate that species density decreased in the afforestration plot. This agrees with the results reported by Ariza (2004) at Yattir forest under conditions similar to the present study. This might be due to the allelopathic effect of the pine trees. According to (Maestre et al., 2003) the allelopathic effect of the pine tree affected the germination and establishment of the understory vegetation. These results highlight the use of afforestration projects in conservation productivity and biodiversity of natural vegetation. This agrees with Alrababah et al., (2007), who concluded that the use of trees, especially P. halepensis, as a method to protect biodiversity and combat desertification under semi-arid conditions needs to be revised, and science-based management strategies are needed for wise and sustainable management of semi-arid Mediterranean rangeland ecosystems

EFFECT OF GRAZING

Dry biomass and plant density significantly ($P \leq 0.05$) decreased in the grazing plots. This agrees with several previous studies (Pantis and Mardiris, 1992; Le-Houerou, 1993; Beeskow et al., 1995; Ali-Shtayeh and Salhat 2010). Salama and Aljoaba (2008) found that sheep and goats consumed about 70 % of plant biomass as early as April, and decreased plant density at southern part of West Bank, which reflects the early and severe overgrazing practices in these rangelands. In addition, Alrababah et al., (2007) found that grazing had no effect on plant diversity, indicating the high resilience against and adaptation to grazing. However, grazing affected species composition and cover parameters. In addition, Le-Houerou (1993) reported that heavy grazing decreased the number, density and cover of palatable species. According to Holechek et al., (1989), the selection of the correct stocking rate is the most important aspect of grazing management. Also, the results showed that there is still high potential to improve the vegetation productivity by excluding grazing for a few years. Ali-shtayeh and Salhat (2010) indicated that grassland has high potential for the rehabilitation after a few years of excluding grazing. For these reasons, further studies are needed to investigate suitable grazing management strategies and stoking rates in Mediterranean rangelands.

The results of this study showed that unpalatable species (e.g. Asphodelus aestivus and Sarcopoterium spinosum) in the grazed plots were dominant based on their dry biomass (Table 2). The increase of unpalatable species might be due to the heavy and selective grazing of palatable species. This is consistent with the hypothesis of increasing of unpalatable species and decreasing of palatable species due to grazing which was documented in several prior studies (Pears, 1970; Mc-Naughton, 1979; Noy-Meir et al., 1989; ; Holechek et al., 1989; valentine, 1990; Mazancourt and Loreau, 2000). This effect is expected to be high when severe grazing is practiced (Salama and Aljoaba, 2008).

Decreasing vegetation cover due to grazing has negative impacts on the soil properties. According to Al-Seekh et al., (2009), rangeland management by controlling grazing in arid and semiarid areas might be the key issue to maintain vegetation cover, and to reduce soil bulk density, that lead to increasing infiltration rate, and increasing soil moisture storage.

CONCLUSION

Natural vegetation conservation and improvements in degraded ecosystems through controlled grazing and developing simple water harvesting structures to conserve soil and water might lead to increasing vegetation biomass and plant density. In addition, our results indicated that more research is needed to evaluate the effect of type of replanted trees on the succession of rangeland ecosystem.

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Table (1) Average vegetation dry biomass (Kg/ha) production under different treatments during the years 2006 and 2007

Treatments	Forbs	Grasses	Shrubs	Total biomass
Stone terraces	1732	1227	140	3099 [a]
Semi-circle bunds	1144	697	647	2488 [b]
Natural vegetation	600	360	762	1722 [c]
Replanted	583	195	941	1719 [c]
Grazing	819	99	183	1101 [d]

Means followed by the same letter in the same column are not significantly different according to Fisher LSD test (at (P › 0.05

Table (3) Average plant density (individuals/m2) under different treatments during the years 2006 and 2007

Treatments	Forbs	Grasses	Shrubs	Average Density
Stone terraces	224.3	88.9	0.8	314.0 [b]
Semi-circle bunds	286.5	116.5	5.2	408.2 [a]
Natural vegetation	168	93.1	6.7	267.8 [b]
Replanted	156.4	29.1	9.6	195.1 [c]
Grazing	121.9	45.7	2.5	170.1 [c]

Means followed by the same letter in the same column are not significantly different according to Fisher LSD test

(at (P › 0.05

Table (2) Relative dry biomass (%) for dominant plant species (accounting for 70%) at the five treatments during the years 2006 and 2007

Stone terraces		Semi-circle		Natural vegetation	
Species	Relative biomass (%)	Species	Relative biomass (%)	Species	Relative biomass (%)
Avena sterilis	31.4	Avena sterilis	27.1	Sarcopoterium spinosum	39.4
Crepis aspera	7.8	Sarcopoterium spinosum	24.9	Avena sterilis	17.3
Erodium gruinum	4.3	Trifolium stellatum	8.1	Asphodelus aestivus	6.9
Bromus spp	4.1	Crupina crupinastrum	7.3	Crupina crupinastrum	0.4
Rhagadiolus stellatus	4.1	Brachypodium distachym	6.4	Trifolium stellatum	4.9
Medicago spp	4.0				
Medicago sp	3.5				
Teucrium capitatum	3.5				
Stipa capensis	3.4				
Notobasis syriaca	3.4				

Replanted		Grazing	
Species	Relative biomass (%)	Species	Relative biomass (%)
Sarcopoterium spinosum	47.5	Asphodelus aestivus	36.0
Asphodelus aestivus	17.5	Sarcopoterium spinosum	16.5
Avena sterilis	6.4	Coridothymus capitatus	
Brachypodium distachym	6.1	Onobrychis caput-galli	4.3
Teucrium capitatum	4.0	Stipa capensis	2.8
		Erodium gruinum	1.9
		Avena sterilis	1.8
		Bromus spp	1.7

Table (4) Relative species density (%) for dominant plant species (accounting for 70%) at the five treatments during the years 2006 and 2007

Stone terraces		Semi-circle		Natural vegetation	
Species	Relative biomass (%)	Species	Relative bio-mass (%)	Species	Relative biomass (%)
Crepis aspera	14.0	Trifolium stellatum	22.4	Avena sterilis	23.5
Avena sterilis	13.0	Avena sterilis	22.2	Bromus spp	17.1
Bromus spp	10.9	Crupina crupinastrum	12.5	Brachypodium distachyon	10.2
Rhagadiolus stellatus	8.6	Brachypodium dis-tachyon	10.8	Evax contracta	7.2
Onobrychis caput-galli	7.1	Aegilops spp	3.6	Trifolium stellatum	7.2
Trifolium stellatum	5.1			Crupina crupinas-trum	6.2
Hedypnois cretica	4.6				
Stipa capensis	4.1				
Medicago sp	3.4				
Erodium gruinum	3.4				

Replanted		Grazing	
Species	Relative biomass (%)	Species	Relative biomass (%)
Brachypodium distachyon	30.5	Evax contracta	26.8
Bromus spp	10.0	Stipa capensis	9.1
Evax contracta	8.1	Bromus spp	8.6
Avena sterilis	6.2	Asphodelus aestivus	7.8
Asphodelus aestivus	4.8	Phalaris sp	4.7
		Brachypodium distachyon	4.6
Sarcopoterium spinosum	3.9	Plantago coronopus	4.1
Rhagadiolus stellatus	3.8	Avena sterilis	3.1
Torilis tenella	3.6	Crepis aspera	2.7
Linum sp	2.7	Torilis tenella	2.4

Map 1. Location of the study site.