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EVALUATION OF ANIMAL HUSBANDRY IN THE NORTHWESTERN COASTAL ZONE OF EGYPT (LITERATURE REVIEW AND SIMULATION).

N. v. Duivenbooden

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CONTENTS

SUMMARY

The northwestern coastal zone of Egypt extends from Alexandria to the Lybian border over a length of about 480 km and a width of 25 to 60 km. The main agricultural activities at present are animal husbandry on natural rangeland, rainfed barley cultivation and tree cultivation, mainly figs and olives. In the most eastern part irrigation is possible. This report deals with animal husbandry only.

In this coastal zone with an arid-mediterranean climate (average annual rainfall is about 125 mm), rangeland herbage is available in limited amounts in summer and autumn. The vegetation consists predominantly of shrubs and subshrubs.

Animal production is determined both by the quantity and quality of the available feed resources. Due to the large number of animals (almost 1.5 million head), the production of the rangeland vegetation is insufficient to feed the still increasing number of animals all the time, and therefore, supplementary feed (manufactured concentrates, grains, straw or hay) is provided to meet the requirements of the animals. The Bedouin obtain the supplements through the agricultural cooperation, but may buy on the (black) market as well. Due to that fact it is difficult to obtain accurate data on this part of the inputs of the animal husbandry system.

The method employed in this study is the system analysis and simulation technique. The simulation model ARID ANIMAL has been developed on the one hand to calculate the feed balance and on the other hand to quantify the inputs and outputs of well-defined animal husbandry systems. ARID ANIMAL is based on the principles of the Pasture System Generator (PSG), developed by Seligman and Spharim (1987) in which all relevant characteristics of animal husbandry systems have been formulated in mathematical equations.

In this study the constraints and possibilities of animal husbandry systems in terms of feed balances have been quantified using the method of systems analysis and simulation. On the basis of the results it is concluded that the present stock number of sheep and goats in the northwestern coastal zone can only be maintained thanks to abundant availability of barley products and high inputs of concentrates. Moreover, independent of the production level aimed at, high quality supplements are necessary to overcome the main dry period if no reduction in flock size is permitted.

PREFACE

This report has been prepared in the framework of the Mariut project. That project, officially designated "Study of production levels and land use planning of the Western Mediterranean region of Egypt (Mariut)", has been a joint activity of the Centre for Agrobiological Research (CABO), the Department of Theoretical Production Ecology of the Agricultural University (TPE), both in Wageningen, the Netherlands and the Ecology group of the Botany Department, Faculty of Science, University of Alexandria, Egypt. It was sponsored by Directorate-General for International Cooperation (DGIS) of the Dutch Ministry of Foreign Affairs.

The aim of the project was to assess the potentials of different agricultural systems for the purpose of land evaluation and regional planning in the northwestern coastal zone of Egypt. Alternative land use systems were defined and their economic feasibility and impact on the natural resources were investigated. The results of such an investigation should lead to formulation of an optimum development plan for the region, based on sustained productivity of the area.

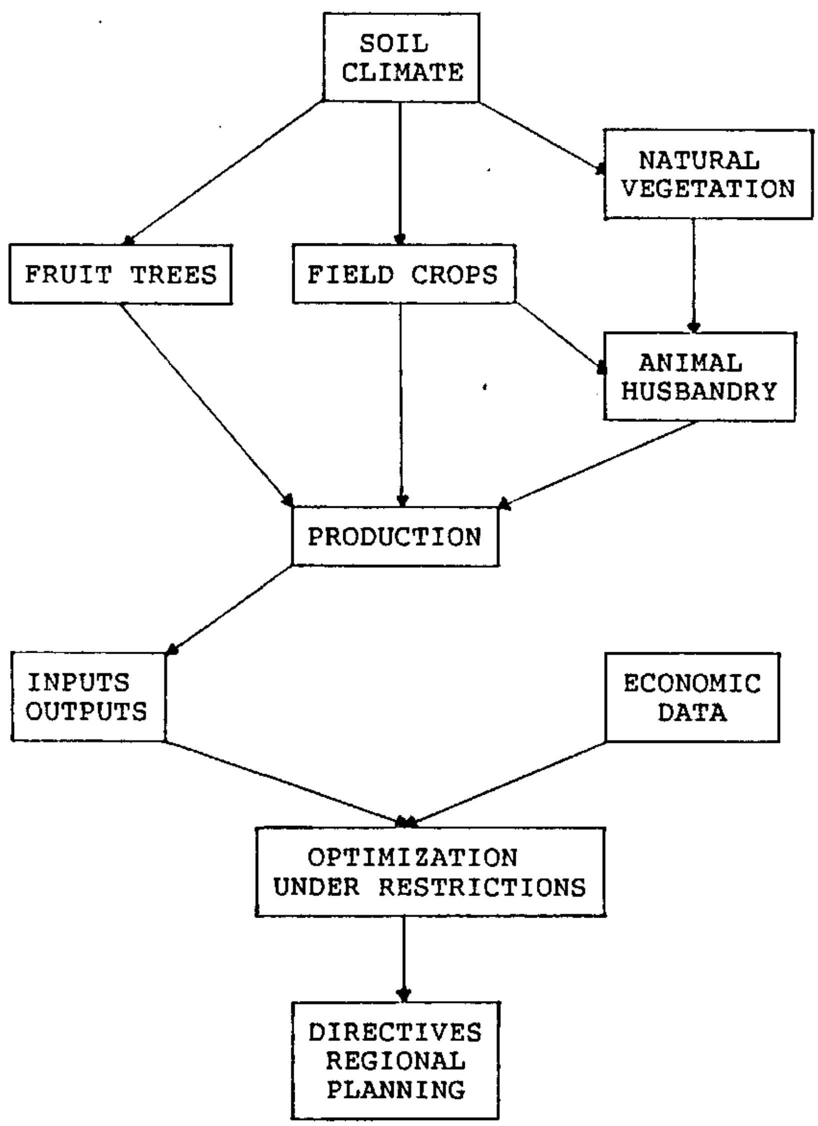
An overall scheme of the method of analysis used in the project is presented below. The potentials for agricultural production are governed by the physical environment, i.e. the soil physical and chemical properties and the climatic conditions.

Three main agricultural activities are distinguished in the region: fruit production, barley cultivation and animal husbandry. Fruit production comprises cultivation of olives and figs. Olive and fig tree are relatively well-suited for the prevailing dryland conditions. Barley is by far the most prevalent field crop in the region, due to its relatively high drought resistance. Animal husbandry comprises sheep and goat meat production. Additionally, donkeys are kept for transport and for animal traction, required for agricultural activities. Cattle are kept on a limited scale only in the irrigated areas. The sheep and goats graze the natural vegetation and the aftermath of the barley fields. In summer they need supplementary feed to cover their maintenance requirements.

For all three branches of agriculture several production techniques have been defined. These include different yield levels and methods of cultivation and various intensification levels for animal husbandry. For each production technique, inputs and outputs are quantified and summarized in an input/output table. Inputs consists of chemical fertilizers, human labour etc.. Outputs comprise olives, figs, meat etc.. All relevant constraints in the region are also quantified and in combination with the economic environment they form the basis for the multiple goal linear programme.

When all constraints are defined, different goals can be persued, depending on the interest of the 'user'. Different groups in the region may have different interests and therefore different goals. In an interactive way an acceptable compromise can be searched for. On the basis of that result directives for regional planning can be formulated.

In this report the background material for the formulation of animal husbandry systems and the defined systems are presented. Barley cultivation and fruit tree cultivation are discussed in a Simulation Report CABO-TT, and CABO Report, respectively.



Scheme of the method of analysis used in the Mariut project.

CHAPTER 1.

INTRODUCTION

Arid and semi-arid regions account for about 30% of the total land surface of the earth and could contribute significantly to agricultural production, if the constraints limiting the present production level could be removed. Traditionally, the greater part of these regions is used for extensive grazing, under a varying degree of nomadism. The northwestern coastal zone of Egypt, however, is one of the arid regions that has a long history of intensive land use, mainly grazing and rainfed farming (barley and figs). The coastal zone extends from Alexandria in the East to Salloum near the Lybian border in the West, approximately 500 km long and 25 (FAO, 1970a) up to 60 km (Ghabbour, 1983) wide, as shown in Figure 1. In this study the northwestern coastal zone is defined as the area from 35 km west of Alexandria to Salloum, and extending inland till the 75 mm isohyet (Figure 2), i.e. almost 1.26 million hectare.

The most important form of land use in the northwestern coastal zone of Egypt (administratively known as the Governorate of Matruh), in terms of area is animal husbandry, and its contribution to the livelihood of the Bedouin increases from Alexandria in westward direction. Only a few traditional nomadic Bedouin still live in the region as most Bedouin have settled in stone houses, hence transhumance is the main animal husbandry system practiced at the moment. In addition, most families are engaged in both arable farming and animal husbandry. Mahmoud (1978) estimates that 70% of the families living in the zone are partly engaged in animal husbandry. Usually, a mixture of both activities is thus practised. The actual situation depends on availability of land, feed and water resources, as well as on marketing opportunities (Ghabbour, 1983; von Braun and de Haen, 1983).

The climate in the coastal zone can be classified as arid-mediterranean with mild winters (average daily air temperatures 10-20 °C) and warm summers (average daily air temperatures 20-30 °C) in the strip up to 40-50 km inland. The climate south of this strip changes to a Mediterranean-Saharan climate, due to phasing out of the maritime effect on air humidity and temperature (FAO, 1970a). The rainy season starts generally in the second half of October, and about three quarters of the total amount of rain falls from November till February, December and January being the rainiest months. The long term annual average rainfall is often estimated at 150 mm, but a value of 125 mm seems more realistic. However, annual rainfall varies considerably from one year to the other and from place to place, decreasing land inwards (Figure 2).

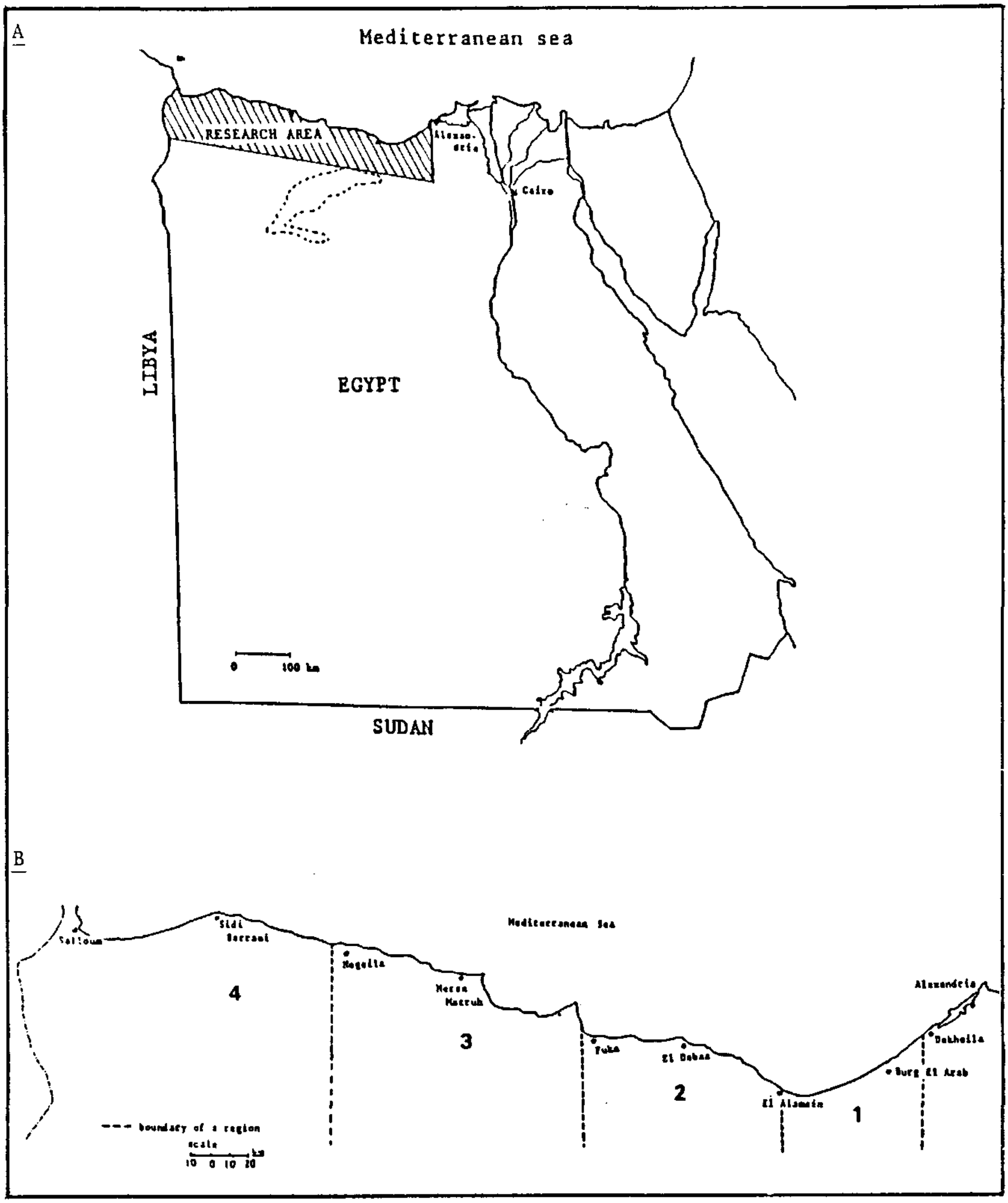


Figure 1. A. Map of Egypt and location of the research area, B. Detail of the northwestern coastal zone showing the 4 pilot regions 1: The Burg el Arab region, 2: The Dabaa region, 3: The Matruh region, 4: The Barrani region.

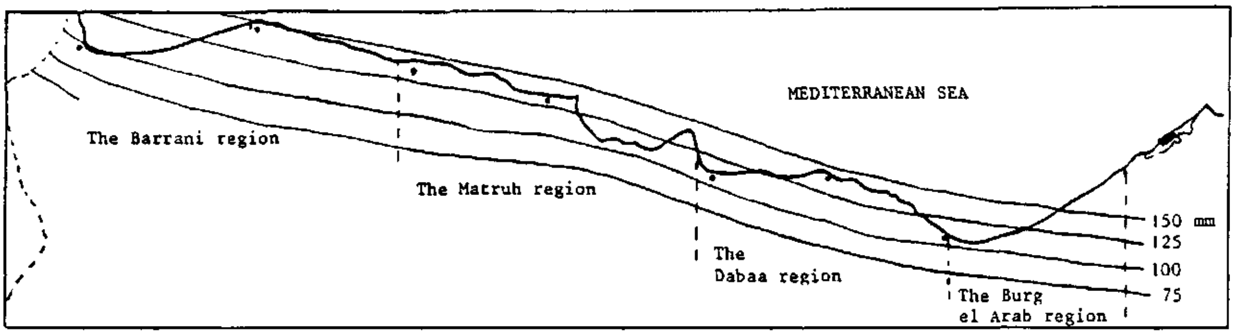


Figure 2. Lines of equal rainfall in the northwestern coastal zone.

The dry summer season lasts from May through September, autumn from October through November, winter from December through February, and spring from March through April.

In the coastal zone almost 1.5 million head of animals are present, a doubling in number compared to 10 years ago (Table 1). This dramatic increase in the sheep and goat population in the region is related to the political situation. Prior to closure of the border between Egypt and Lybia, the Bedouin of the region made a reasonable profit from trading with their neighbours in Lybia. When these possibilities were blocked, the Egyptian government compensated the Bedouin of the region for their lost revenues by granting them export rights for about 180 000 to 200 000 head per year (Abdel Salam et al., 1985).

Table 1. Sheep and goat population (in million head) in the coastal zone between Burg el Arab and Salloum in the period 1965-1984 (FAO, 1970c; St. Agric. Dept. M. Matruh Governorate quoted by Soliman, 1982; C. Agric. Gen. Mob. quoted by Soliman, 1983; Aboul-Naga et al., 1985a).

YEAR	1965	1966	1967	1971	1973	1978	1984
SHEEP	0.300	0.320	0.336	0.415	0.634	1.062	1.18
GOATS	0.110	0.137	0.180	0.233	0.236	0.269	0.30
TOTAL	0.410	0.457	0.516	0.648	0.870	1.331	1.48

Herd nutrition is based only in winter on the available rangeland forage, but in summer and autumn on supplements. The rangeland area is estimated at 90% of the total area, but the area actually grazed by the animals varies from year to year, depending on quantity and distribution of rainfall. In the area close to the sea grazing takes place all year round. The vegetation is dominated by shrubs, bushes and subshrubs (synonyms: dwarfshrubs, halfshrubs), the latter constituting a considerable part in certain areas, while in some places the vegetation is dominated by subshrubs. Subshrubs occur, for instance, in the transition between ridges and depressions, indicating that these species are drought resistant (Abdel-Razik et al., 1984). The subshrubs are classified by Le Houérou (1980a) as the field sage series belonging to the arid bioclimatic zone (100 mm $< P <$ 400 mm), where they constitute the bulk of feed of grazing sheep, goats and camels (Le Houérou, 1980b). The importance of shrubs in animal husbandry systems in semi-arid regions is widely recognized (e.g. Noy Meir and Seligman, 1979; Thalen, 1979; Ayyad and El Kadi, 1981; Ruigrok, 1985). The role of annuals and ephemeroids, except for Asphodelus microcarpus is of minor importance in the coastal zone.

However, the increasing pressure on land use in combination with an unfavourable environment (low soil fertility and low and erratic rainfall) and a change in socio-economic conditions, has resulted in a situation where the productivity of the natural vegetation is reduced. Supplementary feeds (e.g. manufactured concentrates, barley grains) are provided to replace the natural resources in summer and autumn when range herbage is in short supply. At present animal husbandry in the region depends on the supply of concentrates to a far greater extent than generally was assumed. The consequence is that the total costs are very high from a national economic point of view. Another observation is that in times of drought (annual precipitation below 100 mm or an unfavourable distribution), occurring about once every five years, livestock migrate to other areas in search of relatively cheap forage.

In this report animal husbandry of the northwestern coastal zone is evaluated by describing the characteristics of the flock (Chapter 2), the characteristics of individual animals (Chapter 3), available feed resources (Chapter 4) and other inputs into animal husbandry systems (Chapter 5).

Constraints and potentials of animal husbandry are dealt with in Chapter 6. As outlined above, one of the most important constraints is feed availability. To gain insight into that constraint, the feed balance, defined as the difference between feed availability and feed requirements is calculated in the model ARID ANIMAL, using the principles of the Pasture System Generator (PSG), developed by Seligman and Spharim (1987). As insufficient information is available on herd dynamics that process is not simulated dynamically. As in addition to sheep, other animal species are present, all parameters are based on ewe equivalents (Section 2.5). In this study 1985 is defined as the base year. Acronyms in the text refer to the equations of ARID ANIMAL (Appendices I and II).

In Chapter 7 systems for animal husbandry are defined, based on data from preceding chapters. Each system is defined by so-called input/output tables. The systems are defined in a target-oriented way, i.e. the yield of the system is defined first and the requirements to achieve that yield are derived subsequently. Three system types for sheep and goat husbandry are distinguished: extensive, intermediate (essentially based on the current systems) and intensive systems. Data presented in this study are as far as possible related to these system types. Barley production systems and fig and olive production systems are described elsewhere (van de Ven, 1986; 1987a and Abdel-Razik and van de Ven, 1987, respectively). These systems are then used in Multiple Goal Linear Programming. More details about that method are given by van Keulen and de Wit (1987). The values of the coefficients in the input/output tables for animal husbandry systems may be calculated by means of the PSG (Seligman and Spharim, 1987). The purpose of that model is to define the physical inputs and outputs of a number of pastoral systems that are technically and biologically feasible. However, circumstances as prevailing in the northwestern coastal zone differ considerably from those described in the PSG, and therefore, the PSG is adapted. These calculations are the second purpose of ARID ANIMAL.

As some goals in the multiple goal linear programming analysis are related to prices, the economic value of inputs and outputs is discussed as much as possible. Prices are given in Egyptian pounds (LE, 1 LE = 1.20 US$, according to the official rate, February 1987, but 1.69 US$ according to the Bedouin estimate).

As the coastal zone is not homogeneous, pilot regions were distinguished by FAO (1970a), who carried out an extensive project in the sixties. However, as the number of animals has doubled since then, most of their data are considered obsolete. Therefore, four new regions are distinguished (Figure 1), based on differences in climatic conditions. The four regions are:

1. The area between Burg el Arab and El Alamein, the "Burg el Arab region".

By means of the soil reconnaissance maps of FAO (1970b) the total area is estimated at 174 750 ha, of which the rangeland (ARL, not suitable for barley, figs or olives) occupies an estimated 113 120 ha. If the area between the barley fields (ARLBBF) is included, assuming that barley fields receive 250 mm infiltration (van de Ven, 1986; 1987a), the total rangeland area comprises 127 560 ha.

2. The area between El Alamein and Fuka, the "Dabaa region".

The total area, rangeland area and rangeland area including the rangeland between the barley fields, is estimated at 270 080, 222 280 and 254 640 ha, respectively.

3. The area between Fuka and Negeila, the "Matruh region".

The total area, rangeland area and rangeland area including the rangeland between the barley fields, is estimated at 380 140, 322 300 and 355 900 ha, respectively.

4. The area between Negeila and Salloum, the "Barrani region".

The total area, rangeland area and rangeland area including the rangeland between the barley fields, is estimated at 430 500, 393 910 and 411 640 ha, respectively.

This report is partly based on earlier reports (van Duivenbooden, 1985a; 1985b), while information is obtained from reports and articles written by among others:

- FAO, Rome.
- Aboul-Naga et al., Animal Research Institute, Cairo.
- El Naga et al., Dept. of Animal Production, Fac. of Agriculture, University of Alexandria.
- Ayyad et al., Dept. of Botany, Fac. of Science, University of Alexandria.
- SAMDENE and REMDENE staff members (SAMDENE = System Analysis of Mediterranean Desert Ecosystems of Northern Egypt, REMDENE = Regional Environmental Management of Desert Ecosystems in Northern Egypt).

In addition, comments on the paper presented at the workshop "R and D planning: an interactive approach. Land use planning in the Mariut region, Egypt" are included (van Duivenbooden, 1987).

CHAPTER 2.

FLOCK CHARACTERISTICS

2.1 General description

Generally, a flock consists of sheep and goats, but according to Aboul-Naga (Aboul-Naga et al., 1985a; Aboul-Naga, 1987) some flocks (14%) comprise either sheep or goats only, while some Bedouin rear camels only.

Although socio-economic conditions have changed, the size of the flock is still an indicator of the wealth and social status among the Bedouin and sheep are the dominant animal as a source for cash (Aboul-Naga, 1987). In the coastal zone stock numbers are high (Table 1), because of a high demand for animal products especially meat for export to Arab Gulf countries and for local consumption. Animal rearing is further stimulated by the government policy to provide subsidised supplements (Section 4.5).

2.2 Total sheep and goat population

The data presented in Table 1 may be too high, as the Bedouin tend to exaggerate the number of animals in their flocks to obtain larger quantities of subsidised supplements (Aboul-Naga et al., 1985a; El Naga pers. comm., 1984). For calculations performed in this study the total sheep and goat population (TNUSG) is estimated at 1.46 million head.

It can be deduced from Table 1 that stock numbers have about tripled in the last twenty years and are still increasing. The actual herd increase rate is assumed to be equal to that calculated from Table 1 in the period from 1978 to 1984: 1.8% yr^{-1}.

The distribution of the total population of sheep and goats in the coastal zone among the Burg el Arab, the Dabaa, the Matruh and the Barrani regions, expressed as a fraction of the total sheep and goat population (FLD) was in 1967, 0.19, 0.11, 0.38, and 0.32, respectively (FAO, 1970c). However, this distribution has changed since then. Aboul-Naga (1983) reports that the population in the Matruh and the Barrani regions together is 65% of the total population. Furthermore, the Burg el Arab region, including the area near El Hammam, is another relatively densely populated area. Since increasing alternative activities (tourism) take place in the Matruh region, less labour is available for agriculture, and hence it is likely that in that region the sheep and goat population has decreased. Accordingly, the distribution among the Burg el Arab, the Dabaa, the Matruh and the Barrani regions is for preliminary calculations set arbitrarily at 0.20, 0.15, 0.34 and 0.31, respectively. As that distribution is rather important for feed availability in the region, the assumption will be further discussed in Chapter 6.

2.3 Flock size

The flock size (FLS) is also spatially heterogeneous, as estimates show an average flock size ranging from 40 to 200 head in the Burg el Arab region (Abdel Salam et al., 1985), and for the other three regions from 20 to about 1500 head (Aboul-Naga, 1987), with an average flock size of 280 head in the Dabaa region and 250 head in the Matruh region (Table 2, Aboul-Naga et al., 1985a). Generally, the most frequently observed flock size in those regions is about 50 goats and 100-150 sheep, with a tendency among breeders to enlarge their flocks (ALAP, 1986). The flock size averaged over the Dabaa and the Matruh regions is 260 head, consisting of 190 head of sheep and 70 head of goats (Aboul-Naga et al., 1985a). For the Burg el Arab and the Barrani regions the average flock size is set arbitrarily at 150 and 260 head, respectively. The average flock size for the coastal zone is set at 230 head. Unfortunately, no data are available on the number of flocks per region.

The size of the flock being shepherded (FLSSH) differs from that owned by the Bedouin. The former characteristic is discussed in Subsection 5.3.1.

Table 2. Distribution of flock size (in %) in the Dabaa and the Matruh regions (Aboul-Naga et al., 1985a).

	NUMBER OF HEAD PER FLOCK						
ANIMAL TYPE	0-49	50-99	100-150	151-199	200-299	300	Total
SHEEP	16	21	23	9	12	19	100
GOATS	54	25	13	4	4	0	100

2.4 Flock structure

The structure of the flock is characterized both by its age distribution and by the ratio of sheep to goats.

Table 3 shows the age distribution of the flock before the lambing period (July 1967) and in spring (1984) after lambing. It should, however, be realized that such an age distribution may show strong short-term fluctuations. Nevertheless, from that table, especially from the percentage of female yearlings, it can be deduced that at present, in contrast to 18 years ago, a tendency exists to keep young lambs and kids for late fattening or for increase in the breeding stock as suggested earlier. In the present situation this breeding policy is very likely, as supplementary feed supply is not a constraint and mutton prices are extremely high (see Paragraphs 3.1.7.1 and 3.2.7.1).

The ratio of sheep to goats in the flock has changed from 2.7:1 (1965) to about 4:1 in 1978-1984 (Table 1). However, pilot studies by Aboul-Naga et al. (1985a) show that in the Dabaa and the Matruh regions the ratio dropped again to a value of 2.7:1, probably due to an increased preference for goat meat by Arab Gulf countries and by local farmers. Furthermore, the ratio depends on the flock size (Table 4).

Thus, for the average flock size, applying the data of Aboul-Naga et al. (1985a), the average fraction of sheep in the herd (FLFS1) is 0.73. That fraction is subsequently converted to a function based on ewe equivalents (FLFS2) (Section 2.5).

Table 3. Structure of some flocks and fattening groups according to age catagories (in %). S = suckling, W = weaned lambs or kids (a = FAO, 1970c; b = Aboul-Naga et al., 1985a).

ANIMAL	MALES	FEMALE		AGE OF GROWN FEMALES (years)						
		S	W	1	2	3	4	5	5	ref
SHEEP										
BREEDING										
(July)	12.2	17.6			17.0	16.5	13.3	12.2	11.2	a
(spring)	1.2	16.9	32.2	8.9	---------40.8---------------					b
FATTENING										
(July)					1	4	9	20	66	a
GOATS										
BREEDING										
(July)	23	30			8.5	8.5	8.5	8.5	13	a
(spring)	1.1	13.7	36.1	10.1	---------39.0---------------					b

Table 4. Frequency distribution of flock size and percentage of goats in 195 flocks in the Dabaa, the Matruh and the Barrani region (adapted from Aboul-Naga, 1987).

PERC.	FLOCK SIZE								
GOATS	SMALL		MEDIUM		LARGE				TOTAL
	1-50	51-100	101-200	201-300	301-500	501-700	701-1000	1000	
0	4.1	2.6	1.5	0.5					8.7
1- 20		2.6	6.7	7.2	7.7	3.1	3.1	0.5	30.9
21- 40	1.5	5.1	11.8	9.2	6.7	3.1	3.1	0.5	41.8
41- 60	1.0	2.1	3.1	2.6	1.0	1.0	0.5		11.3
61-100	0.5	1.0	1.0						2.5
100	4.1	1.0	0.5						5.6
TOTAL	11.3	14.3	24.6	19.5	15.4	7.8	6.7	1.0	100

2.5 'Average' animal

To account for the various animal species present in the northwestern coastal zone, an 'average' animal must be defined, designated here as the 'ewe equivalent' (EE). One ewe equivalent represents one ewe + one lamb up to 3 months old + 1/5 yearling ewe + 1/25 ram, equivalent to 1.5 mature sheep, weighing about 60 kg with a feed requirement of 450 FU yr^{-1} (Le Houérou and Hoste, 1977). Furthermore, one mature sheep, is equivalent to 1.2 goat, 0.3 donkey, 0.1 camel or 0.2 head of cattle. The conversion factor for sheep (SEECF), goats (GEECF), donkeys (DEECF), camels (CAEECF) and cattle (CTEECF) is 1.5, 1.8, 0.45, 0.15, 0.30 head EE^{-1}, respectively. The total number of ewe equivalents (TEE) is the sum of sheep, goats, donkeys, camels and cattle (all expressed in EE).

Since flock structure is given per head (Table 1) which changes in the course of the year (Table 3) and the moment when total head number was recorded is not known, it is difficult to calculate accurately the number of sheep and goats expressed in ewe equivalents. Estimates of those numbers are based on the relationship between weight and feed requirements applying the data of Aboul-Naga et al. (1985a). Since one mature sheep requires 300 FU yr^{-1} and the feed requirements are proportional to liveweight to the power 0.75 (ARC, 1980), the requirements for a weaned lamb are $(22^{0.75}/40^{0.75}) * 300 = 190$ FU yr^{-1}. The same procedure is applied to the other age categories, and subsequently, the weighted average is calculated. That calculation results in a feed requirement of 247 FU $head^{-1}$ yr^{-1}, hence one average head in the herd equals 0.55 EE. Similarly, one average goat in the herd represents 0.43 EE.

2.6 Flock movement

Two periods with different flock movements are distinguished:

- grazing in winter and spring (green grazing period (PGG) and early dry grazing period (PED))
- summer grazing (main dry period (PMD)).

Generally, the flock, accompanied by shepherds, moves in winter to the south, i.e. land inwards. Grazing in winter and spring takes place in this inland marginal area (from 10-25 km up to 50 km land inward), but that is only possible if the moisture content of the forage is high, so that water availability is not limiting dry matter intake. The distance covered by the animals in this period is about 6 to 8 km per day (Aboul-Naga, pers. comm., 1985). Aboul-Naga (1987) reports a distance covered of 10 to 15 km d^{-1}, but the period to which this refers is not specified. Arbitrarily, for the winter period a distance covered of 7 km is applied.

In the course of spring the flock moves back to the coastal strip (region up to 10-25 km land inward), where water and supplements are provided in summer and autumn.

The animals walk in summer in some regions about 10 to 15 km per day in one direction. Subsequently, they walk back for 1.5 to 2 days to the well or water tap and after watering they move again, but in another direction (El Naga, pers. comm., 1985). For the summer period a distance of 12 km d^{-1} is applied.

In addition, about one third of the pastoralists are on the move in summer and autumn for periods of up to three months seeking better pasture (Aboul-Naga et al., 1985a). In the Dabaa and the Burg el Arab regions the Bedouin move their animals on foot or by pick-up trucks to the irrigated areas (Burg el Arab, Alexandria and Nile delta), whereas in the Matruh region they move them westwards to the Barrani region, where precipitation is higher, and hence forage availability is more abundant (Aboul-Naga et al., 1985a; ALAP, 1986). In dry years this large-scale flock movement may involve more than 10% of the total population (Ghabbour, 1983). Mainly the large flocks are involved in the movement to areas outside the coastal zone in drought years, and of these flocks predominantly the older sheep. Older sheep are transported only, probably because the conditions in the Delta (e.g. higher humidity) adversely affect the pre-weaning and post-weaning growth of Barki lambs (Aboul-Naga, 1977). The very small flocks usually do not participate even in the above described small distance movements, but remain in the vicinity of the place of settlement. Medium-sized flocks are often combined to form large flocks for short distance movements.

It must, however, be realized that no one, except the Bedouin himself, knows the exact number of animals in the flock, and the place where they are grazing. Therefore, no large-scale flock movements are included in the calculations performed.

2.7 Stocking rate

An important characteristic of animal production systems is the stocking rate (animals ha^{-1}). As the area actually grazed and the number of animals are both difficult to estimate due to flock movements (Section 2.6), the stocking rate, if reported at all, is highly variable both in time and space. The stocking rate averaged over the whole year in the Burg el Arab region is reported by various authors and varies between 0.75 head ha^{-1} (Henady, 1986) and 1 to 1.5 head ha^{-1} (El Kadi, 1983). Van Duivenbooden (1985b), however, estimated a stocking rate in the El Omayed area in summer of 1.2 head ha^{-1} when the greater part of the flock was outside the region. As the total rangeland area of the coastal zone including the area between the barley fields is about 1.15 million hectares (Chapter 1), the average stocking rate on the rangeland in the zone is about 1.3 head ha^{-1} as far as sheep and goats are concerned only. Applying the distribution of sheep and goats among the regions, the stocking rates in the Burg el Arab, the Dabaa, the Matruh and the Barrani regions are 2.3, 0.9, 1.4, and 1.1 head ha^{-1}, respectively.

Taking into account the other animals (donkeys and camels), the stocking rate expressed in ewe equivalents per hectare (STRRL), in the Burg el Arab, the Dabaa, the Matruh and the Barrani regions is, 1.8, 0.7, 1.4 and 1.1 EE ha^{-1}, respectively. As the stocking rate in the coastal zone is on average 0.7 EE ha^{-1}, the stocking rate in the Burg el Arab region seems rather high (see also Chapter 6).

2.8 Flock grazing time

Time spent on grazing varies in the course of the year and between sheep and goats, as shown in Table 5. Moreover, it is suggested that the botanical composition of the rangeland and forage availability have some influence on the grazing pattern of the animals (Abdel Salam, 1985). On the other hand, lambs are kept during fattening in open sheds near the pastoralist's household (Aboul-Naga et al., 1985a).

The resting period for grazing animals is 2 hours at noon during winter, 4 hours starting 11 am during spring and 5 hours starting 11 am during both summer and autumn (Abdel-Razik et al., 1986). Accordingly, for the green grazing period and the early dry period the resting time is on average 2.8 h d^{-1}, and for the main dry period 5 h d^{-1}.

Generally speaking, in intermediate systems the animals graze 4 hours a day from November through April and 3 hours from May through October (Table 5). The total grazing time (walking, grazing and resting) (HRGRW) amounts then to 7 h d^{-1} in the green grazing period and the early dry period, and to 8 h d^{-1} in the main dry period (HRGRS).

In addition to the time spent on grazing, the moment at which it occurs is of importance, e.g. the animals are allowed to graze during the night in summer to reduce the heat stress, and give them access to plants covered with dew.

As no data are available, walking speed is estimated, based on the distances covered given in Section 2.6 and the total grazing time. Accordingly, the walking speed of the animals in intermediate systems in summer and in winter is 1.5 and 1.0 km h^{-1}, respectively. These walking speeds are set constant for all systems, in contrast to the total grazing time. For extensive systems the total grazing time in summer (HRGRS) is set at 9.0 h d^{-1} and in winter (HRGRW) at 8.0 h d^{-1}. For intensive systems these values are 4.0 and 6.0 h d^{-1}, respectively.

Table 5. Grazing time (h d^{-1}) of sheep and goats in El Omayed under present circumstances (Abdel Salam, 1985).

	GRAZING TIME	
	SHEEP	GOATS
1979-1980		
May	3.3	3.1
June	3.0	3.0
July	3.0	2.5
August	3.3	2.8
September	2.8	2.4
1980-1981		
October	3.1	2.5
average	2.9	
November	4.4	4.6
December	4.3	5.1
January	4.5	5.1
February	4.5	5.0
March	3.6	3.4
April	3.4	3.4
average	4.3	

CHAPTER 3.

ANIMAL CHARACTERISTICS

The productivity of animal husbandry systems is to a certain extent determined by the characteristics of the animals. In this chapter the characteristics of the animal breeds prevailing in the northwestern coastal zone are discussed in some detail.

3.1 Sheep

3.1.1 General description

The predominant breed in the northwestern coastal zone is the Barki, belonging to the Barbary sheep of northern Africa. As Barbary sheep were introduced in Egypt and north Africa centuries ago, the breed can be considered native to its present habitat (Devendra and McLeroy, 1982). The breed shows a marked ability to survive in the arid and semi-arid region on scarce vegetation and water resources, and is generally considered to be well adapted to the climatic conditions prevailing in the northwestern coastal zone, especially the hot, dry summer (Shehata and Kawashti, 1966; Aboul-Naga, 1983). Under improved conditions such as in the Nile delta hardly any improvements in its performance were observed (Aboul-Naga and Aboul-Ela, 1985a).

The Barki is the lightest and smallest animal compared to the other Egyptian breeds, Ossimi (occurring near Cairo and along the lower Nile), Rahmani (occurring in the Baheira province and NW of the Nile delta), Fellahi (Nile delta), Ibeidi and Saidi (Upper Egypt). Body conformation is characterized by a small head carried on a long neck, and long legs carrying a small body with a narrow back (Mason, 1967; Aboul-Naga, 1983). The tail, not excessively fat, is of normal length, and does not extend below the hocks (Aboul-Naga, 1983). Usually it has an S-shaped or sigmoid flexure and is buried in a mass of fat, except for the tip which most often hangs free. The tail serves as a temporary storage site for excess mobile fat permitting the animals to endure long periods of semi-starvation without apparent harm. The colour of the body parts covered with fleece is mainly white, while the uncovered parts of the face and legs are pigmented uniformly or in patches, often resulting in large rings around the eyes. The fraction of purely white animals in the flock is very small (1%), while the basic colour of the pigmented area is 56% black, 33% brown and 10% intermediate (FAO, 1970c).

The rams of the breed are mainly horned, whereas about 13% of the females were found to have strong, and 12% rudimental, horns.

Figure 3. A group of Barki ewes in the northwestern coastal zone.

3.1.2 Breeding

The number of rams per flock varies strongly with flock size. Some of the small flocks are served by only one ram, while in some large flocks there may be as many as 25 (Aboul-Naga et al., 1985a). In contrast to this observation is the statement that the ewe to ram ratio (SERR) in large flocks (exceeding 200 head) may be as high as 62:1 (Aboul-Naga et al., 1985a). Generally, the ratio varies from 40:1 (Soliman, 1983) to 44:1 (Aboul-Naga et al., 1985a). In this study a ratio of 42:1 is applied.

As rams are kept in the flock all year round, mating and consequently, lambing may take place throughout the year. It also allows for the possibility of lambing twice a year.

Although the lambing periods are long, for instance from August till December, two peak lambing periods can be distinguished: November and May (Aboul-Naga et al., 1985a; ALAP, 1986). Recent studies, however, show that lambing occurs in October and March (Aboul-Naga, 1987; Mansour, pers. comm., 1987). Accordingly, the latter two periods are used in this study.

The total feed requirements in the course of the year (Subsection 3.1.8) are partly a function of the ratio of lambs born in March to those born in October. Data on that ratio under rangeland conditions, however, are not available. Experiments in a more intensive system (3 crops $(2\ yr)^{-1}$, Aboul-Naga and Aboul-Ela, 1985a) showed that autumn mating resulted in a better performance than mating in January and May. Furthermore, the percentage of ewes in oestrus was the highest in August and October, while the lowest values were recorded in spring (Younis, quoted by Aboul-Naga and Aboul-Ela, 1985a). Another factor is the number of days needed for conception, which was significantly higher in May than in January and September. January mating also results in higher lamb losses due to higher ambient temperatures during the lambing period (June-July, Aboul-Naga and Aboul-Ela, 1985a). Arbitrarily, the ratio of lambs born in March to those born in October is set to 0.4:0.6 in this study under the present rangeland conditions. It is likely that in extensive systems less lambs are born in summer, consequently the ratio for those systems is set to 0.35:0.65.

The fraction of ewes that lambs twice a year in the Burg el Arab region is estimated at 0.27 (Soliman, 1983), but it is expected that the following year they lamb only once. That means that 54% of all ewes lamb three times in two successive years. This fraction seems relatively high considering the relatively poor quality of rangeland forage (Chapter 4). It is probably the result of the supplementation with high quality feed. For preliminary calculations it is assumed that in intermediate systems 45% of all ewes lamb three times in two successive years (SFLAMT) and for extensive and intensive systems a value of 0% and 100%, respectively is applied. To calculate the number of lambs born in one year in such a lambing system is thus half the value of SFLAMT (SFLBT) times the corresponding net lambing rate. Hence, the fraction of ewes that give birth once a year is 1-SFLBT.

In more intensive systems lambing takes place in February, October and June (Aboul-Naga et al., 1981). These periods are applied if three lambings in two successive years occur. Next, it is assumed that in that lambing system, no difference can be made in the distribution of lambs born between the three periods of lambing.

3.1.3 Selection and breed improvement

Almost all breeders select rams from their own flock but some breeders in the Matruh region use rams from other flocks. Selection is mainly based on the ram's own phenotypic performance, particularly body size and wool characteristics. In addition, ewe performance, face color and shape of horns, are criteria for ram selection. Criteria to select ewes are the ewe's condition and prolificacy.

Crossing with German Mutton Merino showed no advantage under desert conditions. The first generation showed better performance, but that disappeared in the back-cross to Merino. Crossing with Hungarian Merino resulted in improved wool yield (heavier fleeces of finer fibre and less kemp), but also in higher variability in fiber quality (Ghanem, 1965). Recently, Barki sheep have been crossed with Finn Landrace ewes, but no data on performance of the offspring are available yet (Aboul-Naga and Aboul-Ela, 1985b). Even crossing with Hungarian Merinos with a feedlot management system did not show differences in weight gain between the crosses (Salah et al., 1971). From these experiments it is concluded that under the present conditions and management system, improvement of the productivity of Barki sheep by crossing with other breeds is not feasible.

3.1.4 Productivity

Sheep productivity, the number of hoggets reared per year is expressed by the maximum sheep-herd increase rate (SHPIR), based on the net lambing rate (SNLAMR).

The net lambing rate or weaning rate is a function of breed, management intensity and fertility of the ewe, and expresssed as lambs weaned per ewe available for mating (Gatenby, 1986). It is assumed in this study that all ewes have mated. The net lambing rate is the gross lambing rate (prolificacy multiplied by fertility) minus the pre-weaning mortality rate (LPWPR, Subsection 3.1.6). It is assumed that abortion has already been included in the gross lambing rate, as the observations refer to the number of live lambs per ewe. The incidence of abortion is on average 7 to 8% (Aboul-Naga et al., 1985a).

Prolificacy (litter size, live lambs born per ewe lambed) of Barki sheep seems to be spatially heterogeneous: In the Dabaa region the average is 1.13 lambs ewe^{-1}, while in the Matruh region 1.07 is observed (Aboul-Naga et al., 1985a). Consequently, the average twinning rate is about 10%, which is high compared to other data, i.e. 2 to 5% (Aboul-Naga and Aboul-Ela, 1985a), 5% (Mason, 1967) and 3% Osman (1985). As for the other regions no data are available an average litter size of 1.1 lamb ewe^{-1} is applied for all regions.

In more intensive systems litter size increases with only 2% (Aboul-Naga and Aboul-Ela, 1985a). No data are available for extensive systems. Hence, a litter size of 1.1 lamb ewe^{-1} is applied for all systems. The number of lambs per average ewe in the flock per year (SLS) is then the weighted average of the number of lambs produced by ewes lambing once per year and those produced by ewes lambing three times in two years.

Ewe fertility represents the conception rate (SCONR), the ratio of number of ewes lambing to number of ewes joined. The reported values of the conception rate of Barki sheep vary. Aboul-Naga et al. (1985a) reported a value of 0.84 in the Matruh region and 0.92 in the Dabaa region, whereas Mokhatr et al. (1983) obtained in two experiments under farm conditions average values of 0.84 and 0.86, and FAO (1970e) reported a value of only 0.70. Shearing and shading have effects on the conception rate: Mokhatr et al. (1983) recorded conception rates for shorn shaded, shorn unshaded, unshorn shaded and unshorn unshaded ewes of 1.00, 0.91, 0.73 and 0.70, respectively. Hence, the effect of shearing appeared to be significant. Makhatr et al. (1983) concluded that under desert conditions the effect of heat stress on fertility of ewes is of such a low magnitude that it is not a determinant factor for the relatively poor performance. Hence, other factors than temperature are determinant, which seems to be confirmed by results of experiments carried out by Ghanem and Farid (1982a) showing that Vitamin A supplementation resulted in a higher reproductive performance. As a compromise, a value of 0.88 (average of Aboul-Naga's data) seems an appropriate estimate for the conception rate under rangeland conditions for all regions.

In more intensive systems, however, the conception rate decreases to 0.71 (Aboul-Naga and Aboul-Ela, 1985a), nevertheless total annual litter size increased by 23% compared to one crop per year. It is assumed in this study that in intensive systems all measures necessary are taken to obtain a conception rate of 1.0. In extensive systems it is expected that total annual litter size is less than in the intermediate systems. As litter size is assumed to be equal for all systems, the conception rate is reduced, and set arbitrarily at 0.7.

Maxium sheep-herd increase rate is also determined by the replacement rate (SREPR). This rate is the sum of the culling rate (SCULR) and the death rate of ewes older than one year (SMR, Subsection 3.1.6). In the sixties ewes were used for reproduction on average for 5 breeding seasons (FAO, 1970e), more or less equal to an age of 6 years (FAO, 1970d). At present the average age at which ewes are culled is 6 years (Soliman, 1983) to 8.7 years (Aboul-Naga et al., 1985a). The fraction being culled is 0.09 of old ewes (Aboul Naga et al., 1985a), although differences related to flock size were observed. In the Dabaa region, for instance, the culling rate of old ewes in large flocks is markedly lower than in small flocks, 0.06 versus 0.14. In addition, yearling ewes are culled, the average relative fraction being 0.23 (Aboul-Naga et al., 1985a) which is more or less equal to 0.06 yearling per old ewe per year. In this study the sum of both culling rates, 0.15 is applied for intermediate systems in all regions.

In intensive systems the culling rate may increase to 0.25 ewe ewe^{-1} yr^{-1} (Seligman, pers. comm., 1985), but a value of 0.20 is used for preliminary calculations. In extensive systems where it may be expected that less ewes are culled, an arbitrary value of 0.15 ewe ewe^{-1} yr^{-1} is applied.

However, not all lambs contribute to herd increase, as only female lambs can be used for breeding. The fraction of female lambs (SFFL), generally obtained (0.5) is applied in this study. In addition, not all female lambs are suitable for breeding. This has been taken into account by defining a selection factor (SFFLK) for which in this study a value is assumed of 0.8 in intermediate systems, 0.9 in extensive systems and 1.0 in intensive systems. In the latter systems the female lambs that are not suitable for breeding are fattened before sale.

Applying the preceding values, the potential sheep-herd increase rate in the Matruh region is calculated as 0.15 hogget ewe^{-1} yr^{-1}. That seems a relatively high value compared to the actual increase rate of the total sheep population of 2% yr^{-1} in the last 5 years (Table 2), but it is in agreement with the tendency among the Bedouin to increase their flock size (Aboul-Naga et al., 1985a). Evidently, the estimate of the replacement rate is crucial, but at present no better estimate can be made.

3.1.5 Weights and growth rates

Birth weight of lambs (LBIRW) is about 2.6 kg (Aboul-Naga, 1983), increasing to 3.2 kg under improved conditions (Aboul-Naga, 1977). For extensive systems the birth weight is set arbitrarily at 2.4 kg.

Lambs are weaned at an age of 3.6 months (110 days) at weaning weights (LWEANW) becomes 18 to 22 kg (Mason, 1967; Salah et al., 1971) up to 20 to 25 kg (Aboul-Naga et al., 1985a; Aboul-Naga and Aboul-Ela, 1985a). In this study no differentiation is made between weaning weights of male and female lambs, a value of 22 kg being adopted for intermediate systems, and 21 kg for extensive systems. For more intensive systems (3 crops $(2\ yr)^{-1}$) a lower weaning weight of 18.2 kg is reported (Aboul-Naga and Aboul-Ela, 1985a). That value is applied if 100% of the ewes lamb three times in two successive years.

The weight of a yearling is estimated at about 30 kg (Mason, 1967; FAO, 1970c), whereas a value of 36.8 kg is reported under improved conditions (Aboul-Naga, 1977). Applying reported growth rates for the period of weaning to one year, lamb yearling weight (LHOGW) is calculated as 35 kg. Because the growth rate in extensive sytems is expected to be somewhat lower than in intermediate systems, the weaning weight for these systems is set at 32 kg. On the other hand, in intensive systems a yearling weight of 40 kg seems likely, due to a higher growth rate.

The weights of saleable lambs (LSALEW) and fattened ewes (SFATW) are treated in Paragraph 3.1.7.1. Feeding level determines final body weight as shown in Figure 4. Compared with other data, the 100% feeding level in this figure probably corresponds with an improved breeding system.

The weight of mature ewes ranges from 35 to 50 kg (at the end of pregnancy) (Mason, 1967; Abdel Salam, 1985; Aboul-Naga; pers. comm., 1986). A mature liveweight (SMLW) of 40 kg is applied in this study under present conditions, whereas for extensive and intensive systems a weight is applied of 38 and 42 kg, respectively.

The weight of the rams (SRAMW) ranges from 45 (FAO, 1970c) to 70 kg (Mason, 1967). For extensive, intermediate and intensive systems this weight is set arbitrarily at 48, 57 and 66 kg, respectively.

Measured growth rates of lambs till weaning vary between 0.080 and 0.100 kg d^{-1} (Abdel Salam et al., 1985) which is rather low compared to the growth rate derived from the difference between weaning weight and birth weight, and the estimated time lapse between these moments, 0.18 kg d^{-1}. Accordingly, the latter value is applied for intermediate systems. For intensive systems a growth rate of 0.25 kg d^{-1} is applied.

Measured growth rates after weaning are reported at 0.05-0.07 kg d^{-1} (Abdel Salam et al., 1985), which is relatively high, compared to reported values of as based on the weight difference between weaning weight and yearling weight (30 kg). Applying those values results in a growth rate of 0.03 kg d^{-1}. Sharafeldin et al. (1968) report still higher growth rates and differences between male and female lambs and among lambs born to ewes with different lambing frequencies. However, those values are not quoted here as the lambs were weaned at an age of 2.5 months and probably fed with concentrates. Considering all these data, a growth rate of 0.05 kg d^{-1} is applied in this study.

The growth rate of lambs during fattening on grains and roughages may reach 0.176 kg d^{-1} (Aboul-Naga et al., 1985a; Aboul-Naga, 1987), but calculated from the differences in weight before and after fattening and the lenght of the fattening period in the first article, an average value of 0.152 kg d^{-1} is obtained. When fattened from 6 to 10 months of age the growth rate ranges from 0.090 to 0.127 kg d^{-1} (Aboul-Naga and Aboul-Ela, 1985a). In other experiments growth rates of local breeds (Rahmani, Ossimi and Barki) of up to 0.204 kg d^{-1} were obtained (Table 6) (Aboul-Naga and Aboul-Ela, 1985a). When fed agricultural by-products lambs exhibited growth rates between 0.125 and 0.137 kg d^{-1} (Mohammed et al., 1971), and when fed concentrates, berseem hay and straw values of up to 0.200 kg d^{-1} were measured (Salah et al., 1971). Considering all these data, a growth rate of 0.16 kg d^{-1} is applied for present conditions and 0.2 kg d^{-1} for feedlot fattening.

Very few data are available on growth rates of yearlings and mature ewes. Growth rates of yearlings during fattening may reach values as high as 0.200 kg d^{-1} (improved conditions, Table 6). Under conditions when sheep are properly fed a growth rate of about 0.110 kg d^{-1} seems likely (Figure 4).

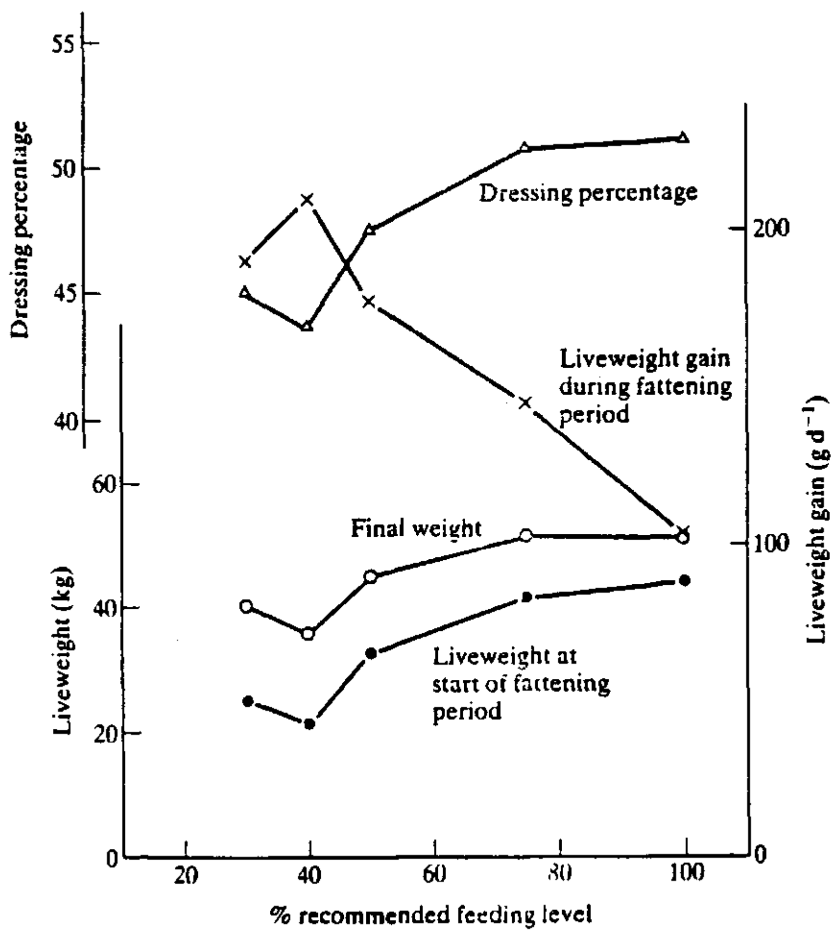


Figure 4. The effect of feeding level on the performance of Barki sheep of 7 to 20 months of age during a subsequent 70-day fattening period (Younis, quoted by Gatenby, 1986).

Table 6. Fattening and carcass performance of local lambs (Rahmani, Ossimi and Barki) under different systems of fattening. FWT = Final weight (kg), ADGR = Average daily growth rate (kg d^{-1}), EFF = Feed conversion efficiency (FU kg^{-1} gain), IFAT = Internal fat (kg), TWT = Tail weight (kg), FCAR = fat % in carcass, period in weeks and age is age in weeks when fattening starts (Aboul-Naga and Aboul-Ela, 1985a).

FATTENING SYSTEM period	age	FWT	ADGR	EFF	IFAT	TWT	FCAR
8	16	29.8	0.168	4.10	0.203	1.833	17.50
8	24	39.1	0.179	4.29	0.263	2.847	20.40
4	32	47.7	0.197	4.11	0.348	4.413	24.70
8	32	54.2	0.204	4.36	0.294	5.496	25.60

3.1.6 Diseases and mortality

One factor reducing the productivity of the animals is the occurrence of diseases. In addition, animal performance may be reduced due to toxicity or deficiency of minerals, which will be dealt with later (Subsection 4.1.2).

The responsability for the herd lies with the Bedouin owner himself or a herdsman. They have a good knowledge of the various plant species and know which of those are best for sheep and goats to eat. However, except for some common diseases, they are not aware of other occurring pests. In addition, the Bedouin are generally not convinced of the beneficial effect of using vaccins. In Table 7 incidence and degree of infestation with some common diseases which occur in three of the regions are given. For the Barrani region no data are available. Shehata (1982) reports incidence of some other (arabic-named) diseases, but degree of infestation is not quantified. Mouth infections are the most common diseases for lambs and kids (Aboul-Naga et al., 1985a). The occurence of calcium deficiency in the Dabaa and the Matruh regions is striking, as the soils are generally calcarious and the vegetation has a high calcium content (Abdel Salam, 1985).

Coughing of sheep and goats is reported in the Burg el Arab region (El Naga, 1981; 1984; Abdel Salam et al., 1985). Since ruminants require no Vitamin C, it was speculated by El Naga that Vitamin A deficiency was the main cause of this infection. Other possible causes could be respiratory problems or longworms, but no further information is available. Ghanem and Farid (1982a) reported that Vitamin A deficiency is not an uncommon problem especially among freshly weaned lambs which seem to suffer most, showing reduced growth rates and increased mortality. Vitamin A supplementation increased growth rates as reported by Abdel Salam et al. (1985).

Table 7. Incidence of common diseases (% of all flocks) in the Dabaa and the Matruh regions (Aboul-Naga et al., 1985a), ? = occurring in the Burg el Arab region, but no information available on degree of infestation (Shehata, 1982).

Disease	Burg el Arab	Dabaa	Matruh
Diarrhoea	?	3	10
Mouth infection	?	45	34
Calcium deficiency		18	32
Pseudotuberculosis		41	41
Internal parasites		5	19
External parasites		6	-

Three main periods during which death occurs can be distinguished:

1. Pre-weaning period.

Lamb losses from birth to weaning are mainly caused by enteritis (40%) and pneumonia (33%) (Aboul-Naga and Aboul-Ela, 1985a). This pre-weaning mortality rate (LPWMR) ranges from 5.4% (Aboul-Naga et al., 1985a) to 8.1% of the lambs born (Aboul-Naga et al., 1985a; Osman, 1985). An average value of 7% is used in this study. Multiplying that value with the conception rate and the litter size yields the number of lambs dying per ewe joined.

The death rate in more intensive systems (3 crops $(2\ yr)^{-1}$) is more or less the same (Aboul-Naga and Aboul-Ela, 1985a).

2. Post-weaning period till 12 months of age.

In contrast to what is assumed in the PSG (Seligman and Spharim, 1987), mortality after weaning cannot be neglected in the northwestern coastal zone. The death rate after weaning until 12 months of age (LAWMR) is still relatively high: 12.4% of the lambs born (Aboul-Naga and Aboul-Ela, 1985a). It is assumed that this death rate is sex-independent and it is set at 12% of the lambs born.

3. After 12 months of age.

The mortality rate of mature sheep due to diseases or other causes is unknown, although Abdel-Salam et al. (1985) report a mortality rate of 25 to 50% of the flock in some summer seasons. Nevertheless, ewe mortality rate (SMR, ewe ewe^{-1} yr^{-1}) in ARID ANIMAL is calculated similarly to that in the PSG (Seligman and Spharim, 1987). Applying the data given before, the ewe mortality rate is calculated as 0.04, which is of the same magnitude (0.027-0.05) as obtained by FAO (1970c; 1970d).

For extensive systems it is assumed that the animal receive less veterinary care, and consequently, death rates are higher. The increase is estimated at 10% for all periods. Assuming that Vitamin A is supplied in intensive systems, resulting in reduced death rates. It is assumed that this reduction is 30%, for all periods. Both adaptations for those systems have been taken into account in the model by SCF1.

3.1.7 Outputs

3.1.7.1 Mutton

The output of the herd, saleable lambs, is a function of ewe prolificacy and target saleweight. The actual amount available for sale depends on whether herd size is increasing or stable, and consequently, on whether lambs are grown to hoggets or sold for meat, which in turn depends on feed availability. In this study the annual quantity of saleable liveweight (MUTTON) is calculated assuming that the herd is increasing at its potential rate (SHPIR).

Generally, lambs are sold at weaning (SLWP1) or after fattening (SLWP2). However, the actual number of sales and timing of the sale are difficult to obtain, as illustrated by the following data: at weaning 37% of the all Bedouin sell female lambs, while 14% of them sell at older age and 81% of them retain female lambs for breeding. For male lambs these figures are: 50 to 69, 43 to 54 and 30 to 44%, respectively (Aboul-Naga et al., 1985a). Therefore, these characteristics had to be estimated. For intermediate systems it is assumed that 60% of the male (SFMLW) and 10% of the female lambs (SFFLS/2) are sold at weaning, and the remainder of the male (SFMLF) and another 10% of the female lambs (SFFLS/2) at older age (after fattening). The remaining 80% of female lambs are kept for breeding and replacement of old non-fertile animals, or as a capital stock for difficult times. In extensive systems more male lambs are sold at weaning (80%), and in intensive systems none. In addition, in extensive systems less female lambs are sold due to a lower selection fraction. For those systems the fraction sold at weaning is set at 5% and at 5% after weaning. In intensive systems all female lambs are retained.

Usually, lambs are fattened at an advanced age, the common marketing age being close to yearling at a weight of 40 to 45 kg (Aboul-Naga and Aboul-Ela, 1985a). Male lambs fattened for a period of 3.5 months (range 3 to 7 months) reach a body weight of 39 to 44 kg at marketing (Aboul-Naga et al., 1985a). FAO (1970c) reports a more intensive fattening practice of only 6 weeks, but lambs were then sold at 34 kg of weight. Taking into account all these data, the fattening weight (LSALEW) is set in this study at 42 kg for both male and female lambs for intermediate systems, and for extensive and intensive systems at 40 and 48 kg, respectively. In a recent study to evaluate different fattening regimes applied in the country with local breeds (Rahmani, Ossimi and Barki) the most economic system was found to be fattening at 6 months of age for a fattening period of 4 weeks to be marketed at 45 to 50 kg (Table 6) (Aboul-Naga and Aboul-Ela, 1985a). In intensive systems this fattening system is assumed to be practiced.

In addition, females which are barren or weak, or which do not deliver (good) offspring, with other words the culled ewes are sold (Aboul Naga et al., 1985a) (SLWP3). These ewes are fattened before sale till a weight of 45 kg (FAO, 1970c). That target weight is applied for intermediate systems, whereas for extensive and intensive systems weights of 42 and 51 kg are applied, respectively.

As sheep are sold on the basis of liveweight, and not on the basis of mutton, the liveweight gain per year (SLWPR, in kg liveweight ewe^{-1} yr^{-1}) must be calculated. As discussed above the liveweight gain consists of the weight of lambs and that of culled ewes. The former value is the product of lamb saleweight and the balance of net lambing rate on one hand, potential sheep herd increase rate (SHPIR) (Subsection 3.1.4), after-weaning mortality rate (LAWMR) and ewe mortality rate (Subsection 3.1.6) on the other hand.

To calculate mutton production from the potential liveweight production rate the latter must be multiplied by the dressing percentage. The value of the latter ranges from 45 to 48% (Abdel Salam et al., 1985; FAO, 1970c; Salah et al., 1971), but may increase to 52% under improved conditions (Figure 4).

Prices on the local market depend on supply and demand, which in turn is dependent on season, the occurence of social events, and age and quality of the animals. In May, for instance, prices generally drop because many Bedouin sell their animals to save on the expenses for supplements in summer (El Naga, pers. comm., 1984). Prices on the local market are low compared to those on the export market: LE 2.3 to 2.8 and 3.7 kg^{-1} liveweight, respectively (Abdel Salam et al., 1985). Other prices quoted are LE 1.8 kg^{-1} liveweight (Aboul-Naga et al., 1985a), probably a local price, LE 4.7 kg^{-1} liveweight for export to Saudi Arabia (Sultan, quoted by Ayyad, pers. comm., 1986) and LE 6 (Mansour, pers. comm., 1987).

No data, however, are available on the number of sheep sold at the local market, nor on the number of sheep consumed by the family on special occasions.

In this study a price of LE 2.5 kg^{-1} liveweight for the local market and LE 4.5 kg^{-1} liveweight for export trade is applied.

3.1.7.2 Milk

Milk produced by sheep is mainly used for lamb suckling, but some Bedouin milk their sheep. Only 26% of all breeders practice this in the Dabaa and the Matruh regions (Aboul-Naga et al, 1985a), but no data are available on the actual number of sheep being milked. Therefore, it is assumed in this study that 15% of total sheep population is being milked (SFMIL).

Sheep lactate for a period of 4 to 5 months after lambing and are milked daily for a period of 1.3-1.6 months, starting about 3.2 months after lambing. Except for the fat content which is about 4.8-5.1% (Aboul-Naga, 1983), no data on milk quality are available. The milk yield is about 0.28 to 0.31 kg ewe^{-1} d^{-1} (Aboul-Naga et al., 1985a) which is somewhat lower than the 0.5 kg ewe^{-1} d^{-1} reported by Soliman (1983), but under desert conditions the former seems more likely. Milk yield declines steadily after a peak at about the second week of lactation, and the rate of decline increases from the 6th week of lactation (Aboul-Naga et al., 1981). Assuming that ewes are milked for 1.5 months, starting 3 months after lambing and have a milk yield (SMMP) under desert conditions of 9.3 kg mth^{-1}, the total hand milked yield is 13.7 kg ewe^{-1} lactation $period^{-1}$. The total milk yield per lactation period is reported to be about 40.8 to 59.3 kg ewe^{-1} (Aboul-Naga et al., 1981), being considerably lower than the 60 to 80 kg ewe^{-1} reported by FAO (1970a). For extensive and intensive systems the monthly milk production is set arbitrarily at 7 and 18 kg mth^{-1}, respectively.

As the milk is completely used by the household for drinking, cooking or converting into butter (Soliman, 1983), it is difficult to attach an economic value to this product.

3.1.7.3 Wool

Apart from the economic value of wool, shearing of sheep is necessary as that improved the performance of ewes and as the presence of wool acted as a barrier to successful mating (Mokhatr et al., 1983).

Shearing of sheep takes place in March and April (Shehata, 1982) or May (Makhatr et al., 1983) and sometimes a second time in September (Aboul-Naga and Aboul-Ela, 1985a).

The quality of the wool of Barki sheep is the highest among Egyptian breeds. In the Burg el Arab region wool is somewhat stronger than in the other regions because of the influence of coarse-wooled sheep from the Nile Delta. Some of its characteristics are: fibre length 10 to 16 cm, fibre diameter 30 to 38 μ, fraction kemp 2 to 8%, fraction medullation 23.1 to 24.0%, and clean fibre yield is 73.7 to 75.2% (Aboul-Naga, 1983; Aboul-Naga and Aboul-Ela, 1985a). Experiments by Ghanem and Farid (1982b) showed that Vitamin A supplementation increased fibre thickness, strenght and elongation.

First fleece weight is 0.75 to 0.92 kg (Aboul-Naga, 1983; Aboul-Naga and Aboul-Ela, 1985b) and the average fleece weight of mature sheep (SWP) is about 1.8 kg yr^{-1} (Aboul-Naga et al., 1985a).

For more details about wool production, reference is made to the articles cited and to Kassab and Karam (1961); Ragab and Ghoneim (1961); Guirgis (1973; 1980); Guirgis and Galal (1972); Ghanem and Farid (1982b) and to Guirgis et al. (1979; 1982).

The unprocessed wool is sold to one of the agricultural cooperations at a price of LE 0.40 to 0.53 kg^{-1} in the Dabaa and the Matruh regions (Aboul-Naga et al., 1985a), and at LE 0.45 kg^{-1} in the Burg el Arab region (Soliman, 1983). The price of wool is low due to a large supply at one time, as the Bedouin have no facilities to store their wool (Soliman, 1982).

In this study it is assumed that only sheep older than one year are shorn (i.e. 76% per EE of sheep, Table 3), and that average fleece weight (SWP) for extensive, intermediate and intensive systems is 1.6, 1.8 and 2.0 kg $head^{-1}$ yr^{-1}, respectively. Sale price is set at LE 0.45 kg^{-1}.

3.1.7.4 Other outputs

Another output mentioned by FAO (1970d) is manure. However, no data are available on the mode and degree of collection, and its economic contribution to the animal production system is difficult to estimate. It is assumed that sheep produce manure at a rate of 260 kg DM yr^{-1}, when the average DM-intake over the year amounts to 1.8 kg DM d^{-1},and digestibility is 0.6. In addition, it is assumed that dependent on system intensity and whether animals are kept in a feedlot, a certain fraction (MANURF) of the total production is collected for fertilizer purposes. It is assumed that for extensive, intermediate and intensive systems, that fraction is 0.05, 0.20 and 0.25, respectively.

No data are available on the nitrogen concentration of manure. Nitrogen concentration depends on the quality of the food ingested, Harpaz (1975) measured at an annual pasture a concentration of 1.2 to 2.9%. In this study a concentration of 2% is applied.

As the manure is used by the Bedouin within their own sytsem (in olive and figs orchards, van de Ven, 1987c), profit and cost of this type of fertilizer are set to zero.

3.1.8 Feed requirements

The feed requirements in terms of energy in both the PSG and ARID ANIMAL are expressed in Scandinavian feed units, FU. Table 8 lists conversion factors for several other energy units.

Table 8. Conversion of several units, expressing nutritional value of feed into Scandinavian Feed Units (FAO, quoted by Munzinger, 1982).

1 Scandinavian Feed Unit	=	1.0 kg barley grains
(FU)	=	0.7 Starch Equivalent (SE)
	=	1.1 Russian Feed Unit
	=	1.001 Unité Fouragère (UF)
	=	0.71 kg Total Digestible Nutrients (TDN)
	=	12.46 MJ Metabolizable energy (ME)
	=	7.47 MJ Net energy (NE, efficiency is set at 0.6 for all purposes)

The total feed requirements of sheep comprise year-long maintenance, flushing before the breeding season, steaming up before lambing, lactation till weaning, lamb fattening after weaning, walking and milk production when ewes are milked.

In this subsection the feed requirements of sheep (in FU ewe^{-1}) are calculated. Forage availability and the balance between requirements and availability will be dealt with later (Chapters 4 and 6, respectively). Anticipating on Subsection 4.1.2, it can be said already that the forage available from the rangeland is insufficient to meet the total annual feed requirements. To gain more insight in the causes of this imbalance, these total feed requirements are split up in feed requirements per month of equal length and per season.

Maintenance requirements (SMRQ).

In the maintenance requirements the requirements for maintenance processes proper and for walking are included.

The requirements for maintenance processes proper are estimated at 26 g digestible dry matter per kg metabolic weight per day, independent of season (Ketelaars, pers. comm., 1985; Zemmelink, 1980). That is equivalent to: (26 g DDM kg^{-1} $W^{0.75}$ d^{-1} * 18.4 kJ GE g^{-1} DDM * 0.8 kJ ME kJ GE^{-1} * 0.6 kJ NE kJ ME^{-1} =) 230 kJ NE kg^{-1} $W^{0.75}$ d^{-1}. Hence, equivalent to 0.94 FU kg^{-1} $W^{0.75}$ mth^{-1}. This is somewhat lower than the requirements calculated by Seligman and Spharim (1987), i.e. 0.96 FU kg^{-1} $W^{0.75}$ mth^{-1}.

The net energy requirements for walking are 0.62 kcal kg^{-1} liveweight km^{-1} (ARC, 1980), equivalent to $3.47.10^{-4}$ FU kg^{-1} liveweight km^{-1}. To account for the number of days per month the factor 365/12 is introduced. In addition, grazing or feedlot operations are discriminated by the factor FFFLOT.

Storage of fat in the tail has been taken into account by increasing the requirements for maintenance processes with 0.01 FU kg^{-1} $W^{0.75}$ mth^{-1} in the green grazing and the early dry period. The efficiency of fat-mobilization in summer is estimated at 80%, and hence the requirements are reduced by 0.008 FU kg^{-1} $W^{0.75}$ mth^{-1} in that period. Finally, it should be realized that weight gain in winter and weight loss in summer cannot be accounted for because of lack of data.

Steaming up requirements (SSURQ).

In more intensive systems extra food, the quantity depending on ewe prolificacy, is given from about 40 days before lambing to help the ewe and lamb survive the critical period shortly before and after lambing. Proper nutrition during that period will increase productivity. Experiments by Aboul-Naga et al. (1981) showed that ewes highly fed at late pregnancy and lactation gained weight during lactation, while those fed normal allowances lost weight. At present the Bedouin do not give additional rations to the animals in this period (Aboul-Naga et al., 1985a). Nevertheless, in this study it is assumed that the steaming up requirements (SSURQ) of the animals have to be met. These steaming up requirements are 0.3 FU ewe^{-1} d^{-1} for animals with 80% net lambing rates and 0.7 FU ewe^{-1} d^{-1} for prolific breeds with 180% net lambing rates. The steaming up requirements for the various systems are derived from these two points assuming a linear relationship with net lambing rate (Seligman and Spharim, 1987).

Steaming up requirements have to be met for 75% in the month preceding the month of lambing and for 25% in the month preceding that one.

Lactation requirements (SLRQ).

Ewe lactation is necessary to allow the lamb to grow from birthweight (LBIRW) to the target weaning weight (LWEANW). At pasture, the lactation requirements are about 3.0 FU kg^{-1} lamb liveweight, when the actual growth rate of the lamb is 0.3 kg d^{-1} (Seligman and Spharim, 1987). However, the growth rate of Barki lambs is much lower (Subsection 3.1.5): 0.18 kg d^{-1}. As the feed requirements for lactation of Barki sheep are unknown, also 3.0 FU kg^{-1} liveweight is applied here. It should be realized, however, that the growth rate of lambs may increase under these conditions. In practice, each animal is given an extra amount of 0.5 kg concentrates per day during lactation (Aboul-Naga et al., 1985a).

To account for those ewes that lost their lambs before weaning but suckled them for most of the lactation period the lactation requirements are increased by 5%. A suckling period of 3.6 months is applied (Paragraph 3.1.7.2).

Milk production requirements (SMILRQ).

For milking purposes, additional feed is required at a rate of 0.6 FU kg^{-1} milk (Seligman and Spharim, 1987). It is assumed that 15% of all ewes (SFMIL) are milked for 1.6 month, starting 3 months after lambing and that the potential monthly milk production is 9.3 kg (Paragraph 3.1.7.2).

Lamb fattening requirements (LFRQ).

The feed requirements of weaned lambs from weaning weight (LWEANW) till sale weight depend on the feed conversion efficiency which decreases with increasing weight (Searle and Graham, quoted by Seligman and Spharim, 1987). As mentioned earlier, the average saleweight after fattening (LSALEW) depends on the system. On the basis of the relation between fattening requirements, saleweight and weaning weight an optimum saleweight can be derived given the costs of concentrates and the price of lambs.

Two sub-requirements are distinguished (LFRQRL and LFRQFL), due to differences in feeding practices. If lambs are kept on the rangeland it is assumed that it takes 4 months to reach the target saleweight, whereas lambs are fed in a feedlot required only 3 months. The fraction of lambs fed in a feedlot is taken into account by the factor FWFLOT.

Hogget growth requirements (LHOGRQ).

Female lambs are kept in the flock for breeding and not for fattening have lower growth rates than male lambs being fattened (Paragraph 3.1.5). Consequently, it takes much more time, i.e. 8 months to reach hogget target weight. It is assumed that requirements are evenly distributed among those 8 months. The feed conversion efficiency is taken as a mean of 5 FU kg^{-1} liveweight between weaning and hogget liveweight (Seligman and Spharim, 1987). The number of female lambs in the flock equals the number of ewes replaced (culling and mortality) (SREPR) plus the number of female lambs kept for breeding purposes (SHPIR).

Ewe Fattening requirements (SFRQ).

Ewes culled before the early dry period are fattened and, assuming a growth rate of 0.17 kg d^{-1} the increase in weight between mature liveweight and fattening weight (SFATW) is realized in one month (April). The feed conversion efficiency of ewes is expected to be somewhat lower than that of hoggets, hence a conversion efficiency of 5.5 FU kg^{-1} liveweight is applied.

Ram feed requirements (SRFRQ).

The ram feed requirements are calculated similarly to those of ewes. As one ram serves a certain number of ewes, the ram feed requirements are divided by that number (SERR).

Flushing requirements (SFLRQ).

Flushing is necessary to allow sheep to attain body condition suitable for breeding and is given for about 40 days before the beginning of the breeding season at a rate of 0.5 FU d^{-1}. When prolificacy of the system is low (less than 1.1 weaned lamb ewe^{-1} yr^{-1}), there is no flushing.

Using the data presented sofar, the total feed requirements of ewes in the Matruh region amount to 360 FU ewe^{-1} yr^{-1}. The values for the various processes in the four seasons are listed in Table 9. From this table it can be deduced that the feed requirements in autumn, winter, spring, and summer are 30, 32, 33 and 27 FU ewe^{-1} mth^{-1}, respectively. Striking is the high requirement in winter and spring, which is mainly caused by the lamb requirements. Since goats and donkeys graze the rangeland as well, the feed requirements per ewe equivalent will be calculated later (Chapter 6).

Table 9. Feed requirements of sheep for different purposes (in FU ewe^{-1}) in the Matruh region under present circumstances in the four seasons. Acronyms are explained in the text.

MONTH	SMRQ	SSURQ	SLRQ	SMILRQ	LFRQ	LHOGRQ	SFRQ	SRFRQ	TOTAL
O,N	36.8	-	18.4	-	2.3	2.6	-	1.2	61.3
D,J,F	59.0	5.9	16.0	0.7	5.9	6.4	-	1.9	95.8
M,A	39.3	0.3	13.1	-	5.5	3.4	4.1	1.2	66.9
M,J,J,A,S	92.0	9.1	13.8	0.6	6.6	9.8	-	2.9	134.8
total	227.1	15.3	61.3	1.3	20.3	22.2	4.1	7.2	358.8

3.1.9 Feed intake

Feed intake of Barki sheep is measured by Abdel-Salam (1985) and Henady (1986). However, the estimates differ considerably probably because completely different methods were used: fistulae sampling and number of bites per minute, respectively. For details reference is made to the original articles. As the method applied by Henady (op. cit.) is considered less accurate and the experiments were carried out in partly protected areas, only attention is paid to the work of Abdel-Salam. The pattern of feed intake in the course of the year is given in Table 10.

Table 10. Average daily consumption of forage by sheep (kg DM $head^{-1}$ d^{-1}) in the course of the year, while the animals are supplemented in June, July and March (Abdel-Salam, 1985).

YEAR	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.
1979/80									0.89	0.69	1.65	1.04
1980/81	1.16	2.12	2.62	1.84	1.71	0.66	1.20					

However, it must be realized in this context that feed intake is not only determined by the absolute amount of biomass available. Additional factors are environmental conditions (daylength), characteristics of the animal, quality of feed and the way of presenting the feed (Zemmelink, 1986). The quality of the diet is determined by the quality of the individual plant species and the contribution of each species to the diet. The botanical composition is spatially heterogeneous (Subsection 4.2.1), and consequently, the diet varies with movement of the animals. Since growth of shrubs and subshrubs occurs almost throughout the year, the diet consists to a large extent of this type of forage. In addition to these subshrubs, varying in palatability per species and in the course of the year, other important components of the diet are ephemerals and ephemeroids. Figure 10 (Subsection 4.2.3) shows that the composition of the diet is such, that protein defiency occurs only in September and October. Apparently, selection between plant parts with high protein concentrations takes place. In addition, if selection between plant parts is possible the production rate of the animals is higher. This means that when one aim for higher production of the animals, more biomass should be available (which is not necessarily all grazed), than based on the calculations of feed requirements only. The relationship between excess feed (feed available, but not consumed) and optimal production of the animal is specific for a plant species (Zemmelink, 1980; 1986). The present grazing pressure, however, is at any rate in El Omayed so high that all available biomass (restricted by physical characteristics of the subshrubs) is grazed completely.

Furthermore, it is recalled that accurate feed intake data are difficult to obtain. Here, an approach is given to calculate the minimum and maximum feed intake of sheep, using equations derived from Ketelaars (1983, 1984) who reviewed data on digestibility and voluntary intake of roughages (grasses and legumes) by sheep of various breeds. According to his theory feed quality determines to a large extent feed intake. Quality of rangeland forage in winter exceeds that in summer, and it is assumed that intake of dry matter during these months (green grazing period and early dry period, Subsection 4.2.3) is not limited. On the other hand the lower quality of forage is summer will limit secondary production. Hence the maximum feed intake in summer is calculated.

To simplify the actual situation, it is assumed that in summer the diet of sheep consists of two feed sources only: concentrates (either manufactured concentrates or grains, Section 4.5) and forage (subshrub species).

Consequently, total intake per metabolic weight per day (I_t) is given by:

$$I_t = I_{con} + I_{for} \qquad (1)$$

where,

I_{con} = intake of concentrates ($g\ DM\ kg^{-1}\ W^{0.75}\ d^{-1}$)
I_{for} = intake of forage ($g\ DM\ kg^{-1}\ W^{0.75}\ d^{-1}$)

The intake of total digestible dry matter is important, to calculate whether the requirements for energy and protein necessary for maintenance are met, and what is left for growth of the animal. As not all dry matter consumed by the animal can be digested, the intake of digestible dry matter per metabolic weight per day (D_t) is calculated by:

$$D_t = (I_{con} * DG_{con}) + (I_{for} * DG_{for}) \qquad (2)$$

where,

DG_{con} = apparent digestibility of concentrates ($g\ g^{-1}$)
DG_{for} = apparent digestibility of forage ($g\ g^{-1}$)

Apparent digestibility is a characteristic of a feed source, determined experimentally. Hence, to calculate the intake of digestible dry matter, digestibility of both feed sources must be known. Given the nitrogen concentration of the manufactured concentrates of 2.9% (derived from Table 26), digestibility (DG) may vary between 0.44 and 0.80 g g^{-1} (Ketelaars, 1984). In view of its low fibre content (16.3%), a value for the apparent digestibility of 0.80 seems reasonable, in view of barley grains and grasses with the same fibre content (Ketelaars, pers. comm., 1986). It is, however, difficult to estimate the digestibility of the subshrubs, as data of experiments carried out during summer are lacking. El Naga (1982) measured an apparent digestibility of 0.63 for pasture plants in the period from December 1980 till July 1981. Other experiments showed that addition of supplements (barley grains) had no effect on the digestibility of roughages (Lamb and Eadie, 1979). Experiments with Scottish Blackface sheep showed an apparent digestibility of organic matter of heather Calluna vulgaris containing 1.3% N of 0.45 (Milne et al., 1979). Given those values, and taking into account that sheep selectivily eat only young and green parts of the subshrubs an estimated apparent digestibility of 0.60 for the subshrubs seems reasonable.

Furthermore, intake of digestible dry matter (D_t) is related to the digestibility (DG) of forage, as shown in Figure 5. It is assumed that the calculated relationship for grasses and legumes is valid for subshrubs as well. Then, the values of maximum amd minimum intake of digestible dry matter as a function of digestibility are given by the equations derived from Figure 5:

$$D_{t,max} = 150\ DG - 45 \quad (3)$$

$$D_{t,min} = 135\ DG - 58 \quad (4)$$

Given the supply of concentrates (I_{con}) of 0.5 kg $sheep^{-1}\ d^{-1}$, equivalent to 31.4 g $kg^{-1}\ W^{0.75}\ d^{-1}$, and apparent digestibilities as mentioned above, the intake of forage can be calculated.

The digestibility of the total ration (DG_{tot}) is the weighted average of the digestibilities of the concentrates (DG_{con}) and the forage (DG_{for}), and thus a function of the intake of forage (I_{for}).

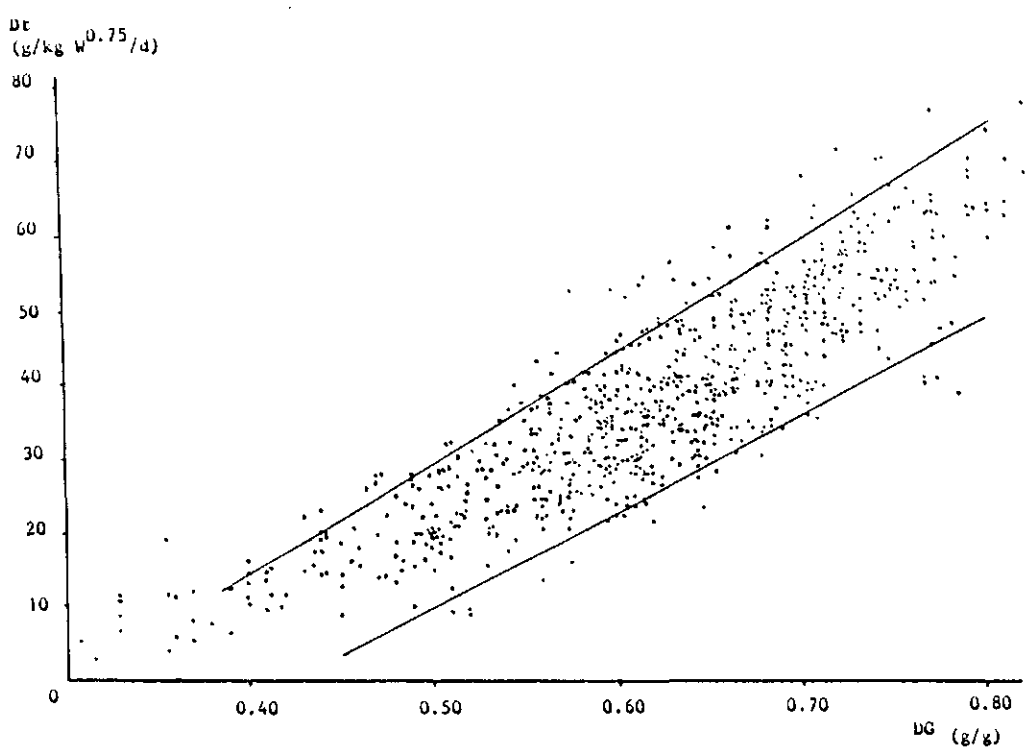


Figure 5. Relationship between the intake of digestible dry matter (D_t) and apparent digestibility of feed (DG). Lines represent maximum and minimum intakes of dry matter. Data of indoor feeding trials with roughages (legumes and grasses) fed ad libitum to sheep of various breeds. Literature data from a review (Ketelaars, unpublished).

Substituting the numerical values given so far yields:

$$DG_{tot} = \frac{25.1 + (0.6 * I_{for})}{31.4 + I_{for}} \qquad (5)$$

This expression is substituted in Equations 3 and 4 combined with Equation 2. Subsequently, I_{for} (maximum or minimum) is then calculated by solving the resulting quadratic equation. Results are a maximum and minimum forage intake for sheep in summer of 790 and 430 g sheep^{-1} d^{-1}, respectively. Using these data and the corresponding weight of an ewe equivalent of 60 kg (Section 2.2), the maximum intake of rangeland forage is 1.62 kg DM EE^{-1} d^{-1}.

Comparing this intake with the values Table 10, it may be concluded that an intake in August of 1.65 kg DM head^{-1} d^{-1} seems very unlikely. The values for June and September are relatively high, but approach much more the calculated maximum.

In the model ARID ANIMAL the required rangeland per EE is calculated based on the feed intake in winter according to the requirements and in summer according to the above mentioned maximum intake. However, the maximum intake of rangeland forage (INTMAX) is also determined by the quantity of supplements provided. High quality supplements increase the total maximum intake, whereas supplements with lower quality reduce the intake further.

If high quality supplements are provided in summer at a rate of 0.5 kg head^{-1} d^{-1}, total intake increases to 1.80 kg DM EE^{-1} d^{-1}. These values differ only slightly from those obtained by de Ridder et al. (1986), in a summer experiment in the Northern Negev of Israel of 1.5 and 1.8 kg DM sheep^{-1} d^{-1} for sheep fed with pasture plants alone and with both pasture plants and concentrates, respectively.

In case supplements are provided, the maximum intake of rangeland forage is below its maximum value. It is, however, difficult to calculate that reduction, but for preliminary calculations it is assumed that conform the current rations of concentrates (Subsection 4.5.1) this reduction amounts to 0.5 to 1.0 kg head^{-1} d^{-1}, or equivalent to 0.7 to 1.3 kg EE^{-1} d^{-1}. In intensive systems more concentrates are supplied, and hence, that reduction is arbitrarily set at 1.3 kg EE^{-1} d^{-1}. In case other roughages are supplied (Subsection 4.5.3), the maximum intake of rangeland forage is reduced accordingly.

3.2 Goats

3.2.1 General description

The goats in the northwestern coastal zone belong to the so-called Baladi-type. Native Egyptian goat or Barki goat are other names that occur in literature. According to FAO (1970e), the frame of the goat and its fairly long hair indicate membership of the Mediterranean descendants from the wild Capra prisca. They are considered to be hardy goats that can stand well scarcity of food and water (Aboul-Naga, 1983).

Baladi goats have a small body and are relatively light animals. Weights will be discussed in more detail in Subsection 3.2.5.

The body is covered with long straight hair, smoother and shorter on neck and head. The hair varies much in colour, from one animal to another: from black to white, while some are spotted and others brown or reddish-brown. Some have horns, which are small and curl back on the head, but others are hornless (Tantawy and Ahmed, 1960) (Figure 6). Ears differ in position and size, but are generally long lapped (Aboul-Naga, 1987). The outline of the face is straight, and the head, which is beardless, is long and possesses two tassels. The udder is long and bagged, with two teats (Tantawy and Ahmed, 1960).

Figure 6. Baladi goats in the northwestern coastal zone.

3.2.2 Breeding

Analogous to sheep, the number of bucks per flock varies with size and region. The ratio of does to bucks (GDBR) is estimated at 40:1 (Soliman, 1983) or 39:1 (Aboul-Naga et al., 1985a). In the Matruh region the ratio may be different, due to the larger proportion of flocks with less than 50 heads, where either one or two bucks are kept in the flock (Aboul-Naga et al., 1985a). Recent studies indicate that the ratio varies with flock size and with the ratio of sheep to goats, ranging from 22.4:1 to 48.4:1. In this study an average value of 36:1 (Aboul-Naga, 1987) is applied.

Similarly to rams, bucks are kept in the flock all year round. Consequently, more than one kidding period per year is possible, and the number of does that kids twice a year in the Burg el Arab region is estimated by Soliman (1983) at 14% of the total doe population. Abdel Salam et al. (1985) give an estimate of 30% for the same region. That fraction seems relatively high and can only be explained by high inputs of high quality feed. It is assumed that those does kid only once in the following year and hence, three kidding cycles in two years are distinguished. The fraction of does that kids three times in two successive years (SFKIDT) is set at 0.3 for all regions.

The kidding periods are more or less the same as those for lambing (Aboul-Naga et al., 1985a), i.e. October ± one month and March ± one month (Aboul-Naga, 1987).

Crucial for the calculation of the feed requirements is the ratio of kids born in March (GFKBM) to those born in October (GFKBO). As females mated in spring time tend to be more fertile and have a higher average litter size than those mated in the other seasons (Tantawy and Ahmed, 1960), and considering that peak kidding periods coincide more or less with peak lambing periods, for intermediate systems that ratio is estimated at 0.4:0.6.

3.2.3 Selection and breed improvement

Similarly to the selection with sheep, most breeders use bucks selected from their own flocks, mainly based on the dam's performance (Aboul-Naga et al., 1985a).

In experiments the local breed was crossed under farm conditions with Egyptian Nubian goats (N) and Damascus goats (D). Both crossbred offspring had a higher milk production than the pure Barki breed (Table 11). In addition, crosses with Damascus goats showed a higher kid survival and better kid performance (although differences with Baladi goats in the latter respect were not significant). Damascus goats are used, because they are goats with the most developed milk production in the Middle-East. It appeared that 1/2B-1/2D shows the best performance (Aboul-Naga et al., 1985b). New breeding experiments are being carried out, but no results are available yet (ALAP, 1986).

Table 11. Milk yield (kg) of Baladi (B), 1/2 Baladi 1/2 Damascus (1/2B 1/2D) and 1/2 Baladi 1/2 Nubian (1/2B 1/2N) goats under farm conditions with single (S) and double (D) birth. A = average NO = Number of does. TOB = type of birth (Aboul-Naga et al., 1985b).

BREED	TOB	NO	MILK YIELD (0-8 WEEKS)	TOTAL MILK YIELD	LACT. PERIOD (weeks)
B	S	35	46.6 (38.8-57.7)	69.8 (38.9- 99.0)	20.2
	D	27	64.3 (43.3-97.4)	95.2 (51.1-147.3)	21.4
	A	62	54.3	80.8	20.7
1/2B 1/2D	S	6	46.9 (30.1-56.0)	90.1 (64.7-104.6)	22.5
1/2B 1/2N	S	6	50.7 (45.5-63.7)	88.5 (76.9-102.4)	21.3

3.2.4 Productivity

Analogous to sheep, goat productivity is expressed as the potential herd increase rate (GHPIR). The rate of increase in herd size depends on the fertility of does and the net kidding rate, equivalent to the weaning rate. This rate is the kidding rate minus the pre-weaning mortality (GPWMR, Subsection 3.2.6).

The average litter size is about 1.3 kid doe^{-1} yr^{-1} when does are fed on the rangeland (FAO, 1970c), but that may increase to 1.5-2.0 when they are reared on a farm (Tantawy and Ahmed, 1960). Aboul-Naga et al. (1985a) reported comparable kidding rates in the Dabaa and the Matruh regions of 1.43 and 1.54, respectively. In a more recent study litter size varied with flock size and with the ratio of sheep to goats in the flock, ranging from 1.07 to 1.56 kids doe^{-1} kidded in the Dabaa, the Matruh and the Barrani regions (Aboul-Naga, 1987). In this study an average value of 1.46 (Aboul-Naga, 1987) is applied for all regions. The number of kids born per doe per year is the weighted average of does kidding once and those kidding three times in two successive years. It is assumed that the abortion rate is already included in the litter size (incidence is on average 9 to 11%, Aboul-Naga et al., 1985a; Aboul-Naga, 1987).

The conception rate (GCONR) is estimated at 0.87 and 0.89 in the Dabaa and the Matruh regions, respectively (Aboul-Naga et al., 1985a). Since no other data are available, the conception rate for intermediate systems is set arbitrarily at 0.88 in all regions. For extensive and intensive systems it is analogously to sheep, set at 0.7 and 1.0, respectively.

The next factor determining the goat-herd increase rate is the replacement rate (GREPR), the sum of the culling rate (GCULR) and the death rate of does older than one year (GMR, Subsection 3.2.6).

In the sixties does were used for reproduction for six breeding years (FAO, 1970c), whereas at present the average age at which old does are culled is 8.7 years (Aboul-Naga et al., 1985a; Aboul-Naga, 1987). The average relative culling rate of yearling does is about 0.26 per year (Aboul-Naga et al., 1985a), whereas 0.06 to 0.11 of total old does are culled (Aboul-Naga et al., 1985a; Aboul-Naga, 1987). Using the most recent data, and given the age distribution within the flock (Table 3), the sum of the two culling rates is 0.07 doe doe^{-1} yr^{-1} for intermediate systems. For extensive and intensive systems the culling rate is set at 0.05 and 0.10, respectively.

The final factor affecting the potential herd increase rate is the fraction of female kids born. Unlike in sheep, less female kids are born than male kids. The value of this fraction (GFFK) is 0.44 (Tantawy and Ahmed, 1960). Furthermore, it is assumed that in extensive, intermediate and intensive systems 80, 90, and 100%, respectively of the female kids are used for breeding (and fattening in intensive systems).

Applying the data given sofar, the potential goat herd increase rate in the Matruh region is 0.20 hogget doe^{-1} yr^{-1}, which is relatively high compared with the actual herd increase rate (0.02, Table 2) and with the sheep-herd increase rate, but it enables the Bedouin to keep relatively more kids than lambs. This in accordance of observations by Aboul-Naga et al. (1985a) that there is a tendency among the Bedouin to shift to breeding goats at the expense of breeding sheep.

3.2.5 Weight and growth rates

Birth weight of kids (GBIRW) increased from about 1.0-1.5 kg in the period 1943-1957 (Ahmed and Tantawy, 1960) to about 2.0 to 2.9 kg at present (Aboul-Naga, 1983). The average value of the latter range, 2.4 kg is almost identical to the value of 2.3 kg obtained under farm conditions (Aboul-Naga et al., 1985b). For intermediate systems the value of 2.4 kg is applied. For extensive and intensive systems the weight is set arbitrarily at 2.0 and 3.0 kg, respectively.

Kids are weaned at an age of 3.4 months (103 days) at a weaning weight (KWEANW) of 14 to 16 kg (Aboul-Naga et al., 1985a). It is assumed that analogously to sheep, weaning weight of goats in intensive systems is lower than in intermediate systems. Therefore, for extensive, intermediate and intensive systems this weight is set at 14, 15, and 14 kg, respectively.

No data are available on yearling weights of kids under rangeland conditions. Aboul-Naga et al. (1985b) report that under farm conditions yearling weight is about 17 kg when weaned at 8 weeks of age. Applying the growth rate given below, kid yearling weight (KHOGW) becomes 23 kg in intermediate systems. For extensive and intensive systems the yearling weight is set at 21 and 28 kg, respectively.

The weight of saleable kids and of culled does are treated in Paragraph 3.2.7.1.

The liveweight of a mature doe (GMLW) is about 30 kg (FAO, 1970c; Tantawy and Ahmed, 1960), while Aboul-Naga (1983) reports a range from 19.9 to 30.9 kg. For extensive, intermediate and intensive systems the mature liveweight is set at 28, 30 and 33 kg, respectively.

The weight of a buck (GBUCKW) under rangeland conditions is about 36 kg (FAO, 1970c). For intermediate systems that weight is applied, while for extensive and intensive systems the weight is set at 34 and 40 kg, respectively.

The growth rates of kids under rangeland conditions till weaning is calculated from the difference in liveweight: 0.12 kg d^{-1}.

If a saleweight of 28 kg (see Paragraph 3.2.1.7) is applied and a fattening period of 3.4 months (Aboul-Naga et al., 1985a) after weaning, the growth rate amounts to 0.136 kg d^{-1}. The growth rate of 0.105 kg d^{-1} as reported by Aboul-Naga et al. (Aboul-Naga et al., 1985a; Aboul-Naga, 1987), seems thus relatively low. In this study a growth rate of 0.136 kg d^{-1} is applied.

3.2.6 Diseases and mortality

Generally, similar diseases occur as with sheep (see Subsection 3.1.6), and analogous to sheep three main periods during which death occurs are distinguished:

1. Pre-weaning period.

Kid losses from birth to weaning (3.4 months of age) occur mainly during the first few weeks of life, the pre-weaning mortality rate varies considerably between flocks and ranges on average from 11% in the Dabaa region to 13% of kids born in the Matruh region, (Aboul- Naga et al., 1985a). Ahmed and Tantawy (1960) observed an average mortality rate at birth of 18% and from then to weaning of 19%, but birth weights were much lower than at present. In that same article they concluded that birthweight significantly effects mortality rate, the heavier the kids at birth, the less their mortality rate. Recent studies show that in the Dabaa, the Matruh and the Barrani regions 0 to 42% of the kids born die in this period (Aboul-Naga, 1987). The average value of 18% (Aboul-Naga, 1987) is somewhat lower than on a farm trial where a survival till weaning of only 73% was obtained (Aboul-Naga et al., 1985b). In this study the value of 18% is applied. Subsequently, the death rate (GPWMR, head $head^{-1}$ joined yr^{-1}) is calculated by multiplying the relative death rate (yr-1) with both conception rate and litter size.

2. Post-weaning period till 12 months of age.

Because data are lacking the death rate after weaning (GAWMR) is set arbitrarily at 10% of kids born.

3. After 12 months of age.

Goat mortality due to diseases is unknown. Therefore, relative doe mortality rate (GMR) is set equal to that of sheep (Subsection 3.1.6) at 0.04 doe doe^{-1} yr^{-1}.

3.2.7 Outputs

3.2.7.1 Meat

Analogous to sheep the amount of saleable liveweight (GMEAT) is calculated assuming that the herd is increasing at its potential rate.

Kids are sold at weaning (GLWP1) or after fattening (GLWP2), but analogous to sheep data on the actual number and on the timing of sale are difficult to obtain. Aboul-Naga et al. (1985) observed that at weaning 25 to 41% of the Bedouin sell female kids, while 7 to 12% of them sell at older age and 74 to 83% of them retain female lambs for breeding. For male lambs these figures are: 42 to 76, 28 to 31 and 62 to 69%, respectively. The last group of animals is mainly kept for household consumption. Therefore, it is assumed in this study that in intermediate systems 60% of the male (GFMKW) and 10% of the female kids (GFFKW/2) are sold at weaning, and 40% of the male (GFMKF) and 10% of the female kids (GFFKW/2) at older age (after fattening). The remaining 90% of the female kids are kept for breeding purposes and replacement of other old animals, or for hard times to obtain cash. In extensive sytems more male kids are sold (95%), and in intensive none at all. Analogous to sheep in extensive systems 5% of female kids are sold at weaning and 5% later. In intensive systems all kids are kept and sold at a later age.

Male kids kept for fattening for an average period of 3.4 months reach a body weight of 25 to 31 kg at marketing (Aboul-Naga et al., 1985a; Aboul-Naga, 1987). Considering these data, the fattening weight (KSALEW) is set at 28 kg for both male and female lambs for intermediate systems and for extensive and intensive systems at 25 and 32 kg, respectively.

In addition, females that are barren or weak, or do not deliver (good) offspring, in other words the culled does (GCULR) are sold (GLWP3). In contrast to sheep, these does are probably not fattened before sale and are usually sold (probably in May) to local butchers at low prices at a weight (GCULW) of 26 kg (Aboul-Naga, 1987). For extensive and for intensive systems the weight is set at 24 and 28 kg, respectively.

Analogous to sheep, goats are sold per kg liveweight. If the meat production has to be calculated, the liveweight production rate must be multiplied by the dressing fraction which is 0.6 kg meat kg^{-1} liveweight (Abdel Salam et al., 1985).

Prices fetched on the export and local market are LE 4.4 and 2.3 to 2.8 kg^{-1} liveweight, respectively (Abdel Salam, 1985). Generally, goat consumption exceeds that of sheep, as the meat of one animal can be finished in one meal by a large Bedouin family (Shehata, 1982). However, no data are available on the number of head sold at the local market nor on the number consumed by the household.

3.2.7.2 Milk

One of the objectives of rearing goats is milk production. Generally, the milk is completely consumed within the household, either as fresh or sour milk or ghee. Although the milk's chemical composition is suitable for cheese making (FAO, 1970f), it is an uncommon practice among Bedouin. No accurate data on milk quality of these goats, however, are available.

About 93% of the breeders in the Dabaa and the Martruh regions milk their goats for a period of about 2.6 months, starting on average 2.3 months after kidding. Does are milked once a day in the period when suckling takes place, and twice a day after weaning of the kid. The average hand-milked yield is about 0.7 kg doe^{-1} d^{-1} over a 79 day lactation period (Aboul-Naga et al., 1985a; Aboul-Naga, 1987) summing up to 55 kg per lactation. Other hand milk production estimates are 50 kg (Soliman, 1983), 50 to 70 kg (Abdel Salam et al., 1985) and 100 kg (FAO, 1970c). Total milk production is estimated at 150 kg per lactation period (FAO, 1970c; Soliman, 1983) which seems high compared to the yield of 81 kg over a lactation period of 21 weeks (range from 9 to 27) when goats are kept under farm conditions (Table 11, Aboul-Naga et al., 1985b). In the latter experiment it was evident that with twin suckling more milk is produced than with single kid suckling: on average 95.2 compared to 69.8 kg milk per lactation. Furthermore, crossbred goats produce more milk than pure Baladi (Table 11).

Considering these data, for extensive, intermediate, and intensive systems the milk yield (GMMP) during a 2.6 month period of milking is set at 18, 21 and 25 kg mth^{-1}, respectively, while it is assumed that 90% of the total goat population is being milked (GFMIL).

3.2.7.3 Hair

Goat hair is usually cut by the Bedouin himself once a year, either in March, April (Shehata, 1982), May (Aboul-Naga et al., 1985a) or May and June (Aboul-Naga, 1987). The average hair yield is about 0.125 kg per head (Shehata, 1982; Aboul-Naga, 1987), but as it is used for local rugs and tents, no economic yield is calculated.

3.2.7.4 Other outputs

From the skin of goats make buckets are made, which are used to collect water from the cisterns or wells.

As from sheep, goat manure may be collected for fertilization of the fig and olive orchards. Assuming an average daily intake of 1.5 kg DM head^{-1} and a digestibility of 0.6, the annual manure production is about 220 kg DM head^{-1}. For manure collection, the same fraction of total manure production (MANURF) is applied. As those outputs are used by the household the economic value is not calculated.

3.2.8 Feed requirements

Feed requirements of goats comprise the same components as for sheep: maintenance requirements (GMRQ), steaming up requirements (GSURQ), lactation requirements (GLRQ), milk production requirements (GMILRQ), kid fattening requirements (KFRQ), hogget growth requirements (KHOGRQ), buck feed requirements (GBFRQ) and flushing requirements (GFLRQ). All requirements are calculated analogous to those of sheep.

Applying those equations, the total feed requirements of goats, 300 FU doe^{-1} yr^{-1}, subdivided by component and by season are given in Table 12. This table shows that the feed requirements in autumn, winter, spring, and summer, are 23, 28, 24 and 24 FU doe^{-1} mth^{-1}, respectively. These requirements are somewhat lower than those of sheep. It is striking that the requirements in spring are more or less equal to those in autumn and summer, that in contrast to sheep.

The feed requirements per ewe equivalent are calculated later (Chapter 6).

Table 12. Feed requirements of goats for different purposes (in FU doe^{-1}) in the Matruh region under present circumstances in the four seasons. Acronyms are explained in the text.

MONTH	GMRQ	GSURQ	GLRQ	GMILRQ	KFRQ	KHOGRQ	GBFRQ	TOTAL
O,N	29.5	-	12.5	0.5	1.3	1.4	0.9	46.1
D,J,F	46.4	6.3	9.4	14.7	3.1	3.6	1.5	85.0
M,A	30.9	0.3	9.7	0.4	2.9	1.9	1.0	47.1
M,J,J,A,S	73.6	9.7	8.3	15.3	3.6	5.5	2.4	118.4
total	180.4	16.3	39.9	30.9	10.9	12.4	5.8	296.6

3.2.9 Feed intake

The intake of forage by goats in winter exceeds that in summer, which is due to differences in digestibility of forage. Table 13 lists the intake pattern in the course of the year, the highest intake being recorded in the wet season.

Table 13. Average daily consumption of forage by goats (kg DM $head^{-1}$ d^{-1}) in the course of the year, for animals supplemented in June, July and March (Abdel Salam, 1985).

YEAR	OKT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUNE	JULY	AUG.	SEPT.
1979/80									0.58	0.44	0.33	0.65
1980/81	0.62	0.68	2.17	1.85	2.49	0.85	1.85					

These values however, seem high compared with data obtained when maximum and minimum intakes are calculated. When calculated analogous to the intake of sheep, the maximum and minimum subshrub intake for goats in summer amounts to 600 and 325 g DM $goat^{-1}$ d^{-1}, respectively. Compared with these data the values reported for September and November seem relatively high.

3.3 Donkeys

Donkeys are important to the Bedouin, as they are used by members of the family for transport purposes, to plough the barley fields and for threshing. In 1966 each family engaged in agriculture in the five pilot regions distinguished by FAO; owned on average 1.2 donkey (FAO, 1970e). No recent data are available on the number of donkeys in the coastal zone. Due to the increased use of pick-up trucks for transport in the last ten years, it is expected that the number of donkeys decreased to about 1 head per family (DNFN). According to van de Ven (1987a) the number of families engaged in agriculture (FANU), and thus the number of donkeys in the Burg el Arab, the Dabaa, the Martruh and the Barrani regions is 5682, 2246, 9558 and 3257, respectively. No data are available on the age distribution of the donkey population.

Donkeys are kept in a shed, generally made of bushes and/or stones. Sometimes they are allowed to graze the natural vegetation between the figs. No data, however, are available on the diet of donkeys.

On average donkeys have a weight between 80 and 100 kg (FAO, 1972; Munzinger, 1982) and a weight of 90 kg is applied here.

The total working time of donkeys consists of operative and non-operative time, with a ratio of 0.3:0.7 (van de Ven, pers. comm., 1987). Operative time is estimated by FAO (1972) at 3 to 3.5 h d^{-1}, but Hermans (pers. comm., 1987) estimates the working capacity of donkeys somewhat higher, i.e. 4 hours. That value is applied in this study. To account for the non-operative time in the calculation of total time available for traction per animal (DTR), a factor 3.33 is introduced. The tractive effort is 1/5 to 1/6 of their weight at a speed of 2.5 to 2.8 km h^{-1} (FAO, 1972). It is assumed that donkeys work at a speed of 2.6 km h^{-1} with a force of 1/5 of their bodyweight and that they are able to work on average 25 days a month irrespective of the time of the year.

The feed requirements of a donkey for maintenance processes (DMRQ) are 1.5 FU d^{-1} (FAO, 1972), equal to 45.63 FU mth^{-1} calculated on the basis of 12 months of equal length.

The feed requirements for traction and walking are calculated according to Hermans (1985), at 0.74 MJ NE h^{-1}. As the efficiency of utilization of metabolizable energy for traction cannot be treated separately from that for maintenance, the value of that efficiency for both purposes is set at 0.6. The energy requirements for traction, 0.10 FU h^{-1} are thus much lower than reported by FAO (1972). For preliminary calculations it is assumed that these requirements are met by barleys grains, and as donkeys are employed in barley cultivations, the requirements are subtracted from the barley grain production (van de Ven, 1986; 1987a).

To account for a net increase of the population of donkeys, which is assumed equal to the increase in human population in the northwestern coastal zone (2.2% yr^{-1}), the feed requirements are multiplied by an arbitrarily chosen factor (1.2).

3.4 Camels

The importance of camel raising has decreased in recent years in the coastal zone for several reasons. The main reason is probably the poor and uncertain reproductive performance of the camels (Yagil, 1986), due to nutritional problems. Camels require large quantities of forage, which is only available in limited quantities due to the high stock number of sheep and goats. In addition, supplementary feed is not subsidised, unlike that for sheep and goats. Moreover, camels are excluded from the export trade, and the local market is almost non-existent, due to the high prices demanded. The role of camels in transportation and ploughing has largely been taken over by trucks and tractors, respectively. Therefore, only a few Bedouin who inherited and maintained camels for generations continue raising camels (Shehata, 1982; Soliman, 1983).

No information is available on the number of camels, nor on their distribution among the four regions. Rather arbitrarily, it is assumed that 200 head occur in the coastal zone, being distributed similar to sheep and goats (Section 2.1). No data are available on the ratio of male to female camels, nor on their age distribution.

The camel in the Delta and probably also in the irrigated areas of the coastal zone is a mixed strain of Sudanese pack camels, the Maqhrabi of Lybia and the camels bred in Upper Egypt (Wilson, 1984). The camel in the rainfed area of the zone is probably the Maqhrabi strain, a general purpose pack type (Wilson, 1984).

Camels weigh about 500 kg (FAO, 1972), 450 to 590 kg (Williamson and Payne, 1978) or 370 to 600 kg (male) and 350 to 520 kg (female; Goe, 1983). In this study the average weight is set at 400 kg.

Common bacterial diseases are skin necrosis, Pasteurellosis and Pulmonary streptothricosis. Camel trypanomosiasis (debab, zoubib, djaffa) is probably the most important health problem of all, being transmitted by a biting fly (Wilson, 1984).

The best age of slaughtering is 2 to 3 years, as taste and dressing percentage decrease with age (63% at 32 months to 56% for a 19 to 20 year old camel, Sohail, (1983)). It should be realized that camels are not fertile before 5 to 6 years of age (Yagil, 1986), so that early slaughtering means a decrease in the potential herd increase rate. As no data are available on sales, it is assumed that 3% of the total population is sold annually at a weight of 350 kg and a dressing percentage of 60%.

Camel milk compares in general favourably with goat milk, but not with that of sheep (Sohail, 1983). Fat content ranges from 2.9 to 5.5%, protein content from 2.5 to 4.5%, lactose content from 2.9 to 5.8% and non-fat solids content from 8.9 to 14.3% (Knoes et al., 1986). Milk production is about 1130 to 1560 kg under desert conditions, but may increase to about 5000 kg under improved conditions (Williamson and Payne, 1978) over a lactation period that ranges from 9 to 18 months (Wilson, 1984). El Bahay (quoted by Knoes et al., 1986) estimates the milk yield of Egyptian camels (probably under desert conditions) at 1600 to 2000 kg. FAO (1970c) estimates total camel milk production in the coastal zone at 1500 ton yr^{-1}. In this report a milk yield of 1800 kg per lactation period of 12 months is applied, which is equally distributed over the year (CAMMP, 150 kg mth^{-1}). Due to the low prolificacy it is further assumed that only 20% of the females are being milked (CAFMIL).

Camel hair production is of minor importance, and it is generally sold to the shearer, who is a specialist (Shehata, 1982). Wilson (1984) estimates the yield at 1.0 to 1.4 kg $head^{-1}$, whereas Sohail (1983) reports a production ranging from 1.5 to 2.0 kg $head^{-1}$. A value of 1.5 kg $head^{-1}$ is applied here and it is assumed that 70% of total head number is sheared annually.

The tractive effort of camels is around 1/6 of their liveweight at a speed of 3.6 km h^{-1} (Wilson, 1984). It is assumed that camels work on average 4 hours during 10 days a month to transport the family. In addition, camels are used for ploughing. That takes place in November during an estimated period of 4 hours during 20 days. As young animals cannot be used for traction, it is assumed that 80% of total number is used for work.

Feed requirements for maintenance purposes (CAMRQ) are estimated at 45 MJ ME d^{-1} for a camel weighing 400 kg (Wilson, 1984), equal to 109.5 FU mth^{-1} (Table 8). These requirements are multiplied by 1.6 to account for other feed requirements that are not calculated separately. The feed requirements for one liter milk are 5 MJ ME and for one hour of work 8.2 MJ ME (Wilson, 1984), being equal to 0.40 FU l^{-1} and 0.66 FU h^{-1}, respectively. Although camels are often milked (Yagil, 1986), no milking requirements are calculated because of lack of data.

In addition, camels require 142 g salt per day (Williamson and Payne, 1978), which is often obtained from saltbush species (see Paragraph 4.2.1.2).

3.5 Cattle

Cattle in the northwestern coastal zone belong to the Damascus Cattle breeds found in the coastal regions from Turkey to Egypt (Williamson and Payne, 1978; Felius, 1986). The breed is locally called Baladi. The Baladi is a finely built medium-size cattle, its hair is red to brown with a light band on the muzzle and a black switch. It is said that the breed is particularly heat-tolerant and that individuals are long-lived. It is considered to be a milking breed, but not used for work purposes (Wiliamson and Payne, 1978). In addition to Baladi cows, crossbreds with Egyptian Friesians may occur (Mansour, pers. comm., 1987).

Cattle occur in the irrigated part of the coastal zone, i.e. the area from Alexandria to El Hammam (the eastern part of the Burg el Arab region), but the number of cows in that region decreases when going westwards (El Sayed, 1980). The number of cattle was 276 in 1981 (Soliman, 1981), but no present estimates are available. In this study a number of 300 head in the Burg el Arab region is assumed. From El Hammam onwards no cows have been reported, but during a fieldtrip (March 1987) 35 cows were observed near Mersa Matruh. It may be expected that more cows are present in the Matruh region, but for preliminary calculations that number is applied.

No detailed data are available on the characteristics of these animals such as use, age distribution, and productivity.

Cows weigh on average 400 kg, and a bull 500 kg. However, based on observations in the Matruh region, the average weight is estimated at 350 kg.

Milk production is estimated to be very low (El Naga, pers. comm., 1984). Mansour (pers. comm., 1987) estimates the production at 500 to 600 liter during a 5 to 6 months lactation period. That production is low compared to 1500 to 3000 kg per lactation as reported by Williamson and Payne (1978) and to 2300 kg lactation period^{-1}, being the average for the whole of Egypt (Al Sayyad, 1976). A milk yield of 550 kg lactation period^{-1} is applied in this study, and as the calving interval is about 15 months (Mansour, pers. comm., 1987), it can be calculated that at least 3 cows are required to have milk throughout the year. As no data are available, it is assumed that milk is produced evenly over the 12 months. Consequently, monthly milk production is 46 kg. Furthermore, it is assumed that 90% of the total head number is being milked (CTFMIL).

Feed requirements for maintenance purposes are estimated at 0.036 FU per kg metabolic weight per day (Munzinger, 1982; Hermans, 1986), being equal to 89 FU cow^{-1} mth^{-1}. That value is multiplied with 1.3 to account for the requirements of milking, steaming up, etc. Because of lack of data elaboration of cattle requirements does not improve accuracy.

Feed requirements for milk are 0.38 FU kg^{-1}, and applying the milk yield as estimated before results in 17.5 FU mth^{-1}.

As feeding is predominantly with daily-cut berseem or maize leaves, cattle are not included in the feed balance calculations of the rangeland (Chapter 6).

3.6 Poultry

Chickens, and in a few cases ducks, geese and turkeys are kept by the families to provide them with cheap meat and eggs. The number of animals kept, generally not exceeding 10 to 12 head per family is limited by the availability of kitchen waste. It is assumed that these animals are fed with kitchen waste only and that no other feeds (grains) are supplied. Generally, the products are used within the household.

A few Bedouin may keep pigeons, but they are mainly kept by inhabitants of villages for eggs and meat production.

No data are available on the production, nor on the total number of those animals in the region. Hence, poultry is not included in the calculations of the animal production systems.

3.7 Other animal species

Buffaloes are kept in Egypt as a triple-purpose animal (milk, meat and traction). It can therefore be expected that buffaloes occur in the irrigated part of the northwestern coastal zone, but no data on head number are available. In an experiment Alim (1982) obtained an average weight of 488 kg and a total milk yield of 1275 kg, with 6.1% fat, 8.8% solid non-fat and 14.8% total solids.

Rabbits are kept both by Bedouin and inhabitants of villages, but no detailed information is available.

Horses are rarely found in the zone, but one was observed during a field trip in the area of Mersa Matruh.

Deer are raised in the area of Mersa Matruh for meat production (Mansour, pers. comm., 1987).

As data are too limited, these animal species are not included in the calculations performed in this study.

CHAPTER 4.

AVAILABLE FEED RESOURCES

4.1 Introduction

The rangeland area in the coastal zone is estimated at 90% of the total area, but the area actually grazed by the animals varies from year to year, depending on quantity and distribution of rainfall.

In the northwestern coastal zone, the Bedouin depend on four types of pasture (Figure 4), namely:

1. The coastal strip with natural vegetation extending 15-20 km inland (Section 4.2).
2. The inland "marginal" area, with natural vegetation, extending from 15-20 km to 50 km inland (Section 4.2).
3. The cultivated areas in the coastal zone, where flocks graze between the barley fields and on their aftermaths after harvest, such as the irrigated areas near Burg el Arab (Section 4.3).
4. The cultivated areas outside the coastal zone, such as the irrigated areas near Alexandria and in the Nile Delta (Section 4.4).

As stressed before, forage production on the pastures of the coastal zone is grossly insufficient, both in quantity and in quality to feed the still increasing number of animals. However, due to the liberal supply of supplementary feed, such high animal densities can be maintained. The supplementary feed source varies from place to place and in the course of time (Section 4.5).

4.2 Rangeland forage

Due to sedentarization of the Bedouin in the coastal strip, and the availability of water and supplements in summer, the natural pasture in that strip is intensively used, whereas the inland marginal areas are used less intensively (Figure 7). Plant production in the inland marginal area is possible due to the maritime effect (FAO, 1970a; Ghabbour, 1983), but at a distance of 50 to 60 km inland, the area is almost completely barren. Grazing in the inland marginal areas takes place only during winter and spring, when the moisture content of the pasture plants is high enough to permit dry matter intake without access to free water. However, in normal years, when rainfall is about 125 mm, green pasture is available for about 3 months only (ALAP, 1986), the grazing areas being controlled by grazing rights exercised by Bedouin families or tribes (Aboul-Naga et al., 1985a).

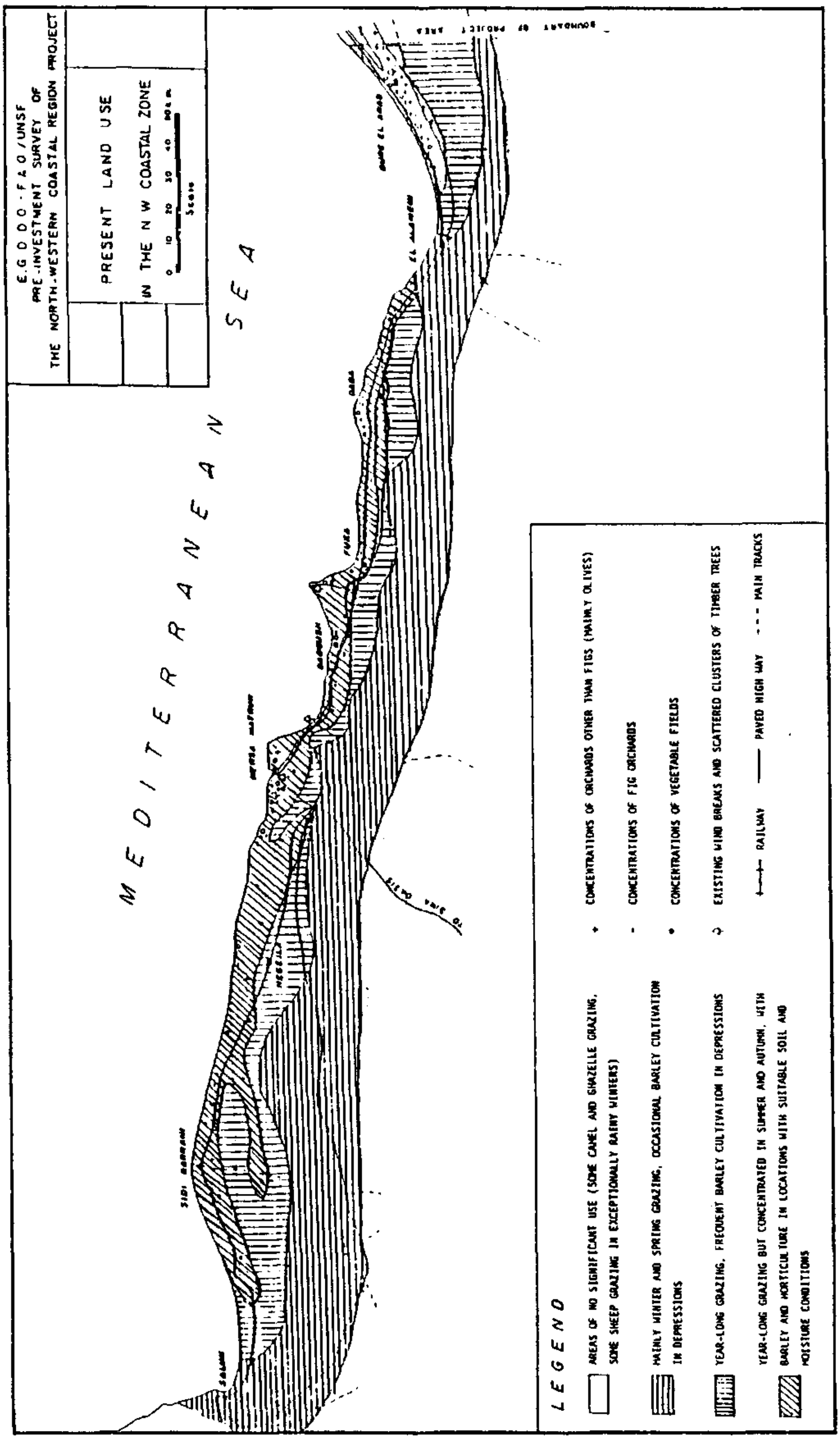


Figure 7. Different forms of grazing in the northwestern coastal zone. (FAO, 1970a).

4.2.1 Botanical composition

4.2.1.1 General description

In contrast to the situation described in the PSG (Seligman and Spharim, 1987), where the natural vegetation of the rangeland consists of annuals only, the natural vegetation in the coastal zone consists of annuals (mostly herbs and only a few grasses), perennial herbs, shrubs, subshrubs (halfshrubs or dwarfshrubs), and a few trees. The botanical composition is spatially heterogeneous, as it depends on soil fertility, topography and climatological conditions, but generally, subshrub species are dominant. Hence, these plants on which the rangeland classification is based (Paragraph 4.2.1.3) are discussed in more detail in the following paragraph.

4.2.1.2 Subshrubs

Subshrubs are considered a separate group among perennial plants, due to their characteristic structure, although the structure and anatomical features of the subshrubs vary per species. The structure is mainly the result of their growth under heavy grazing pressure. Branches that have recently developed are eaten by animals, which leads to changes in the physiological processes in the plant and consequently, secondary buds develop. This process of continuous growth and removal is repeated many times and the result is a very dense structure, with a considerable amount of woody material. The lignotuber which appears under (extremely) heavy grazing pressure constitutes a considerable part of that woody material. The development of lignotubers with their ability to produce shoot sprouts following periods of stress is essential to the survival and perpetuation of shrublands (Specht, 1981). Main subshrub species of the coastal zone are: Echiochilon fruticosum, Gymnocarpos decandrum, Convolvulus lanatus, Artemisia monosperma, Noaea mucronata and Pituranthos tortuosis. For more detailed descriptions of these species, reference is made to e.g. Tackhölm (1974).

Generally, the density of subshrubs decreases rapidly from about 15-20 km from the coast southwards, except in occasional depressions, and in the areas near Sidi Barrani and near Burg el Arab (FAO, 1970c).

Grazing experiments carried out by van Duivenbooden (1985b) in El Omayed have shown that grazing has a stimulating effect on the development and growth of the subshrubs, in terms of extension of the growing season by about two months. Due to the defoliation and the associated reduction in transpiration, residual water remains in the deeper soil layers during the rainy season. This water is then used in the hot and dry season by the subshrubs, if grazing pressure is continued! If the plants are not grazed in summer, uptake of water by the subshrubs stops, and elongation of the branches occurs at the cost of structural reserves (e.g. starch). Moreover, the quantity of dead material per plant is about 10% higher in the non-grazed plants than in those grazed continuously. Hence, grazing in summer is necessary to maintain the vegetation which appears in a poor condition, in an equilibrium state. Protection from grazing of the subshrubs for a prolonged period of time leads to a shift in the botanical composition of the rangeland towards a higher proportion of annuals. That in turn will lead to a lower biomass production on those sandy soils in years with very low rainfall. Similar phenomena have been observed in Tanzania and China (Breman, pers. comm., 1986).

Grazing is thus an important management tool in protecting the vegetation in semi-arid regions, provided that the grazing pressure doe not exceed the tolerance of that plant species. It is known that tolerance differs per plant species, but that has not yet been quantified (Noy-Meir, 1975; McNaughton, 1979).

4.2.1.3 Rangeland classification

Seven main range types have been distinguished by FAO (1970c, Figure 5) based on the occurrence of subshrubs:

I. Salt marsh range type

This type of rangeland, consisting of bushes, occurs in the Burg el Arab and the Dabaa regions and to a lesser extent in the Barrani region. The main species with some value for grazing are Salsola tetranda and Sueda pruinosa. The main grazing period is in autumn following the first rains, except for camels who graze year-round. The amount of forage obtained from this range type is very limited, even though the vegetation density is generally high (FAO, 1970c). Furthermore, on this vegetation type Barki X Merino crossbred lambs lost weight unless supplementary sources for feeding were available. Hence, the use of this type of vegetation is questionable (Hassan et al., 1982).

II. Gymnocarpus range type

This range type comprises two sub-types. The first one occurs on rocky sites with a shallow layer of loamy material overlying the eroded slopes and crest of the first escarpment, about 5-10 km inland. In that sub-type a number of perennial species are present with good grazing value, e.g. Dactylis glomerata var. hispanica. Ephemerals and other annuals such as Rumex pictus, Cutandia dichotoma, Adonis dentatus, and Anthemis microsperma (Ayyad and El Kadi, 1982) are sparse, except on colluvium and aeolian accumulations. Because of heavy grazing, the density of perennials is often low, especially where the escarpment is close to areas with relatively high population densities.

The other sub-type is situated further inland, mainly in the Barrani region, 15-30 km inland and occurs on shallow desert soils consisting mainly of aeolian deposits on bedrock. In certain areas where residual alluvial deposits occur, Artemisia herba-alba is also present, while other perennial species which provide forage include Stipa spp., Pythoranthus tortuosus, Helianthenum ellipticum and Echiochilon fruticosum. Ephemerals and other annuals are relatively abundant, following good winter rains.

Grazing on the first sub-type is mainly in late spring, summer and autumn, while most grazing in the second sub-type takes place in winter, spring and early summer (FAO, 1970c).

III. Artemisia range type

In this range type Artemisia herba-alba is the dominant subshrub. It occurs mainly on medium deep calcareous loamy to sandy soils in various areas (Figure 8). Some relatively extensive areas with A. herba-alba as main palatable subshrub occur in the region south of El Omayed, El Hammam and Burg el Arab. Especially when overgrazed, it is accompanied by dense stands of Asphodelus microcarpus, a tuberous plant, which is a highly selected species (Abdel Salam, 1985). Annuals are relatively dense in places that receive runoff. Grazing takes place mainly in summer and autumn (FAO, 1970c).

IV. Haloxylon range type

This range type occurs on relatively shallow soils. It may be a form of the previous range type, degraded in terms of density after ploughing and grazing. Barley cultivation is common in these areas when rains are good in the beginning of the season and sufficient seed is available from the last harvest. Haloxylon articulatum survives cultivation or re-establishes itself relatively soon, while the more palatable species, such as Artemisia and Pythoranthus disappear. Because of the low palatability of the main subshrub, the main source of herbage for the animals are the annuals, and consequently, grazing takes place in late winter and spring. When other vegetation is sparse H. articulatum is grazed to some extent in summer and autumn (FAO, 1970c).

V. Plantago range type.

This range type occurs primarily on inland semi-stabilized dunes. In addition to Plantago albicans, the palatable species are E. fruticosum and Helianthenum lipii. On deep sandy soils Thymelia hirsuta is a very conspicuous component of the vegetation. According to FAO (1970c) it has a very low palatability, but nevertheless it is often grazed (Abdel Salam, 1985). Furthermore, A. microcarpus occurs in this type of vegetation.

VI. Anabasis range type

This range type is the most xerophytic and extends into the desert south of the other types, and further inland than the area regularly grazed by sheep and goats. In that area rainfall and relative humidity are lower, and the soils are rocky and shallow. Zygophyllum album usually accompanies Anabasis articulata in this type, especially further south. There is usually a fairly wide transition zone to adjacent palatable range types to the north, while eastwards plants such as Aristada ciliata from the drier sandy desert vegetation to the south are common (FAO, 1970c).

VII. Depressions range type

Fairly large depressions occur with relatively dense stands of perennials, such as T. hirsuta, P. tortuosus, Atriplex halimus, Helianthenum spp., S. tetranda and A. herba-alba., on loam or sandy loam soils, often with sand accumulations at the surface. Annuals occur in depressions, where their density may be higher than in other range types, especially after good winter rains. The utilization of this range type by sheep and goats could extend into early summer in good years if more watering points would be available (FAO, 1970c). However, the risk of over-exploitation is rather high.

The use of the different range types and of different plant types is summarized in Tables 14 and 15, respectively.

Table 14. Grazing of different range types in the course of the year (partly derived from FAO, 1970c).

RANGE TYPE	AUTUMN	WINTER			SPRING	SUMMER		
		early	middle	late		early	middle	late
SALT MARSH	+							
GYMNOCARPUS								
inland			+		+			
strip	+		+		+		+	
ARTEMISIA	+		+		+		+	
HALOXYLON			+		+			
PLANTAGO				+		+		
ANABASIS			+		+		+	
DEPRESSIONS			+		+		+	

Table 15. Grazing of different plant types in the course of the year (partly derived from FAO, 1970c).

PLANT TYPE	AUTUMN	WINTER	SPRING		SUMMER	
			early	late	early	late
PERENNIALS						
shrubs	+					+
subshrubs	+	+	+	+	+	+
ANNUALS						
green	+	+	+			
dried up				+	+	

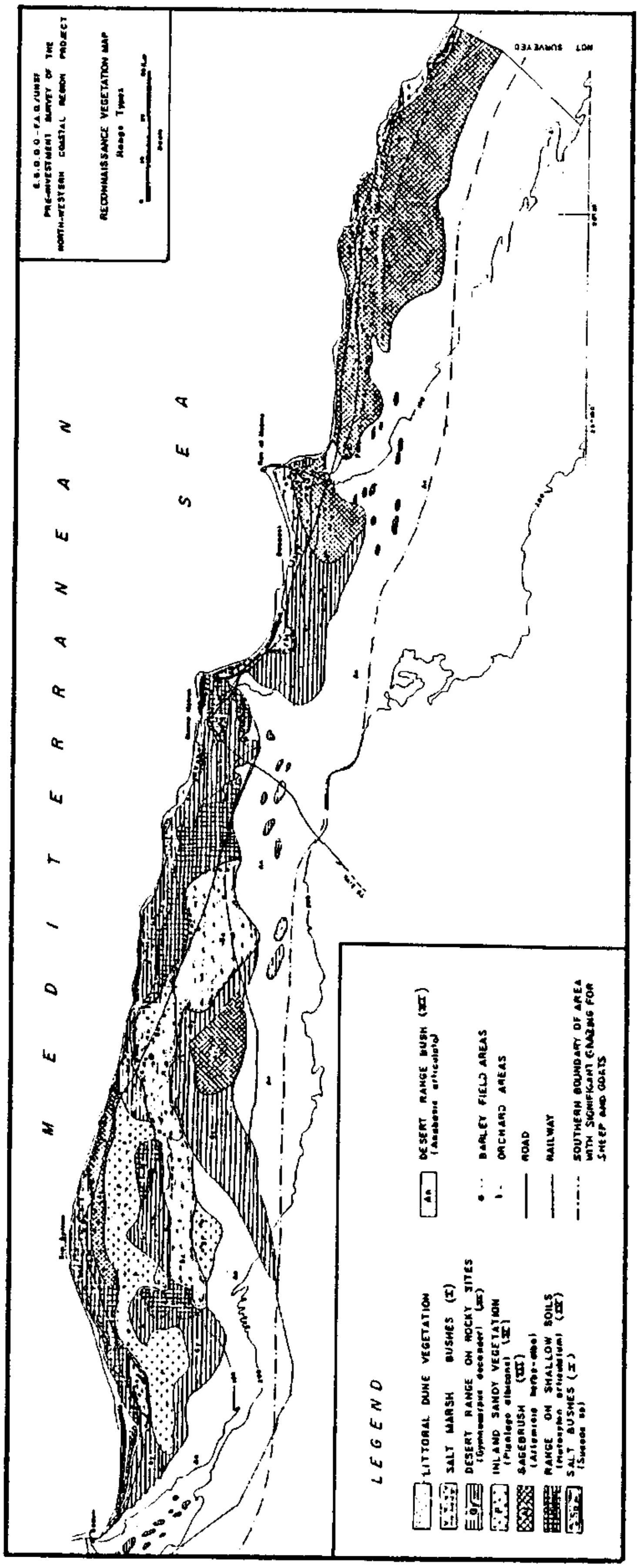


Figure 8. Reconnaissance vegetation map of the northwestern coastal zone (FAO, 1970c).

4.2.2 Biomass production

4.2.2.1 General description

Generally, primary production in semi-arid regions is determined by soil moisture availability and/or soil fertility. The production of the vegetation in the coastal zone is low and the inter-annual variability is high due to the variability in precipitation.

Accurate determination of the standing biomass on the rangeland is very difficult due to the heterogeneity of the vegetation. Generally, peak biomass occurs at the end of winter and in early spring, and standing biomass decreases subsequently (Shaltout and El Ghareeb, 1984). However, regional differences in biomass production exist. Because of the problems associated with measurement of biomass production, primary production of the vegetation was calculated using the simulation model ARID SHRUB developed by van Duivenbooden (1985b), an adapted version of ARID CROP (van Keulen, 1975). In the former model the growth of subshrubs (especially, E. fruticosum), and the soil water balance under grazed and non-grazed conditions in El Omayed are simulated. The fraction of the biomass available for grazing is difficult to establish because it varies with species, e.g. from A. microcarpus only the tips of the leaves are eaten. As no data are available on the relation between standing biomass, available biomass for grazing and ingestion of a species by animals it is assumed in the model that the produced biomass above a certain minimum standing biomass is grazed completely.

If nutrient availability would be sufficient, in other words if production is limited by water availability only, biomass production with an annual precipitation of 125 mm would be about 1300 kg DM ha^{-1} yr^{-1}. Assuming an average nitrogen concentration in the biomass of 1.6% (derived from Table 22), that production would imply a nitrogen uptake by the vegetation of about 21 kg ha^{-1} yr^{-1}. Such a nitrogen supply could be expected from a soil containing about 0.7% organic matter, as 1% organic matter in such a soil yields approximately 30 kg mineralised N ha^{-1} yr^{-1} (Janssen, pers. comm., 1985). Recent soil studies in El Omayed (Gomaa, 1980; van Duivenbooden, 1985b), however, show an organic matter content of only 0.1 to 0.2%. Hence, biomass production of the rangeland is limited by nitrogen availability and under the present conditions an uptake of about 6 kg N ha^{-1} yr^{-1} seems more realistic. Consequently, the production of the subshrubs is lower than determined by moisture availability. This has been taken into account in the model by reducing the maximum rate of photosynthesis of individual leaves (van Keulen and Seligman, 1987). If annuals are present, it is assumed that their production capacity is equal to that of the perennials, but that their growth is at the expense of the perennials, due to limited moisture and nutrient availability.

As no data are available on soil fertility of the rangeland in the other regions, as a first approximation the biomass production of the subshrubs for those regions is simulated as a function of precipitation and standing biomass by means of the model ARID SHRUB. Subsequently, the results are adapted by comparison with the carrying capacity at the end of the sixties (Figure 9, FAO, 1970c), and the reconnaissance soil maps of FAO (1970b). For that purpose, four precipitation (P) zones are distinguished: P exceeding 150 mm; $125 < P < 150$ mm; $100 < P < 125$ mm and $75 < P < 100$ mm, represented by schematic rainfall quantities of 162, 137, 122 and 87 mm, respectively. Standing biomass of the vegetation is set arbitrarily at 250 kg DM ha^{-1} for the area between the barley fields, and at 400 kg DM ha^{-1} for the rangeland for a sparse vegetation, and at 700 kg DM ha^{-1} for a "normal" density vegetation as measured in El Omayed (van Duivenbooden, 1985b). To simulate production of the vegetation in the 'barley area' soil physical characteristics of soil type B1 are used (van de Ven, 1986). Due to a higher soil fertilitity, biomass production between the barley fields exceeds that of the rangeland.

The simulated annual production of the subshrubs (above ground standing biomass is 700 kg DM ha^{-1}) at 112 mm precipitation is about 590 kg DM ha^{-1} yr^{-1}, if left ungrazed. However, that material is useless for grazing at the end of the dry season, because of its very inferior quality. Moreover, in that situation soil moisture will have been almost completely depleted through transpiration. Under grazing, biomass production is slightly lower at about 550 kg DM ha^{-1} yr^{-1}, but the plants remain more green, maintaining a higher nutritive value than the non-grazed plants. Furthermore, biomass production is distributed over a longer period. The results of the simulation runs for the subshrubs are given in Table 16.

Table 16. Simulated biomass production (kg DM ha^{-1} mth^{-1}) of subshrubs in the course of the year with varying standing biomass (STBM, in kg DM ha^{-1}), at different artificial rainfall regimes (P, in mm), between the barley fields, and on the rangeland.

	RANGELAND								BARLEY FIELDS			
P =	87	112	137	162	87	112	137	162	125	125	250	250
STBM =	400	400	400	400	700	700	700	700	250	400	700	1400
OCT.	10	10	35	35	18	18	61	61	8	12	65	86
NOV.	14	43	28	28	23	76	54	54	29	47	69	89
DEC.	48	33	35	36	86	67	66	67	25	39	79	91
JAN.	40	49	55	56	71	76	81	83	34	54	88	102
FEB.	57	67	81	84	76	84	90	93	49	77	99	112
MAR.	72	72	102	106	74	85	95	99	59	97	105	126
APR.	78	91	102	110	61	82	94	102	93	102	109	129
MAY	33	53	62	68	0	43	52	57	72	68	71	73
JUNE	0	42	62	73	0	18	53	63	81	77	83	88
JULY	0	0	38	55	0	0	22	45	65	61	66	67
AUG.	0	0	0	35	0	0	0	40	45	43	46	53
SEPT.	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	352	460	600	686	409	549	668	764	560	677	880	1016

4.2.2.2 Production on different soil types

In the region various soil types are distinguished (FAO, 1970b). Some of them are suitable for barley cultivation (described by van de Ven, 1986), others for fruit tree cultivation (Abdel-Razik and van de Ven, 1987). On the remainder natural vegetation occurs, but it is beyond the scope of this report to describe the various soil types in great detail.

Rangeland productivity varies with soil type, but due to lack of data differentiation between biomass production on all the soil types is not possible. Therefore, various soil types with more or less the same characteristics are pulled. Subsequently, biomass production on these soil types per precipitation regime is estimated. Total biomass production per precipitation regime is the weighted average of the biomass productions on the different soil types within that regime. Next, these data are used as inputs (feed availability) in the model ARID ANIMAL.

The following soil types have been distinguished on which different values of biomass production are expected:

1. D02, D03 (D02)

The coastal dunes consist of oolitic sand with a high $CaCO_3$ content (70-80%) and are not suitable for agriculture, because the soil is too hard to be penetrated by roots. However, some annuals are expected on the loose topsoil of soil type D02, and in a few places where roots can penetrate the cemented soil, perennials are expected. Due to the scattered nature of the vegetation the productivity on this soil type is estimated at 175, 150 and 125 kg DM ha^{-1} yr^{-1}, for P>150 mm, 125<P<150 mm and 100<P<125 mm, respectively.

2. Bp, F4 (Bp)

The Bp soil is poorly drained and very saline with a variable texture, whereas the F4 soil type has a saline to moderately saline topsoil. In most places water is not expected to be a limiting factor for the salt tolerant species, due to the underground supply of salt water (combining Figures 2, 8 and 9). Annual biomass production is estimated at 200 kg DM ha^{-1}.

3. Rd, Rde, Rdg, Rf, Rs (Rd)

The profile of the R-soil types consist of less than 30 cm soil over rock. Based on differences in morphologic features subdivisions are made.

On these rocky soils predominantly subshrubs grow, the vegetation belonging to the Haloxylon range type. Due to the rockiness of the soil surface, the vegetation is scattered and surface runoff occurs. Therefore, biomass production is estimated assuming a standing biomass of 400 kg DM ha^{-1}, as shown in Table 16. From Figure 9 it can be deduced that biomass production in the precipitation regime between 100 and 125 mm equals that of the P-regime between 75 and 100 mm. Accordingly, annual biomass production is set at 350 kg DM ha^{-1} for the regimes with 75<P<125 mm.

4. Rp, Rh, Rr, Rt, DS6 (Rp)

These soil types equal more or less the previous soil types, but the vegetation belongs to the Anabasis, Gymnocarpus, or Haloxylon range type. These soils occur mainly in the southern part of the coastal zone. Production is estimated in first instance, assuming a standing biomass of 700 kg DM ha^{-1}, as shown in Table 16. However, if these simulated values are compared with those from El Omayed as given in Figure 9, it appears that the simulated biomass production is an overestimate. From Figure 9 it can be derived that biomass production is 50 to 83% of that in El Omayed independent of precipitation regime. Accordingly, an annual biomass production of 300 kg DM ha^{-1} is applied here for all rainfall regimes.

5. Ds1, Ds2, Ds3, Ds4, Ds7, Ds8 (Ds1)

The inland dunes consist of oolitic or quartz sand and the soils are divided according to differences in topography and $CaCO_3$ content.

On these soil types mainly shrubs, subshrubs and perennial herbs occur, the vegetation belonging to either the Artemisia, Gymnocarpus or Plantago range type. Density of the vegetation and production are spatially heterogeneous. Production is first estimated, assuming a standing biomass of 700 kg DM ha^{-1}, as given in Table 16. Similarly to the soil type RD, it is difficult to distinguish between P-regimes 75-100 mm and 100-125 mm. Accordingly, annual biomass production for these two regimes is set at 450 kg DM ha^{-1}.

6. C3

On this complex of rock and deep loamy oolitic sand, plants similar to those on the soil type Ds1 are expected, although the density may be lower. Therefore, biomass production is in first instance estimated, assuming a standing biomass of 400 kg DM ha^{-1}, as shown in Table 16. From Figure 9 it can be deduced that the biomass production on this soil type is 62.5% of that simulated in El Omayed. The production of 200 kg DM ha^{-1} yr^{-1} is much lower than obtained for this precipitation regime (Table 16). Accordingly, a yield of 360 kg DM ha^{-1} yr^{-1} seems more appropriate.

7. C4

On this complex of salty and cemented oolitic sand the salt marsh range type occurs. Applying Figure 9, annual biomass production is estimated at 200 kg DM ha^{-1}.

8. Fle

On this soil type, consisting of sandy loam to loam texture and occurring on slightly sloping areas having a topsoil of only 5 to 20 cm in some places, annuals are expected. Due to its sparse nature the annual biomas production is estimated at 150 kg DM ha^{-1} for $125<P<150$ mm and 100 kg DM ha^{-1} for $100<P<125$ mm.

9. Bl, Bs2, B4d, F2, F3, F4, Wb, Ww (BA)

These soils were in first instance considered suitable for barley cultivation. However, it turned out that not all these soils can be cultivated due to shortage of water. Part of the area is therefore used as catchment area (van de Ven, 1986; 1987d). Consequently, on that area where no barley is grown (ARLBBF), natural vegetation occurs which is used as rangeland by the Bedouin. It is assumed that the standing biomass varies between 250 and 400 kg DM ha^{-1}, the annual biomass production is set at 600 kg DM ha^{-1} (Table 16).

10. Miscellaneous

For the area from Sidi Barrani westwards no soil map is available. There is no reason to assume that the soils change and in that area and hence they comprise soil types Rp, Ds6 and Rd. Accordingly, an annual biomass production of 300 kg DM ha^{-1} for $75<P<125$ mm and 400 kg DM ha^{-1} for $P>125$ mm is applied.

4.2.2.3 Production in the four regions

Applying the data given in Paragraph 4.2.2.1, the biomass productions for the four regions is calculated. The results for the Burg el Arab, the Dabaa, the Matruh and the Barrani regions are given in Tables 17, 18, 19 and 20, respectively.

To calculate the feed balance in the course of the year, the distribution of forage available for grazing (RLPD) must be known. That distribution depends on the rainfall regime and is calculated in accordance with Table 16 (STBM = 700 kg DM ha^{-1}).

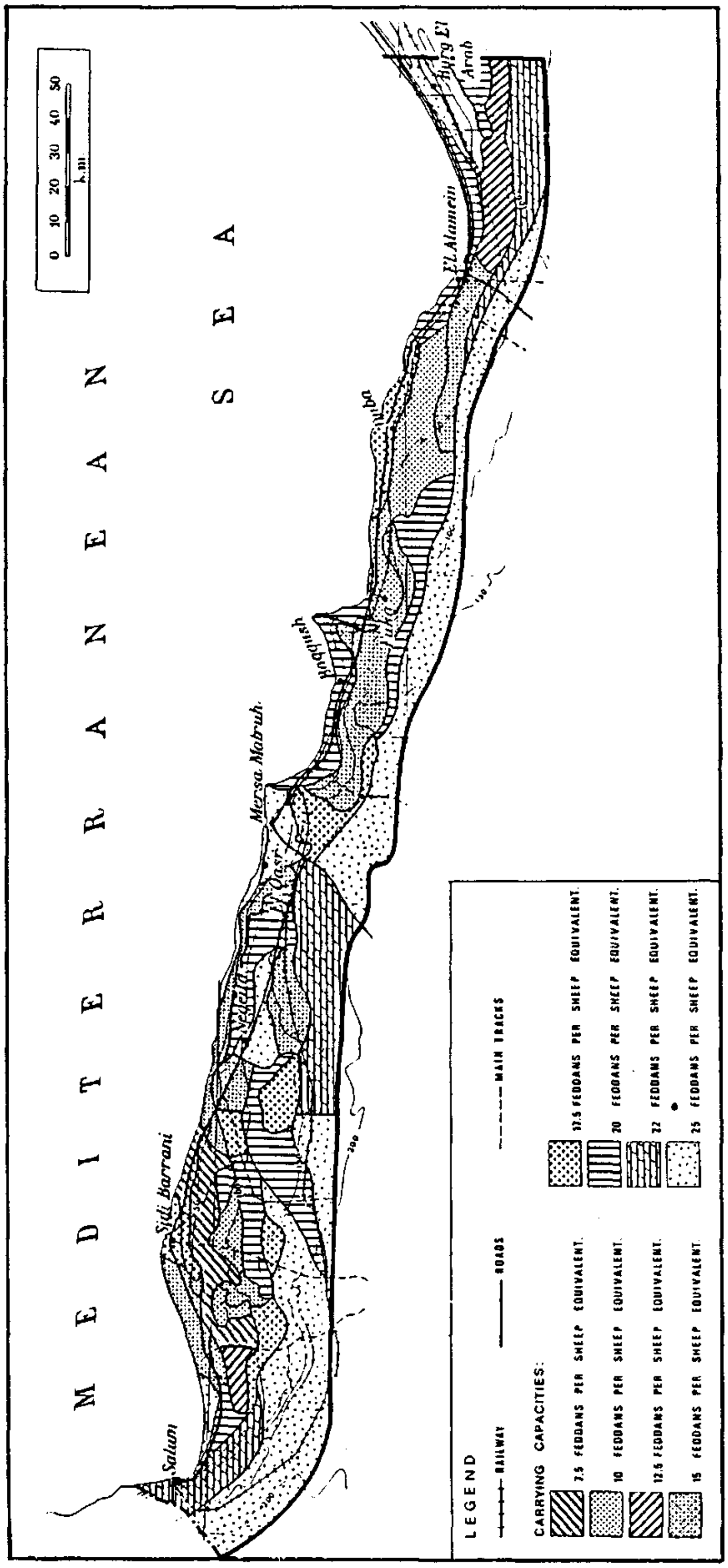


Figure 9. Estimated carrying capacity in 1970 (FAO, 1970a).

Table 17. Estimated annual biomass production of the vegetation available for grazing on different soil types under various rainfall regimes in the Burg el Arab region.

SOIL TYPE	PRECIPITATION (mm)	AREA (ha)	PRODUCTION (kg DM ha^{-1} yr^{-1})	PERIOD OF AVAILABILITY
	P > 150			
DO2		1380	175	October - September
Bp		4600	200	October - October
Rd		3100	685	October - September
subtotal/weighted average		9080	360	October - September
	125 < P < 150			
DO2		700	150	October - August
Bp		4570	200	October - October
Rd		3150	600	October - August
subtotal/weighted average		8420	345	October - August
	100 < P < 125			
DO2		690	125	October - July
Bp		4570	200	October - October
Rd		5900	350	October - July
Dsl		13980	450	October - July
C3		1570	360	October - July
subtotal/weighted average		26710	370	October - July
	75 < P < 100			
Rd		7730	350	October - May
Rp		36090	300	October - May
Dsl		25090	450	October - May
subtotal/weighted average		68910	360	October - May
BA		16990	600	October - Sept.
TOTAL		130110		

Table 18. Estimated annual biomass production of the vegetation available for grazing on different soil types under various rainfall regimes in the Dabaa region.

SOIL TYPE	PRECIPITATION (mm)	AREA (ha)	PRODUCTION (kg DM ha^{-1} yr^{-1})	PERIOD OF AVAILABILITY
	P > 150			
		0		
	125 < P < 150			
DO2		1630	150	October - August
Bp		2450	200	October - October
Rd		22000	600	October - August
Dsl		3000	650	October - August
C4		2300	200	October - August
subtotal/weighted average		31380	520	October - August
	100 < P < 125			
DO2		830	125	October - July
Bp		940	200	October - October
Rd		38240	350	October - July
Rp		9100	300	October - July
Dsl		48890	450	October - July
subtotal/weighted average		98000	390	October - July
	75 < P < 100			
Rd		7050	350	October - May
Rp		65100	300	October - May
Dsl		20750	450	October - May
subtotal/weighted average		92900	340	October - May
BA		32650	600	October - Sept.
TOTAL		254930		

Table 19. Estimated annual biomass production of the vegetation available for grazing on different soil types under various rainfall regimes in the Matruh region.

SOIL TYPE	PRECIPITATION (mm)	AREA (ha)	PRODUCTION (kg DM ha^{-1} yr^{-1})	PERIOD OF AVAILABILITY
	P > 150			
		0		
	125 < P < 150			
DO2		1800	150	October - August
Bp		2090	200	October - October
Rd		7940	600	October - August
Rp		14100	300	October - August
C3		200	360	October - August
Fle		2270	150	October - August
subtotal/weighted average		28400	355	October - August
	100 < P < 125			
DO2		440	125	October - July
Bp		1900	200	October - October
Rd		12940	350	October - July
Rp		121600	300	October - July
Dsl		250	410	October - July
Fie		260	450	October - July
subtotal/weighted av.		137390	305	October - July
	75 < P < 100			
Rd		3900	350	October - May
Rp		152610	300	October - May
subtotal/weighted av.		156510	300	October - May
BA		32000	600	October - Sept.
TOTAL		354300		

Table 20. Estimated annual biomass production of the vegetation available for grazing on different soil types under various rainfall regimes in the Barrani region.

SOIL TYPE	PRECIPITATION (mm)	AREA (ha)	PRODUCTION (kg DM ha^{-1} yr^{-1})	PERIOD OF AVAILABILITY
	P > 150			
DO2		70	175	October - October
	125 < P < 150			
DO2		430	150	October - August
Bp		50	200	October - October
Rd		11700	600	October - August
Rp		26250	300	October - August
Dsl		19540	650	October - August
miscellaneous		13850	400	October - August
subtotal/weighted average		71820	460	October - August
	100 < P < 125			
Rd		300	350	October - July
Rp		66010	300	October - July
Dsl		3200	450	October - July
miscellaneous		66480	300	October - July
subtotal/weighted av.		135990	305	October - July
	75 < P < 100			
Rp		86310	300	October - May
miscellaneous		99720	300	October - May
subtotal/weighted av.		186030	300	October - May
BA		17730	600	October - Sept.
TOTAL		411640		

Table 21. Weighted average of estimated annual biomass production of the vegetation available for grazing for the different rainfall zones, and on the rangeland between the barley fields in the coastal zone.

RAINFALL ZONE (mm)	AREA (ha)	BIOMASS PRODUCTION (kg DM ha^{-1} yr^{-1})
P > 150	9150	359
125 < P < 150	140020	445
100 < P < 125	398090	330
75 < P < 100	504350	316
BA	98130	600

4.2.3 Quality of forage

Forage quality is as important for animal productivity as forage availability (Breman and de Wit, 1983). The quality of a feed resource is mainly determined by its crude protein content and to a lesser extent by its energy content, expressed for instance in Total Digestible Nutrients (TDN) or in Feed Units (Table 8). However, it should be realized that a high TDN value does not always imply high quality!

Sheep and goats require in general a minimum crude protein (CP) concent of 7% on a dry matter basis for maintenance, which is equivalent to 1.1% N (ARC, 1980). Experiments, by Farid et al. (1983) showed a protein requirement of Barki rams of 325 mg N kg^{-1} $W^{0.75}$ d^{-1}, equivalent to 2.0 g protein kg^{-1} $W^{0.75}$ d^{-1} for maintenance and wool production, a value in accordance with general theory (ARC, 1980). Unfortunately, no protein requirements for higher production levels are available. For instance in Syria the total protein requirements of Awassi ewes may be as high as 12% on a DM basis (Nordblom and Thomson, 1987). Although it was observed that the animals selectively ingest only the young, green tips of stems and the leaves of the subshrubs, Figure 10 shows that the diet of the sheep at El Omayed is below maintenance requirements in July, September, October and April. For goats that holds for October only. It must be remarked that generalisation and extrapolation is doubtful, because the described phenomenon is valid only for that particular year in El Omayed. The quality of subshrub species in El Omayed is reasonable (despite the high ash content, Table 22), but apparently, the animals are not able to select their diet in such a way that their maintenance requirements are met. However, that situation is in sharp contrast to the situation in an annual pasture. Despite a lower intake in summer than in winter, the crude protein concent in the diet remains above 7%, due to selective intake of fine litter (de Ridder et al., 1986). For the situation illustrated in Figure 10 it is striking that the protein concent in the diet of sheep in August is high. This is probably caused by a substantial proportion of concentrates in the diet. Why the protein content in the diet decreases from August till October cannot be explained from the data available. The available forage in October is of such low quality that it must have a negative effect on the lambing and kidding rate and on the birth weight of the progeny. Unfortunately, no data on the quality of available forage in the other regions are available. It is assumed in this study that the quality of the plants in these regions is equal to that in El Omayed.

Pasture plants at El Omayed seem to be deficient in Vitamin A and Vitamin E, as supplementary feed experiments showed an increased daily weight gain (Subsection 3.1.6). Moreover, supplementation with salt bricks (a mixture of minerals, vitamins, nitrogen and carbohydrates) resulted in a final body weight, exceeding that of animals supplemented with Vitamin A and E only (Abdel Salam, 1985).

Another quality aspect is that the pasture plants are deficient in phosphorus. The ratio of calcium to phosphorus is in summer 26:1 for A. microcarpus and T. hirsuta, but may reach 10:1 for the subshrubs and 90:1 for Cutandia dichotoma. In winter the situation is even worse: ratios of up to 70:1 for subshrubs may occur (Abdel Salam, 1985). The summer forage is also deficient in sulfur (Abdel Salam, 1985), and Aboul-Naga (pers. comm., 1986) reports zinc and selenium deficiencies in the Dabaa and the Matruh regions, but the degree of deficiency and hence its effect is unknown.

Because insufficient information is available for a complete characterization, in the model forage quality is only described in terms of energy (feed units, FU). As green and dry pasture differ considerably in nutritive value, it is necessary to treat each of the two components separately in constructing the feed balance. Moreover, in pastures feed availability during the dry season is influenced to a large extent by its utilization during the green season, another reason for a separate treatment.

In a schematized setup the annual pasture cycle can be divided into three phases:

a. Green grazing period

The effective green grazing period is, by definition, that period when green pasture availability is sufficient for the animals to satisfy their appetite and meet all nutritional requirements (Seligman and Spharim, 1987). ALAP (1986) reports that this period lasts only 3 months, from December through February. For the intermediate systems it is assumed that these months comprise the green period, whereas for extensive systems it is assumed to last from November till February and for intensive systems from December till January only.

As no experimental data on forage quality in terms of FU are available, the nutritive value is estimated on the basis of literature data. The nutritional value of annual pasture, averaged over the whole green season is about 0.77 FU kg^{-1} DM (Seligman and Spharim, 1987). As the diet of the animals consists of both annuals and subshrubs, the latter having a somewhat lower quality, a nutritional value of 0.75 FU kg^{-1} DM is assumed for forage consumed during this period.

b. Early dry grazing period

The early dry grazing period is the period of two months directly following the green grazing period. It is assumed that also during this period all nutritional requirements of the animals are met by rangeland forage although pasture quality is lower than in the preceding period, but still considerably higher than during the remainder of the dry season. A nutritional value of 0.55 FU kg^{-1} DM is applied for this period.

c. Main dry grazing period

The main dry grazing period is the remaining period, thus for the intermediate systems the period from May till December, for extensive systems from May till November and for intensive systems from April till December. The nutritional value in that period is lower, as available annuals have dried. The nutritional value of the combined diet of shrubs and dry annuals is estimated at 0.45 FU kg^{-1} DM. That value is somewhat higher than the value of 0.2 to 0.4 FU kg^{-1} DM reported by Le Houérou and Hoste (1977), for shrubs and dry annuals, but falls within the range of 0.33 to 0.5 FU kg^{-1} DM reported by Seligman and

Spherim (1987), for dry annuals. In this period intake of poor quality forage is limited due to physiological limitations and the maximum intake is estimated at 1.6 kg d^{-1} EE-1 (Subsection 3.1.9). That intake is insufficient to meet all the requirements of the animals, hence supplements are necessary in this period.

Table 22. Chemical composition of pasture plants in summer (S) and winter (W) in El Omayed (averaged over 1981 and 1982). CP = Crude Protein, CF = Crude Fibre, EE = Ether Extract, NFE = Nitrogen Free Extract. See text for specification of species (Abdel Salam, 1985).

PLANT SPECIES	FEED COMPONENTS									
	ASH		CP		CF		EE		NFE	
	S	W	S	W	S	W	S	W	S	W
HERBS										
A.microcarpus	14.0	21.9	5.0	21.8	27.4	17.1	2.7	3.9	51.0	35.5
Pl.albicans	-	23.7	-	14.2	-	19.8	-	2.2	-	40.1
C.eriophalus	-	44.3	-	15.5	-	18.6	-	2.5	-	19.2
R.pictus	-	45.1	-	11.2	-	12.5	-	2.9	-	28.4
SHRUBS										
T.hirsuta	6.1	20.3	8.7	9.9	29.8	16.0	0.9	5.1	54.6	48.7
A.articulata	13.3	28.7	9.5	7.3	19.7	15.2	1.1	1.7	56.5	47.2
SUBSHRUBS										
G.decandrum	15.6	27.3	6.2	9.7	27.0	23.5	1.5	1.0	49.7	38.6
C.lanatus	14.2	18.1	7.1	8.7	36.5	21.2	0.6	2.0	41.7	50.1
H.lipii	16.6	-	6.8	-	23.0	-	1.2	-	52.5	-
E.fruticosum	21.0	25.2	8.4	8.7	18.4	16.1	1.5	2.3	50.8	52.8
N.mucronata	20.3	22.1	9.4	11.5	33.5	13.7	2.7	1.5	34.4	51.2
average			7.6	9.7						
GRASSES										
C.dichotoma	20.0	11.5	7.5	17.9	19.1	14.3	1.3	2.1	52.2	54.4

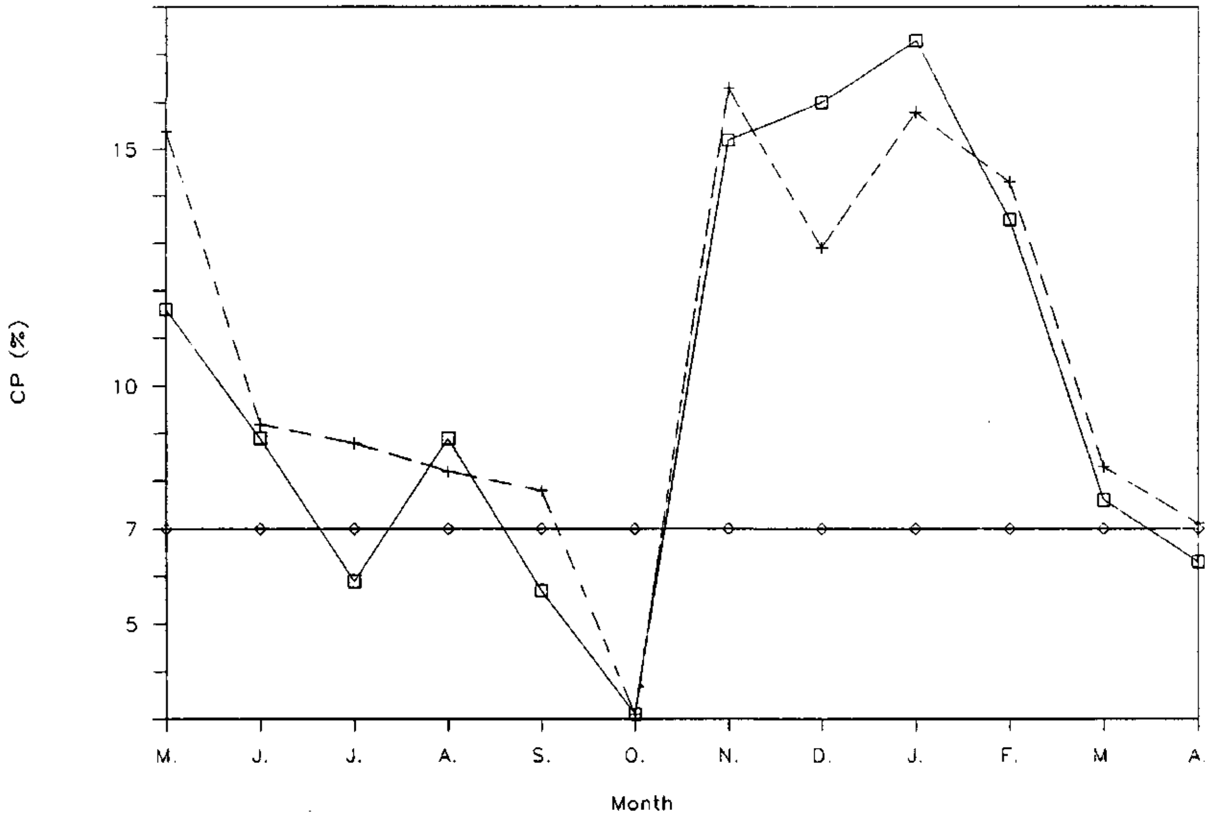


Figure 10. Crude protein concent (CP, in % of DM) of the diet of sheep (□) and goats (+) from May 1980 through April 1981 in El Omayed. Horizontal line expresses minimum concentration required for maintenance (data derived from Abdel Salam, 1985).

4.3 Fodder crops in the coastal zone

In the coastal zone barley is grown for both human and animal consumption. The grains are sold at the market if they are of good quality, if of poorer quality the may be sold to other herdsmen or fed to their own animals (van de Ven, pers. comm., 1986). In this study it is assumed that the latter is the common practice. Crop yields of barley have been estimated, applying a simulation model. The results of the simulation study are discussed in detail by van de Ven (1986), and summarized in a working paper (van de Ven, 1987a). Average yields for the area with barley cultivation in each region, when 250 mm infiltration is realized, are given in Table 23. Note that the irrigated area in the Burg el Arab region has not been included.

Table 23. Weighted average of simulated barley grain (BGWAP) and straw (BSWAP) production (kg DM ha^{-1} yr^{-1}) on the barley fields (ABF, ha) in the four regions without irrigation, weeding and fertilizer, receiving 250 mm infiltration, and corresponding area of rangeland between the barley fields (ARLBBF, ha) (van de Ven, 1987a).

REGION	ABF	BGWAP	BSWAP	ARLBBF
Burg el Arab non-irrigated	6840	480	2640	16020
DABAA	9010	534	2676	32360
MATRUH	12710	654	2956	33600
BARRANI	11330	688	2983	17730
COASTAL ZONE	40830	597	2831	99710

In years with about average rainfall, barley and weed stubbles are grazed by the animals during the summer months. Most of the barley is harvested by sickle or by hand. As sometimes whole plants are pulled up, little stubble is left for the animals (ICARDA, 1983; Ghabbour, 1983).

If rainfall is unfavourable, e.g. too low to expect satisfactory grain yield, the complete crop of barley and weeds is used for forage, and the animals graze the fields. The supplement of barley grains and straw will further be discussed in Paragraphs 4.5.2.2 and 4.5.3.1, respectively.

For the present calculations it is assumed that all the barley straw and grain produced is available for the animals and that availability is evenly distributed over the period from May till November (BGSUD).

In addition to barley, other potential forage sources such as maize, berseem, watermelons, onions, cotton and vegetables are grown in the irrigated areas of the coastal zone and in depressions. Most of these areas is reserved for a 2-year rotation (barley and fallow) or for 3-year rotation (barley, fallow, fodder crops) (El Sayyed, 1980).

4.4 Fodder crops outside the coastal zone

Part of the flock may be transported to areas outside the coastal zone, to utilize agricultural by-products (Section 2.1). These include maize, wheat, barley, berseem, watermelons, onions, clover and cotton. The prize depends on the feed source. As an example, in 1981 a Bedouin paid LE 1.5 $head^{-1}$ mth-1 to graze the stubble of berseem (Soliman, 1983), but no information is available on the present situation. The period during which the animals are dependent on forage from outside the region varies from year to year, but covers at least the period from June till October (El Kadi, 1983).

4.5 Supplementary feed

4.5.1 General description

The animals are only supplemented during the dry season, except in very dry years when supplementation is also necessary in spring. These supplements may consist of:

- concentrates:
    - manufactured concentrates
    - barley grains
- roughages:
    - straw
    - vegetable residues
    - others
- clover

The preference for a certain type of supplement varies along the coastal zone and from breeder to breeder, as can be deduced from Table 24. No details are available about the quantities of each type of supplement used. The optimum level of supplements and the response to their utilization depend on the nutritive value of the basic diet and its availability in the course of the year. The requirements for a certain type of supplement and its quantity depend on the production level aimed at (Chapter 7).

Table 24. The pattern of supplement use in the Dabaa and the Matruh regions (in % of total breeders) (Aboul-Naga et al., 1985a).

REGION	CONCENTRATES	GRAINS	STRAW	HAY	OTHERS
DABAA	92	94	17	21	12
MATRUH	100	93	8	45	12

4.5.2 Concentrates

Concentrates, such as barley grains or manufactured concentrates are high quality, highly digestible feeds. The disadvantages of concentrate feed, however, are its cost and its sometimes limited availability. It is one of the most expensive inputs into pastoral systems and its use is therefore generally restricted to the minimum necessary to achieve the production targets.

In the early sixties the Egyptian government started a program to provide the Bedouin with subsidised concentrates and water. The aims of this program were:

a) to sedentarize the population, probably to prevent them from grazing traditionally migratory areas like the Nile Delta.
b) to compensate for the loss of the migratory forage across the Lybian border that was no longer accessible.
c) to reduce the pressure on the rangeland (Shehata, 1982). This purpose has certainly not been achieved as the increase in number of animals exceeds the increase in the quantity of concentrates supplied.

The total quantity of subsidised concentrates available in the region has tripled in the last six years (Table 25), as a result of the increasing number of animals and the supportive government policy.

Table 25. Distribution of subsidised concentrates (in 10^6 kg) during the period 1975 - 1985 (Agr. Dept. Matr. Govern. quoted by Soliman, 1982; Sultan, pers. comm., 1986).

YEAR	1975	1976	1977	1978	1979	1980	1981	1985
QUANTITY	15.13	17.00	33.52	35.39	37.65	44.3	47.6	48.0

In this study it is assumed that subsidised concentrates (manufactured concentrates and grains) are available to the animals in the main dry period, from May till November.

If an average livestock population of 1.46 million head is assumed (Section 2.2), the quantity of subsidised concentrates available per year (CONAA) is 32.9 kg $head^{-1}$ based on 1985 figures. Averaged over the main dry period mentioned period, that is at present about 5.4 kg per head of sheep or goat per month, which agrees with quantity of 5 kg $head^{-1}$ mth^{-1}, reported by Aboul-Naga (1987). Compared to 1975 concentrate supply that quantity has increased considerably. When assuming 0.95 million head of animals in that year (derived from Table 1) the ration was only 2.6 kg $head^{-1}$ mth^{-1} in the main dry period. However, according to one Bedouin, the present supply of subsidised concentrates is hardly enough to feed the animals 10 days each summer month (van Duivenbooden, 1985a). Members of the field mission of ALAP (January 1986) were confronted with the same complaints. As a result, the Bedouin must buy additional supplements on the (black) market to maintain their present herd size. The amount of concentrate actually supplied daily to the animals varies from place to place in the coastal zone. In the Burg el Arab region the supply is about 0.5 kg per day (Soliman, 1983; El Kadi, 1983). In the Dabaa and Matruh regions the ration amounts on the average to 0.9 kg d^{-1} for both sheep and goats, but the variability is high, ranging from 0.2 to 1.5 kg d^{-1}. An additional extra amount of 0.5 kg $head^{-1}$ d^{-1} is given during lactation (Aboul-Naga et al., 1985a). Ewes that do not reproduce, and male lambs and kids are given more concentrates for fattening, but how much is unknown. Hence, the amount of concentrates actually supplied is simulated (Section 7.1).

According to Aboul-Naga (pers. comm., 1986) the Bedouin spend at present about LE 0.22 $head^{-1}$ d^{-1} on supplementary feed.

4.5.2.1 Manufactured concentrates

Manufactured concentrate (in Arabic "Kusbah" or "Asha") in the coastal zone is a mixture of cottonseed-cake, barley grains and bran (Ayyad and El Kadi, 1981), and its nutritive value (NVCON) equals that 1 kg of barley grains (El Kadi, 1983), i.e. one Feed Unit. That is somewhat higher than that of cottonseed-cake and wheat bran, 0.92 and 0.88 FU kg^{-1} DM, respectively, obtained in Syria by Nordblom and Thomson (1987). The value of 1 FU kg^{-1} DM is applied in this study. Although the quality of the manufactured concentrate in terms of crude protein content is high (Table 25), it is deficient in some elements, such as Fe, Zn and Mn (El Naga, 1982).

The manufactured concentrates are supplied to the Bedouin once each month through the agricultural cooperative. Although the price of subsidised concentrates has increased from LE 0.038 kg^{-1} (El Naga, 1982) to LE 0.042 kg^{-1} in 1985 (Abdel Salam, 1985) and LE 0.074 kg^{-1} at present (Ayyad, pers. comm., 1987), the price is still only half that on the world market, which is about LE 0.186 kg^{-1} (Abdel Salam, 1985). The price of non-subsidised concentrates is LE 0.14 kg^{-1} (Ayyad, pers. comm., 1987), which seems relatively low compared to the world market price. The costs to the farmer are partly covered by the sale of wool, which is organized through the same organisation (Soliman, 1982; Shehata, 1982; El Naga, 1982; Ghabbour, 1983; Soliman, 1983).

In this study it is assumed that the total amount of subsidised concentrates in the coastal zone equals 48 10^6 kg which is distributed among the four regions similar to the number of sheep and goats (FLD).

4.5.2.2 Grains

In addition to manufactured concentrates, the Bedouin have a preferrence for grains over other supplements. Grains are bought on the (black) market, and comprise mainly wheat and barley. Grains are also used for lamb and kid fattening in a feed lot, which is a common practice in the Dabaa and the Matruh regions (ALAP, 1986), but seems absent in the Burg el Arab region.

The chemical composition of the grains is given in Table 26, and its nutritive value (NVBG) equals 1.0 FU kg^{-1} DM.

The price of wheat and barley grain is difficult to establish. At the market s in the Burg el Arab region the price is lower than that of manufactured concentrates: LE 0.08 to 0.10 kg^{-1} (El Naga, pers. comm., 1984; ICARDA, 1983). Ayyad (pers. comm., 1987) reports a price of subsidised barley seeds of LE 0.12 kg^{-1} DM and of non-subsidised of LE 0.16 kg^{-1}. However, in the Dabaa and Matruh regions a price of LE 0.18 kg^{-1} DM is reported (ALAP, 1986), and in a limited survey carried out by van de Ven (1987a) an average price of LE 0.25 kg^{-1} DM was established. That price seems rather high, compared to the price at the world spotmarket of about LE 0.14 kg^{-1} DM. The prices of LE 0.08 - 0.12 kg^{-1} DM seem more likely, as a result of the wheat subsidy program (Scobie, 1981). The procedure is that the government provides wheat at a low price to middlemen, who in turn sell it to bakers and on the (black) market.

Another feeding method tested at present by El Naga is the 'hydroponics' method. Grains are put on roughage substrate and germination takes place when water is given. Ureum is added to the water to increase the crude protein concentration from 8 to 18% (El Naga, pers. comm., 1987).

Table 26. Chemical composition (in %) and Total Digestible Nutrients (TDN, in %) of several supplements and roughages (1 = El Naga, 1981; 2 = Devendra & McLeroy, 1982; 3 = Mohammed et al., 1971; 4 = El Naga, pers. comm. 1984; 5 = Farid & Hassan, 1976).

COMPONENT	MANUFACTURED CONCENTRATES (1)	GRAINS WHEAT BARLEY (2)	STRAW WHEAT (2)	STRAW RICE	HAY BERSEEM (3)
ASH	7.27	2.8	5.1		21.9
CRUDE PROTEIN	18.11	12.60	6.8		11.8
CRUDE FIBRE	16.34	3.60	60.8		27.2
ETHER EXTRACT	5.15	1.5	2.1		2.3
N-free EXTRACT	52.83	79.5	25.2		30.9
TDN (4,5)	61	-	36	42	42 - 53

4.5.3 Roughages

4.5.3.1 Straw

In addition to grains, roughages, i.e. straw from wheat, barley or rice can be bought at the market.

If all barley straw produced in the region is used (under the circumstances described in Table 23) and distributed in the main dry period as given in Section 4.3, the animals in the Matruh region are supplied with 1.37 kg EE^{-1} yr^{-1}, equivalent to 0.75 kg EE^{-1} d^{-1}. If that quantity would actually be provided almost no range forage would be ingested (Subsection 3.1.9). Furthermore, it is at variance with present observations. Aboul-Naga et al. (1985a) report that straw is supplied to the animals in small rations. As no quantitative data are available the described straw production (Table 23) and distribution (Section 4.3) are used to calculate straw availability (Chapter 6).

Due to the low quality of straw (Table 26), its nutritive value (NVBS) is estimated at 0.4 FU kg^{-1} DM (Munzinger, 1982) and 0.45 FU kg^{-1} DM (Seligman and Spharim, 1987; Nordblom and Thomson, 1987). In this study the latter value is applied. The nutritive value of barley and wheat stubble is somewhat higher at 0.48 FU kg^{-1} DM (Nordblom and Thomson, 1987).

The price of barley straw varies considerably from place to place, as prices of LE 0.075 (ICARDA, 1983), LE 0.12 (ALAP, 1986), and LE 0.188 kg^{-1} (Sultan, pers. comm., 1986) are reported. Van de Ven (1987b) reports a price of LE 0.16 kg^{-1}. As these prices are very high (of the same magnitude as concentrates), ownership of barley fields, is very important for sheep breeders.

As rice straw is less well-known, and poor in quality (despite the high TDN value reported by El Naga, Table 26 and as explained in Subsection 4.2.3), the price is low: LE 0.03 kg^{-1} DM (El-Naga, pers. comm., 1984). Munzinger (1982) estimates its nutritive value at 0.31 FU kg^{-1} DM.

To reduce on the costs of supplementation, ALAP (1986) suggests the use of improved (rice?) straw in the diet, at an estimated price of LE 0.05 kg^{-1}. This practice would reduce the costs of supplementary feeding to LE 0.10 $head^{-1}$ d^{-1} (Aboul-Naga, pers. comm., 1986). Also El Naga (1984) points out the advantages of ammoniated straw. At present this practice is till in the experimental stage, but it may be of interest for the future.

4.5.3.2 Vegetable residues

An additional feed source for the animals are vegetable residues, wate products from an onion and garlic processing plant near Alexandria (Soliman, 1983). Apparently, it is economically profitable to transport those products for animal consumption to the drier parts of the coastal zone. However, the price nor the quality could be established.

The nutritive value of the material (NVVE) is estimated at 0.4 FU kg^{-1} DM, in analogy with dry annuals, as most nutrients have been transferred to the main products.

It seems logical that the price increases when going westwards. However, that detail has not been taken into account in the present study and the price reported for the Burg el Arab region of LE 0.04 kg^{-1} DM (Ayyad, pers. comm., 1984) is applied.

4.5.3.3 Other roughages

No quantitative information on the use of other supplements, such as groundnut hulls, orange waste, (roasted) date stones, sugar cane bagasse (Mohammed et al., 1971) and forage rape (Hassan et al., 1984) is available.

Bagasse is of such poor quality that its use as a supplementary feed is discouraged.

The use of planted shrubs (Atriplex spp. and Acacia spp.) as an alternative to the rangeland vegetation and the supplements, as practiced in many other (semi-)arid regions (e.g. Yemen (Ruigrok, 1985) and Syria (Thomson and Nordblom, 1987), is being tested in the northwestern coastal zone, but no results are available yet (ALAP, 1986; Aboul-Naga, pers. comm., 1986). Experiments in Yemen showed that the maximum contribution of Atriplex nummularia to the diet of sheep can be about 55%. Above that, level weight loss and health problems occur (Ruigrok, 1985). Fodder shrubs thus show a promising potential as supplemental forage, and planting of those shrubs is stimulated by the government by paying the Bedouin LE 0.6 $shrub^{-1}$, that is still alive one year after planting (Seligman, pers. comm., 1986).

4.5.4 Clover

The use of clover as forage is reported, but quantitative data are lacking. For more details about berseem, reference is made to e.g. Koraiem et al. (1980) and Rammah et al. (1984).

The chemical composition of berseem hay (Trifolium alexandrinum) is given in Table 26. Bogden (1977) reported a crude protein content of 17 to 23% and an apparent digestibility for herbage and hay of 81 and 70%, respectively. Accordingly, the nutritive value of berseem hay (NVBE) is estimated at 0.7 FU kg^{-1} DM, comparable to the value of 0.77 FU kg^{-1} DM of good green annual biomass (Seligman and Spharim, 1987).

The price of clover hay is about LE 0.12 kg^{-1} (El Naga, pers. comm., 1986; ALAP, 1986), which is more or less equal to the price of concentrates considering the quality difference. However, depending on other components of the diet, supplementary phosphorus is sometimes necesssary to ensure an optimum use of the supplementation with clover.

CHAPTER 5.

OTHER INPUTS INTO ANIMAL HUSBANDRY SYSTEMS

In addition to feed, other inputs such as water, labour, veterinary care, capital for buildings and other facilities are necessary inputs into animal husbandry systems. These inputs are discussed in more detail in this chapter.

5.1 Water

5.1.1 Water requirements

Water is as vital a resource for livestock as feed and its availability affects both feed intake and digestibility. In winter and spring the water content of rangeland forage is sufficient to satisfy the water requirements of the animals. As a consequence, the inland marginal rangeland is mainly grazed in those seasons (Section 4.1). In summer and autumn the animals must be watered. In the coastal zone that is done once a day (70% of the flocks in the Dabaa, the Matruh and the Barrani regions), or once every two days (30%, Aboul-Naga, 1987). Irregular drinking, reduces both water consumption and digestible energy intake, but increases digestibility, as reported for Black bedouin goats (Brosh et al., 1986). Increased digestibility of dry matter, organic matter and cellulose with Barki X Merino cross bred rams was also observed (Farid and Abdel-Aziz, 1984). No experimental data on water intake are available, but generally 4 to 5 liters per watering are consumed (King, 1983). Donkeys require about 15 to 30 l d^{-1} (Munzinger, 1982).

In this study it is assumed that the water requirement (WATRQ) in the main dry season (PMD) is 0.006 m^3 per feed unit or 0.002 to 0.003 m^3 per kg DM of pasture plants consumed, as estimated by Benjamin (quoted by Seligman and Spharim, 1987). For the green grazing period and the early dry period water requirements are taken into account for the animals in a feedlot only.

5.1.2 Water resources

In the coastal zone no permanent rivers are present thus other water resources, such as surface water are of great importance. Surface runoff water is used for barley cultivation (van de Ven, 1986) or diverted to cisterns or galleries for drinking water purposes. In the Matruh and the Barrani regions wadis are found. In some of them dams are constructed, the water either used for irrigation or being collected in cisterns as a source for drinking water. Other water resources are irrigation canals, pipelines and groundwater collected from wells.

Cisterns

Cisterns exist in the coastal zone within 25 km from the coast, except in the Barrani region, where some scattered and rather larger ones exist further south (FAO, 1970a). These structures are used by their owners and by Bedouin who can rent a cistern for LE 50 to 100 per season (FAO, 1970d; Aboul-Naga et al., 1985a). The average storage capacity of a cistern is estimated between 133 and 524 m^3 (FAO, 1970b), while the total storage capacity is about 388 000 m^3 (FAO, 1970c). In dry years the water supply from cisterns is insufficient to meet the water requirements of the population and their animals, especially in the Matruh and the Barrani regions (FAO, 1970c).

The number of cisterns (1200-3000) reported by FAO (1970b; 1970c) up to 7 000 reported by Alim (pers. comm., 1987) is of little use for estimating water availability, as an unknown number has silted up, filled up with sand through desert winds (Shehata, 1982) or has otherwise become useless probably because of changes in water flow patterns, as also observed in other semi-arid regions (Bruins, 1986). In addition to large quantities of silt, a considerable amount of organic material, especially animal droppings, is carried into the cisterns with runoff water. On the other hand, cisterns are being cleaned, repaired and constructed, increasing the total storage capacity. At present cisterns are being constructed in the Matruh region with a target of 3 per family. Their storage capacity ranges from 100 to 1000 m^3, with an average of 300 m^3, which is sufficient for a two years supply of drinking water for a family or for one year for 300 head of sheep and goats (Alim, pers. comm., 1987). Because of the dynamic situation, no accurate estimate of the number of cisterns, actually used, can be given. To improve the utilization efficiency of these water resources, the government subsidizes the owners to clean and repair the cisterns periodically. The costs of cleaning and repair per cistern are estimated at LE 200, while maintenance costs are estimated at LE 10 yr^{-1} (FAO, 1970c).

A disadvantage of cisterns is the occurrence of pathogen micro-organisms in the water, which forms a serious health problem for both man and animal (FAO, 1970c). It is assumed that no medicines are used against these micro-organisms.

Galleries

The most extensive gallery development is at El Qasr. The total annual water withdrawal there is estimated at 230 000 to 300 000 m^3 (FAO, 1970b).

Irrigation canals

In the eastern part of the coastal zone between Alexandria and El Hammam irrigation canals, originating from the Nile, exist. Their water is mainly used for irrigation but may act as a source for drinking water.

Water pipeline

In the area between Alexandria and Mersa Matruh two water pipelines exist, one along the coastal road and the other along the railway. The water originates from Alexandria. The taps for this water (or the reservoirs) are dispersed throughout the area, but may be (e.g. at El Omayed) as far as 5 to 7 km away from the Bedouin (Shehata, 1982). The Bedouin do not pay for water from the pipelines, whereas the population in Mersa Matruh pays LE 0.05 m^{-3} (El Naga, pers. comm., 1984). The water from the pipelines is exclusively used for drinking. The quantity of water arriving in Mersa Matruh ranges from 300 to 650 $m^3\ d^{-1}$ (FAO, 1970e).

A price for water (WPLCP) of LE 0.05 m^{-3} is applied in this study (RUNC1) for the Dabaa, the Matruh and the Barrani regions. It is furthermore assumed that each watering point requires 5 km of piping. The cost of piping (INVAR2) is set equal to that in the PSG (Seligman and Spharim, 1987), i.e. LE 1350 km-1 and life expectancy is estimated at 10 years.

Anticipating on the calculations performed in Chapter 7, it may be concluded that establishment of this type of watering point is very expensive and that it is one of the major investments in animal husbandry systems.

Wells

Wells, either ancient or recently dug, contribute to the drinking water supply, especially in the Matruh and the Barrani regions (Aboul-Naga et al., 1985a). The water, however, contains salt in some places, and its concentration probably exceeds the maximum allowed for sheep and goats, 1.3 to 2.0 and 1.5%, respectively (King, 1983).

As the data about the water resources are not accurate, it is assumed that their use is a function of both region (WATFCR) and system intensity (WATFCS): In the Burg el Arab region water requirements are met for 50% by water from the pipeline or from irrigation water, whereas in the Dabaa, the Matruh and the Barrani regions these fractions are 40, 20 and 0%, respectively. In these regions, the remaining water requirement is met by water from cisterns, wells and galleries. For the entire coastal zone, that fraction is set at 80%. System intensity has been taken into account by reducing cistern requirements. For extensive, intermediate and intensive systems these reductions are assumed to 0, 20 and 40%, respectively. For systems involvoing other animal species that reduction is set at 10%.

It is furthermore assumed that analogous to the PSG (Seligman and Spharim, 1987), one watering point (WPTNUR) is required for every 500 ha of rangeland.

To calculate the number of cisterns, wells and galleries required for animal drinking only (WCINUR), an average storage capacity of 300 m^3 for each of these structures is assumed. The costs of construction (INVAR1) and maintenance (RUNAC1) are estimated at LE 1200 and LE 60 yr^{-1}, respectively, and it is assumed that the life expectancy of the structures is 15 years.

Troughs are built of stone or concrete or old oil-drums are used. The costs of a trough (INV1) are estimated at LE 40 and its life expectancy at 5 years. One trough (WTRNUR) is assumed to suffice for 200 head of sheep and goats or 10 head of donkeys, camels and cattle.

It should be realized that the data given above are used to calculate the water requirements. These requirements may go beyond the present facilities.

5.2. Veterinary care

For diseases that cannot be treated by the Bedouin at home, a veterinary unit (consisting of a clinic, a small laboratory and a sexual health control centre) (FAO/WB, 1977a) can be consulted at certain places. The organization of that service is described by FAO/WB (1977b). One of these units is situated in Burg el Arab, and that seems to be the only one in the northwestern coastal zone. The actual use of such services varies per region. Abdel Salam et al. (1985) report that the use of veterinary services is negligible in the Burg el Arab region and that the Bedouin use traditional practices for health care. Aboul-Naga et al. (1985a) report that 44% of the Bedouin contacted in their survey in the Dabaa and Matruh regions had experience with veterinarians. That result strongly suggests that another veterinary unit exists in the surroundings of Mersa Matruh.

Veterinary services are free of charge, which can be considered an indirect agricultural subsidy. Accordingly, for the calculations of this study the cost of visiting a veterinary unit is set at zero.

Sheep and goats require medicines (not further specified) and the annual costs are LE 5.8 head^{-1} (Ayyad, pers. comm., 1987) (RUNC2). It is assumed that in extensive systems less and in intensive systems more medicines are administered, hence the costs for these systems are set at LE 3.0 and 8.0 head^{-1} yr^{-1}, respectively. A cost of LE 1.0 head^{-1} yr^{-1} is applied for the other animal species.

As discussed before, supplementation with Vitamin A increases prolificacy and reduces lamb and kid mortality (Subsections 3.1.6 and 3.2.6). Considering the high costs of labour and the practical problems associated with frequent supplementation under desert conditions, a single oral dosis of Vitamin A (600 000 I.U.) is recommended, to be administered two months after the beginning of the dry season (Ghanem and Farid, 1982a). Although Vitamin A supplementation in the dry season is considered indispensable, its actual implementation has not been observed in recent studies. Therefore, it is suggested that this measure is only applied in intensive systems. It is assumed that sheep and goats are injected once a year at a cost of LE 0.68 (Ayyad, pers. comm., 1987) (RUNC3).

Availability of salt bricks stimulates digestion of low digestibility-forage, and improves animal performance (Abdel Salam et al., 1985). In this study it is assumed that salt bricks are only provided in intensive systems, and that one brick is necessary for each 2 head of sheep and goats. Furthermore, it is assumed that the brick is sufficient for one year and that the price is LE 1.0 brick^{-1} (RUNC4).

Another veterinary measure, suggested by FAO (1970c), is a network of dips against external parasites. However, the degree of implementation of those dips is unknown. It is assumed therefore, that dips are only constructed for intensive systems and that their life expectancy is 15 years. The costs of construction (INV2) are estimated at LE 1000 and the maintenance costs (RUNC5) at LE 70 yr^{-1}. It is assumed that one dip serves 5000 head of sheep and goats (BUDIRQ).

5.3 Labour requirements

The labour requirements (expressed here in mandays per year) depend on system intensity. In any system the most labour intensive activities are those associated with care of the animals, such as shepherding (LABRQ1), veterinary care (LABRQ2), shearing (LABRQ3), feeding and watering (LABRQ4). In addition, some maintenance work on physical structures has to be done (LABRQ5). These activities are discussed separately.

Due to the high labour requirements in other agricultural systems (e.g. barley cultivation) and its uneven distribution in time, labour availability could be a constraint in April, September and November (van de Ven, 1987c). Hence, the labour requirements for those months are calculated separately. It is assumed in this study that one manday consists of 7 hours. When labour requirements are given in hours per day, they are converted in the model into mandays per month by the factor (365/12 * 1/7=) 4.35.

5.3.1 Shepherding

Normally, a herd is accompanied by one or two shepherds, either the Bedouin himself (and/or a member of his family) or hired shepherds. Furthermore, it is known that the owners rarely leave the flocks to be shepherded only by the hired shepherds (Aboul-Naga, 1987). The fraction of the flocks shepherded by family members varies among the regions. In the Dabaa region 57% of the flocks are shepherded by family members, and in the Matruh region only 32% (Aboul-Naga et al., 1985a; Aboul-Naga, 1987). As no data are available to differentiate between the composition of flocks that are shepherded and those that are not, it is assumed that the distribution is similar for these two types of flock. As labour requirements for shepherding are assumed to be met by labour available in the region no option for the use of hired labour has been defined.

Although differences in the total fraction of flocks being shepherded are reported (90% in the Dabaa region versus 87% in the Matruh region, Aboul-Naga et al., 1985a) these differences are so small that in this study a value of 90% is applied for all regions under present conditions.

The time required for shepherding decreases with system intensity. That has partly been taken into account by varying the fraction of flocks being shepherded (FLFSH), which is set at 1.00, 0.90 and 0.80 for extensive, intermediate and intensive systems, respectively. In addition, the fraction of flocks fed in a feedlot (FFFLOT) varies, as does the time required for grazing (HRGRW and HRGRS, 7 and 8 h d^{-1}, respectively, Section 2.8).

The number of hired shepherds ranges from 1 to 6 per flock depending on flock size, with an average of 1.6 per flock, for an average flocksize of 110 animals (Aboul-Naga et al., 1985a). This corresponds with estimates by El Naga (pers. comm., 1984) of 50 to 80 head per shepherd. A more recent estimate is 100 to 150 head (Aboul-Naga, 1987) probably per hired shepherd. Accordingly, the average flock size being shepherded (FLSSH) is set at 100 head per hired or family shepherd for intermediate systems and at 50 and 150 for extensive and intensive systems, respectively.

It is assumed that for the other animal species no shepherding is required.

5.3.2 Veterinary care

For the present systems it is assumed that in addition to veterinary care at home, the Bedouin sometimes consult a veterinarian. No information is available on the time spent on veterinary care per animal. Rather arbitrarily it is assumed that per flock of sheep and goats the Bedouin consult a veterinary unit twice a year, taking about 4 hours per visit. In addition, 2 hours per month are required for veterinary care at home throughout the year. The total time required (HRVC) is then 2.7 hours mth^{-1}.

For extensive systems no consultation of veterinary units is assumed, i.e. time requirement is 2 h mth^{-1}. For intensive systems much more time is required, especially when double and triple births occur, hence the requirements are set, again arbitrarily, at 5.4 h mth^{-1}.

For the other animal species the time spent on veterinary care is set at 0.5 h $head^{-1}$ mth^{-1}.

5.3.3 Shearing

Shearing of sheep and goats (> 1 year old) takes place in March and April (Shehata, 1982), May (Mokhatr et al., 1983) or May to June (Aboul-Naga, 1987) and sometimes a second time in September (Aboul-Naga and Aboul-Ela, 1985a), whereas camels are sheared in May (Shehata, 1982). Shearing is carried out by the Bedouin himself or by professional shearers from the Delta. For instance, in the Dabaa and the Matruh regions, 40% of the Bedouin shear their own sheep (FLFSB) (Aboul-Naga et al., 1985a), but camels are generally sheared by professionals (Shehata, 1982). The overall average of Bedouin in the region hiring shearers, is estimated at 60%.

No data are available on the time spent per animal. Therefore, it is assumed that shearing of each sheep and goat takes a shearer and his assistent in total 20 minutes (HRSS) and two Bedouin 30 minutes (HRSB) (because of two men the factor 2 is used in the equation, see ARID ANIMAL). It is assumed that both March and April are available for this activity. For camels the time required for shearing is estimated at 30 minutes per head. It is assumed that 70% of total camel herd is sheared by professionals in May.

5.3.4 Feeding and watering

Feeding and watering require labour in the main dry period. In this study it is assumed that the Bedouin spend during that period 1.0 h $flock^{-1}$ d^{-1} (HRFW), including the time spent on unloading of trucks and storage of supplements. Additional time for feeding and watering is required if part of the flock is in feedlots. If the whole flock is in a feedlot, the time required for feeding and watering is estimated at 1.5 h $flock^{-1}$ d^{-1} and if all weaned lambs are fed in the feedlot, the time requirement is estimated at 0.5 h 50 $head^{-1}$ d^{-1}.

For the other animal species the time requirement is estimated at 0.5 h $head^{-1}$ d^{-1}.

5.3.5 Maintenance work

Maintenance work is defined as the activities required for the upkeep of e.g. the concentrate storage buildings, the summer sheds, fences, cisterns and wells. It is assumed that in the intermediate systems the Bedouin spend on average 4 hours per flock per month (HRMT) for these activities. For extensive and intensive systems these requirements are estimated at 2 and 6 h mth^{-1}, respectively.

For the other animal species the time required is estimated at 0.4 h $head^{-1}$ mth^{-1}.

In this study it is assumed that labour carried out by members of the family is free of charge. Earnings of hired shepherds are estimated at LE 0.035 $head^{-1}$ d^{-1} (El Naga, 1984) to LE 0.045 $head^{-1}$ d^{-1} (FAO, 1970e), i.e. comparable with labour costs of LE 6 per flock per day (Sultan, pers. comm., 1985). Another, more common arrangement is sharing of the shepherd in the net profit, its share varying from 0.25 to 0.33, depending on the total net profit (El Naga, pers. comm., 1985). In this study the price of hired labour is set at LE 6 d^{-1} (van de Ven, 1987c).

5.4 Housing and other facilities

Normally, the animals remain outside day and night. Some Bedouin have constructed a small shed where part of the flock may take shelter during the hot hours in summer. This shed is probably also used to isolate pregnant or sick animals from the main flock.

No information is available on the lambing and night-shed requirements per head (BUSRQ). Observations in the Burg el Arab region showed that not all Bedouin own sheds. This has been taken into account by defining a fraction of flocks for which a shed is available (FLFSD). As discussed before (Subsection 3.1.4), availability of shade results in increased conception rates. Hence, it is likely that increasing system intensity will result in increased shed requirements. It is assumed that in extensive systems 30%, in intermediate systems 70% and in intensive systems 100% of the animals have access to sheds. The required shed area for sheep and goats (BUSRQ) depends on prolificacy of the herd. In this study a shed requirement (BUSR) has been assumed, derived from the relation between herd prolificacy and shed requirements as given in the PSG (Seligman and Spharim, 1987) and applying an average prolificacy of sheep and goats (SGAVLR). For donkeys and cattle the area required is estimated at 2.0 m^2 $head^{-1}$. Life expectancy of a shed is estimated at 15 years and construnction costs (INV3) are set at LE 27 m^{-2} equivalent to those in the PSG. Maintenance costs (RUNC6) are estimated at LE 0.01 m^{-2} mth^{-1}.

It is assumed that in the coastal zone corrals are built only if feedlot fattening is practiced. No data are available on the size of the corrals, therefore, 44 m^2 for 50 ewes plus their lambs is applied (Devendra and McLeroy, 1982). As the corral requirements of weaners are treated separately, the requirements are reduced to 0.75 m^2 $head^{-1}$ (BUCORQ). It is assumed that for intensive systems two or more corrals per flock are required. The corral requirements for weaners are, rather arbitrarily set at 70% of those for ewes. On the basis of these assumptions, the total corral area for a flock (BUCOA) and the requirements for barbed wire (BUBWRQ) and poles (BUPORQ) are calculated. A corral (INV4) is constructed using barbed wire (LE 2 m^{-1}, Ayyad, pers. comm., 1987) and either wooden or iron poles (LE 2 and 4 per piece, respectively, Ayyad, pers. comm., 1987). It is assumed that the fence consist of four strings of wire and that the poles are two meters apart. The life expectancy of the corrals is set at 10 years and maintenance costs are considered negligible.

In addition, some Bedouin have constructed stone-walled sheds to store their grains and concentrates, while others use barbed wire to protect fig plantations against sheep and goats. As no quantitative information is available on their use, they are not considered here, but are taken into account in the fig systems (Abdel-Razik and van de Ven, 1987).

No data are available on specific equipment for animal husbandry systems. Clippers for shearing are considered essential. It is assumed that at present two pieces of shearing equipment are available per flock. Their price is LE 74 per piece (Ayyad, pers. comm., 1987), and their life expectancy is set at 5 years (INV5). Costs of other small equipment are included in miscellaneous costs (Section 5.5).

5.5 Capital requirements

Capital requirements consist of investments (INVSAH, long term costs) and annual costs (ANCOST, current costs or running costs and miscellaneous costs).

The magnitude of the capital investments and annual costs have been discussed in the preceding section. It is assumed in this study that Bedouin do not buy animals from the market to increase their flock.

Miscellaneous costs include all costs that have not been specified otherwise. As the rangeland is not fertilized, costs of fertilizer are zero. The Bedouin may grow barley in addition to animal husbandry and the produce may be fed to the animals in summer. That would involve some costs, but that has not been taken into account in the present study.

Completely arbitrarily miscellaneous costs (RUNC7) for the intermediate systems are estimated at LE 0.2 EE^{-1} yr^{-1}. For the extensive and the intensive systems these costs are estimated at LE 0.1 and 0.4 EE^{-1} yr^{-1}, respectively.

5.6 Agricultural subsidies

In addition to the subsidy on manufactured concentrates (Subsection 4.5.2), other direct subsidies on agricultural inputs are supplied, such as on fertilizer, seeds and insecticides (von Braun and de Haen, 1983; Burgers, 1983). These subsidies, however, are supplied in irrigated areas only. Indirect subsidies from which everybody takes advantage include low fuel prices, infrastructural services and low basic food prices, whereas those that are specially aimed at the agricultural sector in the coastal zone include free irrigation water only. For a more detailed treatment of the food subsidy program, reference is made to Aldermann et al. (1982; Aldermann and von Braun, 1986); Von Braun and de Haen (1983) and Scobie (1983). Buying wool from the Bedouin (Paragraph 3.1.7.3) may also be considered an indirect subsidy, as without governmental control the price of wool would be much lower (FAO, 1970d). A separate treatment of these subsidies is not necessary, however, as they are implicitly accounted for by the prices of inputs and outputs applied in this study.

CHAPTER 6.

CONSTRAINTS AND POTENTIALS OF ANIMAL HUSBANDRY IN THE NORTHWESTERN COASTAL ZONE

6.1 Introduction

On the basis of the characteristics of the animals (Chapter 3) and the available resources in the northwestern coastal zone, the constraints and potentials of animal husbandry in the regions can be quantified.

From the preceding chapters it is clear that at present one of the most important constraints to animal husbandry in the northwestern coastal zone is feed availability, because feed requirements exceed feed availability, especially in summer and autumn. Hence, supplementary feed is indispensable.

On the basis of the feed requirements of the animals, and the availability of feed resources, the feed balance can be calculated. The approach adopted in this study would be more appropriately defined as the energy balance, because the quality of feed is expressed in FU (Subsection 4.2.3). However, for the sake of convenience we have preferred the term 'feed balance'.

The simulation model ARID ANIMAL was developed on the one hand to calculate the feed balance and on the other hand to quantify the inputs and outputs of well-defined animal husbandry systems (Chapter 7). The model is based on the principles of the Pasture System Generator (PSG), developed by Seligman and Spharim (1987) in which all characteristics of animal husbandry systems considered relevant in the framework of regional development planning, have been formulated in mathematical equations (see Appendices I and II).

In the PSG all inputs and outputs are related to the 'average ewe' in the herd, but as in the northwestern coastal zone other animal species are also present, in ARID ANIMAL all equations are related to 'ewe equivalents'. The conversion of each type of animal into ewe equivalents has been described in Section 2.2.

Feed requirements for each type of animal are calculated first per head, and subsequently, converted into requirements per ewe equivalent.

To work out the feed balance, some additional assumptions had to be made.

- In addition to sheep and goats, donkeys and camels graze the rangeland. Cattle are not considered here, because they are not dependent on rangeland forage.
- Subsidised concentrates are used completely.

- Barley is cultivated, receiving 250 mm infiltration (van de Ven, 1987a), and all produce is available for the animals.
- The area between the barley fields is used for grazing.
- No animals are transported outside the region.

The feed balance in the four regions is discussed in more detail in the following section. Additional constraints and potentials of animal husbandry are discussed in Sections 6.3 and 6.4, respectively.

6.2 Feed balance in the four regions

ARID ANIMAL calculates for each month starting from October the feed balance, and if negative, the amount of additional supplements required to compensate that deficiency. The term 'additional supplements' is used, because barley straw, barley grains and manufactured concentrates are already supplements to rangeland forage. The feed balance is defined in the model as:

$$FEBAL = (RLFAV + BSAV + BGAV + CONAV) - FUTRQ \quad (6)$$

where,

RLFAV	= Rangeland forage availability	(FU EE^{-1} mth^{-1})
BSAV	= Barley straw availability	(FU EE^{-1} mth^{-1})
BGAV	= Barley grain availability	(FU EE^{-1} mth^{-1})
CONAV	= Subsidised concentrate availability	(FU EE^{-1} mth^{-1})
FUTRQ	= Total feed requirements	(FU EE^{-1} mth^{-1})

To interpret the feed balance, two components must be considered, on the one hand the feed requirements and on the other hand feed availability. Feed requirements (in FU $head^{-1}$) of sheep and goats have been discussed in detail in Subsections 3.1.8 and 3.2.8, respectively. As the feed requirements of the other animal types could not be described in the same detail, emphasis is on sheep and goats. If only sheep or only goats would be present in the region, the feed requirements (in FU EE^{-1}) would be, as presented in Figure 11. If, under the present circumstances only sheep would be present, the feed requirements in winter would be higher, whereas if only goats would be present they would be lower. Due to the high ratio of sheep to goats in the region at present, the actual feed requirements are high in winter and spring, the maximum being reached in January and April. Figure 11 shows on the other hand, that in summer replacement of goats by sheep causes at present a reduction in feed requirements. Under the present conditions feed requirements of sheep and goats are relatively low from May till September, the minimum being reached in July.

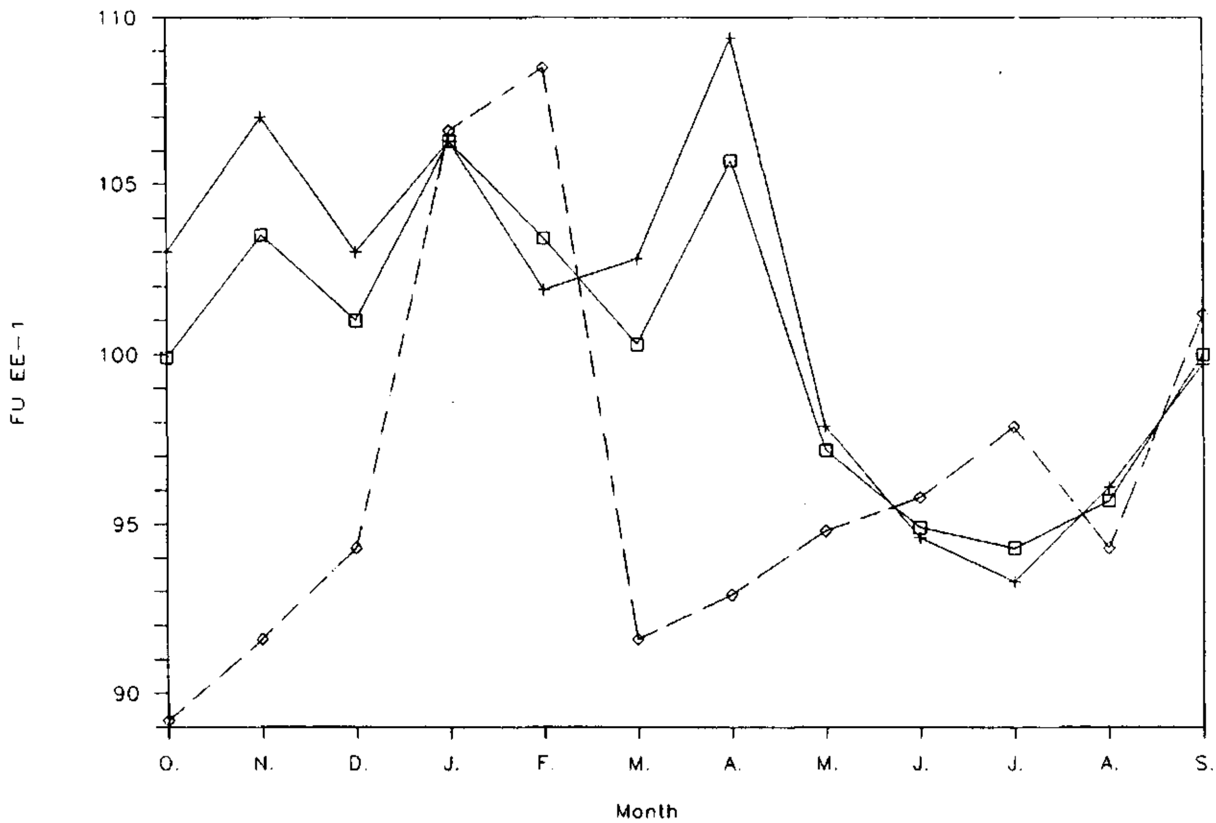


Figure 11. Simulated feed requirements of a mixed population of sheep and goats (ratio sheep to goat head is 2.7:1)(+), of sheep only (□) and of goats only (◇).

Next, feed availability must be considered. Production of rangeland biomass has been discussed in Subsection 4.2.2, availability of barley grain and concentrates in Subsection 4.5.2 and availability of barley straw in Paragraph 4.5.3.1. As rangeland forage availability determines the potentials for animal husbandry in winter, that availability is first discussed in more detail.

Availability of rangeland forage in the course of the year in the four regions is calculated with adapted flock number distributions (the reason why is explained below) and is shown in Figure 12.

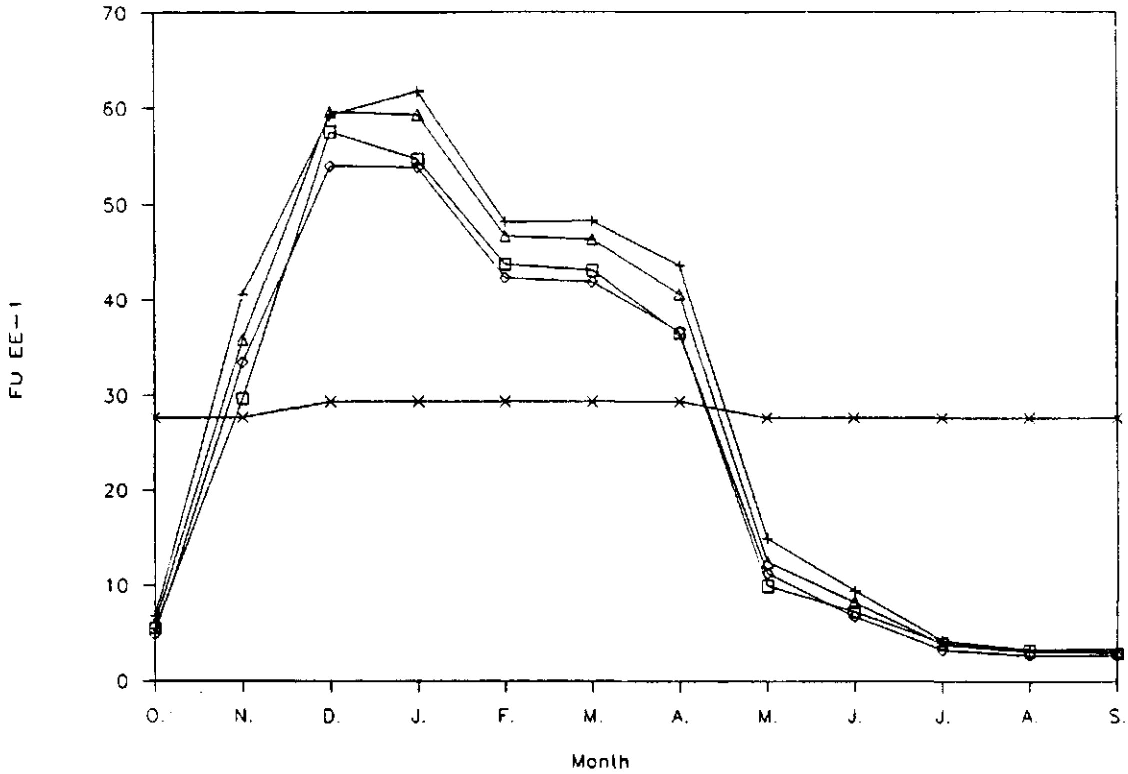


Figure 12. Simulated feed availability of rangeland forage in the course of the year in the Burg el Arab (□), the Dabaa (+), the Matruh (◇) and the Barrani regions (△), x = maintenance requirements.

It may be deduced from Figure 12 that rangeland forage availability under the present stocking rate is insufficient to meet the maintenance requirements of the animals, even if intake of forage would not be limiting. However, intake of poor quality feed is limited (Subsection 3.1.9), and hence high quality supplements are already indispensable in the main dry period for maintenance purposes. Apparently, distribution of rangeland forage availability in the course of the year is a crucial factor.

In autumn, the quality of the rangeland forage is low till the first effective rains start in late October. In November, both quality and availability of the forage increases. In December and January, biomass production is generally high enough to meet the feed requirements. Both quantity and quality of rangeland forage decrease from February onwards, with minimum availability from July till September. Differences in peak forage availability among the four regions are due to differences in distribution of biomass production in the course of the year, resulting from different rainfall patterns (Subsection 4.2.2).

It is known that all the feed requirements of the animals are met by rangeland forage in winter. It is striking, that if applying the distribution of sheep and goats among the regions (FLD) as given in Section 2.1, in the Burg el Arab region feed availability only meets the maintenance requirements for two months (Figure 16A), while in the Dabaa region feed availability exceeds the total feed requirements almost year-long (Figure 17A). That situation cannot be realistic, hence, the estimate of animal distribution used in those calculations is apparently incorrect, and must therefore be adapted. The animal population in the Burg el Arab region is decreased by decreasing FLD from 0.20 to 0.12, whereas in the Dabaa region that fraction is increased from 0.15 to 0.24. To a lesser extent the same phenomenon occurs between the Matruh and the Barrani regions (Figures 18A and 19A). Hence, FLD in the Matruh region is reduced from 0.34 to 0.30, whereas in the Barrani region it is increased from 0.31 to 0.34. This adapted distribution pattern of sheep and goats among the regions is used for further calculations.

The animals graze the inland marginal areas in winter. From Figure 13 in combination with Figure 12 it can be deduced that the inland area where annual rainfall is between 75 and 100 mm is essential for the level of animal production. Without that feed resource additional supplements would already be indispensable to meet the requirements for maintenance only. (Compare Figure 13 and Figure 18B). Note that if rainfall is below normal, supplementary feed is required year-round.

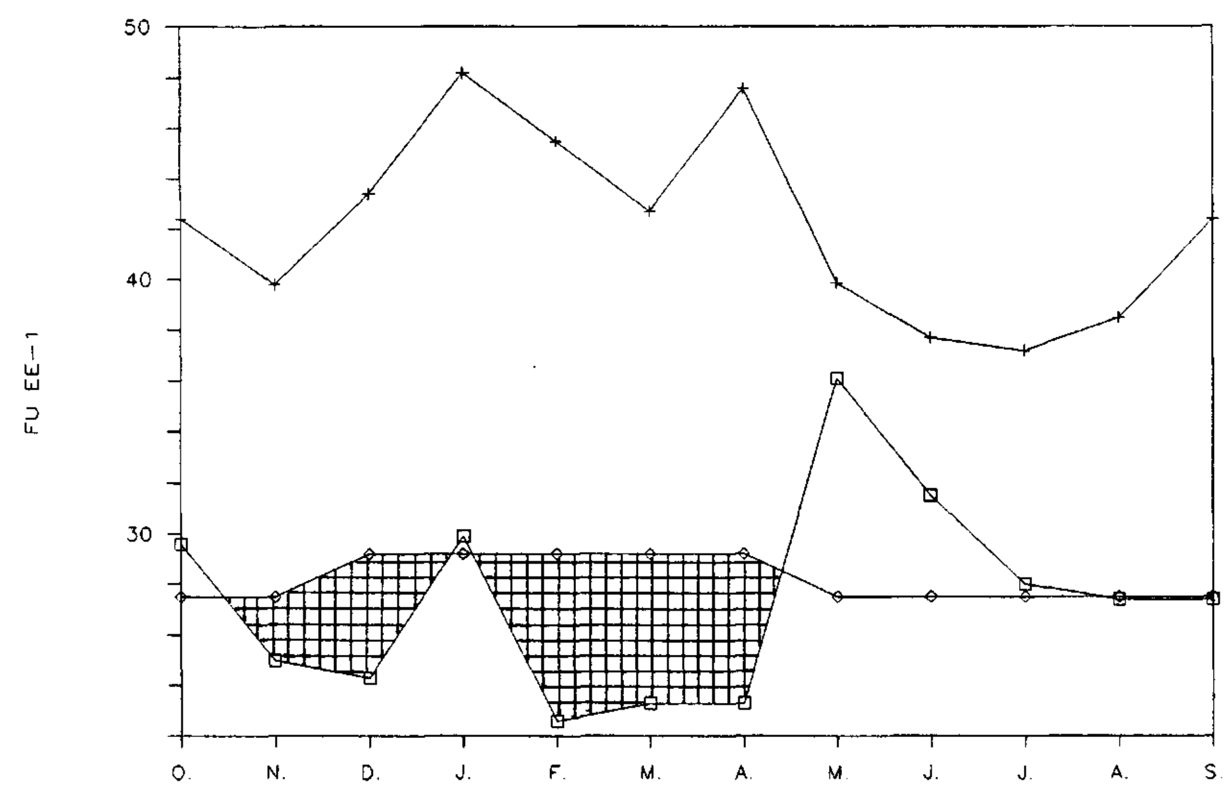


Figure 13. Simulated total feed requirements (+), feed availability (□) and maintenance requirements (◇) in the course of the year in the Matruh region, when the area with precipitation below 100 mm is not used as rangeland. Hatched area represents minimum supplements required.

Table 27. Components of supplement availability in the four regions in the period from May through October (in FU EE^{-1} mth^{-1}) and number of animals dependent on the rangeland (TEE-CTNU, in EE). Acronyms are explained in the text and Appendix II.

REGION	TEE-CTNU	BGAV	BSAV	CONAV
BURG EL ARAB	103 500	5.3	13.1	8.7
DABAA	186 700	4.7	10.7	8.7
MATRUH	248 300	5.6	11.3	8.7
BARRANI	264 700	4.9	9.6	8.7

Figure 14A shows the composition of total feed availability in the Matruh region, and Figure 14B shows total feed availability in the four regions both in the course of the year. In addition, the availability of the various supplement components in the four regions is summarized in Table 27. For the period that the feed balance (Eqn. 6) is negative, the simulated daily ration of supplements in the main dry period in the Matruh region is 0.83 kg DM straw EE^{-1} and 0.47 kg DM concentrates EE^{-1}. The latter value corresponds closely to data presented earlier in this report (Subsection 4.5.2). The consequence of such a high straw supply is that the intake of rangeland forage in that period is very low. From Figure 14B it can further be deduced that under the conditions with high rations of supplementary feed the present number of animals can be maintained.

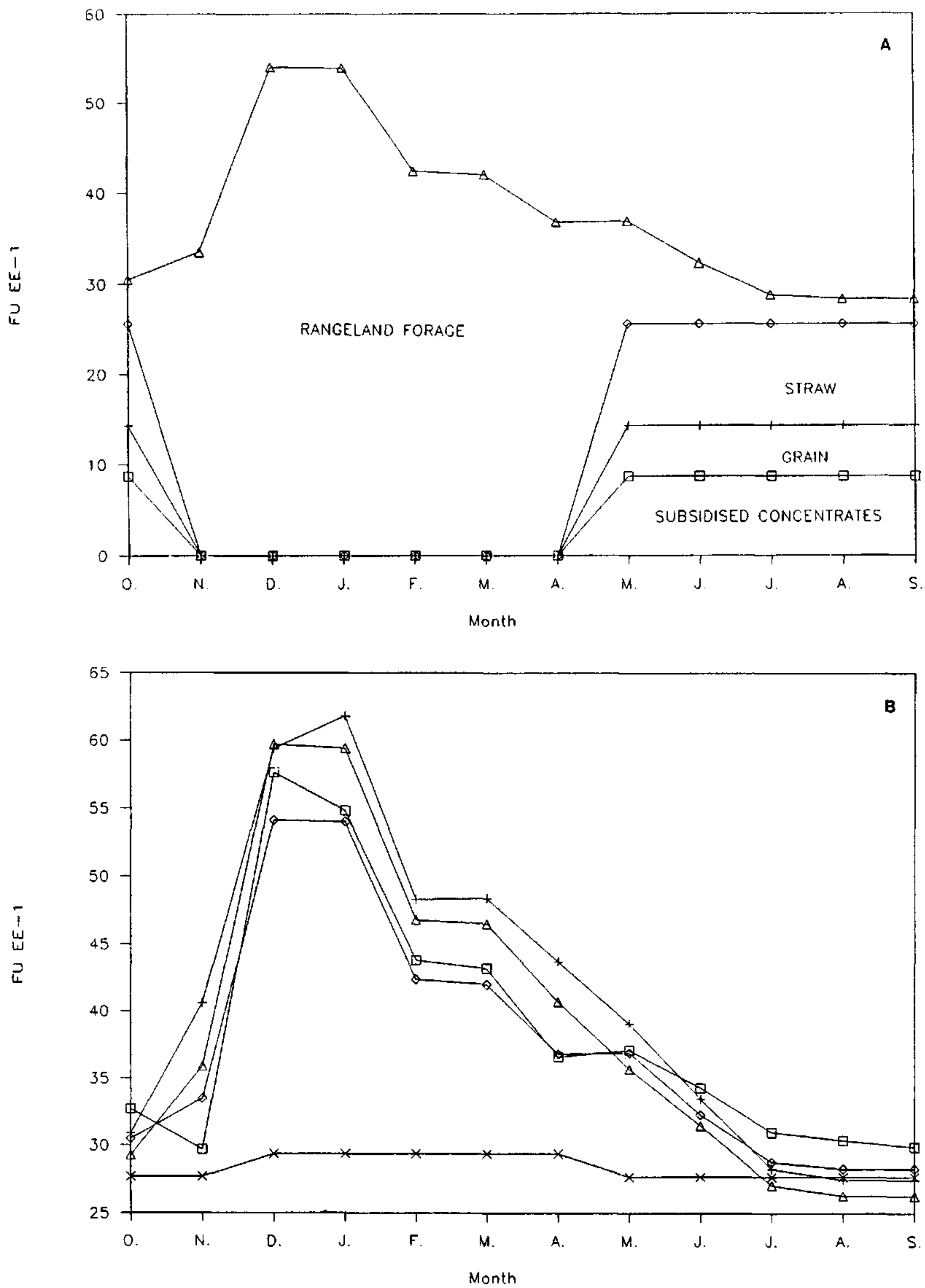


Figure 14. A. Simulated components of feed availability in the course of the year in the Matruh region, and B. Total feed availability in the Burg el Arab (□), the Dabaa (+), the Matruh (◇) and the Barrani region (△), respectively.

On the basis of the balance between feed availability and feed requirements, the possibilities for secondary production can be discussed. The feed balances in the Burg el Arab, the Dabaa, the Matruh and the Barrani regions separately are presented graphically in Figure 15A, and the average for the total coastal zone is presented in Figure 15B. The feed availability and the feed requirements in these regions are shown in Figures 16B, 17B, 18B and 19B, respectively and for the coastal zone in Figure 20.

Apart from the early dry period when supplements are already provided, November and April are months with relatively high additional supplement requirements in all regions except for the Dabaa region. Hence, saving straw and grain till November, and April of the following year seems advisable, but storehouses are not always available, limiting that practice. Furthermore it is clear, that in all regions under the present circumstances additional supplements are required in the main dry period.

Part of the additional supplement requirement may be met by available rangeland forage left from the months with positive feed balances. Then, however, the decreasing quality of rangeland forage with time must be taken into account (NVFOR decreases from 0.75 or 0.55 FU kg^{-1} DM to 0.45 FU kg^{-1} DM in the main dry period). As explained before, however, high quality supplements are still necessary in all regions during the main dry period. Consequently, the total quantity of supplements required depends on the production level aimed at and the number of animals. The quantity required per ewe equivalent is calculated in the next chapter. For the Matruh region, it is calculated there that for intermediate systems in addition to 1.9 ha rangeland EE^{-1}, supplements are required at a rate of 140 kg DM concentrates EE^{-1} yr^{-1} plus 91 kg DM straw EE^{-1} yr^{-1} (Table 32). If the production target is lower, all feed requirements may be met by rangeland forage.

It is calculated that if all Bedouin would aim at the production target assumed to be realized at present, and no feedlot feeding is practiced, the rangeland requirements are 1.94 ha EE^{-1} yr^{-1} (Table 32). Multiplying that value with the present number of ewe equivalents in the Matruh region, leads to the conclusion that available rangeland is a constraint. This is in agreement with the observation that flocks migrate from the Matruh region to the Barrani region in summer (Section 2.3). Consequently, if it is not allowed to transport animals to other areas, the present flock size in the Matruh region is too large.

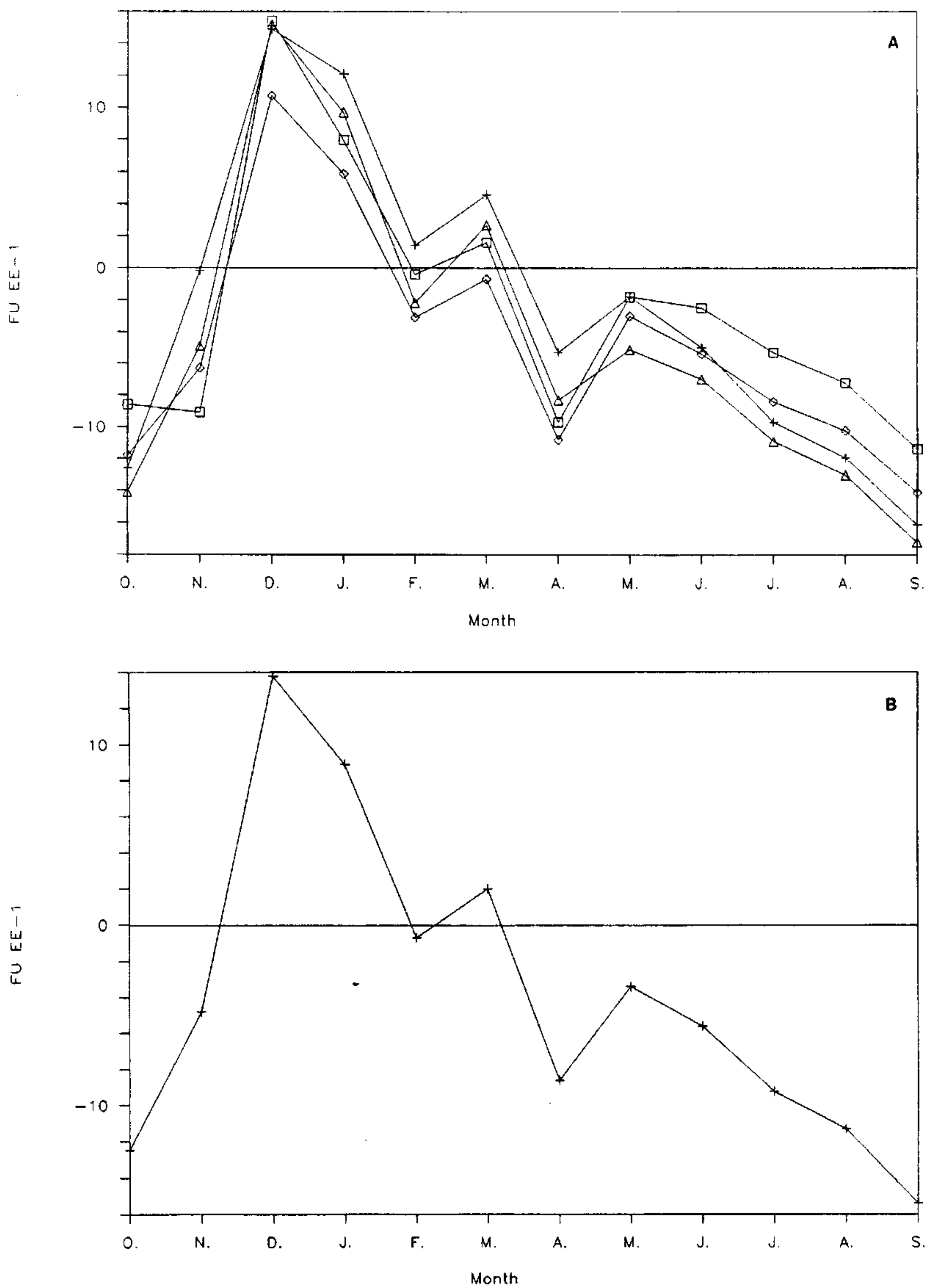


Figure 15. Simulated feed balance in the course of the year, A: in the Burg el Arab (□), the Dabaa (+), the Matruh (◇) and the Barrani regions (△) and B: in the coastal zone.

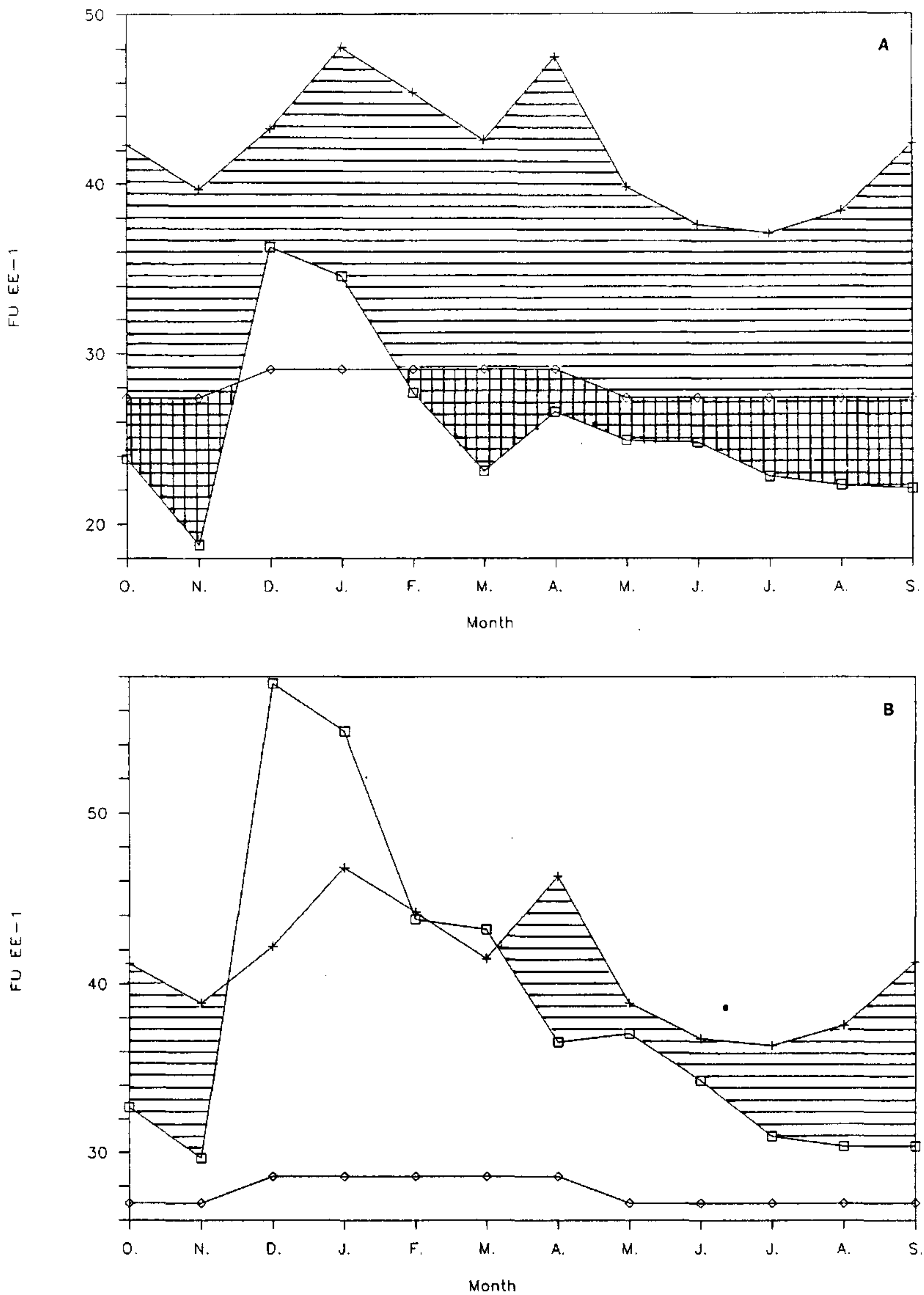


Figure 16. Simulated total feed requirements (+), feed availability (□) and maintenance requirements (◇) in the course of the year in the Burg el Arab region, A: FLD = 0.20, B: FLD = 0.12 (for explanation see text). Hatched area represents additional supplements required.

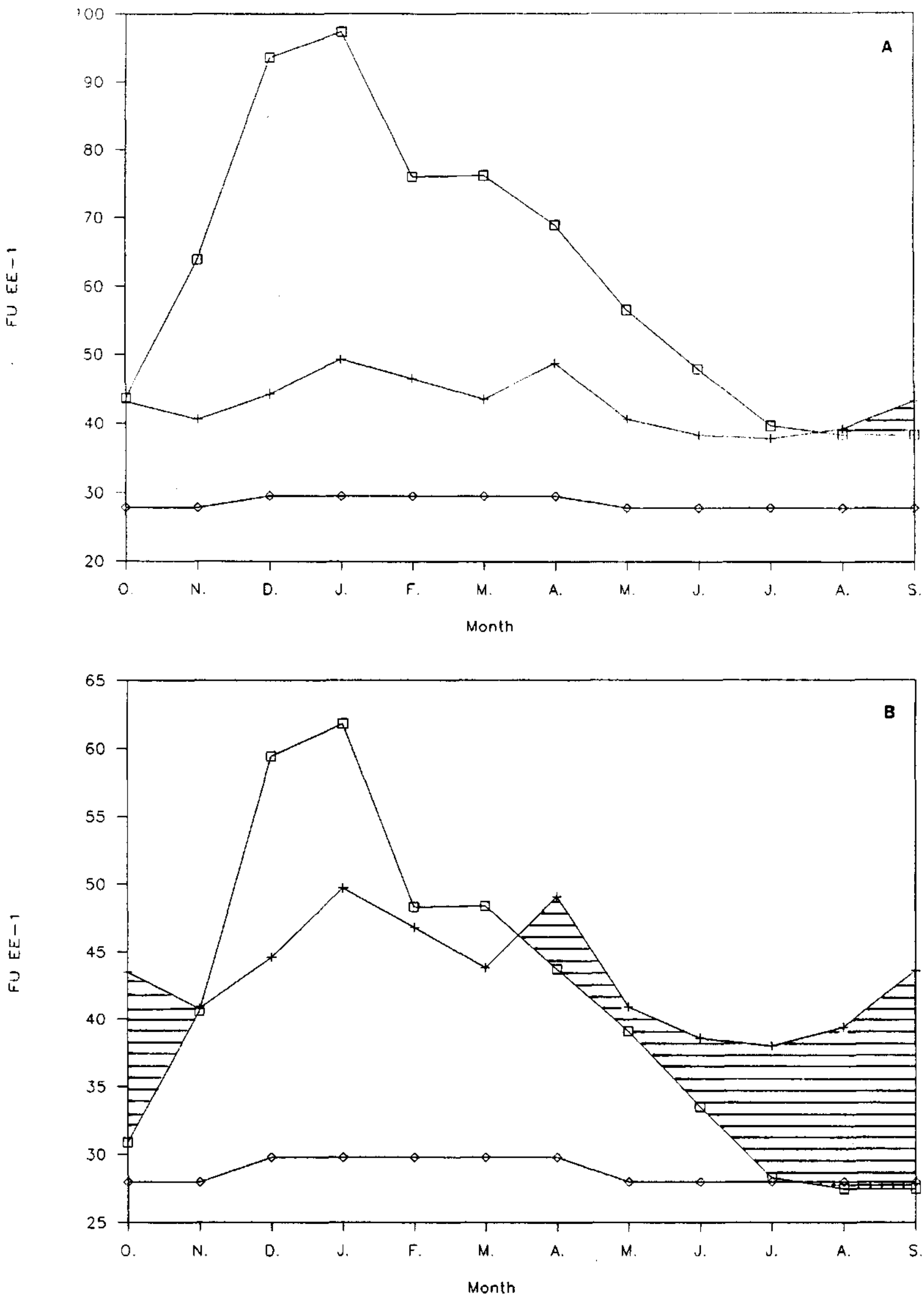


Figure 17. Simulated total feed requirements (+), feed availability (□) and maintenance requirements (◇) in the course of the year in the Dabaa region, A: FLD = 0.15, B: FLD = 0.24 (for explanation see text). Hatched area represents additional supplements required.

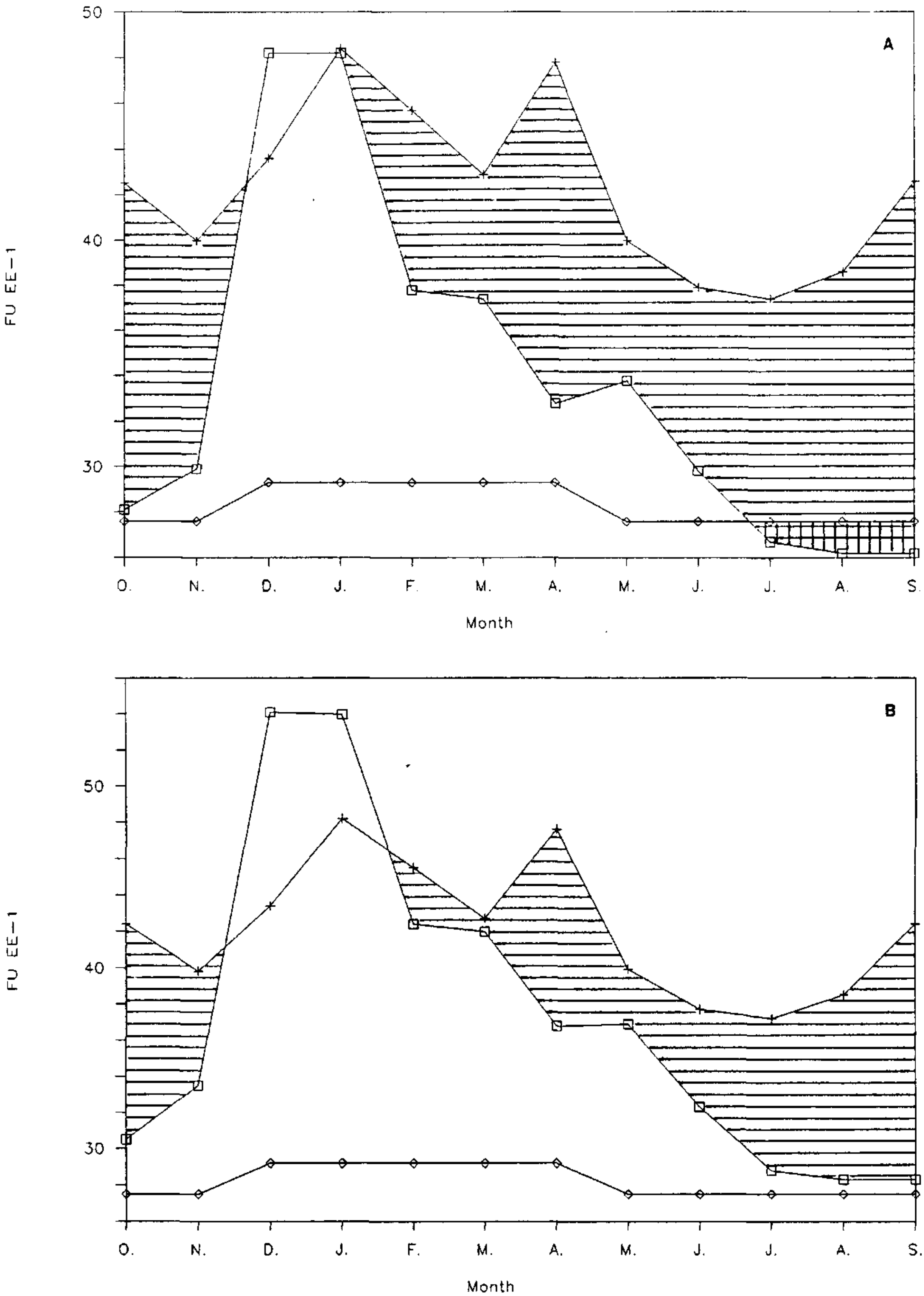


Figure 18. Simulated total feed requirements (+), feed availability (□) and maintenance requirements (◇) in the course of the year in the Matruh region, A: FLD = 0.34 and B: FLD = 0.30 (for explanation see text). Hatched area represents additional supplements required.

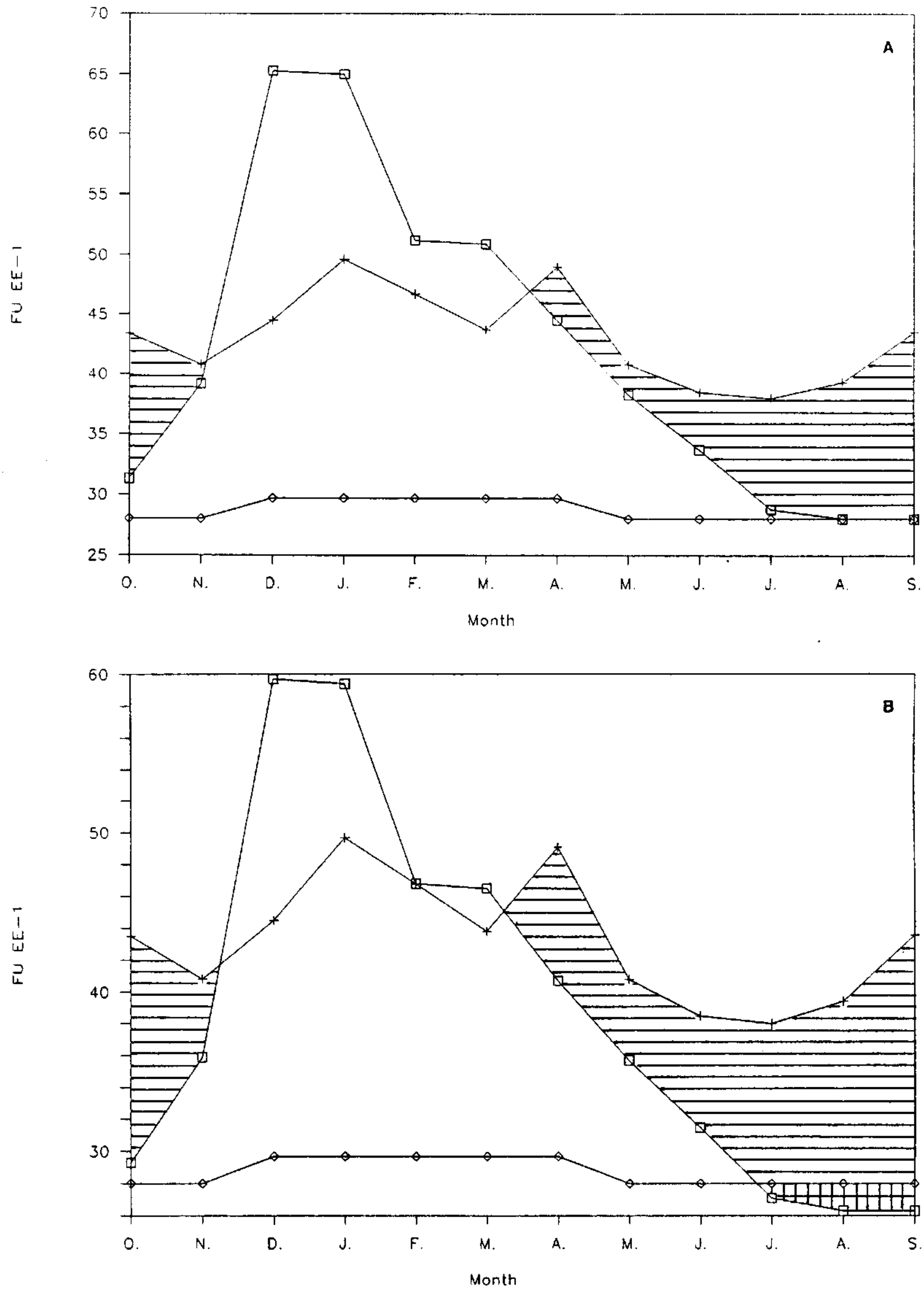


Figure 19. Simulated total feed requirements (+), feed availability (□) and maintenance requirements (◇) in the course of the year in the Barrani region, A: FLD = 0.31 and B: FLD = 0.34 (for explanation see text). Hatched area represents additional supplements required.

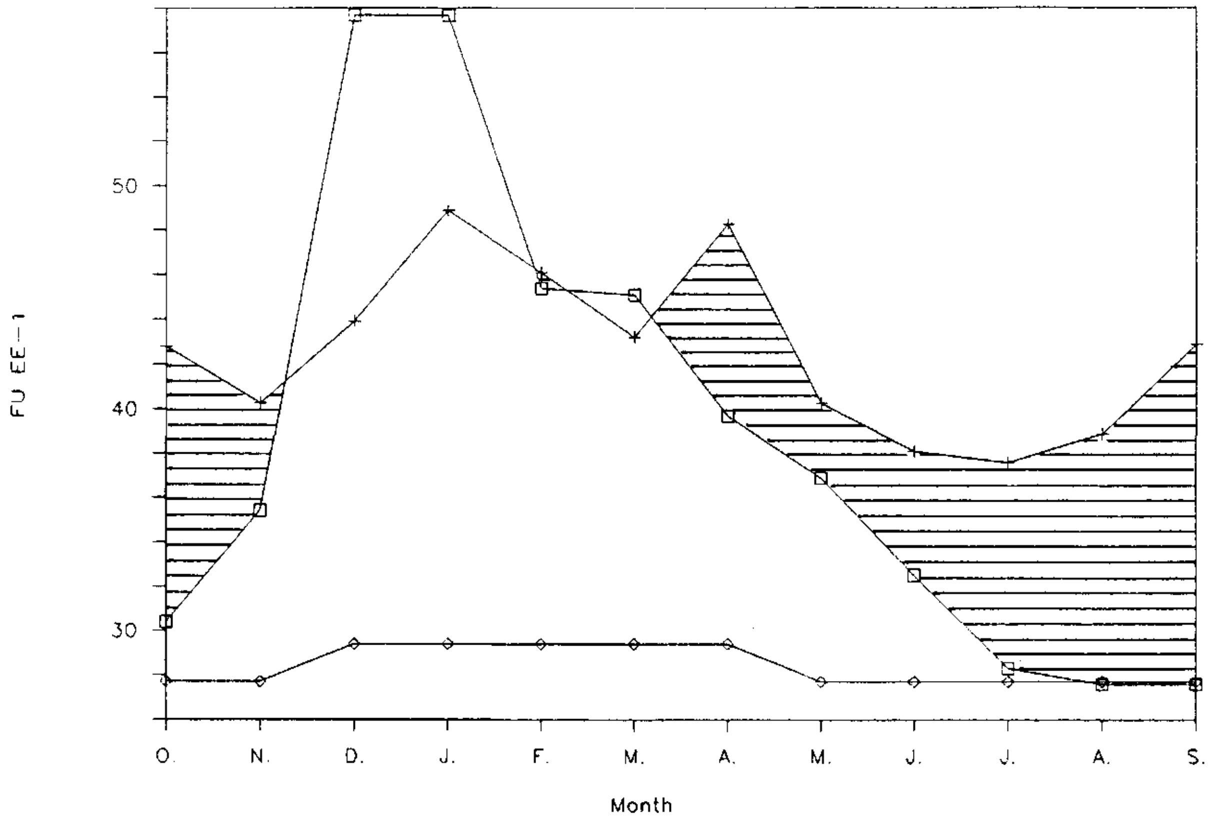


Figure 20. Simulated total feed requirements (+), feed availability (□) and maintenance requirements (◇) in the course of the year in the coastal zone (for explanation see text). Hatched area represents additional supplements required.

To maintain a positive annual feed balance at the intermediate production level, the number of sheep and goats would have to be reduced from 226 700 EE to 188 900 EE, a reduction of 17%. It should be realized that in that case the total amount of subsidised concentrates decreases proportionally, as the supply is related to the actual flock size of sheep and goats.

If a positive annual feed balance would have to be maintained without subsidised concentrates at the intermediate production level, the number of sheep and goats would have to be reduced from 226 700 EE to 166 300 EE, a reduction of 27%.

If a positive annual feed balance would have to be maintained without barley products but with subsidised concentrates only (necessary to compensate for the poor quality of forage in the main dry period) at the intermediate production level, the number of sheep and goats would have to be reduced from 226 700 to 128 500 EE, a reduction of 43%.

The feed balances with the restrictions outlined above are shown in Figure 21.

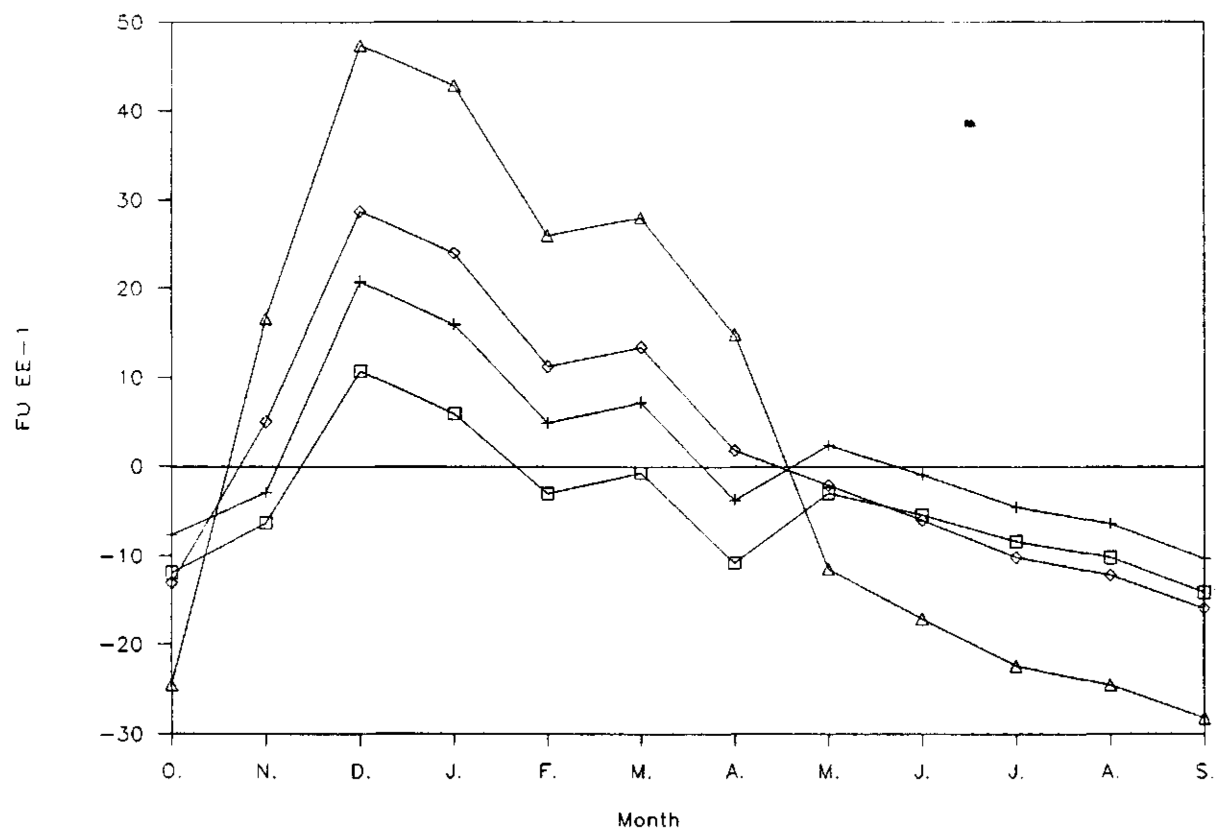


Figure 21. Simulated present feed balance in the Matruh region (□), and simulated positive feed balances if number of sheep and goats is reduced. + : FLD = 0.25, ◇ : no subsidised concentrates, FLD = 0.22, △: no barley products, FLD = 0.17 (for explanation see text).

Subsequently, the role of barley cultivation in animal husbandry systems is considered.

If the area between the barley fields cannot be grazed, but barley products are available in the main dry period, maintaining a positive annual feed balance at the intermediate production level, would require a reduction in the number of sheep and goats from 226 700 to 154 900 EE, a reduction of 32%.

If on the other hand no barley products would be available, the necessary reduction would be 43% (see above).

If both barley products and rangeland between the barleys fields would not be available, under the same restrictions, the number of sheep and goats would have to be reduced from 226 700 to 105 800 EE, a reduction of 53%.

If shrubs were grown on the barley fields and on the areas between the barley fields under the same restrictions the reduction would have to be 18%.

The feed balances with these restrictions are shown in Figure 22.

Apparently, barley cultivation is the second constraint for animal husbandry. Hence, abundance of straw and to a smaller degree of grain enables the Bedouin to profitably operate the animal husbandry system.

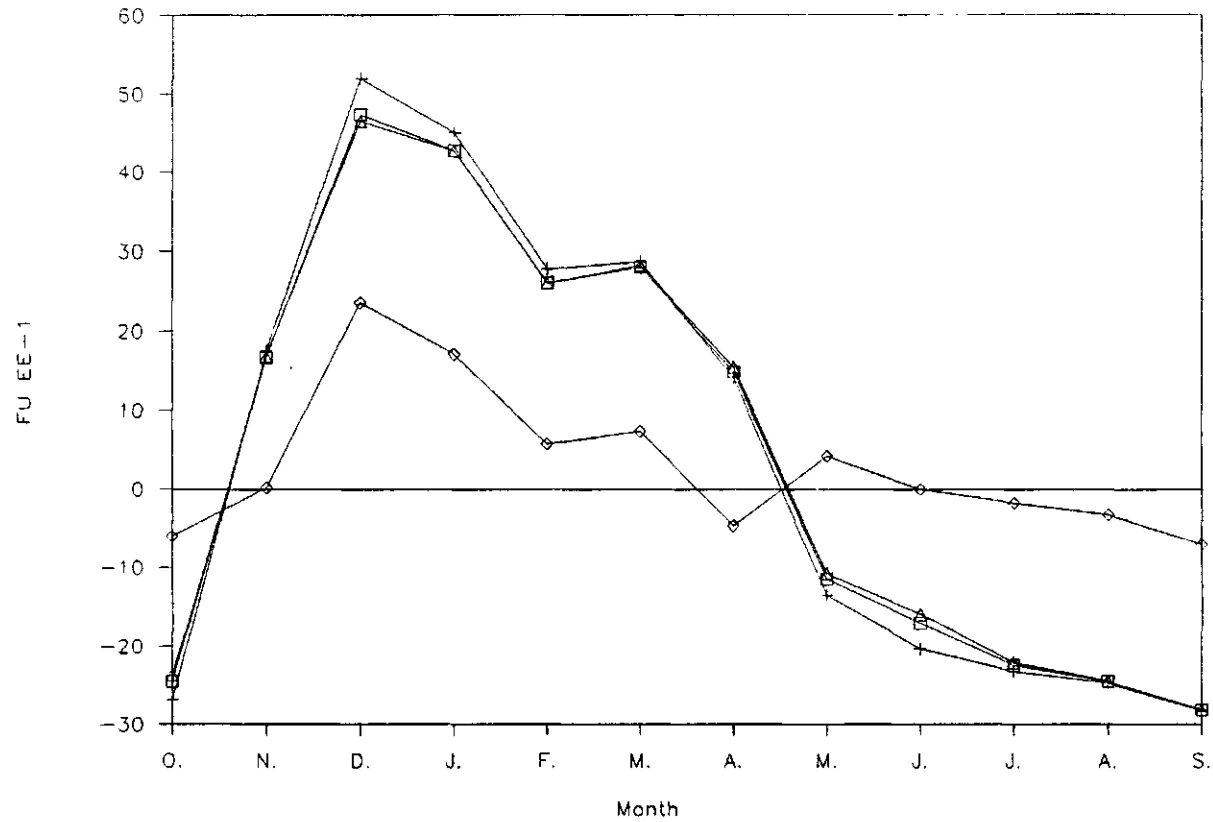


Figure 22. Simulated feed balances in the Matruh region, if number of sheep and goats are reduced, and no barley products (□, FLD = 0.17), no rangeland forage between the barley fields (◇, FLD = 0.205), neither barley products nor rangeland forage between the barley fields are available (+, FLD = 0.14), and if shrubs were planted on the barley fields (△, FLD = 0.18).

In this context, it should be realized that a low stocking rate in winter will lead to more vigorous growth of the natural vegetation with consequently, a higher water use during winter, eventually to such an extent that water availability in summer is severely reduced. In that way the availability of forage from natural rangeland in summer is further reduced and more supplements are necessary. Eventually, the perennial vegetation may die completely and although annuals may partly take over, the total availability of rangeland forage will be much lower.

Unfortunately, lack of time prevented more extensive experimentation (field and modelling) in the present study to calculate the optimum stocking rate at the rangeland in winter, i.e. that rate that would extend the effective green grazing period while maintaining the vegetation in an equilibrium state. That question should be addressed in more detail in the future, to evaluate perennial rangelands and their potentials for animal husbandry.

6.3 Other constraints

In addition to the constraint of feed availability, the following constraints should be taken into account:

1. Housing and veterinary care (Vitamin A and E supplementation).
2. Shearing must be done properly and timely to ensure satisfactory mating performance.
3. Cleaning and repair of wells, cisterns and galeries is important, especially in the western regions.
4. Storing wool properly is a problem due to lack of storage facilities.
5. The mineral balance is not optimal, especially phosphorus and sulphur are lacking.
6. Intake of crude protein from natural vegetation may sometimes be insufficient.

6.4 Improvements in animal husbandry

The present situation in the northwestern coastal zone could be improved (without a breeding program or introduction of animals from outside the region) in the following respects:

1. If Vitamin A would be supplied and shading sheds would be made available, higher conception rates and increased growth rates could be obtained.
2. If saltblocks would be provided, digestibility of rangeland forage would increase and in turn dry matter intake and growth rates could increase.
3. If phosphorus would be provided, wool production could increase, and if storage of wool would be made possible higher prices could be obtained.

CHAPTER 7.

ANIMAL HUSBANDRY SYSTEMS FOR LINEAR PROGRAMMING MODULES

7.1 System definition

To investigate the possibilities for agricultural development in the northwestern coastal zone, in dependence of well-defined objectives, multiple goal linear programming was used. More details about this method are given by van Keulen and de Wit (1987) and de Wit et al. (1987). In this chapter the systems or activities, a set of operations by which a system is defined, are discussed.

The main characteristic of the approach is that the systems are defined in a target-oriented way, i.e. the yield of the system is defined first and the requirements to achieve that yield are derived subsequently. These yields and requirements are defined in input/output tables. In the present study the coefficients in the tables are expressed per ewe equivalent (Section 7.2). The input/output tables for each region, quantified on the basis of the model ARID ANIMAL, are given in Section 7.3. As it is beyond the scope of this report to discuss the results of the multiple goal linear programming exercise, reference is made to van de Ven and van Keulen (1987).

Given the characteristics of the animals and those of the feed resources, animal husbandry systems are defined for sheep and goats, donkeys, camels and cattle. It should be realized that system definition determines the choice that can be made in the LP module. In the following subsections these systems are described in more detail.

7.1.1 Sheep and goat systems

Three types of system for sheep and goat husbandry are distinguished: extensive, intermediate and intensive systems. Independent of system intensity, the quantity of subsidised concentrates (COSMAX) available for the animals is 54 kg EE^{-1} yr^{-1}. In all systems the diet of the animals is fixed in the main dry period, but the composition varies among the systems.

Table 28 shows additional criteria that are used for further system characterization.

Table 28. Characterization of sheep and goat husbandry systems as applied in this study, whith a sheep to goat ratio of 0.73 : 0.27 head head^{-1}, equivalent to 0.76 : 0.24 EE EE^{-1}.

SYSTEM TYPE	BARLEY STRAW AVAILABLE	% OF FLOCK IN FEEDLOT	% OF WEANERS IN FEEDLOT	SYSTEM NUMBER
EXTENSIVE	no	0	0	1
	yes	0	0	2
INTERMEDIATE	no	0	0	3
	yes	0	0	4
	yes	0	50	5
	yes	0	100	6
	yes	20	50	7
	yes	20	100	8
INTENSIVE	yes	0	100	9
	yes	50	100	10
	yes	100	100	11

7.1.1.1 Extensive systems

In the extensive systems, herd nutrition is based as far as possible on available rangeland forage, and consequently, supplement utilization in the main dry period is kept to a minimum.

The target production level, expressed here as the feed unit conversion factor (FUCF, the ratio of required feed units to liveweight production of these systems), is somewhat lower than that of the intermediate systems. For the Matruh region a value of FUCF of 22.1 and of 27.8 FU kg^{-1} liveweight is calculated for sheep and goats, respectively.

Two subsystems are distinguished as listed in Table 28:

SYSTEM 1. Extensive, no barley straw available (AHEXR)

In this system the feed resources are the natural vegetation of the rangeland and of the grazing area between the barley fields. No barley straw is available as supplementary feed.

If supplements are required in the main dry period, they consist of 80% concentrates (either manufactured concentrates or grain, IFCON), 15% vegetable residues (IFVE) and 5% berseem hay (IFBE).

As no straw is available, more rangeland forage must be consumed in the main dry period to meet the roughage requirements. As outlined before, dry matter intake of low quality forage in ruminants is limited (Subsection 3.1.9). The maximum rate of intake of rangeland forage (INTMAX) is set, arbitrarily, at 0.9 kg DM EE^{-1} d^{-1}. In that way, roughage intake in the main dry period comprises at least 25% of the total intake. If maximum rangeland forage intake exceeds the feed requirements in the main dry period, the rangeland requirements in that period (RUPMD) are calculated similarly to those in the other periods (RUPGG and RUPED, see ARID ANIMAL). As that is apparently the case, no supplementary feed is required (Tables 30-34).

SYSTEM 2. Extensive, barley straw available (AHEXS)

The feed resources are the same as in the previous system, except that in addition, barley straw is available. To account for the effect of supplementation with barley straw and vegetable residues, the maximum rate of intake of rangeland forage (INTMAX) is reduced to an arbitrary value of 0.6 kg DM EE^{-1} d^{-1}. The supplementary feed in the main dry period consists of 30% concentrates (IFCON), 30% barley straw (IFBS), 30% vegetable residues (IFVE) and 10% berseem hay (IFBE).

7.1.1.2 Intermediate systems

Intermediate systems are defined as those systems with a production target equal to the ones obtained at present. The inputs may not be exactly those actually used at present, but that is because of lack of accurate data.

Based on the description in ARID ANIMAL a feed unit conversion factor of 15.3 and of 17.9 FU kg^{-1} liveweight is calculated for sheep and goats, respectively.

Six subsystems are distinguished as summarized in Table 28:

SYSTEM 3. Intermediate, no barley straw available (AHCR)

In this system the available feed resources are the natural vegetation of the rangeland and of the grazing area between the barley fields. As no barley straw is available, rangeland is the main resource of roughage and INTMAX is arbitrarily set at 0.9 kg DM EE^{-1} d^{-1}. Additional supplements must then be of high quality, and hence they consist of 90% concentrates (IFCON) and 5% berseem hay (IFBE). Vegetable residues (IFVE) are used as a minor roughage resource (5%).

SYSTEM 4. Intermediate, barley straw available, but no feedlot feeding (AHCS)

In this system the available feed resources are equal to those of the previous system. Barley straw and vegetable residues are additional roughage resources in the main dry period. To account for the effect of supplementation with barley straw and vegetable residues, the maximum rate of intake of rangeland forage (INTMAX) is reduced to an arbitrary value of 0.3 kg DM EE^{-1} d^{-1}. The feed requirements met by supplements consist of 75% concentrates (IFCON), 18% barley straw (IFBS), 4% vegetable residues (IFVE) and 3% berseem hay (IFBE).

SYSTEMS 5 - 8. Intermediate with feedlot feeding (AHCF1 - AHCF4)

The available feed resources in these systems are identical to those in the other intermediate systems. The proportion of the total flock involved in feedlot operations, however, varies among the systems. The proportion of the flock in a feedlot is either 0 or 20% and the proportion of weaners either 50 or 100% (Table 28).

To account for the effect of feedlot feeding and supplementation with barley straw and vegetable residues, the maximum rate of intake of rangeland forage (INTMAX) is reduced to an arbitrary value of 0.3 kg DM EE^{-1} d^{-1}. The feed requirements met by supplements consist of 75% concentrates (IFCON), 18% barley straw (IFBS), 4% vegetable residues (IFVE) and 3% berseem hay (IFBE).

7.1.1.3 Intensive systems

In intensive systems the production level is higher than in the intermediate systems, due to e.g.:

I. Increased use of concentrates and other supplements.

II. Herd improvement (e.g. selection and breeding).

III. Increasing veterinary care.

Another option to improve animal performance compared to the intermediate systems is to apply fertilizer to the rangeland to increase pasture production and to extend the green grazing period. However, as no information is available on this practice it has not been included in the present study.

One intensive system has been defined in the present study, based on improved conditions. In ARID ANIMAL a feed unit conversion factor for sheep of 12.0 and for goats of 12.5 FU kg^{-1} liveweight is calculated. Three subsystems are distinguished, based on the proportion of the flock that is involved in feedlot operations, ranging from 0 to 100% for the flock and from 50 to 100% for weaners.

SYSTEM 9 - 11. Intensive, fixed diet, feedlot feeding (AHIF1-AHIF3)

The available feed resources in these systems are the natural vegetation of the rangeland and of the grazing area between the barley fields. Due to the fact that the animals graze the rangeland in summer only for a short period, the intake of forage is limited in that period. To account for that and for the effect of feedlot feeding and supplementation with barley straw, the maximum rate of intake of rangeland forage (INTMAX) is reduced to an arbitrary value of 0.2 kg DM EE^{-1} d^{-1}. The feed requirements met by supplements consist of 80% concentrates (IFCON) and 20% barley straw (IFBS). The contribution of straw in the diet is enough to ensure the required roughage intake.

7.1.2 Other animal systems

For the other animal species one system per animal species has been defined, because of lack of detailed information and lack of time.

SYSTEM 20. Donkeys

For this system it is assumed that donkeys are completely maintained on the rangeland in the green grazing period and in the early dry period, and for 80% in the main dry period. Supplementary feed consists of 40% concentrates (IFCON), 30% barley straw (IFBS), 20% vegetable residues (IFVE) and 10% berseem hay (IFBE).

SYSTEM 30. Camels

For this system it is assumed that camels are dependent on the rangeland forage throughout the year.

SYSTEM 40. Cattle

For this system it is assumed that cattle depend for 40% on vegetable residues (IFVE) and for 60% on berseem hay (IFBE). It should be realized that in the present definition recources are required, but no outputs (milk and meat) are considered. Hence, this system will not be chosen in the present LP module, but is given for the sake of completeness.

7.2 Input/output variables

For the present purpose of the study only the main characteristic inputs and outputs of the systems described in the previous section have been quantified. Some outputs (e.g. skins of goats) may play an important role in the household, but on a regional basis they can be neglected.

7.2.1 Inputs

SHEEP, GOATS, DONKEYS, CAMELS and CATTLE.

As one 'ewe equivalent' may consist to a varying degree of sheep and goats in SYSTEMS 1-11, the contributing fraction of sheep and goat is calculated. As in the other systems only one type of animal is present, the fraction equals one.

RANARQ.

The annual rangeland requirements (ha EE^{-1} yr^{-1}) are calculated under the assumption that feed requirements of the animals must be met completely from this resource in the green grazing period and in the early dry period, whereas in the main dry period the intake of rangeland forage is limited, as outlined before.

STRAW, CONARQ, BERARQ and VEGARQ.

Supplements required (kg DM EE^{-1} yr^{-1}) in the main dry period may consist of barley straw (STRAW), concentrates (CONARQ, no distinction is made between manufactured concentrates and grain), berseem hay (BERARQ) and vegetable residues (VEGARQ). As described in the preceding section, the composition of supplementary feed varies among systems.

ANCOST.

The annual costs (LE EE^{-1} yr^{-1}) depend on system intensity and include:
- Costs for cleaning of wells, cisterns and galeries
- Costs of water from the pipeline in the Dabaa, the Matruh and the Barrani regions
- Costs of medicines, saltbricks and Vitamin A
- Costs of maintenance of buildings, sheds and corrals
- Miscellaneous costs

The costs of supplements and of hired labour from outside the region are calculated in the LP module.

INVSAH.

The required investments in animal husbandry activities (LE EE^{-1} yr^{-1}) depend on system intensity and comprise:
- Construction of cisterns and pipelines
- Construction of water troughs
- Construction of sheds, corrals, dips and acquisition of equipment

MDOUT,MDSEPT,MDNOV,MDAPR and MDREST (labour).

Labour requirements (manday EE^{-1} yr^{-1}) comprise shepherding, veterinary care, shearing, feeding and watering and maintenance work for physical structures. The requirements vary with system intensity, as described in the corresponding subsections (Section 5.3).

7.2.2 Outputs

SHOGG and GHOGG.

The number of sheep and goat hoggets produced (EE EE^{-1} yr^{-1}) is calculated by the model on the basis of the data presented before. In the LP module these hoggets may be 'sold' or 'kept for breeding', depending on the pre-defined goal.

MUTTON, GMEAT.

MUTTON and GMEAT (kg liveweight EE^{-1} yr^{-1}) are saleable liveweight of sheep and of goats, respectively. It is assumed in this study that only a small proportion of the meat is consumed in the region. As the government granted export licenses for about 180 000 to 200 000 head fetching a higher price (Abdel Salam et al., 1985), the export market will be satisfied first and the remaining mutton and goat meat is sold at the local market. A maximum of 190 000 head is set in the LP module for export.

No data are available on the ratio of sheep to goats in the sale nor on the number of fattened lambs and kids and hoggets. Therefore, it is assumed that the ratio of sheep liveweight produced to goat liveweight produced is 0.6:0.4, somewhat higher than reported by Soliman (1981), because of the increase in goat meat export in recent years.

SWOOL.

Wool production of sheep (kg EE^{-1} yr^{-1}) depends on system intensity. As the hair produced by the goats is only used within the household, that component is not taken into account in the LP module.

MANURE.

It is assumed that a certain fraction, depending on system intensity of the total manure production (kg DM EE^{-1} yr^{-1}) is collected and used in arable farming (Subsection 3.1.7.4).

HRATOT (traction).

Traction (h EE^{-1} yr^{-1}) is supplied by donkeys and camels only.

The technical relations applied in the LP module are schematically depicted in Table 29.

7.3 Input/output tables for the four regions

The input/output tables for the Burg el Arab, the Dabaa, the Matruh and the Barrani regions and the average for the coastal zone, are given in Tables 30, 31, 32, 33, and 34, respectively.

The tables for the four regions are different because of differences in animal population.

Table 29. Schematic representation of the input/output table for animal husbandry systems: + is input, - is output, RHS is Right Hand Side, L is limited, N is not limited. Acronyms are explained in the text and in appendix II.

	SYSTEM										RHS
INPUT/OUTPUT	1	2	3	4 - 8	9	10	11	20	30	40	
animals											
SHEEP	+	+	+	+	+	+	+				N
GOATS	+	+	+	+	+	+	+				N
DONKEYS								+			N
CAMELS									+		N
CATTLE										+	N
feed											
RANARQ	+	+	+	+	+	+	+	+	+		L
STRAW		+		+	+	+	+	+			L
CONARQ	+	+	+	+				+			N
VEGARQ	+	+	+	+				+		+	N
BERARQ	+	+	+	+				+		+	N
others											
ANCOST	+	+	+	+	+	+	+	+	+	+	L
INVSAH	+	+	+	+	+	+	+	+	+	+	L
MDOUT	+	+	+	+	+	+	+		+		N
MDSEPT	+	+	+	+	+	+	+	+	+	+	L
MDNOV	+	+	+	+	+	+	+	+	+	+	L
MDAPR	+	+	+	+	+	+	+	+	+	+	L
MDREST	+	+	+	+	+	+	+	+	+	+	L
outputs											
SHOGG	-	-	-	-	-	-	-				
GHOGG	-	-	-	-	-	-	-				
MUTTON	-	-	-	-	-	-	-				
GMEAT	-	-	-	-	-	-	-				
SWOOL	-	-	-	-	-	-	-				
MANURE	-	-	-	-	-	-	-				
HRATOT								-	-		

Table 30. The technical coefficients of the input/output table for animal husbandry systems in the Burg el Arab region. Acronyms are explained in the text and in Appendix II.

	SYSTEM						
INPUT/OUTPUT	1	2	3	4	5	6	7
animals							
SHEEP	0.76	0.76	0.76	0.76	0.76	0.76	0.76
GOATS	0.24	0.24	0.24	0.24	0.24	0.24	0.24
DONKEYS							
CAMELS							
CATTLE							
feed							
RANARQ	2.39	2.05	2.74	1.60	1.56	1.52	1.35
STRAW		37.29		100.13	84.63	87.34	96.50
CONARQ		16.78	5.98	153.61	158.68	163.76	180.94
VEGARQ		7.99	0.47	8.78	9.07	9.75	10.34
BERARQ		41.95	0.83	20.48	21.16	21.83	24.13
others							
ANCOST	4.99	5.08	9.62	9.62	9.62	9.62	9.64
INVSAH	2.68	2.21	4.53	2.99	2.90	2.81	4.40
MDOUT	0.03	0.03	0.08	0.08	0.08	0.08	0.08
MDSEPT	1.58	1.58	0.67	0.67	0.69	0.72	0.56
MDNOV	1.35	1.35	0.67	0.67	0.69	0.72	0.56
MDAPR	1.35	1.35	0.54	0.54	0.55	0.59	0.45
MDREST	13.38	13.38	5.58	5.58	5.63	5.75	4.55
outputs							
SHOGG	-0.09	-0.09	-0.12	-0.12	-0.12	-0.12	-0.12
GHOGG	-0.04	-0.04	-0.05	-0.05	-0.05	-0.05	-0.05
MUTTON	-16.11	-16.11	-27.21	-27.21	-27.21	-27.21	-27.21
GMEAT	-3.58	-3.58	-6.34	-6.34	-6.34	-6.34	-6.34
SWOOL	-1.23	-1.23	-1.38	-1.38	-1.38	-1.38	-1.38
MANURE	-19.57	-19.57	-39.14	-39.14	-43.05	-50.88	-62.62
HRATOT							

Table 30. Continued.

	SYSTEM						
INPUT/OUTPUT	8	9	10	11	20	30	40
animals							
SHEEP	0.76	0.76	0.76	0.76			
GOATS	0.24	0.24	0.24	0.24			
DONKEYS					1		
CAMELS						1	
CATTLE							1
feed							
RANARQ	1.31	1.27	0.84		1.04	1.54	
STRAW	99.10	194.60	230.84	299.39	19.71		
CONARQ	185.82	350.28	415.51	538.90	11.83		
VEGARQ	10.62				4.22		473.16
BERARQ	24.78				14.78		354.87
others							
ANCOST	9.64	15.33	15.36	15.39	0.84	0.45	0.64
INVSAH	4.35	5.64	5.29	4.33	2.68	1.30	1.50
MDOUT	0.08	0.11	0.11	0.11		0.10	
MDSEPT	0.59	0.25	0.17	0.08	0.35	0.11	0.23
MDNOV	0.59	0.25	0.17	0.08	0.25	0.08	0.17
MDAPR	0.48	0.25	0.17	0.08	0.25	0.08	0.17
MDREST	4.67	1.92	1.20	0.53	1.99	0.61	1.33
outputs							
SHOGG	-0.12	-0.29	-0.29	-0.29			
GHOGG	-0.05	-0.12	-0.12	-0.12			
MUTTON	-27.21	-44.77	-44.77	-44.77			
GMEAT	-6.34	-12.34	-12.34	-12.34			
SWOOL	-1.38	-1.54	-1.54	-1.54			
MANURE	-78.28	-50.88	-78.28	-97.85			
HRATOT					-1800.	-223.9	

Table 31. The technical coefficients of the input/output table for animal husbandry systems in the Dabaa region. Acronyms are explained in the text and in Appendix II.

	SYSTEM						
INPUT/OUTPUT	1	2	3	4	5	6	7
animals							
SHEEP	0.76	0.76	0.76	0.76	0.76	0.76	0.76
GOATS	0.24	0.24	0.24	0.24	0.24	0.24	0.24
DONKEYS							
CAMELS							
CATTLE							
feed							
RANARQ	2.23	1.91	2.56	1.49	1.45	1.41	1.26
STRAW		37.29		100.13	84.63	87.34	96.50
CONARQ		16.78	5.98	153.61	158.68	163.76	180.94
VEGARQ		7.99	0.47	8.78	9.07	9.75	10.34
BERARQ		41.95	0.83	20.48	21.16	21.83	24.13
others							
ANCOST	5.04	5.04	9.69	9.69	9.70	9.70	9.72
INVSAH	1.94	1.50	3.73	2.29	4.23	4.18	4.04
MDOUT	0.03	0.03	0.08	0.08	0.08	0.08	0.08
MDSEPT	1.55	1.55	0.64	0.64	0.65	0.69	0.53
MDNOV	1.35	1.35	0.64	0.64	0.65	0.69	0.53
MDAPR	1.35	1.35	0.54	0.54	0.55	0.58	0.44
MDREST	13.22	13.22	5.40	5.40	5.45	5.57	4.39
outputs							
SHOGG	-0.09	-0.09	-0.12	-0.12	-0.12	-0.12	-0.12
GHOGG	-0.04	-0.04	-0.05	-0.05	-0.05	-0.05	-0.05
MUTTON	-16.11	-16.11	-27.21	-27.21	-27.21	-27.21	-27.21
GMEAT	-3.58	-3.58	-6.34	-6.34	-6.34	-6.34	-6.34
SWOOL	-1.23	-1.23	-1.38	-1.38	-1.38	-1.38	-1.38
MANURE	-19.57	-19.57	-39.14	-39.14	-43.05	-50.88	-62.62
HRATOT							

Table 31. Continued.

INPUT/OUTPUT	SYSTEM 8	9	10	11	20	30	40
animals							
SHEEP	0.76	0.76	0.76	0.76			
GOATS	0.24	0.24	0.24	0.24			
DONKEYS					1		
CAMELS						1	
CATTLE							1
feed							
RANARQ	1.22	1.18	0.78		0.96	1.44	
STRAW	99.10	194.60	230.84	299.39	19.71		
CONARQ	185.82	350.28	415.51	538.90	11.83		
VEGARQ	10.62				4.22		473.16
BERARQ	24.78				14.78		354.87
others							
ANCOST	9.73	15.47	15.52	15.57	0.87	0.50	0.68
INVSAH	3.99	5.26	4.90	3.99	2.43	0.95	1.56
MDOUT	0.08	0.11	0.11	0.11		0.10	
MDSEPT	0.56	0.22	0.14	0.07	0.35	0.11	0.23
MDNOV	0.56	0.22	0.14	0.07	0.25	0.08	0.17
MDAPR	0.47	0.22	0.14	0.07	0.25	0.08	0.17
MDREST	4.52	1.70	1.04	0.39	1.99	0.61	1.33
outputs							
SHOGG	-0.12	-0.29	-0.29	-0.29			
GHOGG	-0.05	-0.12	-0.12	-0.12			
MUTTON	-27.21	-44.77	-44.77	-44.77			
GMEAT	-6.34	-12.34	-12.34	-12.34			
SWOOL	-1.38	-1.54	-1.54	-1.54			
MANURE	-78.28	-50.88	-78.28	-97.85			
HRATOT					-1800.	-223.9	

Table 32. The technical coefficients of the input/output table for animal husbandry systems in the Matruh region. Acronyms are explained in the text and in Appendix II.

	SYSTEM						
INPUT/OUTPUT	1	2	3	4	5	6	7
animals							
SHEEP	0.76	0.76	0.76	0.76	0.76	0.76	0.76
GOATS	0.24	0.24	0.24	0.24	0.24	0.24	0.24
DONKEYS							
CAMELS							
CATTLE							
feed							
RANARQ	2.82	2.41	3.23	1.88	1.83	1.78	1.59
STRAW		37.29		100.13	84.63	87.34	96.50
CONARQ		16.78	5.98	153.61	158.68	163.76	180.94
VEGARQ		7.99	0.47	8.78	9.07	9.75	10.34
BERARQ		41.95	0.83	20.48	21.16	21.83	24.13
others							
ANCOST	5.08	5.08	9.74	9.74	9.74	9.75	9.77
INVSAH	2.22	1.67	4.09	4.92	4.86	4.80	4.62
MDOUT	0.03	0.03	0.08	0.08	0.08	0.08	0.08
MDSEPT	1.55	1.55	0.65	0.65	0.66	0.69	0.53
MDNOV	1.35	1.35	0.65	0.65	0.66	0.69	0.53
MDAPR	1.35	1.35	0.54	0.54	0.55	0.58	0.44
MDREST	13.24	13.24	5.42	5.42	5.48	5.60	4.42
outputs							
SHOGG	-0.09	-0.09	-0.12	-0.12	-0.12	-0.12	-0.12
GHOGG	-0.04	-0.04	-0.05	-0.05	-0.05	-0.05	-0.05
MUTTON	-16.11	-16.11	-27.21	-27.21	-27.21	-27.21	-27.21
GMEAT	-3.58	-3.58	-6.34	-6.34	-6.34	-6.34	-6.34
SWOOL	-1.23	-1.23	-1.38	-1.38	-1.38	-1.38	-1.38
MANURE	-19.57	-19.57	-39.14	-39.14	-43.05	-50.88	-62.62
HRATOT							

Table 32. Continued.

INPUT/OUTPUT	SYSTEM 8	9	10	11	20	30	40
animals							
SHEEP	0.76	0.76	0.76	0.76			
GOATS	0.24	0.24	0.24	0.24			
DONKEYS					1		
CAMELS						1	
CATTLE							1
feed							
RANARQ	1.55	1.49	0.99		1.22	1.81	
STRAW	99.10	194.60	230.84	299.39	19.71		
CONARQ	185.82	350.28	415.51	538.90	11.83		
VEGARQ	10.62				4.22		473.16
BERARQ	24.78				14.78		354.87
others							
ANCOST	9.78	15.52	15.58	15.64	0.90	0.53	0.68
INVSAH	4.56	5.82	5.35	4.18	2.45	1.06	1.56
MDOUT	0.08	0.11	0.11	0.11		0.10	
MDSEPT	0.56	0.22	0.14	0.07	0.35	0.11	0.23
MDNOV	0.56	0.22	0.14	0.07	0.25	0.08	0.17
MDAPR	0.48	0.22	0.14	0.07	0.25	0.08	0.17
MDREST	4.54	1.73	1.06	0.41	1.99	0.61	1.33
outputs							
SHOGG	-0.12	-0.29	-0.29	-0.29			
GHOGG	-0.05	-0.12	-0.12	-0.12			
MUTTON	-27.21	-44.77	-44.77	-44.77			
GMEAT	-6.34	-12.34	-12.34	-12.34			
SWOOL	-1.38	-1.54	-1.54	-1.54			
MANURE	-78.28	-50.88	-78.28	-97.85			
HRATOT					-1800.	-223.9	

Table 33. The technical coefficients of the input/output table for animal husbandry systems in the Barrani region. Acronyms are explained in the text and in Appendix II.

	SYSTEM						
INPUT/OUTPUT	1	2	3	4	5	6	7
animals							
SHEEP	0.76	0.76	0.76	0.76	0.76	0.76	0.76
GOATS	0.24	0.24	0.24	0.24	0.24	0.24	0.24
DONKEYS							
CAMELS							
CATTLE							
feed							
RANARQ	2.61	2.24	2.99	1.75	1.70	1.65	1.48
STRAW		37.29		100.13	84.63	87.34	96.50
CONARQ		16.78	5.98	153.61	158.68	163.76	180.94
VEGARQ		7.99	0.47	8.78	9.07	9.75	10.34
BERARQ		41.95	0.83	20.48	21.16	21.83	24.13
others							
ANCOST	5.12	5.12	9.78	9.78	9.79	9.80	9.82
INVSAH	1.39	3.97	3.18	4.80	4.75	4.69	4.53
MDOUT	0.03	0.03	0.08	0.08	0.08	0.08	0.08
MDSEPT	1.55	1.55	0.64	0.64	0.66	0.69	0.53
MDNOV	1.35	1.35	0.64	0.64	0.66	0.69	0.53
MDAPR	1.35	1.35	0.54	0.54	0.55	0.58	0.44
MDREST	13.23	13.23	5.41	5.41	5.47	5.59	4.41
outputs							
SHOGG	-0.09	-0.09	-0.12	-0.12	-0.12	-0.12	-0.12
GHOGG	-0.04	-0.04	-0.05	-0.05	-0.05	-0.05	-0.05
MUTTON	-16.11	-16.11	-27.21	-27.21	-27.21	-27.21	-27.21
GMEAT	-3.58	-3.58	-6.34	-6.34	-6.34	-6.34	-6.34
SWOOL	-1.23	-1.23	-1.38	-1.38	-1.38	-1.38	-1.38
MANURE	-19.57	-19.57	-39.14	-39.14	-43.05	-50.88	-62.62
HRATOT							

Table 33. Continued.

	SYSTEM						
INPUT/OUTPUT	8	9	10	11	20	30	40
animals							
SHEEP	0.76	0.76	0.76	0.76			
GOATS	0.24	0.24	0.24	0.24			
DONKEYS					1		
CAMELS						1	
CATTLE							1
feed							
RANARQ	1.43	1.39	0.92		1.13	1.68	
STRAW	99.10	194.60	230.84	299.39	19.71		
CONARQ	185.82	350.28	415.51	538.90	11.83		
VEGARQ	10.62				4.22		473.16
BERARQ	24.78				14.78		354.87
others							
ANCOST	9.83	15.58	15.64	15.71	0.92	0.56	0.68
INVSAH	4.48	5.76	5.35	4.29	3.82	2.76	1.56
MDOUT	0.08	0.11	0.11	0.11		0.10	
MDSEPT	0.56	0.22	0.14	0.07	0.35	0.11	0.23
MDNOV	0.56	0.22	0.14	0.07	0.25	0.08	0.17
MDAPR	0.47	0.22	0.14	0.07	0.25	0.08	0.17
MDREST	4.53	1.72	1.05	0.40	1.99	0.61	1.33
outputs							
SHOGG	-0.12	-0.29	-0.29	-0.29			
GHOGG	-0.05	-0.12	-0.12	-0.12			
MUTTON	-27.21	-44.77	-44.77	-44.77			
GMEAT	-6.34	-12.34	-12.34	-12.34			
SWOOL	-1.38	-1.54	-1.54	-1.54			
MANURE	-78.28	-50.88	-78.28	-97.85			
HRATOT					-1800.	-223.9	

Table 34. The technical coefficients of the input/output table for animal husbandry systems in the coastal zone. Acronyms are explained in the text and in Appendix II.

	SYSTEM						
INPUT/OUTPUT	1	2	3	4	5	6	7
animals							
SHEEP	0.76	0.76	0.76	0.76	0.76	0.76	0.76
GOATS	0.24	0.24	0.24	0.24	0.24	0.24	0.24
DONKEYS							
CAMELS							
CATTLE							
feed							
RANARQ	2.55	2.18	2.92	1.71	1.66	1.62	1.44
STRAW		37.29		100.13	84.63	87.34	96.50
CONARQ		16.78	5.98	153.61	158.68	163.76	180.94
VEGARQ		7.99	0.47	8.78	9.07	9.75	10.34
BERARQ		41.95	0.83	20.48	21.16	21.83	24.13
others							
ANCOST	5.08	5.08	9.74	9.74	9.74	9.75	9.77
INVSAH	1.89	1.39	3.71	4.71	4.66	4.60	4.45
MDOUT	0.03	0.03	0.08	0.08	0.08	0.08	0.08
MDSEPT	1.55	1.55	0.65	0.65	0.66	0.69	0.54
MDNOV	1.35	1.35	0.65	0.65	0.66	0.69	0.54
MDAPR	1.35	1.35	0.54	0.54	0.55	0.58	0.45
MDREST	13.26	13.26	5.44	5.44	5.50	5.62	4.43
outputs							
SHOGG	-0.09	-0.09	-0.12	-0.12	-0.12	-0.12	-0.12
GHOGG	-0.04	-0.04	-0.05	-0.05	-0.05	-0.05	-0.05
MUTTON	-16.11	-16.11	-27.21	-27.21	-27.21	-27.21	-27.21
GMEAT	-3.58	-3.58	-6.34	-6.34	-6.34	-6.34	-6.34
SWOOL	-1.23	-1.23	-1.38	-1.38	-1.38	-1.38	-1.38
MANURE	-19.57	-19.57	-39.14	-39.14	-43.05	-50.88	-62.62
HRATOT							

Table 34. Continued.

INPUT/OUTPUT	SYSTEM 8	9	10	11	20	30	40
animals							
SHEEP	0.76	0.76	0.76	0.76			
GOATS	0.24	0.24	0.24	0.24			
DONKEYS					1		
CAMELS						1	
CATTLE							1
feed							
RANARQ	1.40	1.35	0.90		1.10	1.64	
STRAW	99.10	194.60	230.84	299.39	19.71		
CONARQ	185.82	350.28	415.51	538.90	11.83		
VEGARQ	10.62				4.22		473.16
BERARQ	24.78				14.78		354.87
others							
ANCOST	9.78	15.52	15.58	15.64	0.90	0.53	0.68
INVSAH	4.39	5.67	5.27	4.23	2.30	0.83	1.56
MDOUT	0.08	0.11	0.11	0.11		0.10	
MDSEPT	0.57	0.23	0.15	0.07	0.35	0.11	0.23
MDNOV	0.57	0.23	0.15	0.07	0.25	0.08	0.17
MDAPR	0.48	0.23	0.15	0.07	0.25	0.08	0.17
MDREST	4.55	1.76	1.08	0.43	1.99	0.61	1.33
outputs							
SHOGG	-0.12	-0.29	-0.29	-0.29			
GHOGG	-0.05	-0.12	-0.12	-0.12			
MUTTON	-27.21	-44.77	-44.77	-44.77			
GMEAT	-6.34	-12.34	-12.34	-12.34			
SWOOL	-1.38	-1.54	-1.54	-1.54			
MANURE	-78.28	-50.88	-78.28	-97.85			
HRATOT					-1800.	-223.9	

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9. APPENDICES

I. ARID ANIMAL

In this chapter the model ARID ANIMAL is listed (Table 35). The model is written in CSMP; for more details about this language reference is made to Penning de Vries and van Laar (1983). For the present purpose of the model, a time interval of integration of one month is applied.

The corresponding text in this report is indicated in the listing in brackets.

Table 35. Listing of the model ARID ANIMAL.

```
==========================================================================
TITLE ARID ANIMAL, A SYSTEM GENERATOR AND FEED BALANCE SIMULATION MODEL.
TITLE VERSION APRIL 1987

INITIAL

*-----------------------------------------------------------------------
*  REGION AND SYSTEM CHARACTERISTICS
*-----------------------------------------------------------------------
* PARAM REGION
*       1 = The Burg el Arab region, 2 = the Dabaa region,
*       3 = the Martrouh region, 4 = the Barrani region,
*       5 = the NW-zone.
* PARAM SYSTEM
*  EXTENSIVE SHEEP & GOATS (SYSEX)
*       1 = No barley straw available
*       2 = Barley straw available
*  INTERMEDIATE SHEEP & GOATS (SYSP)
*       3 = No barley straw available
*       4 =   0% of flock and   0% of weaners in feedlot
*       5 =   0% of flock and  50% of weaners in feedlot
*       6 =   0% of flock and 100% of weaners in feedlot
*       7 =  20% of flock and  50% of weaners in feedlot
*       8 =  20% of flock and 100% of weaners in feedlot
*  INTENSIVE SHEEP & GOATS (SYSIN)
*       9 =   0% of flock and 100% of weaners in feedlot
*      10 =  50% of flock and 100% of weaners in feedlot
*      11 = 100% of flock and 100% of weaners in feedlot
```

```
*  OTHER ANIMAL SPECIES
*      20 = donkeys
*      30 = camels
*      40 = cattle
*  FEED BALANCE CALCULATION
*      50 = sheep, goats, donkeys and camels graze the rangeland
*           analogous to SYSTEM 4.

PARAM REGION = 1.
PARAM SYSTEM = 1.

DYNAMIC
*-----------------------------------------------------------------------
*                                FEED AVAILABILITY
*-----------------------------------------------------------------------
*
*-------------------------------- RANGELAND ----------------------------
* AREA OF RANGELAND (Chapter 1)

         ARL     = ARL1 + ARL2 + ARL3 + ARL4
         ARLFB   = ARL1 + ARL2 + ARL3 + ARL4 + ARLBBF
         ARL1    = AFGEN(ARL1T,REGION)
         ARL2    = AFGEN(ARL2T,REGION)
         ARL3    = AFGEN(ARL3T,REGION)
         ARL4    = AFGEN(ARL4T,REGION)
         ARLBBF  = AFGEN(ARL5T,REGION)
FUNCTION ARL1T   = 1.,  9080., 2.,     0., 3.,     0., 4.,    70., ...
                   5.,  9150.
FUNCTION ARL2T   = 1.,  8420., 2.,31380., 3., 28400., 4., 71820., ...
                   5.,140020.
FUNCTION ARL3T   = 1., 26710., 2.,98000., 3.,137390., 4.,135990., ...
                   5.,398090.
FUNCTION ARL4T   = 1., 68910., 2.,92900., 3.,156510., 4.,186030., ...
                   5.,504350.
FUNCTION ARL5T   = 1., 16020., 2.,32360., 3., 33600., 4., 17730., ...
                   5., 99710.

* BIOMASS PRODUCTIVITY (paragraph 4.2.2.3)

         RLBP    = RLBP1 + RLBP2 + RLBP3 + RLBP4
```

```
          RLBPFB = RLBP1 + RLBP2 + RLBP3 + RLBP4 + RLBBFP
          RLBP1  = RLAP1 * RLBPD1
          RLBP2  = RLAP2 * RLBPD2
          RLBP3  = RLAP3 * RLBPD3
          RLBP4  = RLAP4 * RLBPD4
          RLBBFP = RLAP5 * RLBPD2
          RLAP1  = AFGEN(RLAP1T,REGION)
          RLAP2  = AFGEN(RLAP2T,REGION)
          RLAP3  = AFGEN(RLAP3T,REGION)
          RLAP4  = AFGEN(RLAP4T,REGION)
          RLAP5  = AFGEN(RLAP5T,REGION)
          RLBPD1 = AFGEN(RLPD1T,TIME)
          RLBPD2 = AFGEN(RLPD2T,TIME)
          RLBPD3 = AFGEN(RLPD3T,TIME)
          RLBPD4 = AFGEN(RLPD4T,TIME)
FUNCTION RLAP1T = 1.,360., 2.,  0., 3.,  0., 4.,175., 5.,359.
FUNCTION RLAP2T = 1.,345., 2.,520., 3.,355., 4.,460., 5.,445.
FUNCTION RLAP3T = 1.,370., 2.,390., 3.,305., 4.,305., 5.,330.
FUNCTION RLAP4T = 1.,360., 2.,340., 3.,300., 4.,300., 5.,316.
FUNCTION RLAP5T = 1.,600., 2.,600., 3.,600., 4.,600., 5.,600.
FUNCTION RLPD1T = 0., 0.06, 0.99, 0.06, 1., 0.07, 1.99, 0.07, ...
                  2., 0.09, 2.99, 0.09, 3., 0.11, 3.99, 0.11, ...
                  4., 0.13, 4.99, 0.13, 5., 0.13, 5.99, 0.13, ...
                  6., 0.13, 6.99, 0.13, 7., 0.08, 7.99, 0.08, ...
                  8., 0.07, 8.99, 0.07, 9., 0.06, 9.99, 0.06, ...
                  10.,0.05,10.99, 0.05,11., 0.02,11.99, 0.02,...
                  12., 0.0, 16., 0.0
FUNCTION RLPD2T = 0., 0.06, 0.99, 0.06, 1., 0.08, 1.99, 0.08, ...
                  2., 0.10, 2.99, 0.10, 3., 0.12, 3.99, 0.12, ...
                  4., 0.13, 4.99, 0.13, 5., 0.14, 5.99, 0.14, ...
                  6., 0.14, 6.99, 0.14, 7., 0.08, 7.99, 0.08, ...
                  8., 0.08, 8.99, 0.08, 9., 0.03, 9.99, 0.03, ...
                   10.,0.02,10.99, 0.02,11., 0.02,11.99, 0.02, ...
                   12.,0.0, 16.,0.0
FUNCTION RLPD3T = 0., 0.01, 0.99, 0.01, 1., 0.14, 1.99, 0.14, ...
                  2., 0.12, 2.99, 0.12, 3., 0.15, 6.99, 0.15, ...
                  7., 0.08, 7.99, 0.08, 8., 0.02, 8.99, 0.02, ...
                  9., 0.01,11.99, 0.01,12., 0.00, 16., 0.0
FUNCTION RLPD4T = 0., 0.01, 0.99, 0.01, 1., 0.06, 1.99, 0.06, ...
                  2., 0.21, 2.99, 0.21, 3., 0.17, 3.99, 0.17, ...
```

```
                     4., 0.19, 4.99, 0.19, 5., 0.18, 5.99, 0.18, ...
                     6., 0.13, 6.99, 0.13, 7., 0.01,11.99, 0.01, ...
                     12.,0.0, 16., 0.0

* FORAGE AVAILABILITY

            RLWBP1 = (RLBP1 * ARL1 + RLBP2 * ARL2 + RLBP3 * ARL3 + ...
                     RLBP4 * ARL4) / ARL
            RLWBP2 = (RLBP1 * ARL1 + RLBP2 * ARL2 + RLBP3 * ARL3 + ...
                     RLBP4 * ARL4 + RLBBFP * ARLBBF) / ARLFB
            RLANBP = INTGRL(0.,RLWBP1/DELT)
            RLFAV  = RLWBP2 * NVFOR * ARLFB / (TEE - CTNU)
            RLAFAV = INTGRL(0.,RLFAV/DELT)
            NVFOR  = AFGEN(NVFORT,TIME)
FUNCTION NVFORT = 0.,0.45, 0.99,0.45, 1.,0.75, 3.99,0.75, 4.,0.55,...
                     6.99,0.55, 7.,0.45, 12.99,0.45


*-------------------------- BARLEY FIELDS --------------------------
* AREA (Section 4.3)

            ABF    = AFGEN(ABFT,REGION)
FUNCTION ABFT    = 1.,6840., 2.,9910.,3.,12710.,4.,11370.,5.,40830.

* STRAW (Section 4.3)

            BSWAP  = BSAP * (PMD-M1)/6.
            BSAP   = AFGEN(BSAPT,REGION)
            BSAV   = ABF * BSWAP * NVBS / (TEE - CTNU)
            BASAV  = INTGRL(0.,BSAV/DELT)
PARAM NVBS       = 0.45
FUNCTION BSAPT   = 1.,2640., 2.,2676., 3.,2956., 4.,2983., 5.,2831.

* GRAIN (Section 4.3)

            BGWAP = BGAP * (PMD-M1)/6.
            BGAP  = AFGEN(BGAPT,REGION)
            BGAV  = ABF * BGWAP * NVBG / (TEE - CTNU)
            BAGAV = INTGRL(0.,BGAV/DELT)
PARAM NVBG      = 1.0
```

```
FUNCTION BGAPT = 1.,480., 2.,534., 3.,654., 4.,688., 5.,597.


*------------------- SUBSIDISED CONCENTRATES ------------------------
*
* ONLY FOR SHEEP AND GOATS (Subsection 4.5.2)

         CONAV  = COSMAX * NVCON * (PMD-M1)/6.
         COSMAX = CONAA * SGEECF
         CONAAV = INTGRL(0.,CONAV/DELT)
PARAM CONAA     = 32.9
PARAM NVCON     = 1.0


*---------------------------------------------------------------------
*                          ANIMAL CHARACTERISTICS
*---------------------------------------------------------------------
*
* S = SHEEP, G = GOAT, CA = CAMEL, CT = CATTLE, D = DONKEY
*
*----------------------- FLOCK CHARACTERISTICS ----------------------
* (Section 2.2)

         TEE    = AMAX1(1.,SNU+GNU+CANU+DNU+CTNU)
         TEEMAX = SNUMAX + GNUMAX + DNUMAX + CANMAX + CTNMAX
         STRRL  = SYSFB * (TEE - CTNU) / ARL
         ARLAV  = SYSFB * ARL / (TEE - CTNU)


*------------------------- SHEEP & GOATS ----------------------------

         TNUSG  = AFGEN(TNUSGT,SYSTEM)
         FLD    = AFGEN(FLDT,REGION)
         FLFG1  = SYSSG * (1. - FLFS1)
         FLFS1  = AFGEN(FLFS1T,SYSTEM)
         FLS    = 1./SGEE * AFGEN(FLST,REGION)
         FLSSH  = 1./SGEE * AFGEN(FLSSHT,SYSTEM)
         SGEE   = 1./((0.55*FLFS1+0.43*FLFG1)+...
                    NOT(0.55*FLFS1+0.43*FLFG1))
         SGEECF = SYSSG * ((FLFS1 * SEECF) + (FLFG1 * GEECF))
```

```
          FFFLOT = AFGEN(FFLOTT,SYSTEM)
          FWFLOT = AFGEN(FWLOTT,SYSTEM)
PARAM SEECF      = 1.5
PARAM GEECF      = 1.8
FUNCTION TNUSGT =  1.,1460000., 11.,1460000, 12.,0., 49.,0., 50.,1460000.
FUNCTION FLDT   =  1.,0.12,  2.,0.24,  3.,0.30, 4.,0.34, 5.,1.0
FUNCTION FLST   =  1.,150.,  2.,280.,  3.,250., 4.,260., 5.,230.
FUNCTION FLSSHT =  1.,50.,   2.,50.,   3.,100., 8.,100., 9.,150., ...
                  11.,150., 12.,100., 50.,100.
FUNCTION FLFS1T =  1.,0.73, 50.,0.73
FUNCTION FFLOTT =  1.,0.0,   2.,0.0,   3.,0.0,  6.,0.0,  7.,0.2,  ...
                   8.,0.2,   9.,0.0,  10.,0.5, 11.,1.0, 12.,0.0, 50.,0.0
FUNCTION FWLOTT =  1.,0.0,   4.,0.0,   5.,0.5,  6.,1.0,  7.,0.5,  ...
                   8.,1.0,  11.,1.0,  12.,0.0, 50.,0.0


*-----------------------------------------------------------------------
*-------------------------- SHEEP ---------------------------------------

          SHEEP  = SFEE
          SFEE   = SYSSG * INSW(SNU-1.,FLFS2,SNU/TEE)
          SNUMAX = SYSSG * 0.55 * FLD * TNUSG * FLFS1
          SNU    = SYSFB * SNUMAX
          SCF    = SEECF * SFEE
          FLFS2  = (FLFS1/SEECF)/(FLFS1/SEECF + FLFG1/GEECF)


* PRODUCTIVITY (Subsection 3.1.4)

          SNLAMR = (SLS * SCONR) - LPWMR
          SCONR  = AFGEN(SCONRT,SYSTEM)
          SLS    = (SFLBO+ SFLBM+ (SFLBT*1.5)) * 1.1
          SREPR  = SCULR + SMR
          SCULR  = AFGEN(SCULRT,SYSTEM)
          SHPIR  = (SFFL * SFFLK * SNLAMR) - SREPR - LAWMR/2.
          SHOGG  = SHPIR * SFEE
          SFML   = 1. - SFFL
          SFFLK  = 1. - SFFLS
          SFMLF  = 1. - SFMLW
          SFFLS  = AFGEN(SFFLST,SYSTEM)
```

```
          SFMLW  = AFGEN(SFMLWT,SYSTEM)
          SFLBO  = (1.-SFLBT) * (1.-SFLBMA)
          SFLBM  = (1.-SFLBT) * SFLBMA
          SFLBMA = AFGEN(SFLBMT,SYSTEM)
          SFLBT  = 0.5 * SFTLAM
          SFTLAM = AFGEN(SFTLAT,SYSTEM)
PARAM SFFL       = 0.5
FUNCTION SCULRT =  1.,0.11,  2.,0.11,  3.,0.15,  8.,0.15, 9.,0.2, ...
                  11.,0.2,  12.,0.0,  49.,0.0,  50.,0.15
FUNCTION SCONRT =  1.,0.7,   2.,0.7,   3.,0.88,  8.,0.88, 9.,1.0, ...
                  11.,1.0,  12.,0.0,  49.,0.0,  50.,0.88
FUNCTION SFFLST =  1.,0.1,   2.,0.1,   3.,0.2,   8.,0.2,  9.,0.0, ...
                  49.,0.0,  50.,0.2
FUNCTION SFMLWT =  1.,0.8,   2.,0.8,   3.,0.6,   8.,0.6,  9.,0.0, ...
                  49.,0.0,  50.,0.6
FUNCTION SFLBMT =  1.,0.35,  2.,0.35,  3.,0.4,   8.,0.4,  9.,0.0, ...
                  49.,0.0,  50.,0.4
FUNCTION SFTLAT =  1.,0.0,   2.,0.0,   3.,0.45,  8.,0.45, 9.,1.0, ...
                  11.,1.0,  12.,0.0,  50.,0.45


* WEIGHTS (Subsection 3.1.5)

          LBIRW  = AFGEN(LBIRT,SYSTEM)
          LWEANW = AFGEN(LWEANT,SYSTEM)
          LHOGW  = AFGEN(LHOGWT,SYSTEM)
          LSALEW = AFGEN(LSALET,SYSTEM)
          SFATW  = AFGEN(SFATT,SYSTEM)
          SMLW   = AFGEN(SMLWT,SYSTEM)
          SRAMW  = AFGEN(SRAMWT,SYSTEM)
FUNCTION LBIRT  =  1.,2.3,  2.,2.3,  3.,2.6,  8.,2.6,  9.,3.2, ...
                  11.,3.2, 12.,0.0, 49.,0.0, 50.,2.6
FUNCTION LWEANT =  1.,21.,  2.,21.,  3.,22.,  8.,22.,  9.,18., ...
                  11.,18., 12.,0.0, 49.,0.0, 50.,22.
FUNCTION LHOGWT =  1.,32.,  2.,32.,  3.,35.,  8.,35.,  9.,40., ...
                  11.,40., 12.,0.0, 49.,0.0, 50.,35.
FUNCTION LSALET =  1.,40.,  2.,40.,  3.,42.,  8.,42.,  9.,48., ...
                  11.,48., 12.,0.0, 49.,0.0, 50.,42.
FUNCTION SFATT  =  1.,42.,  2.,42.,  3.,45.,  8.,45.,  9.,51., ...
                  11.,51., 12.,0.0, 49.,0.0, 50.,45.
```

```
FUNCTION SMLWT  =  1.,38.,  2.,38.,  3.,40.,  8.,40.,  9.,42., ...
                  11.,42., 12.,0.0, 49.,0.0, 50.,40.
FUNCTION SRAMWT =  1.,48.,  2.,48.,  3.,57.,  8.,57.,  9.,66., ...
                  11.,66., 12.,0.0, 49.,0.0, 50.,57.


* MORTALITY (Subsection 3.1.6)

         LPWMR  = 0.07 * SCONR * SLS * SCF1
         LAWMR  = 0.11 * SCONR * SLS * SCF1
         SMR    = 0.04 * SCF1
         SCF1   = AFGEN(SCF1T,SYSTEM)
FUNCTION SCF1T  =  1.,1.1,  2.,1.1,  3.,1.0,  8.,1.0,  9.,0.7, ...
                  11.,0.7, 12.,0.0, 49.,0.0, 50.,1.0


* MEAT PRODUCTION OF MAXIMUM INCREASING HERD (Paragraph 3.1.7.1)

         SLWP   = SLWP1 + SLWP2 + SLWP3
         SLWP1  = LSW * LWEANW * PSMP1
         LSW    = (SFFLS/2. * SFFL + SFMLW * SFML) * SNLAMR
         SLWP2  = LSF * LSALEW * PSMP2
         LSF    = (SFFLS/2. * SFFL + SFMLF * SFML) * (SNLAMR - LAWMR)
         SLWP3  = SCULR * SFATW * M7
         SLWPR  = SLWP * SCF
         MUTTON = INTGRL(0.,SLWPR/DELT)


* MILK PRODUCTION (Paragraph 3.1.7.2)

         SMP    = SMMP * SFSMIL * PSMIL
         SMPR   = SMP * SCF
         SMILK  = INTGRL(0.,SMPR/DELT)
         SMMP   = AFGEN(SMMPT,SYSTEM)
PARAM SFSMIL    = 0.15
FUNCTION SMMPT  =  1.,7.,   2.,7.,   3.,9.3,  8.,9.3, 9.,18., ...
                  11.,18., 12.,0.0, 49.,0.0, 50.,9.3


* WOOL PRODUCTION (Paragraph 3.1.7.3)
```

```
           SWOOL  = SWP * 0.67 * SCF
           SWP    = AFGEN(SWPT,SYSTEM)
  FUNCTION SWPT   =  1.,1.6,  2.,1.6,  3.,1.8,  8.,1.8,  9.,2.0, ...
                    11.,2.0, 12.,0.0, 49.,0.0, 50.,1.8


* MANURE (Paragraph 3.1.7.4)

           SMANUR = 260. * MANURF * SCF
           MANURF = AFGEN(MANURT,SYSTEM)
  FUNCTION MANURT =  1.,0.05,  2.,0.05, 3.,0.1,  4.,0.10,  5.,0.11, ...
                     6.,0.13,  7.,0.16, 8.,0.2,  9.,0.13, 10.,0.20, ...
                    11.,0.25, 12.,0.0, 49.,0.0, 50.,0.10


* FEED REQUIREMENTS (Subsection 3.1.8)

           SMRQ   = SMAPRQ + SWALRQ
           SMRQ1  = (SMRQ + SRFRQ) * SCF
           SMAPRQ = ((0.94 + 0.01) * (PGG + PED) + ...
                    (0.94-0.008) * PMD) * (SMLW**0.75)
           SWALRQ = ((0.011 * 1.0 * HRGRW * SMLW * (PGG+PED)) + ...
                    (0.011 * 1.5 * HRGRS * SMLW * PMD)) * (1.-FFFLOT)
           SSURQ  = 40. * 0.4 * (SNLAMR - 0.05) * PSSU
           SLRQ   = (LWEANW-LBIRW) * 3. * SNLAMR * 1.05/3.6 * PSLAC
           SMILRQ = 0.6 * SMP
           LFRQ1  = LSF * (LSALEW - LWEANW) * (0.75 + 0.12 * ...
                     (LSALEW + LWEANW)/2.) /4.
           LFRQ2  = LSF * (LSALEW - LWEANW) * (0.75 + 0.12 * ...
                     (LSALEW + LWEANW)/2.) /3.
           LFRQRL = LFRQ1 * PSFAT1 * (1.-FWFLOT)
           LFRQFL = LFRQ2 * PSFAT2 * FWFLOT
           LHOGRQ = (SHPIR+SREPR) * (LHOGW-LWEANW) * 5./8. * PSHG
           SFRQ   = SCULR * (SFATW - SMLW) * 5.5 * M6
           SFLRQ  = PSFL * INSW(SNLAMR-1.1,0.,20.)
           SRFRQ  = 1./SERR * ...
                    (((0.94+0.01) *(PGG+PED) * (SRAMW**0.75) + ...
                    (0.94-0.008) *  PMD     * (SRAMW**0.75)) + ...
                    ((1.-FFFLOT) * ...
```

```
                  (0.011 * 1.0 *(PGG+PED) * HRGRW * SRAMW + ...
                  0.011 * 1.5 *  PMD     * HRGRS * SRAMW)))
         STFRQ1 = SMRQ + SRFRQ + SSURQ + SLRQ + SMILRQ + ...
                  LHOGRQ + SFRQ + SFLRQ
         STFRQR = (STFRQ1 * (1.-FFFLOT) + LFRQRL) * SCF
         STFRQF = (STFRQ1 * FFFLOT      + LFRQFL) * SCF
         STFRQ  = STFRQR + STFRQF
         SAFRQ  = INTGRL(0.,STFRQ/DELT)
         SFUCF  = SAFRQ / (MUTTON+NOT(MUTTON))
PARAM SERR      = 42.
* PRODUCTION AND REQUIREMENTS PERIODS
         PGG    = (M1*SYSEX) + M2 + M3 + (M4*SYSNIN)
         PED    = (M4*SYSIN) + M5 + (M6*SYSNIN)
         PMD    = (M6*SYSIN) + M7+ M8+ M9+ M10+ M11+ M0+ (M1*SYSNEX)
         PSMP1  = (M3 * SFLBO) + (M9 * SFLBM) + (M3+M7+M11) * SFLBT/3.
         PSMP2  = (M7 * SFLBO) + (M1 * SFLBM) + (M7+M11+M3) * SFLBT/3.
         PSMIL  = (M3 + 0.6 * M4) * SFLBO + ...
                  (M8 + 0.6 * M9) * SFLBM + ...
                  (M3 + 0.6 * M4) * SFLBT/3. + ...
                  (M7 + 0.6 * M8) * SFLBT/3. + ...
                  (M11 + 0.6 * M0) * SFLBT/3.
         PSSU   = (0.25 * M10 + 0.75 * M11) * SFLBO + ...
                  (0.25 * M3 + 0.75 * M4) * SFLBM + ...
                  (0.25 * M10 + 0.75 * M11) * SFLBT/3. + ...
                  (0.25 * M2 + 0.75 * M3) * SFLBT/3. + ...
                  (0.25 * M6 + 0.75 * M7) * SFLBT/3.
         PSFL   = (0.25 * M5 + 0.75 * M6) * SFLBO + ...
                  (0.25 * M10+ 0.75 *M11) * SFLBM + ...
                  (0.25 * M9 + 0.75 *M10) * SFLBT/3. + ...
                  (0.25 * M5 + 0.75 * M6) * SFLBT/3. + ...
                  (0.25 * M1 + 0.75 * M2) * SFLBT/3.
         PSFAT1 = (M3 + M4 + M5 + M6) * SFLBO + ...
                  (M9 + M10 + M11+ M0) * SFLBM + ...
                  (M3 + M4 + M5 + M6 ) * SFLBT/3. + ...
                  (M7 + M8 + M9 + M10) * SFLBT/3. + ...
                  (M11 +M0 + M1 + M2 ) * SFLBT/3.
```

```
          PSFAT2 = (M3 + M4 + M5) * SFLBO + ...
                   (M9+ M10+ M11) * SFLBM + ...
                   (M3 + M4 + M5) * SFLBT/3. + ...
                   (M7 + M8 + M9) * SFLBT/3. + ...
                   (M11 +M0 + M1) * SFLBT/3.
          PSLAC  = (M0 + M1 + M2 + 0.6 * M3) * SFLBO + ...
                   (M5 + M6 + M7 + 0.6 * M8) * SFLBM + ...
                   (M0 + M1 + M2 + 0.6 * M3) * SFLBT/3. + ...
                   (M4 + M5 + M6 + 0.6 * M7) * SFLBT/3. + ...
                   (M8 + M9 + M10+ 0.6 *M11) * SFLBT/3.
          PSHG   = (M3+ M4+ M5+ M6+ M7+ M8+ M9+ M10) * SFLBO + ...
                   (M9+M10+M11+ M0+ M1+ M2 +M3+ M4)  * SFLBM + ...
                   (M3+ M4+ M5+ M6+ M7+ M8+ M9+ M10) * SFLBT/3. + ...
                   (M7+ M8+ M9+M10+M11+ M0+ M1+ M2)  * SFLBT/3. + ...
                   (M11+M0+ M1 +M2+ M3+ M4+ M5+ M6)  * SFLBT/3.


*-------------------------------------------------------------------
*----------------------- GOATS -------------------------------------

          GOATS  = GFEE
          GFEE   = SYSSG * INSW(GNU-1.,FLFG2,GNU/TEE)
          GNUMAX = SYSSG * 0.43 * FLD * TNUSG * FLFG1
          GNU    = SYSFB * GNUMAX
          GCF    = GEECF * GFEE
          FLFG2  = (FLFG1/GEECF)/(FLFG1/GEECF + FLFS1/SEECF)

* PRODUCTIVITY (Subsection 3.2.4)

          GNKIDR = (GLS * GCONR) - KPWMR
          GCONR  = AFGEN(GCONRT,SYSTEM)
          GLS    = (GFKBO+GFKBM+(GFKBT*1.5)) * 1.46
          GREPR  = GCULR + GMR
          GCULR  = AFGEN(GCULRT,SYSTEM)
          GHPIR  = (GFFK * GFFKK * GNKIDR) - GREPR - KAWMR/2.
          GHOGG  = GHPIR * GFEE
          GFMK   = 1. - GFFK
          GFFKK  = 1. - GFFKS
          GFMKF  = 1. - GFMKW
          GFFKS  = AFGEN(GFFKST,SYSTEM)
```

```
          GFMKW  = AFGEN(GFMKWT,SYSTEM)
          GFKBO  = (1.-GFKBT) * 1.-GFKBMA
          GFKBM  = (1.-GFKBT) * GFKBMA
          GFKBMA = SFLBMA
          GFKBT  = 0.5 * GFTKID
          GFTKID =  AFGEN(GFTKIT,SYSTEM)
PARAM GFFK  = 0.44
FUNCTION GCONRT =  1.,0.7,   2.,0.7,   3.,0.88,  8.,0.88,  9.,1.0, ...
                  11.,1.0,  12.,0.0,  49.,0.0,  50.,0.88
FUNCTION GCULRT =  1.,0.05,  2.,0.05,  3.,0.07,  8.,0.07,  9.,0.1, ...
                  11.,0.1,  12.,0.0,  49.,0.0,  50.,0.07
FUNCTION GFFKST =  1.,0.1,   2.,0.1,   3.,0.2,   8.,0.2,   9.,0.0, ...
                  11.,0.0,  12.,0.0,  49.,0.0,  50.,0.2
FUNCTION GFMKWT =  1.,0.95,  2.,0.95,  3.,0.6,   8.,0.6,   9.,0.0, ...
                  11.,0.0,  12.,0.0,  49.,0.0,  50.,0.6
FUNCTION GFTKIT =  1.,0.0,   2.,0.0,   3.,0.3,   8.,0.3,   9.,1.0, ...
                  11.,1.0,  12.,0.0,  49.,0.0,  50.,0.3


* WEIGHTS (Subsection 3.2.5)

          KBIRW  = AFGEN(KBIRT,SYSTEM)
          KWEANW = AFGEN(KWEANT,SYSTEM)
          KHOGW  = AFGEN(KHOGWT,SYSTEM)
          KSALEW = AFGEN(KSALET,SYSTEM)
          GMLW   = AFGEN(GMLWT,SYSTEM)
          GCULW  = AFGEN(GCULWT,SYSTEM)
          GBUCKW = AFGEN(GBUCKT,SYSTEM)
FUNCTION KBIRT  =  1.,2.0,  2.,2.0,  3.,2.4,  8.,2.4,  9.,3.0, ...
                  11.,3.0, 12.,0.0, 49.,0.0, 50.,2.4
FUNCTION KWEANT =  1.,14.,  2.,14.,  3.,15.,  8.,15.,  9.,14., ...
                  11.,14., 12.,0.0, 49.,0.0, 50.,15.
FUNCTION KHOGWT =  1.,21.,  2.,21.,  3.,23.,  8.,23.,  9.,28., ...
                  11.,28., 12.,0.0, 49.,0.0, 50.,23.
FUNCTION KSALET =  1.,25.,  2.,25.,  3.,28.,  8.,28.,  9.,32., ...
                  11.,32., 12.,0.0, 49.,0.0, 50.,28.
FUNCTION GMLWT  =  1.,28.,  2.,28.,  3.,30.,  8.,30.,  9.,33., ...
                  11.,33., 12.,0.0, 49.,0.0, 50.,30.
FUNCTION GCULWT =  1.,24.,  2.,24.,  3.,26.,  8.,26.,  9.,28., ...
                  11.,28., 12.,0.0, 49.,0.0, 50.,26.
```

```
FUNCTION GBUCKT =  1.,34.,  2.,34.,  3.,36.,  8.,36.,  9.,40., ...
                  11.,40., 12.,0.0, 49.,0.0, 50.,36.

* MORTALITY (Subsection 3.2.6)

         KPWMR = 0.18 * GCONR * GLS * GCF1
         KAWMR = 0.10 * GCONR * GLS * GCF1
         GMR   = 0.04 * GCF1
         GCF1  = SCF1

* MEAT PRODUCTION OF MAXIMUM INCREASING HERD (Paragraph 3.2.7.1)

         GLWP   = GLWP1 + GLWP2 + GLWP3
         GLWP1  = KSW * KWEANW * PGMP1
         KSW    = (GFFKS/2. * GFFK + GFMKW * GFMK) * GNKIDR
         GLWP2  = KSF * KSALEW * PGMP2
         KSF    = (GFFKS/2. * GFFK + GFMKF * GFMK) * (GNKIDR - KAWMR)
         GLWP3  = GCULR * GCULW * M7
         GLWPR  = GLWP * GCF
         GMEAT  = INTGRL(0.,GLWPR/DELT)

* MILK PRODUCTION (Paragraph 3.2.7.2)

         GMP    = GMMP * GFGMIL * PGMIL
         GMPR   = GMP * GCF
         GMILK  = INTGRL(0.,GMPR/DELT)
         GMMP   = AFGEN(GMMPT,SYSTEM)
PARAM GFGMIL    = 0.90
FUNCTION GMMPT  =  1.,15.,  2.,15.,  3.,21.,  8.,21.,  9.,25., ...
                  11.,25., 12.,0.0, 49.,0.0, 50.,21.

* MANURE (Paragraph 3.2.7.4)

         GMANUR = 220. * MANURF * GCF
         MANURE = SMANUR + GMANUR
```

```
* FEED REQUIREMENTS (Subsection 3.2.8)

          GMRQ   = GMAPRQ + GWALRQ
          GMRQ1  = (GMRQ + GBFRQ) * GCF
          GMAPRQ = 0.94 * (GMLW**0.75)
          GWALRQ = ((0.011 * 1.0 * HRGRW * GMLW * (PGG+PED)) + ...
                   (0.011 * 1.5 * HRGRS * GMLW * PMD)) * (1.-FFFLOT)
          GSURQ  = 40. * 0.4 * (GNKIDR - 0.05) * PGSU
          GLRQ   = (KWEANW-KBIRW) * 3. * GNKIDR * 1.05/3.4 * PGLAC
          GMILRQ = 0.6 * GMP
          KFRQ1  = KSF * (KSALEW - KWEANW) * (0.75 + 0.12 * ...
                       (KSALEW + KWEANW)/2.) /4.
          KFRQ2  = KSF * (KSALEW - KWEANW) * (0.75 + 0.12 * ...
                       (KSALEW + KWEANW)/2.) /3.
          KFRQRL = KFRQ1 * PGFAT1 * (1.-FWFLOT)
          KFRQFL = KFRQ2 * PGFAT2 * FWFLOT
          KHOGRQ = (GHPIR+GREPR) * (KHOGW-KWEANW) * 5./8. * PGHG
          GFLRQ  = PGFL * INSW(GNKIDR-1.1,0.,20.)
          GBFRQ  = 1./GDBR * (0.94 * (GBUCKW**0.75) + ...
                   (0.011 * 1.0 * HRGRW * GBUCKW * (PGG+PED) + ...
                   (0.011 * 1.5 * HRGRS * GBUCKW * PMD)) * (1.-FFFLOT))

          GTFRQ1 = GMRQ + GBFRQ + GSURQ + GMILRQ + KFRQRL + ...
                    KHOGRQ + GFLRQ
          GTFRQR = (GTFRQ1 * (1.-FFFLOT) + KFRQRL) * GCF
          GTFRQF = (GTFRQ1 * FFFLOT      + KFRQFL) * GCF
          GTFRQ  = GTFRQR + GTFRQF
          GAFRQ  = INTGRL(0.,GTFRQ/DELT)
          GFUCF  = GAFRQ / (GMEAT+NOT(GMEAT))
PARAM GDBR       = 36.


* PRODUCTION AND REQUIREMENTS PERIODS

          PGMP1  = PSMP1
          PGMP2  = PSMP2
          PGMIL  = (0.7 * M2 + M3 + 0.9 * M4) * GFKBO + ...
                   (0.7 * M7 + M8 + 0.9 * M9) * GFKBO + ...
                   (0.7 * M2 + M3 + 0.9 * M4) * GFKBT/3. + ...
```

```
                   (0.7 * M6 + M7 + 0.9 * M8) * GFKBT/3. + ...
                   (0.7 * M10+ M11+ 0.9 * M0) * GFKBT/3.
          PGSU   = PSSU
          PGLAC  = (M0 + M1 + M2 + 0.4 * M3) * GFKBO + ...
                   (M5 + M6 + M7 + 0.4 * M8) * GFKBM + ...
                   (M0 + M1 + M2 + 0.4 * M3) * GFKBT/3. + ...
                   (M4 + M5 + M6 + 0.4 * M7) * GFKBT/3. + ...
                   (M8 + M9 + M10+ 0.4 *M11) * GFKBT/3.
          PGFAT1 = PSFAT1
          PGFAT2 = PSFAT2
          PGHG   = PSHG
          PGFL   = PSFL


*----------------------------------------------------------------------
*---------------------------- DONKEYS ---------------------------------
* ONLY SYSTEMS 20 + 50
* (Section 3.3)

          DONKEY = DFEE
          DFEE   = SYSD * INSW(DNU-1.,1.,DNU/TEE)
          DNUMAX = SYSD * DNFN * FANU / DEECF
          DNU    = SYSFB * DNUMAX
          DCF    = DEECF * DFEE
          FANU   = AFGEN(FANUT,REGION)
PARAM DNFN       = 1.0
PARAM DEECF      = 0.45
FUNCTION FANUT   = 1.,5682., 2.,2246., 3.,9558., 4.,3257., 5.,20743.

* FEED REQUIREMENTS
* WORKING REQUIREMENTS ARE MET BY BARLEY GRAIN (ALREADY SUBSTRACTED)

          DTFRQ  = 1.2 * DMRQ * DCF
          DMRQ1  = DMRQ * DCF
PARAM DMRQ       = 45.63

* TRACTION

          DTR    = 12. * 4. * 25. * 3.33 * DCF

```

```
* TOTAL TRACTION OF DONKEYS AND CAMELS

          HRATOT = DTR + CATR


*---------------------------------------------------------------------------
*-------------------------- CAMELS ----------------------------------
* (Section 3.4)
* ONLY SYSTEMS 30 + 50

          CAMELS = CAFEE
          CAFEE  = SYSCA * INSW(CANU-1.,1.,CANU/TEE)
          CANMAX = SYSCA * FLD * TNCA / CAEECF
          CANU   = SYSFB * CANMAX
          CACF   = CAEECF * CAFEE
PARAM CAEECF     = 0.15
PARAM TNCA       = 200.

* MILK PRODUCTION

          CAMP   = CAFMIL * CAMMP
          CAMPR  = CAMP * CACF
          CAMILK = INTGRL(0.,CAMPR/DELT)
PARAM CAMMP      = 150.
PARAM CAFMIL     = 0.2

* FEED REQUIREMENTS

          CAMIRQ = 0.40 * CAMP
          CAWRQ  = 0.66 * 0.8 * (40 + 80 * M1)
          CAMRQ1 = CAMRQ * CACF
          CATFRQ = (CAMRQ*1.6 + CAMIRQ + CAWRQ) * CACF
PARAM CAMRQ      = 109.5

* TRACTION

          CATR   = 12. * 0.8 * 46.7 * 3.33 * CACF


*---------------------------------------------------------------------------
```

```
*--------------------------- CATTLE ----------------------------------
* (Section 3.5)
* ONLY SYSTEMS 40 + 50

         CATTLE = CTFEE
         CTFEE  = SYSCT * INSW(CTNU-1.,1.,CTNU/TEE)
         CTNMAX = SYSCT/CTEECF * AFGEN(CTNUT,REGION)
         CTNU   = SYSFB * CTNMAX
         CTCF   = CTEECF * CTFEE
PARAM CTEECF    = 0.30
FUNCTION CTNUT  = 1.,300., 2.,0., 3.,35., 4.,0., 5.,335.,

* MILK PRODUCTION

         CTMP   = CTFMIL * CTMMP
         CTMPR  = CTMP   * CTCF
         CTMILK = INTGRL(0.,CTMPR/DELT)
PARAM CTMMP     = 46.
PARAM CTFMIL    = 0.9

* FEED REQUIREMENTS

         CTMIRQ = 0.38 * CTMP
         CTMRQI = CTMRQ * CTCF
         CTTFRQ = (CTMRQ*1.3 + CTMIRQ) * CTCF
PARAM CTMRQ     = 89.



*--------------------------------------------------------------------
*                          REQUIREMENTS
*--------------------------------------------------------------------
*
*------------------- TOTAL FEED REQUIREMENTS -------------------------

* TOTAL REQUIREMENTS

         FUTRQ  = STFRQ + GTFRQ + DTFRQ + CATFRQ
         FUARQ  = INTGRL(0.,FUTRQ/DELT)

```

```
* TOTAL MAINTENANCE REQUIREMENTS
          FUTMRQ = SMRQ1 + GMRQ1 + DMRQ1 + CAMRQ1
* TOTAL FEED REQUIREMENTS TO BE MET BY RANGELAND
          FUTRQR = STFRQR + GTFRQR + DTFRQ + CATFRQ
* RANGE UTILIZATION POTENTIAL
          RUPGG  = FUTRQR * PGG / NVFOR
          RUPED  = FUTRQR * PED / NVFOR
          RUPMD  = PMD/NVFOR * (((0.8 * DTFRQ) + CATFRQ) + ...
                   SYSSG * AMIN1(FUTRQR,INTMAX * 30.42 * SGEECF))
          INTMAX = AFGEN(INTMAT,SYSTEM)
          RUPAGG = INTGRL(0.,RUPGG/DELT)
          RUPAED = INTGRL(0.,RUPED/DELT)
          RUPAMD = INTGRL(0.,RUPMD/DELT)
          RANARQ = (RUPAGG + RUPAED + RUPAMD) / (RLANBP+NOT(RLANBP))
FUNCTION INTMAT = 1.,0.9,  2.,0.6,  3.,0.9,  4.,0.3,  8.,0.3, ...
                  9.,0.2, 10.,0.2, 11.,0.0, 49.,0.0, 50.,0.3
* TOTAL FEED REQUIREMENTS TO BE MET BY SHED OR FEEDLOT FEEDING
          FUTRQF = STFRQF + GTFRQF + FRQSUP + CTTFRQ
          FRQSUP = FRQS * INSW(FRQS-1.,0.,1.)
          FRQS   = (FUTRQR * PMD) - (RUPMD * NVFOR)
* SUPPLEMENT REQUIREMENTS
          CONRQ  = IFCON * FUTRQF / NVCON
          BSRQ1  = IFBS  * FUTRQF / NVBS
          VEGRQ1 = IFVE  * FUTRQF / NVVE
          BERRQ1 = IFBE  * FUTRQF / NVBE
          CONARQ = INTGRL(0.,CONRQ/DELT)
          STRAW  = INTGRL(0.,BSRQ1/DELT)
          VEGARQ = INTGRL(0.,VEGRQ1/DELT)
```

```
         BERARQ = INTGRL(0.,BERRQ1/DELT)

         IFCON  = AFGEN(IFCONT,SYSTEM)
         IFBS   = AFGEN(IFBST,SYSTEM)
         IFVE   = AFGEN(IFVET,SYSTEM)
         IFBE   = AFGEN(IFBET,SYSTEM)
PARAM NVVE      = 0.4
PARAM NVBE      = 0.7
FUNCTION IFCONT =  1.,0.80,  2.,0.3,   3.,0.9,  4.,0.75,  5.,0.75, ...
                   8.,0.75,  9.,0.8,  19.,0.8,                     ...
                  20.,0.4,  29.,0.4,  30.,0.0, 49.,0.0,  50.,0.71
FUNCTION IFBST  =  1.,0.00,  2.,0.3,   3.,0.0,  4.,0.22,  5.,0.18, ...
                   8.,0.18,  9.,0.2,  19.,0.2,                     ...
                  20.,0.3,  29.,0.3,  30.,0.0, 49.,0.0,  50.,0.22
FUNCTION IFVET  =  1.,0.15,  2.,0.3,   3.,0.05, 4.,0.04,  5.,0.04, ...
                   8.,0.04,  9.,0.0,  19.,0.0,                     ...
                  20.,0.2,  29.,0.2,  30.,0.0, 39.,0.0,            ...
                  40.,0.3,  49.,0.3,  50.,0.02
FUNCTION IFBET  =  1.,0.05,  2.,0.1,   3.,0.05, 4.,0.03,  5.,0.03, ...
                   8.,0.03,  9.,0.0,  19.,0.0,                     ...
                  20.,0.1,  29.,0.1,  30.,0.0, 39.,0.0,            ...
                  40.,0.7,  49.,0.7,  50.,0.05


*------------------------------------------------------------------------
*                          FEED BALANCE
*------------------------------------------------------------------------
* A NEGATIVE FEED BALANCE MEANS A FORAGE SHORTAGE

         FUAV   = RLFAV + BSAV + BGAV + CONAV
         FUAAV  = INTGRL(0.,FUAV/DELT)

         FEBAL  = (FUAV - FUTRQ)
         FEBALR = (FEBAL * INSW(FEBAL,1.,0.)) + ...
                  ((FEBAL/NVFOR * 0.45 * (PGG+PED)) + ...
                   (FEBAL * PMD)) * INSW(FEBAL,0.,1.)
         FEBALA = INTGRL(0.,FEBALR/DELT)
         FEBAAB = ABS(FEBAL) * INSW(FEBAL,1.,0.)
         FFRQRL = 100. * RLFAV / (FUTRQ+NOT(FUTRQ))

```

```
            CONRQ2 = IFCON * FEBAAB / NVCON
            BSRQ2  = IFBS  * FEBAAB / NVBS
            VEGRQ2 = IFVE  * FEBAAB / NVVE
            BERRQ2 = (IFBE * FEBAAB + BERCT) / NVBE
            BERCT  = CTTFRQ
            CONAR2 = INTGRL(0.,CONRQ2/DELT)
            STRAW2 = INTGRL(0.,BSRQ2/DELT)
            VEGAR2 = INTGRL(0.,VEGRQ2/DELT)
            BERAR2 = INTGRL(0.,BERRQ2/DELT)
*---------------------------------------------------------------------
*                          OTHER REQUIREMENTS
*---------------------------------------------------------------------
*
*----------------------- WATER ---------------------------------------
*(Section 5.1)
            WATRQ  = 0.006 * (FUTRQ * PMD + (PGG+PED) * FUTRQF)
            WATARQ = INTGRL(0.,WATRQ/DELT)
            WATCI  = WATRQ * WATFCR * WATFCS
            WATACI = INTGRL(0.,WATCI/DELT)
            WATFCR = AFGEN(WFCRT,REGION)
            WATFCS = AFGEN(WFCST,SYSTEM)
            WATPL  = WATRQ  - WATCI
            WPTNUR = RANARQ / 500.
            WPLNUR = WPTNUR - WCINUR * INSW(WPTNUR-WCINUR,0.,1.)
            WCINUR = WATACI / 300.
            WTRNUR = SGEE / 200. + (DCF + CACF + CTCF)/10.
 FUNCTION WFCRT  =  1.,0.5,  2.,0.6,  3.,0.8,  4.,1.0,  5.,0.8
 FUNCTION WFCST  =  1.,1.0,  2.,1.0,  3.,0.8,  8.,0.8,  9.,0.6, ...
                   11.,0.6, 12.,0.9, 49.,0.9, 50.,0.8
*----------------------- LABOUR -------------------------------------
*(Section 5.3)
            MDREST = INTGRL(0.,MANDB/DELT)
            MDOUT  = INTGRL(0.,MANDH/DELT)
            MDSEPT = (LABR1S + LABR2 + LABR41 + LABR42 + LABR5) * M11
```

```
          MDNOW  = (LABR1S*SYSNEX + LABR1W*SYSEX  + LABR2 + ...
                   LABR41*SYSNEX  + LABR42 + LABR5) * M1
          MDAPR  = (LABR1S*SYSIN  + LABR1W*SYSNIN + LABR2 + ...
                   LABR41*SYSIN   + LABR42 + LABR5) * M6
          MANDH  = (HRSS * (1.-FLFSB) * 2. * SGEECF * (M5+M6)/2. + ...
                   CAFEE * 0.7 * 2. * 0.5 * M7)/7.
          MANDB  = LABRQ1 + LABRQ2 + LABRQ3 + LABRQ4 + LABRQ5

          LABRQ1 = LABR1S * (PMD - M11 - (M6*SYSIN) - (M1*SYSNEX)) + ...
                   LABR1W * (PGG + PED - (M1*SYSEX) - (M6*SYSNIN))
          LABRQ2 = LABR2  * (PMD + PGG + PED - M1 - M6 - M11)
          LABRQ3 = LABR3  * M5
          LABRQ4 = LABR41 * (PMD - M11 - (M6*SYSIN) - (M1*SYSNEX)) + ...
                   LABR42 * (PMD - M11 - M6 - M1)
          LABRQ5 = LABR5  * (PGG+PED+PMD-M11-M1-M6)

          LABR1S = HRGRS * FLFSH * (1.-FFFLOT) * 4.35 / FLSSH
          LABR1W = HRGRW * FLFSH * (1.-FFFLOT) * 4.35 / FLSSH
          LABR2  = HRVC/7. * 1./FLS + 0.5 * (DCF + CACF + CTCF)
          LABR3  = HRSB/7. * 2. * FLFSB * 0.5 * SGEECF
          LABR41 = 4.35/FLS * (1.-FFFLOT) * SYSSG + ...
                   0.5 * 4.35 * (DCF + CACF + CTCF)/10.
          LABR42 = (FFFLOT * HRFW1/FLS) + (FWFLOT * HRFW2/50.) * 4.35
          LABR5  = HRMT/7. * (SYSSG/FLS + (DCF+CTCF)/10.)
          HRGRS  = AFGEN(HRGRST,SYSTEM)
          HRGRW  = AFGEN(HRGRWT,SYSTEM)
          HRFW1  = AFGEN(HRFW1T,FFFLOT)
          HRFW2  = AFGEN(HRFW2T,FWFLOT)
          HRVC   = AFGEN(HRVCT,SYSTEM)
          HRMT   = AFGEN(HRMTT,SYSTEM)
          FLFSH  = AFGEN(FLFSHT,SYSTEM)
          FLFSB  = AFGEN(FLFSBT,SYSTEM)
PARAM HRSB       = 0.5
PARAM HRSS       = 0.3
FUNCTION HRGRST =  1.,9.,   2.,9.,   3.,8.,   8.,8.,   9.,3.,   ...
                  11.,3.,  12.,0.,  49.,0.,  50.,8.
FUNCTION HRGRWT =  1.,8.,   2.,8.,   3.,7.,   8.,7.,   9.,3.,   ...
                  11.,3.,  12.,0.,  49.,0.,  50.,7.
FUNCTION HRVCT  =  1.,2.0,  2.,2.0,  3.,2.7,  8.,2.7,  9.,5.4,  ...
                  11.,5.4, 12.,0.0, 49.,0.0, 50.,2.7
```

```
FUNCTION HRFW1T =  0.,0.0, 0.5,0.9,  1.,1.5
FUNCTION HRFW2T =  0.,0.0, 0.5,0.3,  1.,0.5
FUNCTION HRMTT  =  1.,2.0,  2.,2.0,  3.,4.0,  8.,4.0,  9.,6.0,  ...
                  11.,6.0, 12.,0.0, 19.,0.0, 20.,4.0, 50.,4.0
FUNCTION FLFSHT =  1.,1.0,  2.,1.0,  3.,0.9,  8.,0.9,  9.,0.8,  ...
                  11.,0.8, 12.,0.0, 49.,0.0, 50.,0.9
FUNCTION FLFSBT =  1.,0.8,  2.,0.8,  3.,0.4,  8.,0.4,  9.,0.2,  ...
                  11.,0.2, 12.,0.0, 49.,0.0, 50.,0.4


*---------------------------- BUILDINGS -----------------------------
* (SECTION 5.4)
* SHEDS

         BUSRQ  = FLFSHD * BUSR * SGEECF + 2.0 * (DCF+CTCF)
         FLFSHD = AFGEN(FLFSDT,SYSTEM)
         BUSR   = AFGEN(BUSRT,SGAVLR)
         SGAVLR = FLFS1 * SNLAMR + FLFG1 * GNKIDR
FUNCTION FLFSDT =  1.,0.3,  2.,0.3,  3.,0.7,  8.,0.7,  9.,1.0,  ...
                  11.,1.0, 12.,0.0, 49.,0.0, 50.,0.7
FUNCTION BUSRT  =  0.,0.0, 0.5,0.0, 0.75,0.1, 0.9,0.7, 1.5,1.0, ...
                  1.8,2.0, 2.4,2.5

* DIPS

         BUDIRQ = SGEECF / 5000. * SYSIN

* CORRALS

         BUCOA  = ((BUCORQ * SGEECF * FFFLOT) + ...
                  (0.7 * BUCORQ * SGAVLR)) * FLS * (1.+ 1.*SYSIN)
         BUBWRQ = 4. / FLS * 4. * SQRT(BUCOA)
         BUPORQ = 1./4. * BUBWRQ/2.
PARAM BUCORQ    = 0.75


*--------------------------- CAPITAL ---------------------------------
* RUNNING COSTS (Section 5.5)

         RUNCRQ = RUNC1 + RUNC2 + RUNC3 + RUNC4 + RUNC5 + RUNC6 + RUNC7
```

```
          ANCOST = RUNAC1 + INTGRL(0.,RUNCRQ/DELT)
          RUNAC1 = WCINUR * 60.
          RUNC1  = WATPL * WPLCP
          WPLCP  = AFGEN(WPLCPT,REGION)
          RUNC2  = (SGEECF + DCF + CACF + CTCF) * MEDCP/12.
          MEDCP  = AFGEN(MEDCPT,SYSTEM)
          RUNC3  = SGEECF  * 0.7/12. * SYSIN
          RUNC4  = SGEECF/2. * 1.0/12. * SYSIN
          RUNC5  = BUDIRQ  * 70./12.
          RUNC6  = BUSRQ * 0.01
          RUNC7  = 1./12. * AFGEN(MISCT,SYSTEM)
FUNCTION WPLCPT =  1.,0.0,  2.,0.05, 3.,0.05, 4.,0.05, 5.,0.05
FUNCTION MEDCPT =  1.,3.0,  2.,3.0,  3.,5.8,  8.,5.8,  9.,8.0,  ...
                  11.,8.0, 12.,1.0, 49.,1.0, 50.,5.8
FUNCTION MISCT  =  1.,0.1,  2.,0.1,  3.,0.2,  8.,0.2,  9.,0.4,  ...
                  11.,0.4, 12.,0.2, 50.,0.2


* INVESTMENTS (Section 5.5)

          INVRQ  = INV1 + INV2 + INV3 + INV4 + INV5
          INVSAH = INVAR1 + INVAR2 + INTGRL(0.,INVRQ/DELT)
          INVAR1 = WCINUR * 1200./15.
          INVAR2 = 5. * WPLNUR * 1350./10.
          INV1   = WTRNUR *   40./( 5.*12.)
          INV2   = BUDIRQ * 1000./(15.*12.)
          INV3   = BUSRQ  *   27./(15.*12.)
          INV4   = (BUBWRQ * 2. + BUPORQ * 3.)/(10.*12.)
          INV5   = SYSSG * 2. * 74./(5.*12.*FLS)


*------------------- OUTPUT AND RUN CONTROL --------------------------

* M ARE PUSH FUNCTIONS. MO=OCTOBER, M1=NOVEMBER, ETC.
* SYS ARE PUSH FUNCTIONS. SY1=SYSTEM 1, ETC.
          M0     = FCNSW(TIME-0.,0.,1.,0.)
          M1     = FCNSW(TIME-1.,0.,1.,0.)
          M2     = FCNSW(TIME-2.,0.,1.,0.)
          M3     = FCNSW(TIME-3.,0.,1.,0.)
          M4     = FCNSW(TIME-4.,0.,1.,0.)
```

```
          M5     = FCNSW(TIME-5.,0.,1.,0.)
          M6     = FCNSW(TIME-6.,0.,1.,0.)
          M7     = FCNSW(TIME-7.,0.,1.,0.)
          M8     = FCNSW(TIME-8.,0.,1.,0.)
          M9     = FCNSW(TIME-9.,0.,1.,0.)
          M10    = FCNSW(TIME-10.,0.,1.,0.)
          M11    = FCNSW(TIME-11.,0.,1.,0.)
          SYSEX  = AFGEN(SYSEXT,SYSTEM)
          SYSP   = AFGEN(SYSPT,SYSTEM)
          SYSIN  = AFGEN(SYSINT,SYSTEM)
          SYSFB  = FCNSW(SYSTEM-50.,0.,1.,0.)
          SYSNEX = SYSP + SYSIN + SYSFB
          SYSNIN = SYSEX + SYSP + SYSFB
          SYSSG  = SYSEX + SYSP + SYSIN + SYSFB
          SYSD   = AFGEN(SYSDT,SYSTEM)
          SYSCA  = AFGEN(SYSCAT,SYSTEM)
          SYSCT  = AFGEN(SYSCTT,SYSTEM)
FUNCTION SYSEXT =  1.,1.,  2.,1.,  3.,0., 50.,0.,
FUNCTION SYSPT  =  1.,0.,  2.,0.,  3.,1.,  8.,1.,  9.,0., 50.,0.
FUNCTION SYSINT =  1.,0.,  8.,0.,  9.,1., 11.,1., 12.,0., 50.,0.
FUNCTION SYSDT  =  1.,0., 19.,0., 20.,1., 29.,1., 30.,0., ...
                  49.,0., 50.,1.,
FUNCTION SYSCAT =  1.,0., 29.,0., 30.,1., 39.,1., 40.,0., ...
                  49.,0., 50.,1.,
FUNCTION SYSCTT =  1.,0., 39.,0., 40.,1., 50.,1.

PRINT REGION,SYSTEM,ARL,TEEMAX,SNUMAX,GNUMAX,          ...
      SHEEP,GOATS,DONKEY,CAMELS,CATTLE,                ...
      RANARQ,STRAW,CONARQ,BERARQ,VEGARQ,               ...
      ANCOST,INVSAH,MDOUT,MDSEPT,MDNOV,MDAPR,MDREST,   ...
      SHOGG,GHOGG,MUTTON,GMEAT,SWOOL,MANURE,HRATOT,    ...
      SFUCF,GFUCF,COSMAX,WCINUR
METHOD RECT
TIMER FINTIM = 12.,DELT=1.,PRDEL=1.,OUTDEL=1.
* TIMER VARIABLE ARE IN MONTHS, 0=OCTOBER 1= NOVEMBER
END RERUN
PARAM SYSTEM = 2.
END RERUN
PARAM SYSTEM = 3.
```

```
END RERUN
PARAM SYSTEM = 4.
END RERUN
PARAM SYSTEM = 5.
END RERUN
PARAM SYSTEM = 6.
END RERUN
PARAM SYSTEM = 7.
END RERUN
PARAM SYSTEM = 8.
END RERUN
PARAM SYSTEM = 9.
END RERUN
PARAM SYSTEM = 10.
END RERUN
PARAM SYSTEM = 11.
END RERUN
PARAM SYSTEM = 20.
END RERUN
PARAM SYSTEM = 30.
END RERUN
PARAM SYSTEM = 40.
END RERUN
PARAM SYSTEM = 50.
PRINT REGION,SYSTEM,ARLFB,FEBAL,FEBALA,STRRL,ARLAV,   ...
      CONAR2, STRAW2,BERAR2,VEGAR2,                  ...
      FUTRQ, FUTMRQ,RLFAV,BSAV,BGAV,CONAV,FUAV,       ...
      RLAFAV,BAGAV,BASAV,CONAAV,FUAAV,FFRQRL,         ...
      SNU,GNU,DNU,CANU,CTNU,TEE
END RERUN
PRINT REGION,SYSTEM,SMRQ,SRFRQ,SSURQ,SLRQ,SMILRQ,     ...
      LFRQRL,LHOGRQ,SFRQ,SFLRQ,STFRQ1,SNLAMR,SHPIR,   ...
      GMRQ,GBFRQ,GSURQ,GLRQ,GMILRQ,KFRQRL,KHOGRQ,     ...
      GFLRQ,GTFRQ1,GNKIDR,GHPIR,BUSRQ,WCINUR
END
STOP
ENDJOB
```

II. LIST OF ACRONYMS USED

All acronyms used in ARID ANIMAL are listed in Table 36.

Table 36. Listing of acronyms used in ARID ANIMAL. Number in brackets indicate line in the model.

ACRONYMS	EXPLANATION	UNITS
ABF	= Area of barley fields where barley is grown receiving 250 mm infiltration (129,136,145)	ha
ABFT	= Function table ABFT, independent variable REGION (129,130)	-
ANCOST	= Annual running costs (868, 938)	LE EE^{-1} yr^{-1}
ARL	= Total area of rangeland without area between barley fields (47,115,173,174,935)	ha
ARL1	= Area of rangeland, P > 150 mm (47,48,49,114,116)	ha
ARL2	= Area of rangeland, 125 < P < 150 mm (47,48,50,114,116)	ha
ARL3	= Area of rangeland, 100 < P < 125 mm (47,48,51,114,116)	ha
ARL4	= Area of rangeland, 75 < P < 100 mm (47,48,52,115,117)	ha
ARL1-5T	= Function tables ARL, independent variable REGION	-
ARLAV	= Area of rangeland available for (174,972)	ha EE^{-1}
ARLBBF	= Area of rangeland between barley fields, P = 125 mm (48,53,117)	ha
ARLFB	= Area of rangeland available if feed balance is calculated this exceeds ARL due to ARLBBF (48,117,119,972)	ha
BAGAV	= Annual barley grain availability (146,975)	FU EE^{-1} yr^{-1}
BASAV	= Annual barley straw availability (137,975)	FU EE^{-1} yr^{-1}

BERARQ = Annual berseem requirements if systems are calculated (708,937) — kg DM EE^{-1} yr^{-1}

BERAR2 = Annual berseem requirements if feed balance is calculated (756,973) — kg DM EE^{-1} yr^{-1}

BERCT = Berseem requirements as cattle feed (751,752) — FU EE^{-1} mth^{-1}

BERRQ1 = Berseem requirements if systems are calculated (704,708) — kg DM EE^{-1} mth^{-1}

BERRQ2 = Berseem requirements if feed balance is calculated (751,756) — kg DM EE^{-1} mth^{-1}

BGAP = Annual barley grain production (143,144) — kg DM ha^{-1} yr^{-1}

BGAPT = Function table BGAP, independent variable REGION (144,148) — -

BGAV = Barley grain availability (145,146,737,974) — FU EE^{-1} mth^{-1}

BGWAP = Barley grain production weighted average for summer months (143,145) — kg DM ha^{-1} mth^{-1}

BSAP = Annual barley straw production (134,135) — kg DM ha^{-1}

BSAPT = Function table BSAP, independent variable REGION (135,139) — -

BSAV = Barley straw availability (136,137,737,974) — FU EE^{-1} mth^{-1}

BSRQ1 = Barley straw requirements if systems are calculated (702,706) — kg DM EE^{-1} mth^{-1}

BSRQ2 = Barley straw requirements if feed balance is calculated (749,754) — kg DM EE^{-1} mth^{-1}

BSWAP = Barley straw production, weighted average in the summer months (134,136) — kg DM ha^{-1} mth^{-1}

BUBWRQ = Barbed wire requirements (859,860,895) — m EE^{-1}

BUCOA	= Total (Buildings) corral requirements (857,859)	m^2
BUCORQ	= Total area of corral required (857,858,861)	m^2 $head^{-1}$
BUDIRQ	= Number of dips required in intensive systems (853,876,893)	EE^{-1}
BUPORQ	= Number of poles required for fencing (860,895)	EE^{-1}
BUSR	= (Buildings) Shed requirements (842,844)	m^2 $head^{-1}$
BUSRQ	= (Buildings) Shed requirements (842,877,894,981)	m^2 EE^{-1}
BUSRT	= Function table BUSR, AVPR, independent variable (844,848)	SYSTEM
CACF	= Camel conversion factor taking into account contribution of camels to the total population (602,609,618,619,624,776,806,809,872)	head EE^{-1}
CAEECF	= Camel-ewe equivalent conversion factor (600,602,603)	head EE^{-1}
CAFEE	= Fraction of camels of the total animal population in that system (598,599,602,793)	EE EE^{-1}
CAFMIL	= Fraction of camels being milked (608,612)	-
CAMELS	= Number of camels (598,936)	EE
CAMILK	= Annual milk production of camels (610)	kg EE^{-1} yr^{-1}
CAMIRQ	= Camel milking requirements (616,619)	FU $head^{-1}$ mth^{-1}
CAMMP	= Monthly milk production of camels (608,611)	kg $head^{-1}$ mth^{-1}
CAMP	= Milk production of camels (608,609,616)	kg $head^{-1}$ mth^{-1}
CAMPR	= Milk production of camels (609,610)	kg EE^{-1} mth^{-1}
CAMRQ	= Maintenance requirements of camels (618,619,620)	FU $head^{-1}$ mth^{-1}

CAMRQ1 = Maintenance requirements of camels $FU\ EE^{-1}\ mth^{-1}$
(618,670)

CANMAX = Total number of camels occuring at present, set as right hand side for the first year in the linear programming module EE
(172,600,601)

CANU = Number of camels in the region EE
(171,599,601,976)

CATFRQ = Total feed requirements of camels $FU\ EE^{-1}\ mth^{-1}$
(619,665,675,681)

CATR = Camel traction $h\ EE^{-1}\ yr^{-1}$
(590,624)

CATTLE = Number of cattle EE
(31,166,628,632,936)

CAWRQ = Camel draught requirements $FU\ head^{-1}\ mth^{-1}$
(617,619)

CONAA = Subsidised concentrate availability $kg\ head^{-1}\ yr^{-1}$
(156,158)

CONAAV = Available subsidised concentrates in the region $kg\ EE^{-1}\ yr^{-1}$
(157,975)

CONARQ = Annual concentrates (either manufactured concentrates or grains) required if systems are calculated $kg\ DM\ EE^{-1}\ yr^{-1}$
(705,937)

CONAR2 = Annual concentrates (either manufactured concentrates or grains required if feed balance is calculated $kg\ DM\ EE^{-1}\ yr^{-1}$
(753)

CONAV = Concentrate availability $FU\ EE^{-1}\ mth^{-1}$
(155,157,737,974)

CONRQ = Monthly concentrate requirements if systems are calculated $kg\ DM\ EE^{-1}\ mth^{-1}$
(701,705)

CONRQ2 = Monthly concentrate requirements if feed balance is calculated $kg\ DM\ EE^{-1}\ mth^{-1}$
(748,753)

COSMAX = Available subsidised concentrates in the region $kg\ EE^{-1}\ yr^{-1}$
(155,156,940)

CTCF = Cattle conversion factor taking into account contribution of cattle to the total population $head\ EE^{-1}$
(636,643,651,652,776,806,809,811,842,872)

CTEECF = Cattle-ewe equivalent conversion factor $head\ EE^{-1}$
(634,636,637)

CTFEE = Fraction of cattle of the total animal population in that system $EE\ EE^{-1}$
(632,633,636)

CTFMIL = Fraction of cattle being milked -
(642,646)

CTMILK = Annual milk production of cattle $kg\ EE^{-1}\ yr^{-1}$
(644)

CTMIRQ = Milking requirements of cattle $FU\ head^{-1}\ mth^{-1}$
(650,652)

CTMMP = Potential milk production of cattle $kg\ head^{-1}\ mth^{-1}$
(642,645)

CTMP = Milk production of cattle $kg\ head^{-1}\ mth^{-1}$
(642,643,650)

CTMPR = Milk production of cattle $kg\ EE^{-1}\ mth^{-1}$
(643,644)

CTMRQ = Maintenance requirements of cattle $FU\ head^{-1}\ mth^{-1}$
(651,652,653)

CTMRQ1 = Maintenance requirements of cattle $FU\ EE^{-1}\ mth^{-1}$
(651)

CTNMAX = Total number of cattle occuring at present, set as right hand side for the first year in the linear programming module EE
(172,634,635)

CTNU = Number of cattle in the region EE
(119,136,145,171,173,633,635,976)

CTNUT = Function table CTNU, independent variable REGION -
(634,638)

CTTFRQ = Total feed requirements of cattle $FU\ EE^{-1}\ mth^{-1}$
(652,694,752)

DCF = Donkey conversion factor taking into account contribution of donkeys to the total population $head\ EE^{-1}$
(571,580,581,776,806,809,811,842,872)

DEECF = Donkey-ewe equivalent conversion factor $head\ EE^{-1}$
(569,571,574)

DFEE	= Fraction of donkeys of the total animal population in that system (567,568,571)	$EE\ EE^{-1}$
DMRQ	= Maintenance requirements of donkeys (580,581,582)	$FU\ head^{-1}\ mth^{-1}$
DMRQ1	= Maintenance requirements of donkeys (581,670)	$FU\ EE^{-1}\ mth^{-1}$
DNFN	= Number of donkeys per family (569.573)	head
DNU	= Number of donkeysin the region (171,568,570,976)	EE
DNUMAX	= Total number of goats occuring at present, set as right hand side for the first year in the linear programming module (172,569,570)	EE
DONKEY	= Number of donkeys (166,567,936)	EE
DTFRQ	= Total feed requirements of donkeys (580,665,675,681)	$FU\ EE^{-1}\ mth^{-1}$
DTR	= Donkey traction production (586,590)	$h\ EE^{-1}\ yr^{-1}$
FANU	= Number of families (569)	-
FANUT	= Function table FANU, independent variable REGION (572,575)	-
FEBAAB	= Absolute value of negative feed balance (745,748,749,750,751)	$FU\ EE^{-1}\ mth^{-1}$
FEBAL	= Feed balance (740,741,742,743,745,972)	$FU\ EE^{-1}\ mth^{-1}$
FEBALA	= Annual feed balance (744,972)	$FU\ EE^{-1}\ yr^{-1}$
FEBALR	= Feed balance increase or decrease (741,744)	$FU\ EE^{-1}$
FFFLOT	= Fraction of flock fed in feedlot (188,331,347,353,515,533,534,804,805,808,810,814,857)	-
FFLOTT	= Function table FFFLOT, independent variable SYSTEM (188,198)	-
FFRQRL	= Percentage of feed requirements met by rangeland forage (746,975)	%

FLD	= Factor accounting for the distribution of sheep and goats among the regions (180,209,410,600)	-
FLDT	= Function table FLD, independent variable REGION (180,193)	-
FLFG1	= Fraction of goats in the flock (181,185,186,187,212,410,413,845)	head $head^{-1}$
FLFG2	= Fraction of goats in the flock (409,413)	EE EE^{-1}
FLFS1	= Fraction of sheep in the flock (181,182,185,186,187,209,212,413,845)	head $head^{-1}$
FLFS1T	= Function table FLFS1, independent variable SYSTEM (182,197)	-
FLFS2	= Fraction of sheep in the flock (208,212)	EE EE^{-1}
FLFSB	= Fraction of flocks sheared by Bedouin (792,807,819)	-
FLFSBT	= Function table FLFSB, independent variable SYSTEM (819,834)	-
FLFSDT	= Function table FLFSHD, independent variable SYSTEM (843,846)	-
FLFSH	= Fraction of flocks being shepherded (804,805,818)	-
FLFSHD	= Fraction of flocks kept in sheds (842,843)	-
FLFSHT	= Function table FLFSHT, independent variable SYSTEM (818,832)	-
FLS	= Average flock size (183,806,808,810,858,859,896)	EE
FLSSH	= Average size of the flock being shepherded (184,804,805)	EE shepherd-1
FLSSHT	= Function table FLSSH, independent variable SYSTEM (184,195)	head shepherd-1
FLST	= Function table FLS, independent variable REGION (183,194)	head
FRQS	= Supplement requirements (695,696)	FU EE^{-1} mth^{-1}
FRQSUP	= Supplement requirements (694,695)	FU EE^{-1} mth^{-1}

FUAAV = Annual feed availability $FU\ EE^{-1}\ yr^{-1}$
(738,975)

FUARQ = Annual feed requirements $FU\ EE^{-1}\ yr^{-1}$
(666)

FUAV = Feed availability $FU\ EE^{-1}\ mth^{-1}$
(737,738,740,974)

FUTMRQ = Total maintenance requirements in the region $FU\ EE^{-1}\ mth^{-1}$
(670,974)

FUTRQ = Total feed requirements in the region $FU\ EE^{-1}\ mth^{-1}$
(665,666,740,746,766,974)

FUTRQF = Total feed requirements in the region to be met in feedlots $FU\ EE^{-1}\ mth^{-1}$
(694,701,702,703,704,766)

FUTRQR = Total feed requirements in the region to be met by rangeland $FU\ EE^{-1}\ mth^{-1}$
(675,679,680,682,696)

FWFLOT = Fraction of weaned lambs/kids fed in feedlot -
(189,339,340,523,524,810,815)

FWLOTT = Function table FWFLOT, independent variable SYSTEM -
(189,200)

GAFRQ = Annual feed requirements of goats $FU\ EE^{-1}\ yr^{-1}$
(536,537)

GBFRQ = Feed requirements fo goat bucks $FU\ head^{-1}\ mth^{-1}$
(512,527,531,980)

GBUCKT = Function table GBUCKW, independent variable SYSTEM -
(455,468)

GBUCKW = Goat buck weight kg
(455,527,528,529)

GCF = Goat conversion factor taking into account contribution of goats to the total population $head\ EE^{-1}$
(412,488,495,505,512,533,534)

GCF1 = Goat correction factor for system intensity -
(474,475,476,477)

GCONR = Goat conception rate doe lambed $(doe\ mated)^{-1}$
(417,418,474,475)

GCONRT = Function table GCONR, independent variable SYSTEM -
(418,435)

GCULR = Goat culling rate $head\ head^{-1}\ yr^{-1}$
(420,421,487)

GCULRT	=	Function table GCULR, independent variable SYSTEM (421,437)	-
GCULW	=	Goat culling weight (454,487)	kg
GCULWT	=	Function table GCULW, independent variable SYSTEM (454,466)	-
GDBR	=	Goat doe to buck ratio (527,538)	-
GEECF	=	Goat-ewe equivalent conversion factor (187,191,212,412,413)	head EE^{-1}
GFEE	=	Fraction of goats of the total animal population in that system (408.409,412,423)	EE EE^{-1}
GFFK	=	Fraction of female kids born (422,424,434,484,486)	-
GFFKK	=	Fraction of female kids kept after weaning (422,425)	-
GFFKS	=	Fraction of female kids sold (425,427,484,486)	-
GFFKST	=	Function table GFFKS, independent variable SYSTEM (427,439)	-
GFGMIL	=	Fraction of goats being milked (494,498)	-
GFKBM	=	Fraction of kids born in March (419,430,552)	-
GFKBMA	=	Fraction of kids born in March (429,430,431)	-
GFKBO	=	Fraction of kids born in October (419,429,545,546,551)	-
GFKBT	=	Fraction of kids born in February, June and October (419,429,430,432,547,548,549,553,554,555)	-
GFLRQ	=	Goat flushing requirements (526,532,981)	FU $head^{-1}$ mth^{-1}
GFMK	=	Fraction of male kids born (424,484,486)	-
GFMKF	=	Fraction of male kids kept after weaning (426,486)	-
GFMKW	=	Fraction of male kids sold at weaning (426,428,484)	-

GFMKWT	= Function table GFMKW, independent variable SYSTEM (428,441)	-
GFTKID	= Fraction of does kidding three times in two successive years (432,433)	-
GFTKIT	= Function table GFTKID, independent variable SYSTEM (433,443)	-
GFUCF	= Meat production efficiency of goats (537,940)	FU kg^{-1} liveweight
GHOGG	= Goat hogget production (423,939)	EE EE^{-1} yr^{-1}
GHPIR	= Potential rate of increase of goat herd (422,423,525,981)	head $head^{-1}$ yr^{-1}
GLRQ	= Lactation requirements of goats (517,980)	FU $head^{-1}$ mth^{-1}
GLS	= Goat litter size = prolificacy (417,419,474,475)	kids born (doe lambed)-1 yr^{-1}
GLWP	= Goat liveweight production (482,488)	kg liveweight $head^{-1}$ mth^{-1}
GLWP1	= Kid liveweight sold at weaning (482,483)	kg liveweight $head^{-1}$ mth^{-1}
GLWP2	= Kid liveweight sold after weaning (482,485)	kg liveweight $head^{-1}$ mth^{-1}
GLWP3	= Liveweight of does after culling (482,487)	kg liveweight $head^{-1}$ mth^{-1}
GLWPR	= Liveweight production rate of goats (488,489)	kg liveweight EE^{-1} mth^{-1}
GMANUR	= Manure production of goats (505,506)	kg DM EE^{-1} yr^{-1}
GMAPRQ	= Maintenance requirements of goats (511,513)	FU $head^{-1}$ mth^{-1}
GMEAT	= Annual liveweight production of goats (489,537,939)	kg liveweight EE^{-1} yr^{-1}
GMILK	= Annual milk production of goats (496)	kg EE^{-1} yr^{-1}
GMILRQ	= Milking requirements of goats (518,531,980)	FU $head^{-1}$ mth^{-1}
GMLW	= Mature liveweight of doe (453,513,514,515)	kg

GMLWT = Function table GMLW, independent variable SYSTEM (453,464) | -

GMMP = Monthly milk production of goats (494,497) | kg $head^{-1}$ mth^{-1}

GMMPT = Function table GMMP, independent variable SYSTEM (497,499) | -

GMP = Milk production of goats (494,495,518) | kg $head^{-1}$ mth^{-1}

GMPR = Milk production of goats (495,496) | kg EE^{-1} mth^{-1}

GMR = Mortality rate of goats (420,476) | head $head^{-1}$ yr^{-1}

GMRQ = Maintenance requirements of goats (511,512,531,980) | FU $head^{-1}$ mth^{-1}

GMRQ1 = Maintenance requirements of goats (512,670) | FU EE^{-1} mth^{-1}

GNKIDR = Net kidding rate of goats (417,422,484,486,516,517,845,981) | kids weaned (doe $mated)^{-1}$ yr^{-1}

GNU = Number of goats in the region (171,409,411,976) | EE

GNUMAX = Total number of goats occuring at present, set as right hand side for the first year in the linear programming module (172,410,411,935) | EE

GOATS = Number of goats (408,936) | EE

GREPR = Replacement rate of goats (420,422,525) | head $head^{-1}$ yr^{-1}

GSURQ = Steaming up requirements of goats (516,531,980) | FU $head^{-1}$ mth^{-1}

GTFRQ = Total feed requirements of goats (535,536,665) | FU EE^{-1} mth^{-1}

GTFRQ1 = Total feed requirements of goats (531,533,534,981) | FU $head^{-1}$ mth^{-1}

GTFRQF = Total feed requirements of goats to be met in feedlot (534,535,694) | FU EE^{-1} mth^{-1}

GTFRQR = Total feed requirements of goats to be met by rangeland (533,535,675) | FU EE^{-1} mth^{-1}

GWALRQ = Feed requirements of goats for walking (511,514) — FU $head^{-1}$ mth^{-1}

HRATOT = Total traction time available (590,939) — h EE^{-1} yr^{-1}

HRFW1 = Time required for feeding and watering for a flock in a feedlot (810,814) — h $flock^{-1}$ d^{-1}

HRFW2 = Time required for feeding and watering for weaned lambs and kids in a feedlot (810,815) — h $flock^{-1}$ d^{-1}

HRFW1T = Function table HRFW1, independent variable FFFLOT (814,828) — -

HRFW2T = Function table HRFW2, independent variable FWFLOT (815,829) — -

HRGRS = Time required for grazing in summer (331,349,515,529,804,812) — h $flock^{-1}$ d^{-1}

HRGRST = Function table HRGRS, independent variable SYSTEM (812,822) — -

HRGRW = Time required for grazing in winter (330,348,514,528,805,813) — h $flock^{-1}$ d^{-1}

HRGRWT = Function table HRGRW, independent variable SYSTEM (813,824) — -

HRMT = Time required for maintenance work (811,817) — h mth^{-1}

HRMTT = Function table HRMT, independent variable SYSTEM (817,830) — -

HRSB = Time required for shearing by Bedouin (807,820) — h $head^{-1}$ man^{-1}

HRSS = Time required for shearing by professionals (792,821) — h $head^{-1}$ man^{-1}

HRVC = Time required for veterinary care (806,816) — h $flock^{-1}$ mth^{-1}

HRVCT = Function table TIVC, independent variable SYSTEM (816,826) — -

IFBE = Fraction berseem in total supplements (704,713,751) — -

IFBET = Function table IFBE, independent variable SYSTEM (713,726) — -

IFBS = Fraction barley straw in total supplements (702,711,749) — -

IFBST = Function table IFBS, independent variable SYSTEM (711,719) -

IFCON = Fraction concentrates in total supplements (701,710,748) -

IFCONT = Function table IFCON, independent variable SYSTEM (710,716) -

IFVE = Fraction vegetables in total supplements (703,712,750) -

IFVET = Function table IFVE, independent variable SYSTEM (712,722) -

INTMAT = Function table INTMAX, independent variable SYSTEM (683,688) -

INTMAX = Maximum intake of forage in summer (682,683) kg DM EE^{-1} d^{-1}

INV1 = Investments in water troughs (888,892) LE EE^{-1} mth^{-1}

INV2 = Investments in dips (888,893) LE EE^{-1} mth^{-1}

INV3 = Investments in sheds (888,894) LE EE^{-1} mth^{-1}

INV4 = Investments in corrals (888,895) LE EE^{-1} mth^{-1}

INV5 = Investments in equipment (888,896) LE EE^{-1} mth^{-1}

INVAR1 = Annual investments in cisterns, wells and galeries (889,890) LE EE^{-1} mth^{-1}

INVAR2 = Annual investments in water pipelines (889,891) LE EE^{-1} yr^{-1}

INVRQ = Total investment requirements (888,889) LE EE^{-1} mth^{-1}

INVSAH = Total annual investments (889,938) LE EE^{-1} yr^{-1}

KAWMR = After-weaning mortality rate of kids (422,475,486) head $head^{-1}$ yr^{-1}

KBIRT = Function table KBIRW, independent variable SYSTEM (449,456) -

KBIRW = Birth weight of kids (449) kg

KFRQ1 = Feed requirements for kid fattening if fed on rangeland — FU $head^{-1}$ mth^{-1}
(519,523)

KFRQ2 = Feed requirements for kid fattening in fed in feedlot — FU $head^{-1}$ mth^{-1}
(521,524)

KFRQFL = Feed requirements for kid fattening to be met in feedlot — FU $head^{-1}$ mth^{-1}
(524,534)

KFRQRL = Feed requirements for kid fattening to be met on rangeland — FU $head^{-1}$ mth^{-1}
(523,531,533,980)

KHOGRQ = Hogget requirements of kids — FU $head^{-1}$ mth^{-1}
(525,532,980)

KHOGW = Hogget weight — kg
(451)

KHOGWT = Function table KHOGW, independent variable SYSTEM — -
(451,460)

KPWMR = Pre-weaning mortality rate of kids — head $head^{-1}$ yr^{-1}
(417,474)

KSALET = Function table KSALEW, independent variable SYSTEM — -
(452,462)

KSALEW = Sale weight of kid — kg
(452,485,519,520,521,522)

KSF = Number of kids sold after weaning — head $head^{-1}$ yr^{-1}
(485,486,519,521)

KSW = Number of kids sold at weaning — head $head^{-1}$ yr^{-1}
(483,484)

KWEANT = Function table KWEANW, independent variable SYSTEM — -
(450,458)

KWEANW = Kid weaning weight — kg
(450,483,519,520,521,522)

LABR1S = Labour requirements for shepherding in summer — d EE^{-1} mth^{-1}
(787,788,790,796,804)

LABR1W = Labour requirements for shepherding in winter — d EE^{-1} mth^{-1}
(788,790,797,805)

LABR2 = Labour requirements for veterinary care — d EE^{-1} mth^{-1}
(787,788,790,798,806)

LABR3 = Labour requirements for shearing — d EE^{-1} mth^{-1}
(799,807)

LABR41 = Labour requirements for feeding and watering in summer — d EE^{-1} mth^{-1}
(787,789,791,800,808)

LABR42 = Labour requirements for feeding and watering if animals are in a feedlot — d EE^{-1} mth^{-1}
(787,789,791,801,810)

LABR5 = Labour requirements for maintenance work — d EE^{-1} mth^{-1}
(787,789,791,802,811)

LABRQ1 = Labour requirements for shepherding — d EE^{-1} mth^{-1}
(794,796)

LABRQ2 = Labour requirements for veterinary care — d EE^{-1} mth^{-1}
(794,798)

LABRQ3 = Labour requirements for shearing — d EE^{-1} mth^{-1}
(794,799)

LABRQ4 = Labour requirements for feeding and watering — d EE^{-1} mth^{-1}
(794,800)

LABRQ5 = Labour requirements for maintenance work — d EE^{-1} mth^{-1}
(794,802)

LAWMR = After-weaning mortality rate of lambs — head $head^{-1}$ yr^{-1}
(222,277,290)

LBIRW = Lamb birth weight — kg
(251)

LBIRT = Function table LBIRW, independent variable SYSTEM — -
(251,258)

LFRQ1 = Feed requirements for lamb fattening if fed on rangeland — FU $head^{-1}$ mth^{-1}
(335,339)

LFRQ2 = Feed requirements for lamb fattening if fed in a feedlot — FU $head^{-1}$ mth^{-1}
(337,340)

LFRQFL = Feed requirements for lamb fattening to be met in a feedlot — FU $head^{-1}$ mth^{-1}
(340,354)

LFRQRL = Feed requirements for lamb fattening to be met on rangeland — FU $head^{-1}$ mth^{-1}
(339,353,979)

LHOGRQ = Feed requirements for sheep hogget production — FU $head^{-1}$ mth^{-1}
(341,352,979)

LHOGW = Sheep hogget weight — kg
(253)

LHOGWT = Function table LHOGW, independent variable SYSTEM -
(253,262)

LPWMR = Pre-weaning mortality rate of lambs head $head^{-1}$ yr^{-1}
(217,276)

LSALET = Function table LSALEW, independent variable SYSTEM -
(254,264)

LSALEW = Lamb saleweight kg
(254,289,335,336,337,338)

LSF = Lambs sold after fattening head $head^{-1}$ yr^{-1}
(289,290,335,337)

LSW = Lambs sold after weaning head $head^{-1}$ yr^{-1}
(287,288)

LWEANT = Function table LWEANW, independent variable SYSTEM -
(252,260)

LWEANW = Lamb weaning weight kg
(252,287,335,336,337,338)

M0 = Auxiliary variable to specify October -
(365,372,384,387,392,393,395,399,401,402,)
(549,551,553,901,903)

M1 = Auxiliary variable to specify November -
(363,365,367,382,387,392,393,395,399,401,402,)
(551,553,617,789,796,797,798,800,801,901,904)

M2 = Auxiliary variable to specify December -
(363,376,382,387,393,395,399,401,402,545,547,)
(551,553,905)

M3 = Auxiliary variable to specify January -
(363,366,367,368,370,374,376,383,385,388,390,)
(393,395,398,399,400,402,545,547,551,553,906)

M4 = Auxiliary variable to specify February -
(363,364,368,370,374,383,385,388,390,396,398,)
(399,400,402,545,547,554,907)

M5 = Auxiliary variable to specify March -
(364,378,381,383,385,388,390,394,396,398,400,)
(402,552,554,792,799,908)

M6 = Auxiliary variable to specify April -
(342,364,365,377,378,381,383,385,394,396,398,400,)
(402,548,552,554,791,792,796,797,798,800,801,909)

M7 = Auxiliary variable to specify May -
(291,365,366,367,371,377,386,391,394,396,398,)
(400,401,487,546,548,552,554,793,910)

M8	=	Auxiliary variable to specify June (365,369,371,386,391,394,397,398,400,401,546,) (548,552,555,911)	-
M9	=	Auxiliary variable to specify July (365,366,369,380,384,386,389,391,397,398,399,) (400,401,546,555,912)	-
M10	=	Auxiliary variable to specify August (365,373,375,379,380,384,386,389,397,398,399,) (400,401,549,555,913)	-
M11	=	Auxiliary variable to specify September (365,366,367,372,373,375,379,384,387,389,392,) (397,399,401,402,549,555,787,796,798,800,801,914)	-
MANDB	=	Total labour required during the 'rest of the year' (785,794)	d EE^{-1} mth^{-1}
MANDH	=	Labour hired from outside the region (786,792)	d EE^{-1} mth^{-1}
MANURE	=	Manure of sheep and goats collected (315,503,506,939)	kg EE^{-1} yr^{-1}
MANURF	=	Fraction of manure being collected (317,318,505)	-
MANURT	=	Function table MANURF, independent variable SYSTEM (318,319)	-
MDAPR	=	Labour required in April (709,938)	d EE^{-1} yr^{-1}
MDNOV	=	Labour required in November (788,938)	d EE^{-1} yr^{-1}
MDOUT	=	Labour required from outside the region (786,938)	d EE^{-1} yr^{-1}
MDREST	=	Labour total required for the rest of the year (785,938)	d EE^{-1} yr^{-1}
MDSEPT	=	Labour required in September (787,938)	d EE^{-1} yr^{-1}
MEDCP	=	Costs of medicines (872,873)	LE EE^{-1} yr^{-1}
MEDCPT	=	Function table, MEDCP, independent variable SYSTEM (873,880) MISCT = Function table miscellaneous costs, independent variable SYSTEM (878,882)	- -

MUTTON = Annual liveweight production of sheep — kg EE^{-1} yr^{-1}
(293,357,939)

NVBE = Nutritive value of berseem — FU kg^{-1} DM
(704,715,751)

NVBG = Nutritive value of barley grains — FU kg^{-1} DM
(145,147)

NVBS = Nutritive value of barley straw — FU kg^{-1} DM
(136,138,702,749)

NVCON = Nutritive value of manufactured concentrates — FU kg^{-1} DM
(155,159,701,748)

NVFOR = Nutritive value of rangeland forage — FU kg^{-1} DM
(119,121,679,680,681,696,742)

NVFORT = Function table NVFOR, independent variable TIME — -
(121,122)

NVVE = Nutritive value of vegetables — FU kg^{-1} DM
(703,714,750)

PED = Auxiliary variable to specify early dry period — -
(328,330,345,348,364,514,528,680,742,766,797,798,802)

PGFAT1 = Auxiliary variable to specify kid fattening
if fed on rangeland — -
(523,556)

PGFAT2 = Auxiliary variable to specify kid fattening
if fed in feedlot — -
(524,559)

PGFL = Auxiliary variable to specify goat flushing period — -
(526,559)

PGG = Auxiliary variable to specify green grazing period — -
(328,330,345,348,363,514,528,679,742,766,797,798,802)

PGHG = Auxiliary variable to specify hogget growth period — -
(525,558)

PGLAC = Auxiliary variable to specify kid suckling period — -
(517,551)

PGMP1 = Auxiliary variable to specify goat meat production
at weaning — -
(483,543)

PGMP2 = Auxiliary variable to specify goat meat production
after fattening — -
(485,544)

PGSU = Auxiliary variable to specify goat steaming up period — -
(516,550)

PMD =	Auxiliary variable to specify main dry period (329,331,346,349,365,515,529,681,696,743,766,) (796,798,800,801)	-
PSFAT1 =	Auxiliary variable to specify lamb fattening if fed on rangeland (339,383,556)	-
PSFAT2 =	Auxiliary variable to specify lamb fattening if fed in a feedlot (340,388,557)	-
PSFL =	Auxiliary variable to specify sheep flushing period (343,378,559)	-
PSHG =	Auxiliary variable to specify hogget growth period (341,398,558)	-
PSLAC =	Auxiliary variable to specify lamb suckling period (333,393)	-
PSMIL =	Auxiliary variable to specify sheep milking period (298,368)	-
PSMP1 =	Auxiliary variable to specify sheep meat production at weaning (287,366,543)	-
PSMP2 =	Auxiliary variable to specify sheep meat production after fattening (289,367,544)	-
PSSU =	Auxiliary variable to specify sheep steaming up period (332,373,550)	-
RANARQ =	Annual rangeland requirement (687,773,987)	ha EE^{-1} yr^{-1}
REGION =	Region in the coastal zone (9)	-
RLAFAV =	Annual feed availability of rangeland (120,975)	FU EE^{-1} yr^{-1}
RLANBP =	Annual biomass production of rangeland (118,687)	kg DM ha^{-1} yr^{-1}
RLAP1 =	Annual biomass production of rangeland $P > 150$ mm (69,74)	kg DM ha^{-1} yr^{-1}
RLAP2 =	Annual biomass production of rangeland, $125 < P < 150$ mm (70,75)	kg DM ha^{-1} yr^{-1}

RLAP3	= Annual biomass production of rangeland, 100 < P < 125 mm (71,76)	kg DM ha^{-1} yr^{-1}
RLAP4	= Annual biomass production of rangeland, 75 < P < 100 mm (72,77)	kg DM ha^{-1} yr^{-1}
RLAP5	= Annual biomass production of rangeland between barley fields (73,78)	kg DM ha^{-1} yr^{-1}
RLAP15T	= Function tables RLAP1-5, independent variable REGION (74,83,75,84,76,85,77,86,78,87)	-
RLBBFP	= Biomass production rate of rangeland between the barley fields (68,73,117)	kg DM ha^{-1} mth^{-1}
RLBP	= Biomass production rate of total rangeland (67)	kg DM ha^{-1} mth^{-1}
RLBP1	= Biomass production rate of rangeland, P > 150 mm (67,68,69,114,116)	kg DM ha^{-1} mth^{-1}
RLBP2	= Biomass production rate of rangeland, 125 < P < 150 mm (67,68,70,114,116)	kg DM ha^{-1} mth^{-1}
RLBP3	= Biomass production rate of rangeland, 100 < P < 125 mm (67,68,71,114,116)	kg DM ha^{-1} mth^{-1}
RLBP4	= Biomass production rate of rangeland, 75 < P < 100 mm (67,68,72,115,117)	kg DM ha^{-1} mth^{-1}
RLBPD14	= Distribution of annual biomass production in the course of the year (69,79,70,73,80,71,81,72,82)	-
RLBPFB	= Biomass production of rangeland for feed balance calculation (68)	kg DM ha^{-1} mth^{-1}
RLFAV	= Feed availability of rangeland (119,120,737,746,974)	FU EE^{-1} mth^{-1}
RLPD14T	= Function tables RLBP1-4, independent variable TIME (79,88,80,95,81,102,82,106)	-

RLWBP1 = Weighted average biomass production (114,118) — kg DM ha^{-1} mth^{-1}

RLWBP2 = Weighted average biomass production, including rangeland between barley fields (116,119) — kg DM ha^{-1} mth^{-1}

RUNAC1 = Annual runnning costs for maintenance of cisterns, wells and galeries (868,869) — LE EE^{-1} yr^{-1}

RUNC1 = Costs of water (867,870) — LE EE^{-1} mth^{-1}

RUNC2 = Costs of medicines (867,872) — LE EE^{-1} mth^{-1}

RUNC3 = Costs of Vitamin A supplementation (867,874) — LE EE^{-1} mth^{-1}

RUNC4 = Costs of salt bricks (867,875) — LE EE^{-1} mth^{-1}

RUNC5 = Costs of maintenance of dips (867,876) — LE EE^{-1} mth^{-1}

RUNC6 = Costs of maintenance of sheds (867,877) — LE EE^{-1} mth^{-1}

RUNC7 = Miscellaneous costs (867,878) — LE EE^{-1} mth^{-1}

RUNCRQ = Monthly running costs (867,868) — LE EE^{-1} mth^{-1}

RUPAED = Intake of rangeland forage in early dry period (685,687) — kg DM EE^{-1}

RUPAGG = Intake of rangeland forage in green grazing period (684,687) — kg DM EE^{-1}

RUPAMD = Intake of rangeland forage in main dry period (686,687) — kg DM EE^{-1}

RUPED = Rate of intake of rangeland forage in early dry period (680,685) — kg DM EE^{-1} mth^{-1}

RUPGG = Rate of intake of rangeland forage in green grazing period (679,684) — kg DM EE^{-1} mth^{-1}

RUPMD = Rate of intake of rangeland forage in main dry period (681,686,696) — kg DM EE^{-1} mth^{-1}

SAFRQ = Annual feed requirements of sheep (356,357) — FU EE^{-1} yr^{-1}

SCF = Sheep conversion factor taking into account contribution of sheep to the total population (211,292,299,309,317,327,353,354) — head EE^{-1}

SCFI = Sheep correction factor for system intensity (276,277,278,279,477) — -

SCFIT = Function tables SCFI, independent variable SYSTEM (279,280) — -

SCONR = Sheep conception rate (217,218,276,277) — ewe lambed (ewe mated)$^{-1}$

SCONRT = Function table SCONR, independent variable SYSTEM (218,237) — -

SCULR = Sheep culling rate (220,221,291,342) — head head-1 yr^{-1}

SCULRT = Function table SCULR, independent variable SYSTEM (221,235) — -

SEECF = Sheep-ewe equivalent conversion factor (187,190,211,212,413) — head EE^{-1}

SERR = Ewe to ram ratio (344,358) — -

SFATT = Function table SFATW, independent variable SYSTEM (255,266) — -

SFATW = Sheep fattening weight (255,291,342) — kg

SFEE = Fraction of sheep of the total animal population in that system (207,208,211,223) — EE EE^{-1}

SFFL = Fraction female lambs born (222,224,234,288,290) — -

SFFLK = Fraction female lambs kept after weaning (222,225) — -

SFFLS = Fraction female lambs sold (225,227,288,290) — -

SFFLST = Function table SFFLS, independent variable SYSTEM (227,239) — -

SFLBM = Fraction of lambs born in March, except fraction born in 3 lambings per two years (SFLBT) (219,230,366,369,374,384,389,394,399) — -

SFLBMA = Fraction of lambs born in March -
(229,230,231,431)

SFLBMT = Function table SFLBMA, independent variable SYSTEM -
(231,243)

SFLBO = Fraction of lambs born in October -
(219,229,366,367,368,373,378,383,388,393,398)

SFLBT = Fraction of lambs born for equally distributed among October, February and June -
(219,229,230,232,366,367,370,371,372,375,376,)
(377,380,381,382,385,386,387,390,391,392,395,)
(396,397,400,401,402)

SFLRQ = Flushing requirements of sheep $FU\ EE^{-1}\ mth^{-1}$
(343,352,979).

SFML = Fraction male lambs born -
(224,288,290)

SFMLF = Fraction male lambs kept after weaning -
(226,290)

SFMLW = Fraction male lambs sold at weaning -
(226,228,288)

SFMLWT = Function table SFMLW, independent variable SYSTEM -
(228,241)

SFRQ = Feed requirements for ewe fattening $FU\ EE^{-1}\ mth^{-1}$
(342,352,979)

SFSMIL = Fraction of total sheep being milked -
(298,302)

SFTLAM = Fraction of sheep lambing three times in two years -
(232,233)

SFTLAT = Function table SFTLAM, independent variable SYSTEM -
(233,245)

SFUCF = Feed unit conversion factor $FU\ kg^{-1}$ liveweight
(357,940)

SGAVLR = Average net lambing rate of sheep and goats lambs/kids $head^{-1}\ yr^{-1}$
(844,845,858)

SGEE = Sheep and goats conversion factor taking into account present flock structure $head\ EE^{-1}$
(183,184,185,776)

SGEECF = Sheep and goats conversion factor $head\ EE^{-1}$
(156,187,682,792,807,842,853,857,872,874,875)

SHEEP	=	Number of sheep (207,936)	EE
SHOGG	=	Sheep hogget production (223,939)	EE EE^{-1} yr^{-1}
SHPIR	=	Potential rate of increase of sheep herd (222,223,341,979)	head head-1 yr^{-1}
SLRQ	=	Lactation requirements of sheep (333,351,978)	FU EE^{-1} mth^{-1}
SLS	=	Sheep litter size = prolificacy (217,219,276,277)	lambs born $(ewe\ lambed)^{-1}$ yr^{-1}
SLWP	=	Sheep liveweight production (286,292)	kg head-1 mth^{-1}
SLWP1	=	Lamb liveweight sold at weaning (286,287)	kg EE^{-1} mth^{-1}
SLWP2	=	Lamb liveweight sold after fattening (286,289)	kg EE^{-1} mth^{-1}
SLWP3	=	Liveweight of culled ewes sold in May (286,291)	kg EE^{-1} mth^{-1}
SLWPR	=	Liveweight production rate of sheep (292,293)	kg EE^{-1} mth^{-1}
SMANUR	=	Manure production of sheep (317,506)	kg DM EE^{-1} mth^{-1}
SMAPRQ	=	Maintenance requirements of sheep (326,328)	FU EE^{-1} mth^{-1}
SMILK	=	Annual milk production of sheep (300)	kg EE^{-1} yr^{-1}
SMILRQ	=	Milking requirements of sheep (334,351,978)	FU EE^{-1} mth^{-1}
SMLW	=	Sheep mature liveweight (256,329,330,331,342)	kg
SMLWT	=	Function table SMLW, independent variable SYSTEM (256,268)	-
SMMP	=	Monthly milk production of sheep (298,301)	kg $head^{-1}$ mth^{-1}
SMMPT	=	Function table SMMP, independent variable SYSTEM (301,303)	-
SMP	=	Milk production of sheep (298,299,334)	kg $head^{-1}$ mth^{-1}
SMPR	=	Milk production of sheep (299,3000	kg EE^{-1} mth^{-1}

SMR	= Sheep mortality rate (220,278)	head head^{-1} yr^{-1}
SMRQ	= Maintenance requirements of sheep (326,327,351,978)	FU head^{-1} mth^{-1}
SMRQ1	= Maintenance requirements of sheep (327,670)	FU EE^{-1} mth^{-1}
SNLAMR	= Sheep net lambing rate (217,222,288,290,332,333,845,979)	lambs weaned (ewe mated)$^{-1}$ yr^{-1}
SNU	= Number of sheep in the region (171,208,210,976)	EE
SNUMAX	= Total number of sheep occuring at present, set as right hand side for the first year in the linear programming module (172,209,210,935)	EE
SRAMW	= Weight of ram (257,345,346,348,349)	kg
SRAMWT	= Function table SRAMW, independent variable SYSTEM (257,270)	-
SREPR	= Sheep replacement rate (220,222,341)	head head^{-1} yr^{-1}
SRFRQ	= Ram feed requirements (327,344,351,978)	FU head^{-1} mth^{-1}
SSURQ	= Steaming up requirements of sheep (332,351,978)	FU head^{-1} mth^{-1}
STFRQ	= Total feed requirements of sheep (355,356,665)	FU EE^{-1} mth^{-1}
STFRQ1	= Total feed requirements of sheep (351,353,354,979)	FU head^{-1} mth^{-1}
STFRQF	= Total feed requirements of sheep to be met in feedlot (354,355,694)	FU EE^{-1} mth^{-1}
STFRQR	= Total feed requirements of sheep to be met by rangeland (353,355,695)	FU EE^{-1} mth^{-1}
STRAW	= Annual barley straw requirements if systems are calculated (706,937)	kg DM EE^{-1} yr^{-1}
STRAW2	= Annual barley straw requirements if feed balance is calculated (754,973)	kg DM EE^{-1} yr^{-1}

STRRL = Stocking rate at the rangeland (173,972) — EE ha^{-1}

SWALRQ = Requirements of sheep for walking (326,330) — FU $head^{-1}$ mth^{-1}

SWOOL = Annual wool production of sheep (309.939) — kg EE^{-1} yr^{-1}

SWP = Total wool production of sheep (309,310) — kg $head^{-1}$ yr^{-1}

SWPT = Function table SWP, independent variable SYSTEM (310,311) — -

SYSCA = Auxiliary variable to specify systems with camels (599,600,923) — -

SYSCAT = Function table SYSCA, independent variable SYSTEM (923,930) — -

SYSCT = Auxiliary variable to specify systems with cattle (633,634,924) — -

SYSCTT = Function table SYSCT, independent variable SYSTEM (924,932) — -

SYSD = Auxiliary variable to specify systems with donkeys (568,569,922) — -

SYSDT = Function table SYSD, independent variable SYSTEM (922,928) — -

SYSEX = Auxiliary variable to specify extensive systems (363,788,797,915,920,921) — -

SYSEXT = Function table SYSEX, independent variable SYSTEM (915,925) — -

SYSFB = Auxiliary variable to specify feed balance calculation (173,174,210,411,570,601,635,918,919,920,921) — -

SYSIN = Auxiliary variable to specify intensive systems (364,365,790,791,800,853,858,874,875,917,919,921) — -

SYSINT = Function table SYSIN, independent variable SYSTEM (917,927) — -

SYSNEX = Auxiliary variable to specify all systems except extensive systems (365,788,789,796,800,919) — -

SYSNIN = Auxiliary variable to specify all systems except intensive systems (363,364,790,797,920) — -

SYSP = Auxiliary variable to specify system 3 and 4 (916,919,920,921) — -

SYSPT	= Function table SYSP, independent variable SYSTEM (916,926)	-
SYSSG	= Auxiliary variable to specify systems with sheep and goats (181,187,208,209,409,410,682,808,811,896,921)	-
SYSTEM	= System	-
TEE	= Total ewe equivalents in the region (119,136,145,171,173,174,208,409,568,599,633,976)	EE
TEEMAX	= Total number of equivalents occuring at present, set as right hand side for the first year in the linear programming module (172,935)	EE
TNUCA	= Total number of camels in the zone (600,604)	head
TNUSG	= Total number of sheep and goats in the zone (179,209,410)	head
TNUSGT	= Function table TNUSG, independent variable SYSTEM (179,192)	-
VEGARQ	= Annual vegetables requirements if systems are calculated (707,937)	kg DM EE^{-1} yr^{-1}
VEGAR2	= Annual vegetables requirements if feed balance is calculated (755,973)	kg DM EE^{-1} yr^{-1}
VEGRQ1	= Vegetables requirements if systems are calculated (703,707)	kg DM EE^{-1} mth^{-1}
VEGRQ2	= Vegetables requirements if feed balance is calculated (750,755)	kg DM EE^{-1} mth^{-1}
WATACI	= Annual water requirements met by cisterns, wells and galleries (769,775)	m^3 EE^{-1} yr^{-1}
WATARQ	= Annual water requirements (767)	m^3 EE^{-1} yr^{-1}
WATCI	= Water requirements met by cisterns, wells and galleries (768,769,772)	m^3 EE^{-1} mth^{-1}
WATFCR	= Fraction of WATCI, function of region (768,770)	-

WATFCS	= Fraction of WATCI, function of system (768,771)	-
WATPL	= Water requirements met by water from pipeline (772,870)	m^3 EE^{-1} mth^{-1}
WATRQ	= Total water requirements (766,767,768,772)	m^3 EE^{-1} mth^{-1}
WCINUR	= Number of cisterns, wells and galeries required (774,775,869,890,940,981)	-
WFCRT	= Function table WATCI, independent variable REGION (770,777)	-
WFCST	= Function table WATCI, independent variable SYSTEM (771,778)	-
WPLCP	= Price of water (870,871)	LE m^{-3}
WPLCPT	= Function table WPLC, REGION (871,879)	-
WPLNUR	= Number of pipeline taps required (774,891)	-
WPTNUR	= Number of watering points required (773,774)	-
WTRNUR	= Number of watering troughs required (776,892)	-