

# **System approach to grazing in a desert ecosystem: a case study in Saudi Arabia<sup>1</sup>**

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## **Abstract**

This paper highlights a system approach to grazing in a desert ecosystem used by the Range and Animal Development Research in northern region of the Kingdom of Saudi Arabia .Various factors affecting plant and animal production in a high potential desert system (wadi bottom) is discussed. Use of cultural treatment for increased forage production, effect of protection, use of native species for rehabilitation work, utilization of supplemented irrigated shrubs in the feed calendar for semi intensive systems, flock management for reduced grazing pressure are among the different aspects studied for integrated management of rangeland resources which have considerable implication in combating desertification. Summary of major results from the various research topics is reported.

***Key words: Cultural treatment, protection, native species, grazing management***

## **Introduction**

Saudi Arabia is an extremely arid country. Forage production is therefore very low with considerable spatial variability and because of its low potential, small stock numbers of predominantly hardy camels (not more than 20 camels) used both as transport and for milk production in addition to few goats and special breed of sheep (Najdi) that can utilize forage growing on high sand masses such as the Great Nafud and the Dihana deserts were kept by Bedouins.

Similar to most countries in the near east, animal production used to fluctuate with feed availability. Drought years used to reduce livestock numbers and animal numbers used to increase following wet years. In the Kingdom tribal boundaries are very well known and range use was regulated by the tribes. The system of land use has drastically changed with the start of the oil boom. Increased revenue from oil resulted society with a high per capita income.

The oil wealth was also an incentive and as a matter of fact encouraged by the government to increase human population. The result is a nation in which its population is doubling every 20 years. The high per capita income increased demand for range products and particularly meat. The government therefore encouraged increase of livestock population through a system of subsidies. Initial subsidies were per capita head of livestock owned by individual Bedouin operator. This was later changed to feed subsidy and particularly barley.

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<sup>1</sup> This study was carried out during the author's assignment as FAO range management specialist in the Range and Animal Development Research Center/ Kingdom of Saudi Arabia

Because of the high cost of meat small ruminant production became very attractive and particularly the more manageable Naimi breed from Jordan. This changed range livestock production from small stock subsistence holdings to highly Mechanized commercial herds. All livestock production even for small stocks is raised with foreign labor.

This completely changed the socioeconomics of livestock production and practically there is no true subsistence pastoral production system or true nomadic population.

Traditional pastoralists more or less settled in villages and have access to modern city services (Schools, hospitals, electricity, water etc). Most acquired agricultural land. Taking advantage of the agricultural subsidy and foreign labor including skilled farmers, most Bedouins started growing fodder crops (mainly barley and alfalfa).

The government of Saudi Arabia realized the problem and started rehabilitation and conservation programmes through two major programmes 1) establishing large but unfenced protected area such the Alharra in northern Saudi Arabia, almost half the size of the entire country of Syria (several of these areas are spread through out the kingdom). 2. By establishing large enclosures as satellite research station where range improvement, soil and water conservation, grazing management and range monitoring studies were carried to generate data for policy decisions for large scale rehabilitation programmes.

This paper highlights holistic system approach to applied research conducted by the Range and Animal Development Research Center which was established as a collaborative work between the Food and Agriculture Organization of the United Nations and the Kingdom of Saudi Arabia under Unilateral Trust Fund agreement.

Extensive surveys of the different habitats were carried out during the early years of project inception. Survey results concluded: downward trend in range condition with undesirable plants becoming dominant, absolute lack of grazing management, range livestock production depend on subsidized barley and no data is available that can be used for range condition and trend evaluation for policy analysis and management decisions.

Research program was therefore initiated to generate data that can be used for sustainable management conveniently discussed under range improvement and plant/animal interaction.

## **1. Range Improvement**

Several trials all aimed at the improvement of vegetation for range-livestock production using principles of restoration ecology were carried out. Techniques used include protection as tool for assisted regeneration, seed propagation of indigenous range for reseeding degraded rangelands, use of cultural treatments and establishment of supplementary irrigated shrubs.

### **1.1 Improvement by protection**

Response of vegetation community to deferment or rest from grazing is an important factor determining the potential for improvement of degraded rangelands. Too early and too close grazing eliminated large communities of the vegetation in the high potential run-in habitats (Wadis). No information was available on the rate of

recovery and the effect of deferring grazing from heavily grazed but high potential sites. Little was known about the vegetation retrogression with heavy grazing intensity, interaction of the different vegetation components and their response to seasonal precipitation. A research was therefore carried out in Wadi Tamriat research station to document vegetation recovery when the range is completely rested from grazing.

Monitoring of the response of vegetation over a six year period in wadi sites of northern Saudi Arabia have shown substantial changes for all vegetation attributes measured at both protected and heavily grazed sites( Mirreh and ALDaraan1995). The response has been one of considerable improvement in range condition in the protected area and continuous deterioration of the grazed area. Total vegetation cover increased from 8.7% to 70.8% under protection and decreased from 8.0% to 0.7% under heavy grazing during the same period). There was evidence of serial replacement, succession trend of the vegetation in the protected areas has shown increased density of the more desirable species such as *Salsola villosa*, *Atriplex leuococlada* and disappearance of species such as *Achillea fragrantissima* and *Astragalus spinosus*. Undesirable species were on the increase under uncontrolled heavy grazing before almost bare ground state Table 1). Variability in dry matter production is very high and is more pronounced in the dry matter production from annuals (Table2) and is related to the seasonal precipitation. This high variability in production has considerable implication in management and particularly stocking rates.

**Table-1:** Changes in vegetation composition over 6 years in protected and grazed area

Species	% Composition			
	Starting year		Year six	
	Protected	Grazed	Protected	Grazed
<i>Achillea fragrantissima</i>	33.0	21.0	01.0	64.0
<i>Anabasis setifera</i>	00.0	00.0	24.0	00.0
<i>Artemisia herba alba</i>	00.0	04.0	03.0	04.0
<i>Astragalus spinosus</i>	33.0	05.0	00.0	00.0
<i>Atriplex leuococlada</i>	18.0	00.0	31.0	00.0
<i>Fagonia glutinosa</i>	00.0	54.0	00.0	23.0
<i>Haloxylon salicornicum</i>	08.00	06.0	02.0	09.0
<i>Salsola villosa</i>	07.0	10.0	39.0	00.0

**Table-2:** Kilogram dry matter per hectare (kg/dm/ha) and coefficient of variation (CV) measured in wadi Tamriat for a period of six years.

	Y E A R						Mean	CV
	1984	1985	1986	1987	1988	1989		
Total vegetation	182	306	374	1269	3125	622	966	111
Annuals	156	156	253	1067	2752	328	785	130
Perennials	26	150	221	202	373	294	211	56

### 1.2 Seed production and reseeded

The Department of Forestry and Range in the Ministry of Agriculture was engaged in extensive range reseeded operations throughout the Kingdom. The depletion of native seed source however, forced them to resort to exotic species. Trials were conducted comparing 12 exotic and 4 indigenous species by seeding under rainfed in a Wadi site ( Mayala). Only one of the 12 exotic species *Atriplex bunburiya* was able to survive and flower with a crown diameter of more than 60 cm but failed to produce seeds (Mirreh and Aldiran1988). The survival percentage of the native species ranged from 46% in *Atriplex halimus* to 94% in *Artemisia herba alba*. The highly preferred species of *Salsola villosa* ( *S.vermiculata*) had respective survival of 86% and 76. Both *Atriplex leucoclada* and *Salsola villosa* species produced seeds for self regeneration in the third year following a good year of rainfall in their second year of establishment.

The failure of the exotic seeds and the success of the indigenous species trials, the deterioration of the rangelands and the increased alarm from extinction of many range species and the urgent need for maintaining the status quo of endemic genetic resources, necessitated the establishment of the seed propagation center at Buseita. More than 40 species of perennial shrubs native to the northern rangelands (Most of the species have a wide geographical coverage and can be found in different regions of Saudi Arabia) are currently produced with more than 10 tons of seeds.

Seeds are extensively used by the department of Range Management. Seeds and seedlings are also widely used by private farmers to produce fodder under light irrigation in abandoned wheat and barley fields and by private ranch owners.

### 1.3. Fodder shrubs

In the Kingdom of Saudi Arabia because of the financial affluences meat consumption is high and lamb prices are extremely high. This resulted establishment of mega sheep production schemes. Large scale projects are located in Buseita plain with annual rainfall of less than 50 mm with high summer temperature, high evapo-transpiration and soils with relatively high solutes of gypsum. Considerable investments were made in these projects but farmers may face problems with water depletion and soil salinization. Government policy changes in grain subsidy may attract none livestock farmers to produce fodder for livestock to utilize the sunk cost of their investment. Considering the

high water demand of traditional fodder crops and the fact that the major cost of livestock goes for maintenance feed, protein rich shrubs with high water use efficiency may be more appropriate base-feed for these projects.

The following are excerpt of the results of trial to evaluate, production dynamics, forage value and sheep performance as a sole diet and when supplemented with barley grain (Details can be found Mirreh et al 1996 in Biology and Ecology of Fodder Shrubs).

The trial was conducted in typical poor desert soil of the project HQ for six salt bush exotic and indigenous shrubs receiving an equivalent of approximately 420mm per year from sprinkler system and from natural rainfall (less than 50mm).

Dry matter average yield was 6.6 tons per hectare with 50% consumable dry matter. Grazing sheep were found to be highly selective on halophytic shrub mixture. The native *Atriplex leucoclada* was the most selected while *Atriplex nummularia* was the least selected. Sheep were also highly selective on plant parts removing more than 96% of the leaves of the most selected species. Continuous stocking with sheep over a three year period encouraged more woody biomass and a cut back for rejuvenation was not achieved with sheep grazing. Halophytic shrubs were characterized by low organic matter (72% in the leaves), low energy (1.85 Mcal/kg in young leaves and 1.68 Mcal/kg in old leaves), high mineral matter (28% in young leaves) and high crude protein (18% in young leaves).

Sheep utilizing salt bush as sole diet could not maintain weight and average daily loss in three consecutive years with at least four months grazing per year ranged from 23 gm/h/d to 61 gm/h/d. However, animals gained weight when grazed *Atriplex*-barley-stubble mixture or when supplemented with 400 grams of barley. The difference between supplemented and non supplemented was approximately 64 gm/h/d indicating that halophyte shrubs may be integrated with farming or feeding system that take advantage of their long period of retaining high crude protein and their high water use efficiency if energy supplement is supplied. Because of the high salt content of halophytes, estimated free water consumption was 69 ml/g of sodium chloride in the summer months thus approximately 11 liters per head per day of good quality water should be available for sheep utilizing halophyte shrubs during the summer.

### **1.3 Cultural treatment**

The majority of the rangelands in northern part of Saudi Arabia are gravel plains which are either devoid of vegetation or support sparse shrubs. The soils of sterile plains consist of gravel and stones overlying structure less sandy loam. These soils have very poor infiltration due to surface crusting and produce runoff. Mechanical land treatments such as contour furrowing (Branson et al 1966; and Wight et al, 1978) and pitting Slayback et al, 1973; and Barnes et al, 1958) were used to prevent water from running off the land and to create shallow depressions to store surface water. The treatment generally resulted in higher water infiltration (Wight et al, 1981) and higher herbage production both in quantity and quality (Valentine, 1980). The two treatments of contour furrowing and pitting compared for increasing water penetration and providing better seed bed in the 50 mm sterile gravel plains of Tamriat in northern Saudi Arabia.

The results from the trial (Mirreh and AlDaraan 1987) indicated that furrowing and pitting increased water infiltration and herbage production and reduced soil bulk density (table 3). The contour furrowing treatment was effective in intercepting native seeds and

had significantly higher herbage yield than pitting. The direction of orientation of the furrows did not significantly affect the herbage yield.

**Table 3.** Forage yield, bulk density, soil moisture and depth of infiltration in the treatment.

	<b>contour furrows</b>	<b>pits</b>	<b>Control</b>
Forage yield (dry matter/ha)	293.00 a	72.00 b	0.000 c
Bulk density	1.29	1.32	1.59
Depth of infiltration (cm)	28.80 a	27.10 a	12.00 b
Moisture content (cm <sup>3</sup> H <sub>2</sub> O/cm <sup>3</sup> soil)	0.17 a	0.14a	0.07 a

## 2. Plant and Animal Interaction

Several experiments involving plant-animal interaction were conducted in different years. In 1987, 36 mature castrated sheep were stocked in 227 hectare pasture between March to September to determine intake when forage availability is not limiting. Seasonal dry matter utilization was determined from paired fenced and grazed plots using before and after grazing clippings.

In October 1987 breeding ewes were substituted with the castrates. Initially 40 breeding ewes were stocked and mated in the range. The herd was built to 200 between 1987 and 1991. Free grazing with shepherd was practiced. Selling of male lambs at 120-150 days was followed. Mating season for all the years started in July. Breeding ewes were weighed from birth to mating on monthly basis while lambs were weighed from birth to selling for males and for one year cycle for females.

Forage preference by sheep in one year cycle was determined using grazed plants counts. Effect of deferment on plant and animal performance was studied in fenced pastures. Plant density and cover was used as criteria. Each pasture was measured in three dates including just before and after grazing.

Chemical contents of the perennial species in the area and composite of annuals were analyzed for four seasons in one year to evaluate nutritional adequacy of the range at different times of the year. Weather conditions and particularly rainfall was recorded in the station for all years. Results of these studies were reported in different technical papers (Mirreh et al 1988, Mirreh et al 1990 Mirreh et al 1991, Mirreh 1991 and Mirreh 1993) and are summarized here:

### 2.1 Production variability with rainfall

Perennial component of the vegetation were found to be low in diversity where one or two species constitute more than 50% of the plant community. Dry matter production varied from less than 50 kg per hectare to more than 3000 kg/ha. Variability in annual dry matter production was considerably higher than the variability in annual precipitation. The total precipitation though important in its influence in production, yet direct significant correlation was not found. The frequency of effective rainfall events greater

than 5 mm together with the confounding effect of run-in water from outside may have significant influence in dry matter production. For example, precipitation of the area in 1991, 1992 and 1993 was similar but the production was respectively 415 kg, 40 kg and 30 kg for 1991, 1992 and 1993 (Table4). Indicating rainfall is not a good indicator of production in wadi sites that receive runoff from outside their watershed. One good flow of water into the wadi beds may store enough moisture in the soil and may offset rainfall deficiency in a poor year. Apparently soil moisture during the growing period may be better indicator. Variability in dry matter was more pronounced for annual species with coefficient of variation of 172% for the 10 year period. Perennial dry matter variation had a lower coefficient of 79% during the same period. Though year to year variability of the production of annual plant was high yet they constituted 76% of the total dry matter production over the ten year period ranging from 50%to90%. This indicates the importance of annuals.

**Table 4.** Dry matter and rainfall measured in Tamriat (1984-1993)

	YEARS										Aver- age	CV %
	84	85	86	87	88	89	90	91	92	93		
Total	182	306	474	1269	3125	622	45	415	40	30	650.8	145
Annuals	156	156	253	1067	2752	328	10	214	10	00	494.2	172
Perennials	26	150	221	202	373	294	35	201	30	30	156.2	79
Rain(mm)	44	75	42	122	40	12	29	32	32	39	46.7	

## 2.2 Forage preference

Dietary preference of grazing castrates studied in the spring of 1988 has shown that 87% of the diet came from annuals (Mirreh et al 1988). Dry annuals were also more preferred than green perennials. Preference rating of perennial species using percentage of plants grazed for a period of two years after annuals dry up showed poor preference of Naimi sheep for most perennials when the plants are green. This is particularly true for the sapphire-like species of *Anabasis setifera*, *Halothamnus iraqensis*, *Haloxylon salicornicum* and *Agathophora iraqensis*. Highest preferences were found for species of *Salsola villosa*, *Salsola tetrandra* and *Atriplex leuococlada*. Some grazing of *Artemisia herba alba* and *Achillea fragrantissima* started in October when grazable portions of the preferred species were reduced by grazing. Animals were none selective during the winter and grazed all species. Seasonal changes in grazing behavior was associated with changes in leaf plasticity of perennial shrubs where tender parts were cut in the spring while leaf stripping was the pattern in the summer.

## 2.3 Range quality dynamics

The chemical content and nutritional value of twelve perennial species commonly found in the Widyan of northern Saudi Arabia and composite of annuals was studied for four seasons in one year cycle to evaluate their nutritional adequacy for grazing animals. The perennial shrubs had a long period of retaining high crude protein (CP). On percentage dry matter basis (DM), the CP was 14, 12, 10 and 7 in the spring, summer, autumn and winter respectively. Annuals have CP of 22% dropping to 8% as early as

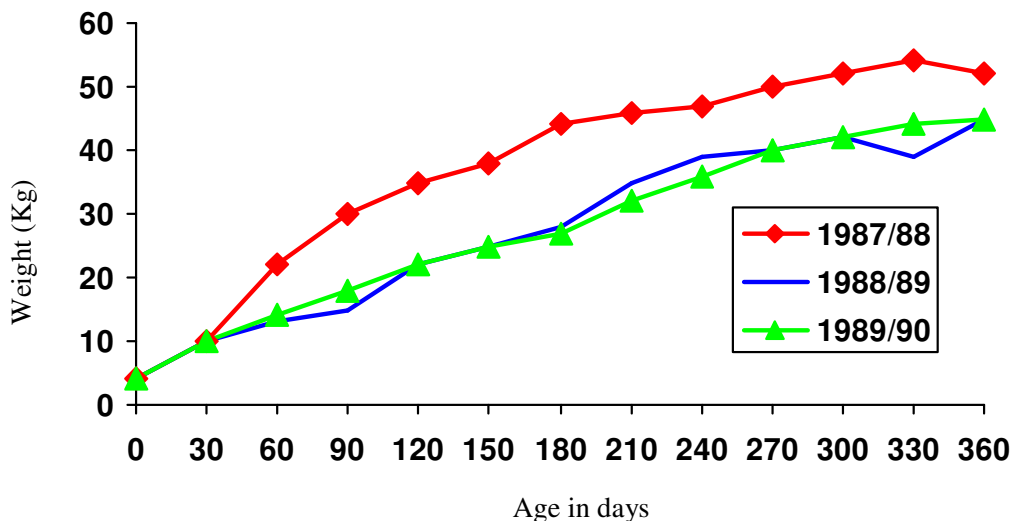
May. The digestible and metabolizable energy values (DE and ME) of the shrubs averaged respectively 2.1 Mcal/kg and 1.75 Mcal/kg.

Changes in chemical content indicate that the range can be divided in terms of nutrient content of available forage into production, maintenance and sub-maintenance phase. The production phase constitute the short spring period between February to April when annual forbs and grasses are available for grazing. The maintenance phase is the period of availability of green perennials from April to October. The period between November to February is the sub-maintenance when perennials dry up in the winter.

### 2.3 Response of animals to climatic variability

The variability of the quantity and the quality of available forage was reflected in the performance of the animals. Lambs born in November to January compared for three consecutive years (1988-1990) in none supplemented range have shown similar birth weight and growth for the first 30 days of suckling for all the years. However, lamb growth in 1988 was considerably higher than 1989 and 1990 (Figure1). Average weaning weight at 120 days for single born male lambs was 36.5, 22.5 and 22.2 kg for 1988, 1989 and 1990 respectively. Female lambs born 1987-88, 1988-89 and 1989-90 reached 50.43, 42.66 and 42.8 kg respectively as 360 day old yearlings. The large difference in weight of lamb growth was attributed to the large difference in dry matter production and particularly the dry matter yield of the nutrient rich annuals. The dry matter of annuals in the Spring of 1988 was more than two tons. Dry matter production from annuals was less 400 kg/ha in the spring of 1989. Though the rainfall was slightly less than the average, the period of availability was shortened by long and extremely cold winter in 1988 extending to March 1989 followed by desiccating winds in the spring of 1989. In the spring of 1990 dry matter production was extremely low. Therefore, in normal and below normal years lamb growth was poor and off-range marketing of lambs was found to hold lambs in the range between 3 to 6 months after weaning to reach market weight thus putting more pressure on the range.

**Figure 1.** Weight changes of range base lambs from birth to 360 days for 2 years



Ewes grazing the range lost 9.5, 11.73 and 12.49 kg (from birth to weaning of their lambs) amounting to 18, 22 and 23 percent of their body weight in the years 1987/88, 1988/89 and 1989/90 respectively (Table5). Heavy ewes in excess of 60 kg at birth were the most severely affected, losing 22 to 29% of their weight from birth to weaning.

In 1988 growing season all the weight lost during the lactation period of the ewes in the previous winter, were compensated between weaning to mating in July. During the mating period (July-August) of 1989 and 1990 the mating weight of the mature ewes were respectively 4.2 and 6.1 kg lower than their lambing weights. Compensatory weight gain from weaning to mating was related to grazable forage quantity from green annuals and perennials during the spring and summer. In 1988 the pasture production was high for both annuals and perennials. In 1989 the previous extended cold winter reduced the growth and perhaps shortened the period of availability of green annuals. In the spring of 1990 the grazable forage of both annuals and perennials was limiting though the above ground standing biomass was high, thus the whole range was supplemented with 0.8 kg of whole barley in May. Because the supplementation period started in May the total weight lost during the winter was not restored during the mating period. Apparently, perennial plants provide maintenance diet for grazing animals. Growth of range base animals will therefore be mainly influenced by the quantity and length of availability of annuals in the growing season.

**Table5.** Weight changes of suckling ewes from birth to mating for a period of three years.

	1987/88	SD	1988/89	SD	1989/90	SD
Birth weight (kg)	52.50	7.36	53.95	5.66	54.04	6.11
Weaning weight (kg)	42.94	7.29	42.22	3.54	41.55	4.55
Mating weight (kg)	52.85	7.45	49.75	4.46	47.96	5.23

## 2.4 Impact of deferred grazing on plant and animal performance

Response of vegetation in two pastures of 100 hectares each stocked with sheep at two separate grazing periods were monitored. Cover measurement at three different periods, for early and late grazed pastures is given in Table 6. In the early grazed pasture there was a net reduction of 4.05% from May to July. Most of the reduction came from the highly preferred *Salsola villosa* which constituted 57% of the total cover reduction. Plant cover slightly increased in with autumn regrowth in the early grazed pasture. In the late grazed pasture there was a slight increase in total perennial cover between May and July. During the grazing period total perennial vegetation declined by 6.9%. Again the major reduction was from the preferred species of *Salsola villosa*.

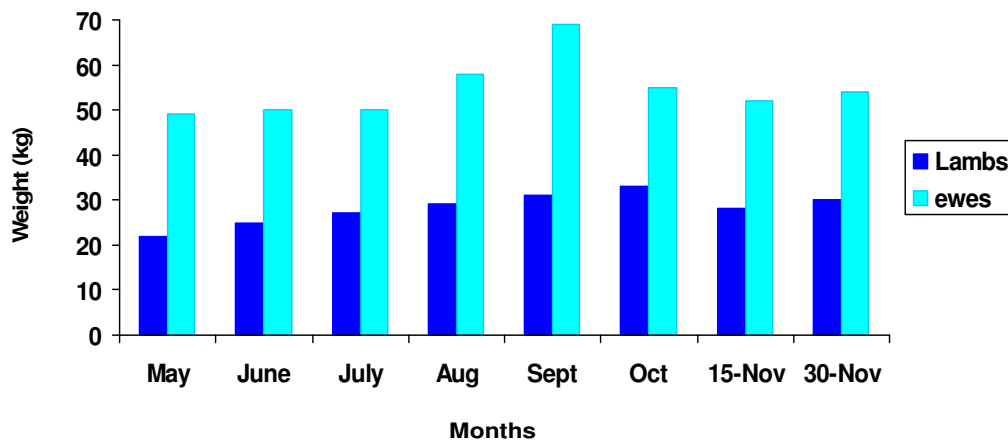
Cover of annuals standing as hay declined by approximately 40% due to natural disappearance between the beginning of May to end of July in the rested pasture. And annuals totally disappeared between May and July in the grazed pasture. The relatively low reduction in cover of perennial plants and the disappearance of annuals is an indication that annuals constitute the bulk of the forage for grazing animals when they are present.

**Table 6.** Coverage of vegetation for three months in early and late grazed similar pastures of wadi Tamriat (1991).

Species	Early grazed pastures (May 6 to July 31)			Late grazed pastures (Aug. 1 to Nov. 10)		
	May	Jul.	Oct.	May	Jul.	Oct.
<i>Salsola villosa</i>	13.33	11.46	10.94	15.64	15.64	11.69
<i>Anabasis setifera</i>	3.93	2.16	2.44	3.04	1.56	2.24
<i>Halothamnus iraqensis</i>	1.06	1.29	0.81	0.33	0.65	0.54
<i>Achillea fragrantissima</i>	0.01	0.70	0.60	0.66	0.01	0.00
<i>Atriplex leuococlada</i>	0.53	0.10	0.44	0.00	1.89	0.16
<i>Haloxylon salicornicum</i>	0.75	0.52	0.87	2.02	3.07	1.65
<i>Artemisia herba alba</i>	1.06	0.87	0.81	1.40	1.46	1.10
<i>Astragalus spinosus</i>	0.21	0.16	0.25	0.00	0.00	0.00
Annual species	40.10	0.00	0.00	35.30	21.18	0.00
Total vegetation	61.42	17.26	17.16	58.39	45.46	17.38
Total perennials	21.32	17.26	17.16	23.09	24.28	17.38

Weight changes of the grazing flock are given in Figure 2. In the early grazed pasture, adult ewes and replacement lambs respectively gained 136 and 141 grams per day in May when green annuals were available. The average daily gain progressively declined until it reached 12 and 33 grams in July for adults and lambs respectively. However, when the sheep were placed in the rested pasture in August the average daily gain again increased for both classes of animals. Adult ewes gained 223 grams per day while lambs gained 91 grams per day. The relatively higher weight gain for adult females was attributed to the confounding effect of the foetus since animals were in their early pregnancy (2-4 weeks). The relatively high gain of the grazing flock in August compared to the drop in weight in June-July is attributed to the availability of the annuals in the rested pasture. In both pastures sheep performance was related to the availability of annuals. Mirreh et al (1990) and Mirreh et al (1991) reported the progressive decline in shrub quality and the progressive decline in animal performance under free selection and free access grazing in Tamriat. It was reported that animals can be maintained without supplement in this kind of range upto the end of October (Mirreh et al 1991 and Mirreh et al 1990) in an average year of rainfall

**Figure 2.** Weight changes of lambs and adult ewes in early and late grazed pastures.



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