Chapter 4

The use of the microcatchment water harvesting for fodder shrub production

Chapter 4: The use of the microcatchment water harvesting for fodder shrub production

Y. Al-Satari, M. Ali Mudabber, T. Oweis, A. Al-Kabneh, A. Al-Rossan, Y. Naser and M. Karrou

4.1 Introduction

The Badia constitutes about 90% of the total land area of Jordan, which is 89 342 km^2. Its average annual rainfall is < 200 mm. The area with annual rainfall of 100–200 mm is considered the promising rangeland for rehabilitation. The Badia (part of the rangeland) supplies the livestock sector with about 20% of forage needs, while all the other sources provide the sector with only about 5% of forage.

Fodder shrubs in the low rainfall areas are subject to water shortage, overgrazing, and coppicing. Within the rangeland, 1 ha of shrubs produces about 0.5 t of fresh forage and increases the feed productivityas compared to the pasture without shrubs. Fodder shrub plantations, in addition to their role in range protection, have increased productivity by 500% as compared to unprotected rangeland (Ministry of Agriculture, 2005).

Water harvesting techniques are a means of collecting rainfall from microcatchments and concentrating them in the root zone area and hence increasing the amount of soil water available for shrubs. These techniques allow the establishment of healthy shrubs that can withstand drought and grazing. They also improve soil characteristics, e.g. infiltration rate and organic matter contents, and play an important role in soil conservation and erosion control.

There are several kinds of fodder shrubs grown at the Jordanian Rangeland; but *Atriplex* spp. are the most important (Abu-Zanat, 1996) because of adaptation to the environment. These shrubs also tolerate high levels of soil salinity, and *A. halimus* is one species often planted as a feed resource. The relative success of fodder shrubs in the region is due to their drought tolerance, ability to accumulate green fodder over several seasons or years that can be used as livestock feed, their deep roots and high water use efficiencies, and the 3–5-fold increase in productivity. However, this plant must be integrated into various production systems (animal, croping, and mixed) that are economical and acceptable (Le Houerou, 1997).

Fodder shrubs are good sources of forage for livestock feed, and some are highly palatable. In addition, *Atriplex* spp. have a high crude protein content of about 10–15%. In addition to natural native vegetation, they are a good complementary source of feed in the rangeland.

The overall objective of the Badia Benchmark Project is to improve the livelihood of rural and pastoral communities in the Badia. The specific objectives of the rangeland activity are:

- To determine and demonstrate the effect of the location, slope, and water harvesting structure (WHS) on *A. halimus* and *Salsola vermiculata* productivity;
- To develop suitable rangeland and livestock grazing management in the *Badia* (requiring 5–7 y from the planting date).

4.2 Methodology

4.2.1 Description of the study area and treatments

Fodder shrubs (*A. halimus and S. vermiculata*) were planted in about 100 locations. The planted area was 162.7 ha. For this study, two main locations were selected: Mharib and Al-Majidyya villages, which receive an average of about 130 and 150 mm of annual rainfall, respectively. They are characterized by a deterioration of vegetation cover due to drought, introduction of mechanization, soil plowing for barley cultivation, early grazing, and overgrazing. The remaining vegetation consists of *Poa bulbosa, Anabasis syriaca, Hordeum glaucum, and Bromus* sp. The soils are silty clay loams with an effective rooting zone < 60 cm. The selected sites had slope gradients of 2–10%. The upper part of the location with slopes of > 5% was termed 'slope 1', and the lower part with < 5% slopes 'slope 2'. The selected locations were evaluated in terms of slope gradient, slope length, and soil depth to select the proper intervention in terms of water-harvesting structures for plantations of fodder shrubs and barley cultivation (Abu-Zanat et al., 2006).

The two main locations were planted with fodder shrubs to compare the suitability of microcatchments for plantations: 70 ha at Mharib and 25 ha at Al-Majidyya.

The spacing between microcatchments averaged 9 m. The seedlings were planted at 2-m spacings within the microcatchments. The spacings between the rows of microcatchments and shrubs resulted in 556 shrubs/ha. The microcatchments or WHSs, which included the Vallerani bund structure (VBS; Photo 4.1a) and the Vallerani contour ridges or Vallerani continuous structure (VCS; Photo 4.1b), were opened using a Vallerani implement (Photo 4.2).

Nine-month-old seedlings of *A. halimus* and *S. vermiculata* were planted in holes inside the microcatchments in January 2006. At the two sites there was a total of about 38 000 planted seedlings. The first location was planted with *A. halimus* on December 2004, covering 1.2 ha and using about 400 shrubs. Other seedlings were planted with *A. halimus* and *S. vermiculata* on December 2006 and January 2007.

Photo 4.1a. Vallerani bund contour ridges.

Photo 4.1b. Vallerani bund contour ridges.

Photo 4.2. Vallerani implement.

4.2.2 Experimental design and data analysis

The treatments were arranged in a split-split-block in randomized complete block design with sub-sampling. Data were recorded for two years (2007 and 2008) for the two main sites. The slope gradient (slope 1 and slope 2), WHSs (VBS and VCS), and shrub species (*A. halimus* and *S. vermiculata*) occupied the main plots, the sub-plots, and the sub-sub-plots, respectively.

Data were analyzed using the GLM procedures of (SAS 1995) system for a split-split-block arrangement. All factors were included in the analysis with their possible interactions. The independent variables included in the model were slope gradient, WHS, and shrub species. The dependent variables were survival percentage, and fresh, browse, and dry matter production. Duncan's multiple range test was used for mean separation.

4.2.3 Measurements

About 800 shrubs were selected randomly from Mharib and Al-Majidyya for monitoring survival and biomass production in 2007 and 2008. Within each treatment, 15 plants were used for recording the required data on the vegetation.

Survival rate: The percentage of shrubs alive (number of shrubs alive compared to the total number of shrubs) planted on March 2007 and June 2008.

Empirical equations: From each shrub species (*A. halimus and S. vermiculata*), 75 plants were selected randomly from the plantation grown at Al-Majedeyah study site. The height, excluding the inflorescence, and the largest and smallest canopy diameters were recorded for each shrub. The general shape for each shrub species was identified for estimating the plant volume. The 150 selected shrubs were cut at ground level and the fresh weight recorded for each individual shrub. Browses (leaves and small twigs < 5 mm in diameter) were separated for each shrub and weighed, then dried in an air-circulating oven at 70°C for 72 h for dry weight determination. Stepwise regression (SAS, 1995) was performed on the recorded variables to determine the empirical equations for predicting fresh, browse, and dry weights per shrub. They were used to determine the shrub volume (SVOL) of the elliptical-shaped shrubs using the following equation:

$$SVOL = (4/3)\times(3.14)\times(PH/2)\times(SD/2)\times(LD/2)$$

where PH = plant height, SD = shortest shrub diameter, and LD = longest shrub diameter (Howard, 1995).

Fresh yield (FY): The total shrub biomass (leaves and wood) production above ground level.

Browse yield (BY): The total shrub fresh biomass (including leaves and twigs < 5 mm in diameter) production above ground level.

Dry yield (DY): The total shrub dry matter (including leaves and twigs < 5 mm in diameter) production above ground level.

The productivity was determined using the empirical equations generated from destructive sampling in the 2007/08 growing season. Data of shrub dimensions (PH, SD, LD, and SVOL) and survival percentage were used for calculating FY, BY, and DY (kg/ha).

4.3 Results

4.3.1 Rainfall

The quantities of rainfall received in 2005/06, 2006/07, and 2007/08 seasons represented 90, 86, and 64% at Mharib and 87, 112, and 59% at Al-Majidyya of their respective long-term annual averages (Table 4.1).

Table 4.1. Rainfall amounts in the two locations and thre e seasons

Location	Mharib		Al-Majidyya	
	Rainfall (mm)	Proportion of average (%)	Rainfall (mm)	Proportion of average (%)
2005-06	117	90	131	87
2006-07	112	86	168	112
2007-08	83	64	89	59

4.3.2 Growth parameters

The equations for the best-fit models for shrub fresh, browse, and dry weights are shown in Table 4.2. The PH, SD, LD, and SVOL variables were the best to predict fresh, browse, and dry weights of *A. halimus* and *S. vermiculata*. These equations are not suitable for short plants with heights or canopy diameters < 20 cm, but were applicable to shrub plantations in microcatchments in arid regions receiving 100–200 mm of annual rainfall.

The survival rate compared to the overall mean of fodder shrubs planted at Mharib and Al-Majidyya was 92%, a good result for three years after planting. The overall productivity means were 465.82, 200.55, and 73.29 kg/ha for fresh, browse, and dry yields, respectively (Table 4.3).

The interaction ‘Location × Crop Type’ had a highly significant effect on survival rate ($P < 0.0001$). The survival rates of *S. vermiculata* shrubs planted at Al-Majidyya and Mharib were 97 and 93%, respectively (Table 4.4). This shows a good establish-

Table 4.2. Empirical equations for predicting fresh, dry, and browse weights (g/shrub) for *A. halimus* and *S.vermiculata* plants grown at Mharib and Al-Majidyya sites during spring 2008.

Shrub Species	Response	Equation**	R^2
A. halimus*	Fresh weight (g)	508.93 – 1.41 SD – 0.72 LD + 0.004 SVOL	0.82
	Browse weight (g)	0.22 + 2.09 PH + 2.60 SD + 0.0008 VOL	0.60
	Browse dry weight (g)	–29.30 + 1.25 PH + 0.92 SD + 0.0002 VOL	0.64
S. vermiculata*	Fresh weight (g)	–191.95 + 3.85 SD + 5.36 LD + 0.001 VOL	0.80
	Browse weight (g)	53.27 – 3.40 PH + 4.25 SD + 0.001 VOL	0.58
	Browse dry weight (g)	–1.17 – 1.25 PH + 2.45 SD + 0.0003 VOL	0.51

Note: *38-month-old shrubs (10 months as seedlings in the nursery and 28 months after planting in the field)
**PH: plant height, SD: shortest shrub diameter, and LD: longest shrub diameter (cm).

Table 4.3. Overall means ± standard error (SE) of Fodder shrubs (*A.halimus* and S.*vermiculata*) planted on Dec, 2006 at Mharib watershed.

Variable	Mean ± SE
Survival rate (%)	92 ± 1
Fresh yield (kg/ha)	465.82 ±12.48
Browse yield (kg/ha)	200.55 ± 4.55
Dry yield (kg/ha)	73.29 ± 1.48

Table 4.4. Effect of the interaction of locations and crop type on fodder-shrub survival rate (%) planted at Mharib and Al-Majidyya.

Location	Crop Type	
	A.halimus	***S.vermiculata***
Al-Majidyya	92 b	97 a
Mharib	71 c	93 ab

Note: Means with the same letter are not significantly different.

ment of *S. vermiculata* at Al-Majidyya, probably due to the higher rainfall received at this location; additionally, soil and other factors were slightly better in Al-Majidyya. This is in agreement with (Abu-Zanat et al. 2004), who showed that water harvesting increased shrub survival rate and biomass.

The 'Location × WHS' interaction had a significant effect on FY (P = 0.0142), BY (P = 0.0546), and DY (P = 0.0599). The FY, BY, and DY for VCS at Al-Majidyya were 720.98, 292.48, and 100.86 kg/ha, respectively (Table 4.5). The VCS technique seemed suitable for fodder shrub establishment at Al-Majidyya, represents the low rainfall areas receiving annual rainfall of 100–200 mm. A suitable amount of water was collected to satisfy the requirements for growth and development of shrubs that usually develop in an arid zone of annual average rainfall of 200–400 mm (Le Houerou, 1984).

The 'Location × WHS × Crop Type' interaction had a highly significant (P = 0.0164) effect on DY. The *A. halimus* DYs under VBS and VCS treatments at Al-Majidyya were 106 and 119 kg/ha, respectively. This is probably due to the higher amount of rainfall collection and the deeper soil at Al-Majidyya compared to Mharib. It may also indicate a benefit of growing *A. halimus* compared to *S. vermiculata* (Table 4.6).

Table 4.5. Fresh, browse, and dry yields (kg/ha) for fodder shrubs planted at two locations (Mharib and Al-Majidyya) under two WHS (VBS and VCS).

Location	WHS	FY	BY	DY
Al-Majidyya	VBS	602.50 b	255.06 b	90.2 b
	VCS	720.98 a	292.48 a	100.9 a
Mharib	VBS	267.02 c	125.55 c	51.4 c
	VCS	217.64 c	108.65 c	44.4 c

Note: Means followed by the same letter within the same column are not significantly different.

Table 4.6. Dry yield (kg/ha) for *A. halimus* and *S. vermiculata* planted at two locations (Mharib and Al-Majidyya) under two WHS (VBS and VCS).

Location	WHS			
	VBS		VCS	
	A. halimus	***S. vermiculata***	***A. halimus***	***S. vermiculata***
Al-Majidyya	106 a	72 b	119 a	77 b
Mharib	54 c	51 c	41 c	45 c

Note: Means followed by the same letter are not significantly different.

The 'Location × Slope × Crop Type' interaction had a significant ($P = 0.0466$) effect on DY. The *A. halimus* DY in slope 1 at Al-Majidyya was 156.54 kg/ha, probably due to good rainfall collection in the WHS in slope 1 compared to slope 2 for *A. halimus* (Table 4.7). This indicated that slope 1 (which had low slopes of < 5%) had greater soil depth, water collection, and infiltration rate. This is in addition to the benefits of higher average annual rainfall at Al-Majidyya.

The 'Location × Slope × WHS × Crop Type' interaction had a significant effect on FY ($P = 0.0379$) and BY ($P = 0.0204$). The *A. halimus* FY and BY using VCS for slope 1 at Al-Majidyya were 1387.36 and 533.84 kg/ha, respectively (Table 4.8). The higher FY and BY at Al-Majidyya was due to higher rainfall received and deeper soil: 150 mm and 100 cm at Al-Majidyya, respectively, compared to 130 mm and 50 cm at Mharib. Thus the soil stored more water from the WHSs (microcatchments) which increased

Table 4.7. Dry yield (kg/ha) for A. halimus and S. vermiculata planted at two locations (Mharib and Al-Majidyya) in two slopes (>5% and < 5%).

Location	Slope			
	Slope 1		Slope 2	
	A. halimus	***S. vermiculata***	***A. halimus***	***S. vermiculata***
Al-Majidyya	156.54 a	90.36 b	86.87 b	59.87 c
Mharib	60.45 c	61.19 c	32.72 d	42.62

Note: Means followed by the same letter are not significantly different.

Table 4.8: Fresh and dry yield (kg/ha) for *A. halimus* and *S. vermiculata* planted at two locations (Mharib and Al-Majidyya) under two WHSs (VBS and VCS) in two slopes.

Location	Crop	WHS	Slope	Fresh yield	Browse yield
Al-Majidyya	*A. halimus*	VBS	Slope 1	1186.93 b	477.78 b
			Slope 2	668.17 c	262.16 cd
		VCS	Slope 1	1387.36 a	533.84 a
			Slope 2	787.32 c	301.66 c
	S. vermiculata	VBS	Slope 1	340.08 ef	182.09 fg
			Slope 2	287.98 fg	134.82 gh
		VCS	Slope 1	428.07 de	209.60 ef
			Slope 2	244.50 fg	121.95 hi
Mharib	*A. halimus*	VBS	Slope 1	682.81 c	248.13 de
			Slope 2	262.65 fg	092.96 i
		VCS	Slope 1	473.91 d	156.59 gh
			Slope 2	334.05 ef	132.05 gi
	S. vermiculata	VBS	Slope 1	290.23 fg	145.86 gi
			Slope 2	198.66 fg	102.74 i
		VCS	Slope 1	258.32 fg	131.49 gi
			Slope 2	164.45 g	92.57 i

Note: Means followed by the same letter are not significantly different.

the evapotranspiration by plants at Al-Majidyya and thus caused better shrub establishment and growth compared to Mharib. The *A. halimus* showed higher fresh, browse, and dry yields compared to *S. vermiculata* because it is a taller denser plant, of larger size, and with more wood.

4.4 Conclusions

Al-Majidyya was more suitable for planting fodder shrubs and forage production.
The *S. vermiculata* seemed to be more drought tolerant in terms of survival than *A. halimus*; however, *A. halimus* showed more adaptation in terms of total forage production.
The VCS technique showed high efficiency in rainfall collection and forage production.
The low slopes (< 5%) showed high efficiency in forage production.
For higher forage production, it is recommended that *A. halimus* shrubs be planted at Al-Majidyya using a Vallerani continuous structure in the low slopes (< 5%).

4.5 References

Abu-Zanat, M. 1996. Production and Utilization of Multi-Purpose Fodder Shrubs and Trees in West Asia, North Africa and Sahel Livestock Research Priorities Workshop. Amman, Jordan.

Abu-Zanat, M.W., G.B. Ruyle and N.F. Abdel-Hamid. 2004. Increasing range Production from Fodder Shrubs in low rainfall areas. Journal of Arid Environments 59: 205–216.

Abu-Zanat, M., Y. Satari and A. Kaabneh. 2006. Demonstration of Micro-Catchments and Fodder Plantation for Increasing Range Production in the Badia of Jordan.

The Badia Benchmark Site-Jordan, Community-Based Optimization of the Management of Scarce Water Resources in Agriculture in West Asia and North Africa Project. Progress Report No. 2. submitted to National Center for Agricultural Research and Technology Transfer (NCARTT), Jordan.

Howard, A. 1995. Calculus with Analytic Geometry. 5th Edition, John Wiley Sons, New York, USA.

MoA (Ministry of Agriculture). 2005. Livestock Directorate Annual Report. Amman, Jordan.

Le Houerou, H.N. 1997. Germplasm for Arid Land Rehabilitation: NW Egypt and Jordan. Report to ICARDA {Initiative for Collaboration to Control Natural Resources Degradation (Desertification) of Arid Lands in the Middle East} (ICCNRD) 24 August 1997.

Le Houerou, H.N. 1984. Rain use efficiency: a unifying concept in arid land ecology. *Journal of Arid Environments* 7: 1–35.
SAS. 1995. SAS/STAT User’s Guide. SAS Institute Inc., Cary, NC, USA.

4.6 Acknowledgements

We would like to thank Dr. Khaleel Jawasreh his help in the for statistical analysis of this work.