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Science for resilient livelihoods in dry areas

Grazing management for the sustainable use of rehabilitated rangelands of Majidya (Jordanian Badia)

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RESEARCH PROGRAM ON Livestock

Contents

1. Background

The Jordan Badia constitutes 80% of the Hashemite Kingdom of Jordan. The Badia occupies predominantly arid and semiarid climates receiving rainfall of less than 200 mm/year. Livestock production is the main rural livelihood in the Badia. However, these rural households face major challenges including climate change and steady rangeland degradation. Furthermore, land use changes through expansion of barley cultivation and urban-based economic development are marginalizing Badia users. The deteriorated status of the natural resource base poses challenges for pastoral households to sustain their livestock and vital social, cultural, economic, and ecological assets.

Micro-catchment water harvesting is a useful technique for improving vegetation and reducing land degradation. Water harvesting when coupled with planting of drought-tolerant forage native shrub species such as *Atriplex halimus* results in a win–win situation for the environment and for the pastoralists residing in these difficult environments. ICARDA, in collaboration with the National Agricultural Research Center (NARC), investigated and developed different restoration approaches to counter this decline using an innovative, participatory, and multi-dimensional approach. ICARDA has established a Badia benchmark site near Al-Majidya village. The overall objective of the "Restoration of Badia ecosystem services for enhanced community livelihood" activity is to restore and increase resilience of the fragile Jordanian rangeland ecosystem and local communities, to counteract further degradation through mismanagement—foremost overgrazing through livestock—and to investigate and promote suitable rangeland restoration and beneficial rangeland and livestock management techniques. Grazing affects the plant communities, species composition, vegetation attributes, and plant biomass. Grazing management systems affect the herbage productivity, quality, and biodiversity. However, overgrazing is one important disturbance causing rangeland degradation. Sustainable use of biomass production through participatory rational grazing is one of the most effective methods to improve ecological conditions in rangelands. Therefore, the aim of our present work is to determine how much forage is available in the restored Badia benchmark site at Majidya to allow implementing an appropriate grazing management plan to improve and maintain rangeland health and condition. This plan can be used during grazing seasons for existing herds at Majidya, and therefore calculate the stocking rates or grazing frequency and duration.

2. Methodology

2.1. Site description

The improved target area of Majidya, used for the grazing activity, covers approximately 10 ha and is located 32 km southeast of Amman (31°43′04″N 36°07′36″E) (Figure 1) at an elevation of 855 m and receives 100–150 mm of annual precipitation (126 mm for 2018/2019, 200 mm for 2019/2020, and 95 mm for 2020/2021). The soil is characterized as silty loam and silty clay loam. The site is situated on two hill slopes separated by a small wadi. Perpendicular to the slope, intermittent contour lines were made using a Vallerani machine and shrubs were planted in fall 2016 to consolidate the contours, reduce erosion, and restore vegetation cover.

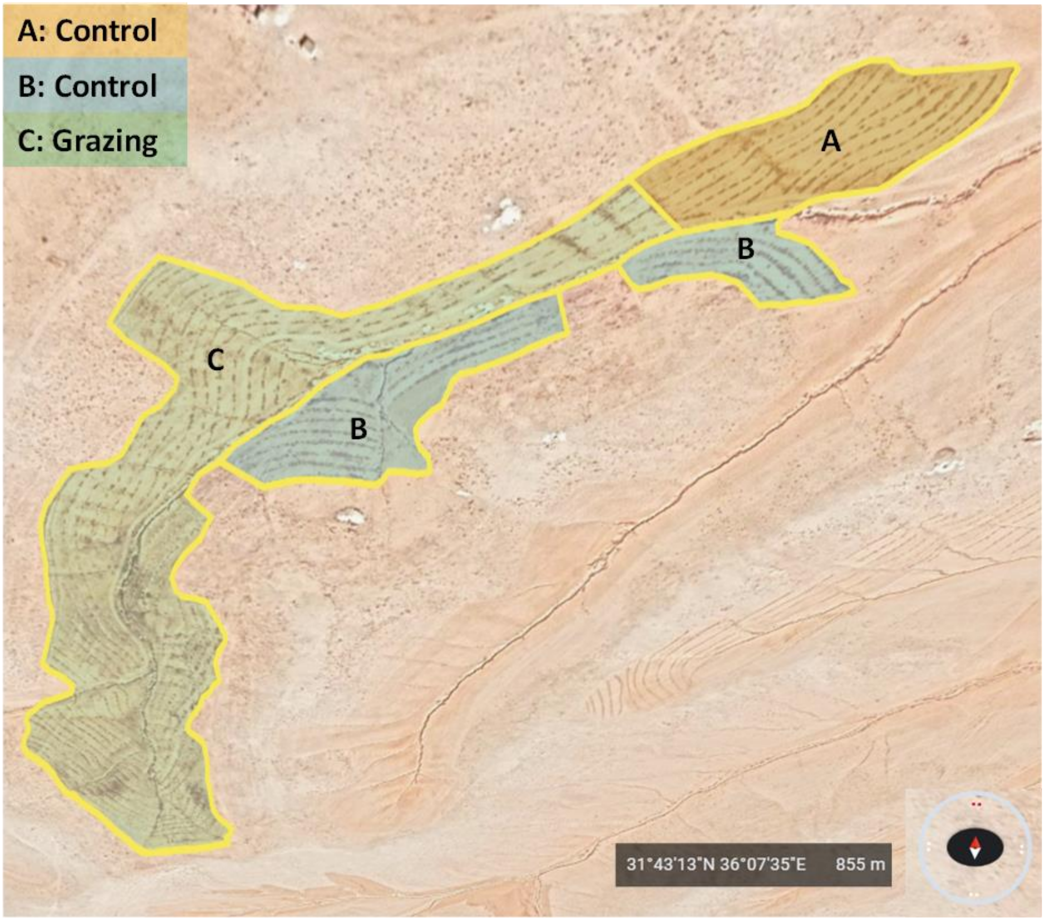

Figure 1. Location of the study area

2.2. Data collection

2.2.1. Plant material

Three species (*Retama raetam,* Salsola *vermiculata* and *Atriplex halimus*) were planted in the site. *R. raetam* is a rangeland species which is not a preferred plant (non-palatable) by livestock especially small ruminants, so it was excluded. *Salsola vermiculata* is a highly palatable species; unfortunately, it was planted in mixture with *R. raetam* and its size was still small, so it was also excluded from the grazing. *A. halimus* has good palatability and excellent growth (Figure 2). The grazing activity focused on this shrub species which was fortunately planted on the west side of the wadi as the grazing activity relatively easier.

			
Retama reatam	*Salsola vermiculata* (pink flower)	*Salsola vermiculata* (white flower)	*Atriplex halimus*

Figure 2. Shrub species planted at the Majidya site and present during fall 2019

2.2.2. Technique

After three years of full protection, in fall 2019, the *A. halimus* plants were ready for utilization. To enhance *A. halimus* biomass production and prevent plants becoming unpalatable and woody, fall and early spring grazing events were planned every year: fall 2019, spring 2020, fall 2020, and spring 2021. During fall, annual biomass was negligible and grazing was limited to perennial forage *A. halimus*. However, in spring when peak biomass and species richness occur, annual plants made enormous contributions to biomass production. Given the heterogeneity in shrub size, it was decided to classify all *A. halimus* shrubs based on their size. First, the average size of shrubs was estimated to four types: new seedlings and small, medium, and large plants (Figure 3).

			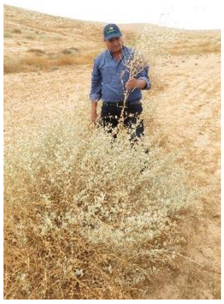
Large	Medium	Small	Reference branch

Figure 3. Methods for estimating biomass production from existing data: biomass production of branch reference, number of branches of each shrub, and the number of shrubs.

Due to the variability of vegetation cover distribution (annuals) related to topographic factors, the area was further divided into two blocks (upstream 2 ha and downstream 5.7 ha) across different microtopographic conditions and vegetation states.

There were three 50-m long transects in each block in each site. Vegetation cover and species composition were estimated using the line intercept method (Daget and Poissonet 1971). Each of the 100 hits/line within each transect was recorded according to plant species and type of ground touched: stones, wind veil, crust, or litter (Figure 4).


Figure 4. Point-intercept and quadrat method to estimate vegetation cover and forage biomass in spring 2021.

We set up three transects in each block, with several quadrats (each 0.5 m^2) according to the size of the block, to estimate the biomass production of annual species (Figure 5). In block 1 (downstream) we set up 12 quadrats (six at the bottom and six in the middle); whereas in block 2 (upstream), which was the longest, we set up 17 quadrats (eight at the bottom and nine in the middle) (Figure 6). The biomass production of *A. halimus* was estimated using a non-destructive method called “reference unit,” which is most commonly used to estimate browse biomass of shrubs. As recommended, the reference unit (usually consisting of a shrub branch) should reflect 10–20% of the foliage on an average-sized shrub in the sampled target site. On each sampling occasion a total of 12–15 shrubs (i.e. replications) for each size were identified and the number of branches per each shrub size was estimated. The grazable materials of the selected branches were separated and dried at 65°C for 48 h to determine the dry matter (DM) content. To determine total biomass production, the number of branches per shrub size was multiplied by the number of shrubs of each size.

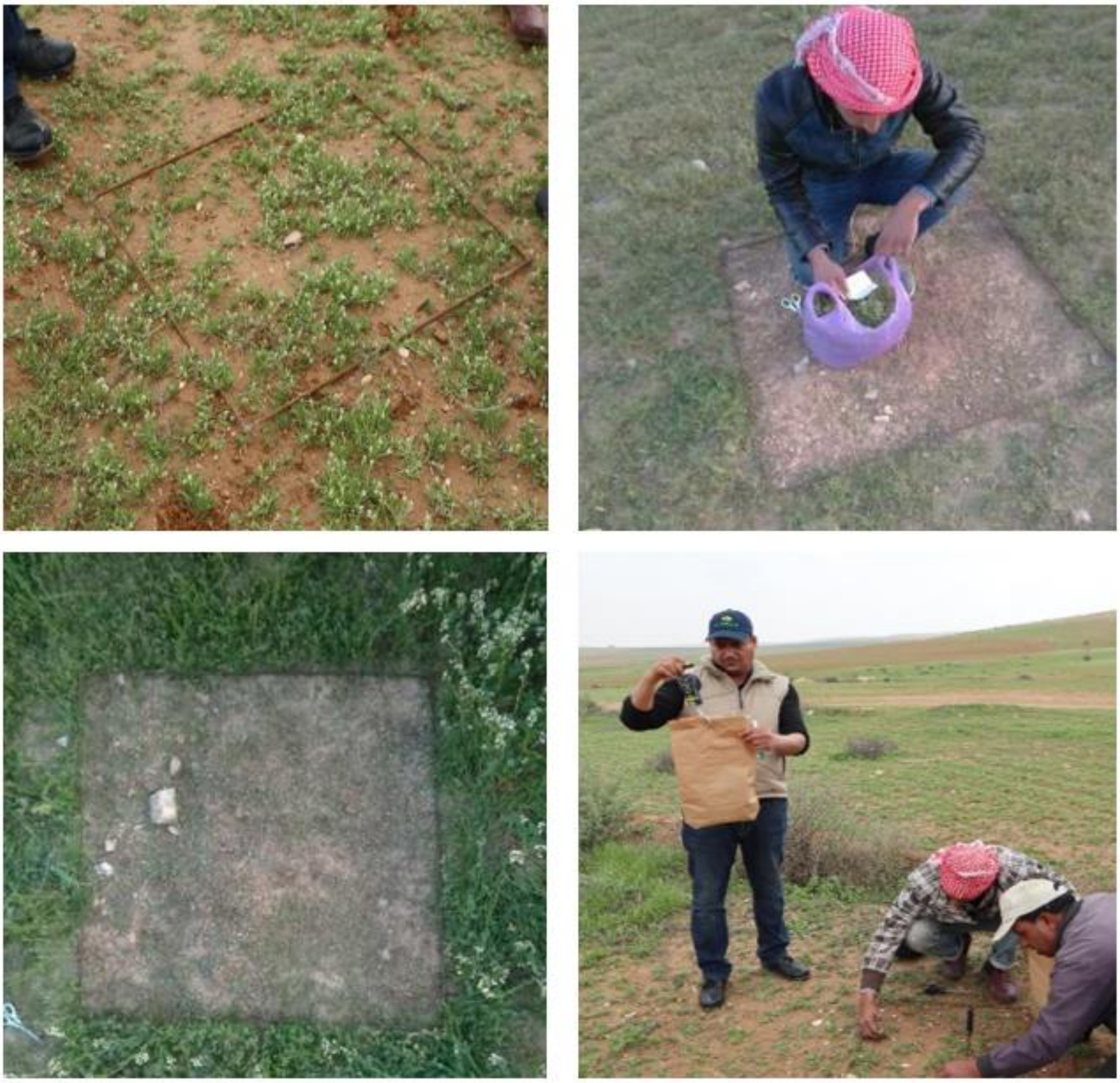

Figure 5. Method of using quadrats for estimating biomass production.

In spring 2020, due to coronavirus COVID-19 epidemic related measures, a field visit during the growth peak was not possible; however, communication with the local community led to identifying three persons who helped in data collection. A training session was conducted for these three persons over the phone, accompanied by sending pictures on how to place the quadrats and how to cut the plants. A close follow-up with these persons was done over the phone and through sending pictures of each sampling quadrat to identify the location of each quadrat and the plant cover. All living biomass above the soil in the quadrat was cut and weighed to estimate the DM.

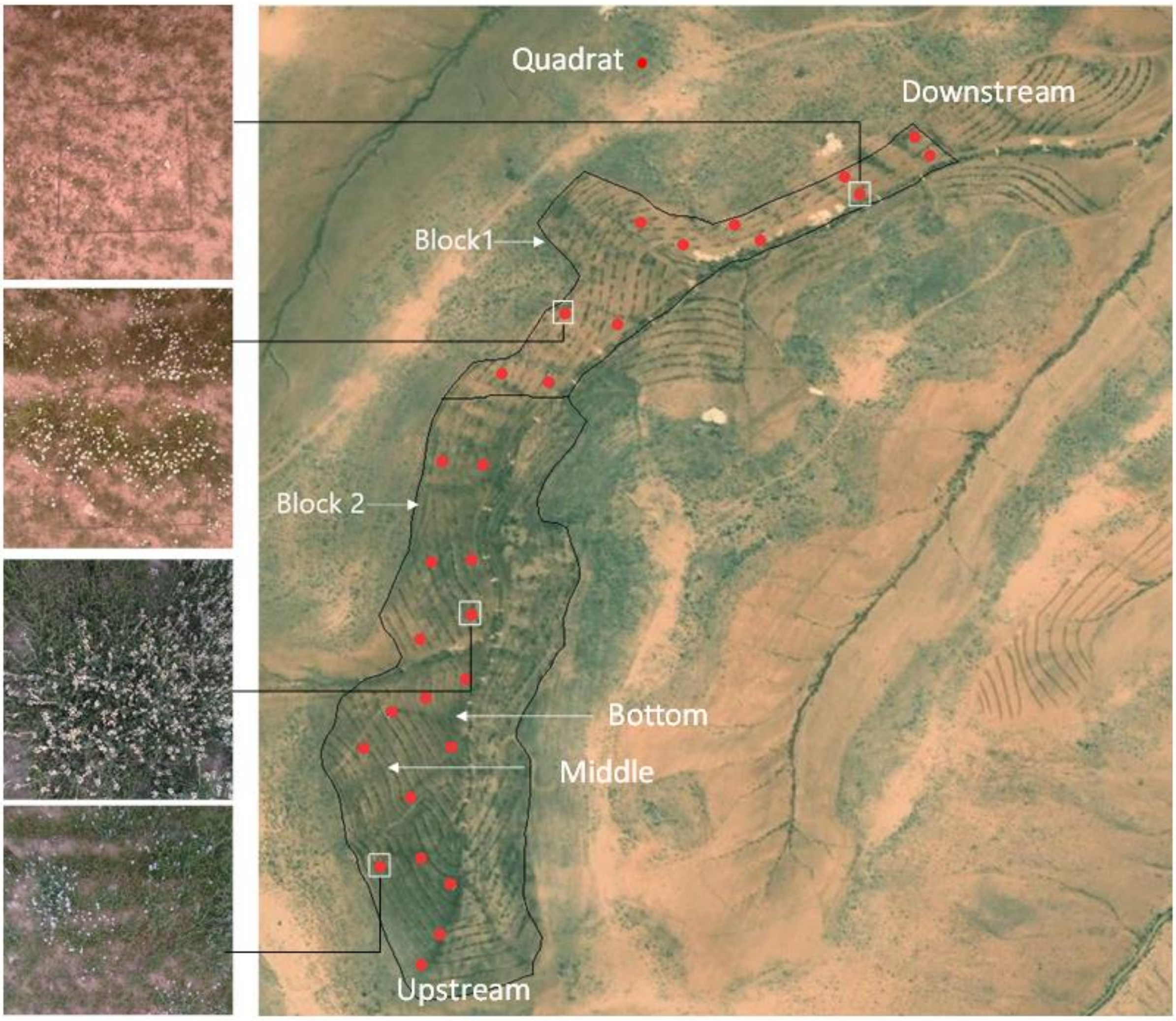

Figure 6. Study area and experimental design for different microtopographic conditions and state of vegetation.

Carrying capacity is the maximum stocking rate possible that is consistent with maintaining or improving vegetation or related resources. The carrying capacity of rangeland determines how many animals can be supported by the annual biomass production without causing harm to rangeland. It can be determined as the ratio of total rangeland production to the annual needs of an animal as follows:

$$Carrying\ capacity\ = Available\ forage\ \div\ Forage\ demand/head.$$

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3. Results

3.1. Species richness

Species richness recorded in 2020 was 89% higher than 2021, with 51 species observed in 2020 but only 27 in 2021 (Table 1). This was mainly because rainfall in 2021 was lower than 2020, which affected plant growth. Figure 7 shows the diversity of plant species recorded in the Majidya site.

Table 1. List of species recorded in the studied area (March 2020 and March 2021)

March 2020	March 2021
Anabasis syriaca Iljin	*Adonis dentata* L.
Androsace maxima L.	*Adonis dentata* L.
Astragalus caprinus L.	*Anabasis syriaca* Iljin
Astragalus palaestinus Eig.	*Androsace maxima* L.
Atriplex halimus L.	*Anthemis haussknechtii* Boiss. & Reut.
Bellevalia zoharyi Feinbr	*Atriplex halimus* L.
Brassica tournefortii Gouan	*Brassica nigra* (L.) W.D.J. Koch.
Bromus scoparius L.	*Brassica tournefortii* Gouan
Calendula arvensis L.	*Calendula tripterocarpa* Rupr.
Campanula rapunculus L.	*Dipcadi erythraeum* Webb & Berthel.
Carduus getulus Pomel	*Eruca vesicaria* (L.) Cav.
Carduus nutans L.	*Filago contracta* (Boiss.) Chrtek & Holub
Chlorogalum pomeridianum (DC.) Kunth	*Fumaria densiflora* DC.
Crepis capillaris (L.) Wallr.	*Gagea reticulata* (Pall.)
Daucus carota L.	*Gymnarrhena micrantha* Desf.
Dipcadi erythraeum Webb & Berthel.	*Hordeum murinum subsp. glaucum*
Diplotaxis erucoides (L.) DC.	*Koelpinia linearis* Pall.
Echinochloa colona (L.) Link	*Lepidium coronopus* (L.) Al-Shehbaz
Eruca vesicaria (L.) Cav	*Malva parviflora* L.
Erucaria pinnata (Viv.) Täckh. & Boulos	*Muscari neglectum* Guss. ex Ten.
Fumaria densiflora DC.	*Onopordum alexandrinum* Boiss.
Fumaria parviflora Lam.	*Papaver subpiriforme* Fedde
Gagea reticulata (Pall.)	*Picris asplenioides* L.
Hordeum murinum subsp. glaucum	*Rostraria cristata* (L.) Tzvelev.
Hypecoum pendulum L.	*Salvia pratensis* L.
Ifloga spicata (Forssk.) Sch. Bip.	*Schismus arabicus* Nees.
Iris sisyrinchium L.	*Strigosella africana* (L.) Botsch.
Koelpinia linearis Pall.	*Vicia sativa* L.
Lathyrus aphaca L.	
Launaea nudicaulis (L.) Hook. fil.	
Malcolmia africana (L.) R. Br.	
Matricaria aurea (Loefl.) Sch. Bip	
Matricaria chamomilla L.	
Matthiola aspera Boiss.	
Muscari neglectum Guss. ex Ten.	
Papaver subpiriforme Fedde	

Plantago ovata Forssk.
Prospero autumnale (L.) Speta
Roemeria hybrida (L.) DG.
Rostraria cristata (L.) Tzvelev.
Salvia pratensis L.
Salvia verbenaca L.
Schismus arabicus Nees.
Sinapis alba L.
Sinapis arvensis L.
Sisymbrium irio L.
Sonchus asper (L.) Hill
Strigosella africana (L.) Botsch.
Vaccaria pyramidata Medik.
Vicia sativa L.

Figure 7. Diversity of wildflowers growing in the studied area: species richness and biomass do go hand-in-hand in rehabilitated rangeland, which constitutes a refuge for diverse plant species.

3.2. Determining forage production

From the latest sampling (spring 2021) there was approximately 1,800 adult *A. halimus* shrubs available for browsing. In addition, there were about 3,000 newly established seedlings (1-

year-old). These seedlings emerged from the seeds falling from adult *A. halimus* plants. The total numbers of plants were divided into four classes according to their size: seedling, small, medium, and large (Table 2).

Table 2. Distribution of the three main sizes of *A. halimus*

Size	Number
Small	250
Medium	1,500
Large	50

For the total area, the forage production was obtained by multiplying biomass production of each plant by the number of plants. The DM content of the reference unit was estimated at 55 g in fall 2019, 46.8 g in spring 2020, 98.9 g in fall 2020, and 32.7 g in spring 2021. We found also a significant positive correlation of forage production with plant height, diameter, and number of branches. The total DM produced in the area planted with *A. halimus* averaged 2,682; 2,280; 1,024 and 393 kg in fall 2019, spring 2020, fall 2020, and spring 2021, respectively. Forage production from annual herbaceous plants was negligible in fall 2019 but was 12,475 kg in spring 2020 (2502 and 7396 kg in blocks 1 and 2, respectively), 5073 kg in fall 2020, and 3251 kg in spring 2021.

Results from previous studies related to feeding *A. halimus* to livestock indicated good nutritive value. Chemical composition of *A. halimus* shows that the leaves are rich in protein, as they contain 19–25% of their dry weight in nitrogenous compounds and provide 0.56 feed unit (FU)/kg of DM (Novikoff 1977), and 1 kg of DM of annual herbaceous plants provide 0.33 FU (Le Houérou and Hoste 1977). From these results and our estimation of biomass production, we estimated the UF provided during each season (Table 3).

Table 3. Change in forage production with season

	Fall 2019	Spring 2020	Fall 2020	Spring 2021
Total production of *A. halimus* (kg)	2,681	2,280	1,023	739
Total production of annual plants (kg)	-	10,195	5,073	3,251
Total FU of *A. halimus*	1,502	1,277	573	414
Total FU of annual plants	-	16,121	1,674	1,073
Total FU	1,502	17,247	2,247	1,487

3.3. Calculating carrying capacity

Houérou and Hoste (1977) showed that 1.2 goats need 300 FU/year, and so one goat needs about 0.7 FU/day. The utilization of natural arid rangeland should not exceed 60% of available forage to ensure regeneration and uniform forage production in the following years (Zaroug 1985; Gamoun et al. 2015). Thus, we can determine the feed units that should be consumed to not exceed 60% of available forage (Table 4) as follows:

$$Carrying\ capacity = \frac{Total\ forage\ production \times 60\%}{Daily\ FU\ required \times Number\ of\ heads} = n\ days.$$

Table 4. Change in carrying capacity with season

	Fall 2019	Spring 2020	Fall 2020	Spring 2021
Total FU	1,501.5	17,247	2,247	1,487
Total UF to be used (60%)	901	10,348	1,348	892
Total number of goats in the herd	188	150	130	
Total number of sheep in the herd	0	180	0	
Total UF needed for 1 goat/day	0.7	0.7	0.7	
Total UF needed for 1 sheep/day	0.83	0.83	0.83	
Total FU needed for the goats in the herd /day	131.6	105	91	
Total FU needed for the goats in the herd /day	0	149.4	0	
Total FU needed for the sheep and goats in the herd /day	131.6	254.4	91	
Number of grazing days: carrying capacity	≈7	≈40	≈15	

This is the equilibrium carrying capacity that the planted area can support without being damaged. This should ensure the maintenance of vegetation cover. Moreover, it is necessary to leave at least 40% of the vegetation so that grazing does not damage seedlings and so that fast recovery can be achieved in one year of higher precipitation.

4. Conclusion

Rangeland improvement and controlled grazing on arid rangelands are effective tools for sustainable management of these harsh but resilient ecosystems. Grazing management is a tool to balance the capture of energy by the plants, the harvest of that energy by animals, and the conversion of that energy into a marketable product. Timing of grazing and growth rate of plants after grazing events are key factors in controlling frequency, intensity, and duration of grazing. These factors enhance soil stability, forage production, efficiency of forage use, and livestock production.

The calculation of carrying capacity was based on the amount of DM produced by the rehabilitated rangeland either from planted shrubs or productivity of natural annual herbaceous plants. However, the carrying capacity changes throughout the year and, despite the limitation of the present study due to coronavirus COVID-19 epidemic related measures, we collected data to improve grazing management which was reported in a timely and accurate way.

Due to the grazing management adopted, where livestock were grazed for a short period, a limit of 7, 42, and 15 days were used in this area during fall 2019, spring 2020, fall 2020, and spring 2021, respectively.

The objective of determining the potential of the existing grazing areas in an economically and environmentally justifiable way was achieved. A change in grazing management, be it more days grazing or a greater number of livestock in spring 2020, also led to increasing the carrying capacity. The carrying capacity was highest in spring and thereafter declined rapidly until early fall when grazing was limited to the shrubs.

5. References

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