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Effectiveness of water harvesting technique on selected pastoral shrub: a case of the Syrian Badia (Qaryatien)

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Abstract

This research intends to cast light on the importance of water harvesting in the Syrian Badia, a region with an extreme shortage of water resources. The study was carried out during the rainy season of 2010 at the research centre of Mehassa (Qaryatien) in the Syrian Badia. Semi-circular ponds with 40m-diameter were constructed, parallel to the contour lines for water harvesting. Blank ponds with no embankment were simultaneously dug at similar dimensions. The impact of slope steepness of the water ponds on the harvested water volume was evaluated using slopes of 5% and 2%. Both ponds (constructed and blank) were planted with three types of pastoral shrubs *Atriplex halimus, Atriplex lecoclada,* and *Salaola vermiculate*. The water balance study showed that the constructed ponds preserved excess water of 51.10% for all types of pastoral plants compared with the blanks. It also revealed that the field capacity of the soil in the water ponds increased by 11.11% compared with blanks, with the highest values for soils with a slope of 5% relative to 2%, which will support the growth of more pastoral shrubs. It was noticed that the consumption of water for the pastoral plants cultivated in the constructed ponds increased at the 5% slope more than that at the slope of 2%.

Keywords: water balance, pastoral plants, water harvesting techniques, Syrian Badia (Qaryatien).

1. Introduction

Water is considered as one of the most important limiting factors for agricultural production in arid and semi-arid areas, and the stability of the population in these areas. The exploitation and the misuse of water resources lead to a significant reduction in land productivity and desertification. Rainwater harvesting has been a viable alternative to cope with the increasing water demands for irrigation and drinking purposes, especially in these arid and semi-arid regions (Jack and Osman, 1995).

The water harvesting system is dependent on the source and the form of runoff and the used method to concentrate and collect water. The main element of rainwater harvesting techniques is the knowledge of the ratio between runoff area and water collection area. Usually, the water is stored and the plant is cultivated (in cultivated areas), provided that the soil has sufficient water to supply the cultivated crops until rainfall season (Abdel Al, 1994).

The general principle of water harvesting systems is that there are two major areas: the surface runoff area (the catchment area) and the storage area (agricultural area). The water harvesting area can be divided into macro-catchments, micro catchments and floodwater harvesting (IDRC et al., 1993).

Studies conducted in the Syrian Badia for the use of water harvesting and propagation techniques showed that the quantity of water harvested in reservoirs during the period 1995-1998 ranged from 11,900 to 22,000 m^3 (Arar, 1993). These waters are suitable for irrigating crops, watering livestock and humans use after treatment. These quantities can be sufficient to water 66000 sheep for three months at a rate of 8 litres/sheep/day, and enough to cultivate 2000 hectares at a rate of 100 litres. The use of water harvesting techniques also resulted in an emergence of associated plant species, and to an increased rate of pastoral plants, by reducing runoff and rehabilitating of vegetation. Besides, it reduces agricultural soil erosion to 40% on the catchments in which the ponds were constructed (Somme and Abdel-Al, 2002).

Despite the lack of rainfall in arid and semi-arid areas, the soils are susceptible to a high rate of erosion due to flash floods and a lack of vegetative cover. Therefore these characteristics of dry areas require caution when a particular water harvesting technique is selected (UNEP, 1982; Joddi, 1999).

Water harvesting can help to conserve natural resources, particularly soil and vegetation, with implications for good livestock feedstuffs (ICARDA, 1997).

The use of rainwater harvesting in arid and semi-arid areas, where precipitation often occurs fora few months, it is probably one of the most effective means to secure water for human, animal, and plants. Though, rainwater harvesting is associated with some uncontrollable factors such as climatic conditions or soil conditions. However, the good investment and the use of available rainwater, no matter how much little it is, provide basic sources of water in some cases (Arab

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Organization for Agricultural Development, 1999).

The main objective of this project is to rationalize the use of water in the Syrian Badia due to the lack of water resources, using methods and techniques that contribute to increasing their productivity and efficiency. The most important of these methods is water harvesting with a simple technique and low costs that can effectively contribute to improving the management of natural resources (water, soil, vegetation), particularly improved vegetation cover and the provision of a livestock feed base, as well as the water supply for livestock and domestic use of water (Arar, 1995).

2. Materials and Methods

2.1. Location of the study area

This study was carried out at the Agricultural Scientific Research Center in Mehassa, 120 km northeast of Damascus and 15 km south of Qaryatien Town. It is located at 37.2°,14’,37’’ longitude, 34.08°,13’,34’’ latitude and (735) m altitude, with a total area of 7000 ha (Figure 1).

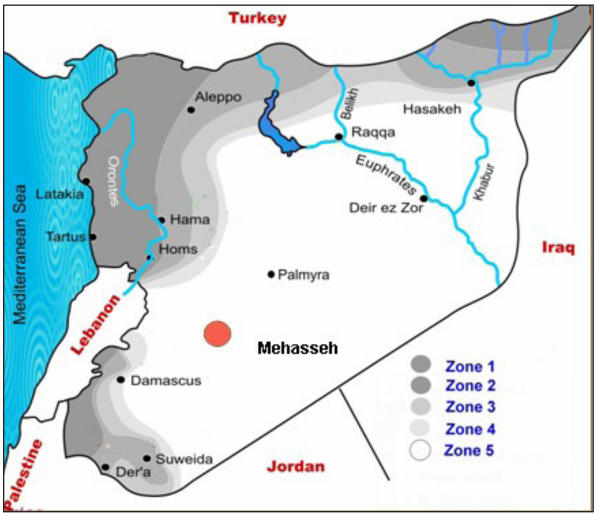

Figure 1. Location map of the studied site. (Ministry of agriculture in Syria)

Note: (Zone from 1 to 5 in the map: is the areas of agricultural stability in Syria, and this map indicates that the study area is outside the borders of the fifth agricultural stability zone, where the rainfall rate is less than 200 mm. So that the studied area consider a marginal area (Badia).

The site is characterized by a hot and dry climate in summer and a cold one in winter with low rainfall of 114 mm per year. This study was carried out during the rainy season of 2010, where rainfall was monitored at the experiment site. The highest rainfall rate was during January with 27.7 mm, and the total rainfall in this season was 78.2 mm. In January, runoff occurred at a rainfall intensity of 11.89 mm/h (Table 1).

2.2. Field work

Two hillsides with different slopes(5% and 2%) were selected, and several semi-circular bunds were established on the contour lines directly at the studied slopes, using the Nevo device which is available In the study site. The ponds of a 40m diameter were drawn, and then a special tractor was used to dig the lines of the contour and open the ponds. The blank was drawn without making an edge. The height of the top edge reached (80) cm and the lowest point reached (60) cm at a slope of 5%; taking into account the unification of the diameters of the bunds and the blank (40) meters. The spacing between the bunds on the contour line was(10) meters and the distance between the contour line was(10) meters. The catchment areas were unified so that each bund on each contour line is isolated from the adjacent bund in the same contour line, and the other bunds on the second contour line. Therefore the catchment area is the square of semi-circular bund with a radius of (20) m.

The bunds and the blank were cultivated in different types of pastoral plants *(Atriplex halimus - Atriplex lecoclada - Salsola vermiculata*), on a 2.5 m spacing between one plant and the other, in the lower third of the arch after a light rainfall of (2) mm. Neutron probe tube was planted on the depth of (50) cm in each section to measure the moisture of soil after the rainfall and periodically every two weeks for each treatment (bund–blank), due to the type of planted shrubs. A rain intensity gauge was put to measure the rainfall intensity (mm/h), and mineral reservoirs were distributed in the experiment to estimate the amount of runoff water.

Table 1. Climatic characteristics of the studied site during 2010.

Month / Climatic element	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Rainfall (mm)	27.7	9.6	13.6	20.4	0.4	0	0	0	0	3	0	3.5
Total rainfall mm78.2												
Minimum Temperature	3.9-	6.3-	3.1-	2.2	4.2	9.8	11.8	16.2	11.2	4.4	1.8-	4.5-
Maximum Temperature	19.7	24.8	29	28.4	32.9	33	38.5	39.3	34.7	33.1	26.1	3.7-
Evaporation (mm/month)	6.93	6.91	6.92	6.91	6.89	27.5	28.1	27.05	27.15	27.24	27.36	27.3
Monthly eva-transpiration	42	61	86	136	223	222	217	224	196	143	80	41
Wind speed (m/sec)	3.8	3.8	3.6	4.1	4.3	4.6	4.4	6	3.6	3.2	3.1	4.5
Relative humidity (%)	74.1	64.2	57.9	51.4	35	44.2	45.3	49.1	48.7	50.3	68.0	73.1
Solar Brightness	116.95	136.97	192.79	242.52	269.35	270.20	271.5	268.90	209.31	175.46	154.97	117.19

2.3. Transactions and Reversals

The experiment was designed in a complete randomized design, where Treatment 1 included "Topography slope" of two slopes; 2% and 5%. On the other hand, the Treatment 2 included the "Type of plant" where three types of pastoral plants were selected**;** *Atriplex halimus, Atriplex lecoclada,* and *Salsola vermiculata*. Three replications were adopted for each treatment at every studied slope, thus the number of experiments were experimental pieces at the studied slopes Figure 2. The area of the experimental piece (the area of a semicircular with a diameter of 40 m) was 628 m^2.

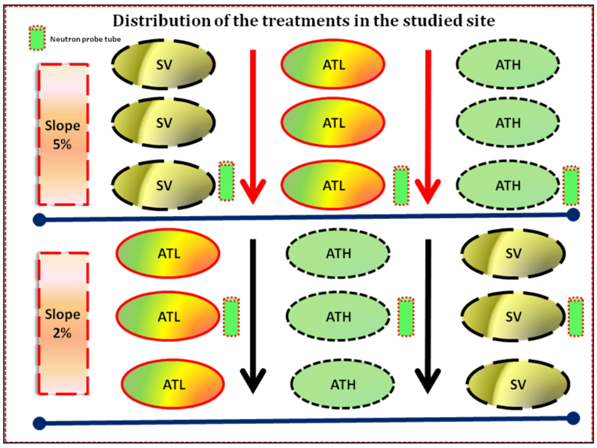

Figure 2. Distribution of treatments in the studied site (SV: *Salsola vermiculata* shrubs, ATL: *Atriplex lecoclada* shrubs, ATH: *Atriplex halimus* shrubs) (Jirdi, 1992)

2.4. Measurements

2.4.1. Physical and hydrological-Physical analyses (Jirdi, 1992)

The physical and hydrological-physical analyses included the following:

1. Determination of the moisture of the soil (%).
2. Determination of the bulk density (g/cm3).
3. The rate of water percolation in soil by the form of a double roller.
4. Calculate the total porosity%.
5. Determination of field capacity%.
6. Determination of permanent wilting point%.
7. Calculation of available water%.

2.4.2 Field measurements

1. Soil samples were taken from the ponds before planting, and from the blank at the depth of (0-25 cm) to conduct some laboratory analysis related to the study.
2. Measuring the amount of rain precipitation by a metric meter installed beside the experiment.
3. Determination of moisture at the depth of (0-45cm) after each rainfall by a Neutron probe device, and Table 2 shows the tracking of the moisture readings(%) of the studied soil.
4. Water storage is estimated and calculated from the following relationship (Kheder et al., 1996):

   $$Ws = W * Bd * H * S * 10000$$

   Where Ws is the water storage (m^3 / ha), W is the soil moisture (measured as part of one), Bd is the Bulk Density(g / cm ^{3}), H is the depth of the studied depth (m), and S is the Plot Area (m^2).
5. Determination of rainfall intensity mm/h using the rain gauge installed at the experiment site.
6. Determination of runoff using runoff coefficient (Somme and Abdel-al, 2002) as follows:

   Total annual runoff = Runoff coefficient (K)* Total annual precipitation
7. The efficiency or percentage of water storage (%) was computed by calculation of the following relationship:

   Water storage efficiency (%) = (% water storage after the runoff - %water storage before runoff) / (% water storage after the runoff
8. The amount of runoff of the rainwater (cr) was calculated using the following relationship:

   $$cr = (s^* c^* e)$$

   where cr is the amount of surface runoff of the rainwater contained in the studied catchment (Liter), s is the amount of runoff of rainwater (L/m2) collected ina tank, c is the concentration of the flow solution (g/L) which is harvested ina tank, and e is the soil water storage efficiency (%)
9. Estimation of the water budget of the soil at the studied catchment (Darwish, 2009):

   The water budget equation= water inflow - outflow

   $$P + Q \text{ inflow} = ET + \Delta S + Q \text{ outflow}$$

   $$\Delta S = P - (I + ET)$$

   Where ΔS is the Change in water storage in studied soil, P is the total precipitation of rainfall water in the catchment area (mm), I is the soil percolation (mm/hr), and ET is the Monthly Evapotranspiration (mm/month) which is calculated by using of one of the used mathematical relationships (the relationship of penman), and here its value was estimated by using the program ETo calculator.
10. Assessment of water balance of the studied pastoral plants and calculation of water consumption of the cultivated pastoral plants (Darwish, 2009):

    $$ET = ET_o * K_C$$

    Where ET is the water requirement for crop (mm/day), ETo is the reference evapotranspiration (mm/day), and Kc is the crop coefficient.
11. Calculation of crop coefficient for pastoral plants:

    $$K_C = ET / ET_o$$

Table 2. Weight waters values by kind of agriculture at slope 5%, 2%.

Plant	Treatment	Weight moisture Readings (%)		Bulk density (g/cm^3)
		Before runoff	After Runoff	
Atriplex HalimusATH (slope2%)	bund	8.75	16.26	1.25
	blank	8.32	13.86	1.25
Atriplex HalimusATH (slope5%)	bund	8.98	18.19	1.25
	blank	6.70	12.78	1.25
Atriplexe lecoclada ATL (slope2%)	bund	7.47	14.76	1.25
	blank	7.17	12.94	1.25
Atriplexe lecoclada ATL (slope5%)	bund	10.19	16.19	1.25
	blank	7.36	11.66	1.25
Salsola vermiculata SV (slope2%)	bund	8.85	12.72	1.25
	blank	8.57	10.29	1.25
Salsola vermiculataSV (slope5%)	bund	9.26	14.41	1.25
	blank	8.75	16.26	1.25

3. Results and discussion

Water storage and the efficiency of water storage in the soil is presented in Table 3. It showed significant increases in water storage and the efficiency of water storage in the soil of the constructed ponds compared with the blank (without edges). Also, the results showed, The storage of water and the efficiency of water storage increased with increasing slope steepness from 35.73% To 50.60% For 5%, and from 30.41% to 46.21% for slope2%, respectively (Table 3).

Table 3. Water storage and the efficiency of water storage in the soil at the studied slopes (5%, 2%).

Plant	Treatment	Water storage m^3/ha		Water storage efficiency %	L.S.D*
		Before runoff	After runoff		
ATH (slope2%)	bund	492.00	914.69	46.21	7.28**
	blank	468.00	779.46	39.96	
ATH (slope5%)	bund	505.50	1023.47	50.60	10.25**
	blank	376.70	718.77	47.59	
ATL (slope2%)	bund	420.00	830.26	49.41	6.60**
	blank	403.50	728.10	44.58	
ATL (slope5%)	bund	574.50	911.23	37.06	8.95**
	blank	414.00	655.68	36.86	
SV (slope2%)	bund	498.00	715.65	30.41	5.31**
	blank	482.00	579.00	16.75	
SV (slope5%)	bund	520.90	810.53	35.73	7.63**
	blank	498.00	658.79	25.77	

*** L.S.D is the indicator of statistical analysis represents the Least Significant Difference at 5% Significant level.**

Comparison of soil properties and hydrological parameters in response to different water harvesting techniques is tabulated in Table 4. It shows that the field capacity of the soil increased about (5.48%) and (1%) at the slopes 5% and 2%, so that, the available water at the constructed ponds raised in all cultivated plants compared with the blank, and their values at slope 5% were higher than at the slope 2%. The reason may be due to the surface runoff of rainwater carries with it the soil and some of the transported organic materials that collect behind the ponds of the water harvesting technique, and this affects the improvement of the soil texture and its ability to save water, at last, this led to increasing the field capacity.

Table 4. Some physical properties of soil studied at two slopes (5% and 2%).

Type of plant	Slope (%)	Treatment	Field capacity before runoff (%)	Field capacity after runoff (%)	Permanent wilt point before runoff (%)	Permanent wilt pointafter runoff%%	Available water before runoff (%)	Available water after runoff (%)
Atriplex Halimus ATH	5%	bund	19.9	20.99	5.0	4.08	14.9	16.91
		blank	19.0	20.90	5.1	4.2	13.9	16.7
	2%	bund	20.2	20.39	8.8	8.79	11.4	12.69
		blank	20.0	20.01	7.4	7.32	12.6	12.69
Atriplexe lecoclada ATL	5%	bund	20.5	21.3	5.5	4.28	15	17.02
		blank	20.0	21.2	6.0	5.29	14	15.91
	2%	bund	20.5	20.8	5.2	5.01	15.30	15.79
		blank	19.8	19.83	4.15	4.11	15.65	15.72
Salsola vermiculata SV	5%	bund	20	20.04	7.9	7.8	14.68	14.83
		blank	19.9	20.00	5.22	5.17	14.68	12.24
	2%	bund	20	22.5	5.8	5.44	14.2	17.06
		blank	19	20.8	5.5	5.23	13.5	15.57

On the other hand, the amount of runoff water in the studied catchments was estimated from the volume of the collected water inside the distributed mineral reservoirs behind the bunds at the studied slopes, and the results were presented in Table (5).

The results In Table (5) showed, that water storage in the soil at all cultivated types of plants, has increased behind the bunds compared with the blank and its values at slope 5%was higher than its values at the slope 2%.

Table 5. Amount of runoff water and water storage efficiency at studied slopes (5% and 2%).

Plant	Treatment	Square of Catchment area (m^2)	Water storage (m^3/ha)	Water storage efficiency (%)	Concentration of runoff water (g/L)	Amount of surface runoff (m^3/ha)	L.S.D
ATH (slope5%)	bund	628	1023.47	50.60	0.62	511.87	5.21**
	balk	628	718.77	47.59	0.15	81.70	
ATH (slope2%)	bund	628	914.69	46.21	1.2	807.67	7.55**
	balk	628	779.46	39.96	0.65	322.38	
ATL (slope5%)	bund	628	911.23	37.06	0.5	268.87	5.41**
	balk	628	655.68	36.86	0.24	92.36	
ATL (slope2%)	bund	628	830.26	49.41	0.3	195.97	4.22**
	balk	628	728.10	44.58	0.08	41.35	
SV (slope5%)	bund	628	810.53	35.73	0.5	230.58	4.88**
	balk	628	658.79	25.77	0.24	64.88	
SV (slope2%)	bund	628	715.65	30.41	0.3	103.96	4.33**
	balk	628	579.00	16.75	0.08	12.35	

The water balance was estimated for the studied catchments at all studied slopes (5% and 2%) according to the type of cultivated plants Table (6), first, The Water balance of soil was10782.3 m^3/ha in all types of cultivated plants. It was calculated by subtracting the total value of water lost to soil (percolation) from the total value of the collected water catchment area. (12117.9-1335.6), however, The soil balance of the studied slopes (5% and 2%) has increased for all types of cultivated plants behind the ponds compared with blank after the surface runoff of the rainwater by (11227.9-10723.9 = 504) m^3/ha, and in the rate of (4.48%).On the other hand, the water budget for the soil of the catchment areas at the studied slopes behind the pond sat all types of cultivated plants before the occurrence of runoff at the beginning of rainy season was (4766.10) m^3 /ha, it decreased at the end of the rainy season period (4388.95) m^3/ha, and in the rate of (7.92%). Also, the water budget for the soil of the catchment areas at the studied slopes behind the blank at all types of cultivated plants before the occurrence of runoff at the beginning of rainy season was (4389.40) m^3/ha, where it decreased at the end of the rainy season period (1799.02) m^3/ha, and in the rate of (59.02%). The water budget of the studied soil at the two studied slopes (5% and 2%) increased by (59.01%) behind the constructed ponds on all types of cultivated plants. The use of water harvesting techniques by ponds in the studied area contributed to collecting of runoff water inside the soil of the catchments and to ensure sufficient quantity of available water for cultivated plants to follow up its growth by (51.10%) compared with blank (Tables 6-7).

Table 6. Water balance of the soil in the studied catchments at the two slopes (5%, 2%).

Type of plant	Slope (%)	Treatment (bund – blank)	Moisture before runoff (m^3/ha)	Moisture after runoff (m^3/ha)	Annual rainfall (m^3/ ha)	Infiltration (mm/h)	Amount of runoff (m^3/ha)	Evaporation (mm/month)	Evapo-transpiration calculated according to penman equation (mm/month)	**Water balance of the soil before runoff**	**Water balance of the soil after runoff**
Atriplex Halimus	2 %		492.00	914.69	782	3.6	807.67	69.3	420	784.7	1233.06
		bund	468.00	779.46	782	3.6	322.38	69.3	420	760.7	612.54
	5 %	blank	505.50	1023.47	782	4.8	511.87	69.3	420	798.2	1046.04
		bund	376.70	718.77	782	4.8	81.70	69.3	420	669.4	311.17
Atriplex Lecoclada	2 %	blank	420.00	830.26	782	3.6	195.97	69.3	420	712.7	536.93
		bund	403.50	728.10	782	3.6	41.35	69.3	420	696.2	280.15
	5 %	blank	573.50	911.23	782	4.8	268.87	69.3	420	866.2	690.80
		bund	414.00	655.68	782	4.8	92.36	69.3	420	706.7	258.74
Salsola vermiculata	2 %	blank	498.00	715.65	782	3.6	103.96	69.3	420	790.7	330.31
		bund	482.00	579.00	782	3.6	12.35	69.3	420	774.7	102.05
	5 %	blank	520.90	810.53	782	4.8	230.58	69.3	420	813.6	551.81
		bund	489.00	658.79	782	4.8	64.88	69.3	420	781.7	234.37
Total			5643.1	9325.63	9384	504	2733.94	831.6	5040	10723.97	11227.97

Table 7. Water balance of the pastoral plants behind the bunds and blank at the studied slopes (5%, 2%).

Type of plant	Slope (%)	Treatment (bund – blank)	Water storage before runoff (m^3/ ha)	Evaporation from soil (mm/day)	Given water (m^3/ha)			Water storage afterrunoff (m^3/ha)	Monthly consumption (m^3/ha)	**Annual consumption (rainy season) (m^3/ha)**	**ET_O reference evaporation (m^3/ha)**		
					Irrigation	Rain fall	Total				Penman	Blany cridel	Ivanove
Atriplex Halimus	2 %	bund	49250.	69.3	0	277	277	914.69	21.193	635.79	480	435	420
		blank	468.00	69.3	0	277	277	779.46	17.485	524.56	480	435	420
	5 %	bund	505.50	69.3	0	277	277	1023.5	24.369	731.07	480	435	420
		blank	376.70	69.3	0	277	277	718.77	18.506	555.17	480	435	420
Atriplex Lecoclada	2 %	bund	420	69.3	0	277	277	830.26	20.779	623.36	480	435	420
		blank	403.5	69.3	0	277	277	728.1	17.923	537.7	480	435	420
	5 %	bund	573.5	69.3	0	277	277	911.23	18.361	550.83	480	435	420
		blank	414	69.3	0	277	277	655.68	15.159	454.78	480	435	420
Salsola vermiculata	2 %	bund	498	69.3	0	277	277	715.65	14.358	430.75	480	435	420
		blank	482	69.3	0	277	277	579	10.337	310.1	480	435	420
	5 %	bund	520.9	69.3	0	277	277	810.53	16.758	502.73	480	435	420
		blank	489	69.3	0	277	277	658.79	5.6597	169.79	480	435	420
Total					0	3324.00	3324.00	9325.66	200.89	6026.63	5760.00	5220.00	5040.00

4. Conclusions

The study of water balance in the system (soil-plant) by using large semi-circular bunds of water harvesting technique led to the following:

1. The water balance of the studied soil increased by (59.01%), in the constructed ponds at slopes of 5% and 2%, and for all types of cultivated plants compared with blank.
2. The field capacity of the soil in the ponds increased by11.11%for all types of cultivated plants compared with blank(without bunds). Their values were higher at a 5% slope sites relative to those at a slope 2%, thus the available water increased to the pastoral shrubs.
3. The use of water harvesting technique by bunds, in the studied area, contributed to collecting of runoff water of the rainwater inside the soil of the catchments, and this ensures sufficient quantity by (51.10%) of available water for cultivated plants to follow up the growth compared with blank (without bunds).
4. The consumption of water for the whole pastoral plants behind the bunds increased at the slope 5% more than the slope 2%.
5. For the first time in the studied area, the value of the crop coefficient (KC) was calculated for *Atriplex halimus*, *Atriplex lecoclada*, and the *salsola vermiculata*.

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