Country Pasture / Forage Resource Profiles

SUDAN

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1. INTRODUCTION

1.1 Location

Sudan lies in northeast Africa between latitudes 4^0 and 22^0 north and longitudes 22^o and 38^0 east (see Figure 1). Covering an area of 2.5 million km^2, it has a predominantly rural population of about 30 million, which is growing at the rate of 2.6% per annum (according to the World Factbook the July 2006 population estimate was 41,236,378 with a 2.55% growth rate). The country is traversed by the River Nile and its tributaries which have varying degrees of influence on irrigated agriculture and livestock production systems. There are also a large number of seasonal rivers and water courses; large ones, such as the Gash and Baraka, originate within the Ethiopian highlands, form two inland deltas in Sudan, and are important for flood irrigation agriculture. Also there is a vast resource of groundwater, estimated at about 9000 billion m^3, which has a varied distribution, quantity and quality in different parts of the country, with the Nubian Sandstone acquifer the most important.

Figure 1. Map of Sudan

1.2 Land Area, Arable and Pastoral Areas

Of about 84 million ha. of arable land (with reasonably fertile soils), 1.63, 8.21 and 7.93 million ha. respectively were under irrigated agriculture, traditional rain-fed cultivation and mechanized farming in the 1994/95 season. The National Comprehensive Strategy aims to considerably increase these areas by the 2001/02 season (see Table 1). The main crops produced by each sub-sector are also shown in Table 1. Forests and woodlands cover about 64.36 million ha. while rangelands are estimated to cover 24 million ha. (National

Committee on Food Security, 1996) Forage from rangelands is estimated to provide, depending upon the region, from 55-80% of the national herd feed requirements.

Table 1. Agricultural Sub-sector and Main Crop Areas*

Sub-sector	Area (million ha)		Main Crops
	1994/95	2001/02	
Irrigated Farming	1.63	3.78	Sorghum, wheat, cotton, sunflower groundnuts, vegetables, fruit trees, alfalfa, forage sorghum
Traditional Rain-fed	8.21	9.12	Sorghum, millet sesame, groundnuts, water melon, roselle, cowpea
Mechanized Farming	7.93	12.60	Sorghum, sesame, cotton, guar

* Sources: Agricultural Planning, Ministry of Agriculture and Forestry, the National Comprehensive Strategy Vol. 1.

1.3 Ruminant Sector

Livestock form an important component of the agricultural sector, with production mainly based on traditional pastoral systems (90% of the livestock in the country belong to the traditional pastoral production systems). The Ministry of Animal Wealth estimates the camel, cattle, sheep and goat population in 2004 at 3.3, 38.3, 48.0 and 42.0 million head, respectively (see FAO figures in Table 2) as well as 37.0 M poultry and 0.75 M asses.

Livestock provide milk, meat, hides and skins, hair, manure, animal draught and transport, subsistence and income. The production of milk and meat by different classes of livestock is shown in Table 2. The contribution of the agriculture sector to the GDP in 1999 was 49.8%, of which 27.5% was from the plant production component and 22.3% was contributed by livestock.

Live animals (especially sheep eg. in 2003 some 1, 351,685 live sheep were exported), meat and hides and skins are important items in the country's exports (Table 2) and contribute significantly to foreign exchange earnings. Considerable quantities of dairy products are imported with some 66,104 tonnes of milk equivalents imported in 2003 of a cost of US$ 18,332,000.

Table 2. Livestock Numbers, Production, Imports and Exports 1995-2005

Item	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cattle nos. (,000,000)	31.7	33.1	34.6	35.8	37.1	38.3	38.2	38.3	38.3	38.3
Camel nos. (,000,000)	2.9	2.9	3.0	3.0	3.1	3.2	3.3	3.3	3.3	3.3
Sheep nos. (,000,000)	37.2	39.8	42.4	44.8	46.1	47.0	48.1	48.0	48.0	48.0
Goat nos. (,000,000)	35.2	36.0	36.5	37.4	38.6	40.0	41.5	42.2	42.2	42.0
Beef & veal prod. (,000 mt)	226.4	250.0	265.0	276.0	296.0	320.0	325.0	325.0	325.0	325.0
Sheep meat prod. (,000 mt)	129.6	133.0	140.8	142.4	143.0	150.0	144.0	144.0	144.0	144.0
Goat meat prod. (,000 mt)	112.7	122.0	123.0	114.0	118.0	122.0	126.0	126.0	126.0	126.0
Total milk prod. (,000,000 mt)	4.4	4.4	4.7	4.8	4.9	5.0	5.1	5.1	5.1*	5.1
Greasy wool production	34.0	42.0	44.0	45.0	45.5	46.0	46.0	46.0	46.0	46.0
Camel exports (nos) (,000)	15.3	33.0	92.9	44.6	61.4	97.4	50.9	61.0	35.7	n.r.
Cattle exports (nos.) (,000)	10.1	3.0	2.9	0.01	0.2	0	1.9	0.3	0	n.r.
Goat exports (nos.) (,000)	57.2	6.6	51.4	20.0	5.1	0.1	19.8	51.3	50.0	n.r.
Sheep exports (nos.) (,000)	1187.8	1050.4	1181.9	1389.0	583.6	6.6	1576.9	1351.7	1400.0	n.r.
Meat exports** (,000 mt)	13.4	11.8	14.7	9.7	8.6	6.5	8.4	8.1	1.3	n.r.
Hides and skins exports (Mt)	3486	1460	1116	236	4210	3738	3874	4063	5598	n.r.
Milk equivalent imports (,000 mt)	19.1	37.8	45.1	44.3	43.5	70.1	86.9	66.1	92.1	n.r.

Source: FAO Database 2005; n.r. = no record
*In 2004 total milk production comprised cow milk 3.3 M tonnes; goat milk 1.3 M tonnes; sheep milk 465,000 tonnes and camel milk 82,250 tonnes
**Meat exports comprise: beef and veal, mutton and lamb, and goat (mutton and lamb comprise 75%)

1.4 Farming Sector

Land tenure is a critical issue for both cultivated areas and grazing lands. In the past the tribe, the principle unit of social organization, had the responsibility for allocation of land for various uses within the boundaries of the tribal domain (dar). In 1903 the Land Acquisition Ordinance gave the government powers to acquire land for irrigation schemes and other public purposes (Craig, 1991). Following this the 1905 Land Settlement Ordinance made general provision for the settlement and registration of claims to lands known to be waste, forest or unoccupied; such lands should be deemed the property of government unless claims to the contrary were proven. The two ordinances were then consolidated with others in the 1925 Land Settlement and Registration Ordinance. The 1970 Unregistered Land Act introduced an important modification by stating that any land, occupied or unoccupied, which had not been registered before the commencement of the Act should be the property of the government. This Act, together with the abolition of the traditional tribal institutions, has worked to the detriment of rangelands, with the loss of the controlling authority and traditional regulation of use.

More recently, and with the establishment of the federal system of government, arrangements are being made for the division of land and resources between the federal and state governments.

Although privately owned (registered) lands are not affected by the various acts, they are subject to continuous fragmentation due to the Islamic inheritance law.

Agricultural holding size varies according to the region and system of production: in the Gezira Scheme the size of tenancy is about 12 ha, while it is 6 ha. in the new Halfa Scheme; in Kuku Dairy Project in Khartoum State the tenancy is about 4 ha., while the average holding for vegetable growers in the same state is around 1.5 ha. and along the banks of the Nile freehold land may vary from less than 0.5 ha to a few ha.; in the mechanized farming areas the size of holding is around 400 ha., while in the traditional rain-fed areas a holding may vary from 2-30 ha. (Craig, 1991).

2. SOILS AND TOPOGRAPHY

2.1 Major Topographic Features

Sudan consists mostly of flat or undulating plains and low lying plateaux; throughout the central part of the country small rocky hills protrude from the superficial deposits that form the plains. In some cases hills are grouped in large masses such as the Nuba Mountains and the Ingessans Hills; the Imatong and Dongotona Mountains in the south rise to 3000 m. or more. The Red Sea area is composed of a narrow coastal plain 20 to 50 km. wide with the Red Sea Hills running parallel to the coast and rising to 1500 m., with a plateau to the west of about 1000 m. elevation. Jabel Marra in western Sudan is a volcanic area that rises to more than 3000 m. and is the highest peak in the country; this area has a distinctive climate which, in combination with the local soils, has generated specialized agricultural and forestry production systems which differ from other parts of the country.

2.2 Major Soil Types

The country is characterized by variable soil types, which reflect the broad climatic zonation of the country and the modifying effects of local factors such as topography and parent material. Soil types (Harrison and Jackson; Craig, 1991) include:

Yermosols: common in the desert and semi-desert zones where rainfall is generally less than 200 mm/annum; mostly produced under conditions of desert erosion; three distinct groups:

- skeletal soils of eroded desert mountains;
- gravel (pavement) where the topsoil has been blown away leaving a layer of flat polished gravel, and
- wind blown sands.

Arenosols: stabilised dune sands cover large areas in western Sudan and are also known as 'Qoz'; they were formed in a period of drier climate during the Quaternary Era and were stabilised by vegetation under favourable moisture conditions; still stable in areas where burning, overgrazing, tree clearance and irrational cultivation have not destroyed the vegetation cover.

The 'Qoz' sands are coarse-textured, buff to red in colour becoming paler with depth with a low cation exchange capacity; profile is generally structureless and pH ranges from 5 to 9; content of organic matter and mineral nutrients is naturally low; characterized by high permeability to water and relatively high water availability during the dry season (which is why, under the same rainfall regime, the Qoz supports better perennial vegetation than heavy cracking clays). The Qoz sands are highly susceptible to erosion by wind and water; are easy to cultivate using hand tools hence most of the traditional production activities are practised on these soils. Long years of cultivation exhaust these soils causing a sharp drop in fertility and declining productivity; important wet season grazing areas as they are free from biting insects and muddy conditions that encourage hoof diseases among livestock.

Within areas dominated by stabilised sands a non-cracking type of clay soil known locally as 'Gardud' occurs; this has better potential for retaining water and nutrients and under natural conditions they are compacted and have low infiltration, thus most rain water is lost as runoff; 'Gardud' soils are difficult to cultivate using traditional hand tools and therefore are mostly untouched by cultivators.

Vertisols: dark cracking clays, which are often refered to as black cotton soils; mostly alluvial in origin from material transported by the Blue and White Nile, but some might have been formed in situ from basaltic rocks, such as the cracking clays of Gedarif State. These soils are characterized by clay contents of 60% or more, are alkaline in pH and have gypsum and calcium carbonate concretions, particularly in the lower horizons. Areas with Vertisols have impeded drainage and their vegetation is the result of edaphic rather than climatic factors. Vertisols support mechanized farming as well all large scale irrigated farming. Although areas like the Butana plains are used for wet season grazing, most lands covered with heavy cracking clays are utilized for grazing after the rainy season and are important for the supply of crop residues, particularly sorghum stovers.

Nitosols: reddish-brown tropical soils with agrillic horizons and some organic matter, mainly occurring in the hilly areas with dense bushland in southeastern Sudan.

Ferralsols: red tropical soils with organic topsoils over oxic subsoils in the southwestern part of the country on the Nile-Congo watershed divide; reddish sandy loams overlying a layer of more consolidated ironstone; in some cases the topsoil is completely eroded to form a flat ironstone pavement; slightly acid to neutral (pH 5-7) and of relatively low fertility.

Fluvisols: soils of recent alluvium located along the Nile and its tributaries, along major water courses and inland deltas of the Gash and Tokar; prime agricultural land for basin, flood and pump irrigation.

Hill soils: various types occur and they owe their origin to hill and mountain formations; some, such as the soils of Jabel Marra, are derived from volcanic rocks and are of reasonable fertility and physical characteristics.

3. CLIMATE AND AGRO-ECOLOGICAL ZONES

3.1 Climate

The size of the country and the fact that it stretches from 4^0 to 22^0 north, the presence of the Red Sea and the occurrence of various mountains means that the country experiences a wide range of climatic conditions. The major contrasts in rainfall and humidity result in distinct climatic types (with different agricultural crops and production systems; Craig, 1991): these range from desert in the north to arid Mediterranean along the Red Sea; to tropical arid and semi-arid with a short summer rainy season in the central parts to tropical sub-humid with a progressively longer wet season in the south and south west. The winter rainfall together with the high humidity of the Red Sea makes the coastal area a distinct climatic type and the Jabel Marra mountain range (+ 3000 m) in western Sudan enjoys much higher rainfall (1000 mm annum) than the surrounding low land and may even experience freezing temperature during winter.

In the past 38 years rainfall in the Sudan has shown a very high variability north of latitude 14^0 N with limited variability to the south.

In common with other parts of the Sahelian zone there has been a major recent decline in annual rainfall and an increase in periods of drought in the Sudan; drought can be widespread over the country or localized. From 1961-1998 two widespread periods of drought occurred, in 1967-1973 and 1980-1984; the latter was more severe than the former. The same period witnessed a series of localized droughts during 1987, 1989, 1990, 1991 and 1993 in different parts of the country but mainly in western Sudan (HCENR, 199). All had adverse effects on vegetation resources, man (displacement and famine), livestock and agricultural production systems.

Floods also have similar adverse effects; these can be localized resulting from exceptionally heavy rainfall and runoff (flash floods) or floods associated with the overflow of the river Nile and its tributaries, or seasonal rivers such as the Gash. Most are unpredictable, but some of the rivers are monitored; thus the Ministry of Irrigation and Water Resources monitors the Blue Nile once it enters Sudan.

Mean annual temperature varies between 26-32^0C except for the highlands of the Imatonge in the extreme south (Negishot 18.1^0C) Jabel Marra in the west (Nierteti 22.6^0C) and the Red Sea mountains (Erkowit 22.8^0C). The highest temperature on record was 49.1^oC in Dongola in June 1978 and the lowest was –1^0C in Zalingei (Jabel Marra) in December 1961 and January 1962 (HCENR, 1999).

3.2 Agro-ecological Zones

The ecological zones of the Sudan according to Harrison and Jackson (1958) are shown in Table 3.

3.3 Major Agricultural Enterprises in Each Zone

(i) Desert zone: irrigated agriculture is practised along the banks of the River Nile and Atbara River and on the neighbouring lands where irrigation water is conveyed by canals; mainly small privately owned plots, cooperative agricultural schemes, semi-governmental as well as privately owned schemes growing field crops, vegetables, spices and fruit trees. Different systems of irrigation include:

Table 3. Ecological Zones of the Sudan*

Zone	% of Sudan area	Mean annual rainfall (mm)	Wet season	Dry season	Main land use types
Desert	28.9	<75	July to September	October to June	• Irrigated agriculture • Grazing along seasonal water courses
Semi-desert	19.6	75-300	July-September-November-January	November-June March-September	• Irrigated agriculture • Dry land farming in conjunction with water harvesting-Pastoral
Low rainfall savanna	27.6	300-800	May-September	November-April	• Irrigated agriculture • Rain-fed traditional cultivation • Mechanized farming • Pastoral • Forestry
High rainfall savanna	13.8	800-1500	April-October	December-February	• Rain-fed traditional cultivation • Mechanized farming • Pastoral • Forestry
Flood region	9.8	600-1000	May-October	December-April	• Traditional cultivation • Pastoral • Wild life
Mountain vegetation	0.3	300-1000	Variable	Variable	• Traditional cultivation • Pastoral • Forestry – Horticulture

* Source: Harrison and Jackson 1958.

- basin irrigation depending on diversion of Nile water during flood periods; crops are then grown utilizing residual moisture stored in the soil; crops include faba bean, field bean, maize, lablab, vegetables;

- water pumped from the Nile and conveyed by canals to irrigate fields where crops such as cotton, sorghum, wheat, beans, spices, alfalfa, sorghum, fruit trees and vegetables, are grown;

- water pumped from ground acquifers and conveyed by canals or modern irrigation systems (drip or central pivot) to fruit trees, vegetables and field crops.

Grazing is limited to seasonal watercourses and low-lying areas following the sporadic variable showers.

(ii) Semi-desert Zone: This zone has rainfall <300 mm/annum hence rain-fed cultivation is limited to traditional farming on the 'Qoz' sand (mainly millet) and areas with higher clay content where runoff harvesting is practised to grow sorghum. Irrigated agriculture utilizing water from the Blue Nile, the White Nile and Atbara River is practised on large scale schemes, e.g. Gezira, New Halfa, Guneid and White Nile Agricultural Corporation schemes. Water flows by gravity from dams or is pumped directly to irrigate fields where crops such as cotton, sorghum, wheat, groundnuts, sugar cane, fodder crops and vegetables are grown. Flood irrigation, utilizing seasonal rivers such as the Gash and Baraka, is practised in Kassala and the Red Sea states. Gates, bunds and canals are used to direct water flow to farmland which is subsequently cultivated with crops such as millet, sorghum, cotton, groundnuts and vegetables.

(iii) Low Rainfall Savanna Zone: hosts irrigated agriculture as the large scale schemes such as Gezira extend south into this Zone. Other large irrigated blocks include El-Suki, El-Rahad, Blue Nile Agricultural Corporation, White Nile Agricultural Corporation and the large scale sugar cane plantations of Kenana, Asalaya and West Sennar. Traditional farming on clay soils produces sorghum and sesame while on sandy soil millet, sesame, groundnuts, roselle and water melon grow. This Zone is also the major producer of gum Arabic from *Acacia senegal* trees. Mechanized farming is practised, particularly towards the southern part of the zone; this is mostly large scale commercial rain-fed cultivation where cultural operations are partially or totally mechanized; production units are 400 ha in size and main crops grown include sorghum, cotton, sesame and lately guar has been introduced.

Pastoralism is a major type of land use in this Zone where pastoralists practice seasonal movements with their livestock between wet and dry season grazing lands.

(iv) High Rainfall Savanna: traditional cultivation, mechanized farming and postoralism are practised, as in the Low Rainfall Savanna Zone, however, in the higher rainfall areas in the south west two crops may be produced per year due to the bimodal nature of the rainfall. Forestry is an important activity producing fuelwood and wood for local industries.

(v) The flood plain: is also known as the Sudd, where the land is flooded to different degrees and for variable periods; is one of the largest fresh water swamps in the world. The conditions of the Sudd environment make transhumant pastoralism inevitable and has given rise to a mixed economy of herding, traditional cultivation, fishing and hunting. Main crops grown are maize, sorghum, cowpeas, tobacco and pumpkins.

(vi) Mountains: Jabel Marra is the area utilized for agricultural production on a reasonable scale; important for horticultural production e.g. citrus, mangoes, potatoes, other vegetables and field crops such as wheat and sorghum, and timber.

4. RUMINANT LIVESTOCK PRODUCTION SYSTEMS

4.1 Scale of Enterprise

In the Sudan livestock are raised mainly by pastoral and agro-pastoral groups, with the former dependent on livestock and the latter on both livestock and cultivation. The herd size may vary from below fifty head to a few thousands per household. Pastoral herds are mainly semi-nomadic, as is the case in western Sudan and southern Blue Nile where traditional movements occur between wet and dry season grazing areas. The wet season range is an attrative grazing area during the rainy season due to the availability of both pastures and water and because of the unfavourable conditions (mud and biting insects) in the dry season grazing areas.

In the Butana (central eastern Sudan) the household economy is based on an agro-pastoralist system of production where both livestock (goats, sheep, cattle and camels) and crop production (sorghum) are practiced (Babiker, 1997). The geographical location within this important grazing area, and pastoralist mobility patterns, determine the proportion in the herd of each animal type as well as the relative importance of livestock production and cultivation in the household economy (Babiker, 1997). This differs from pastoral production systems in western Sudan where tribes are specialised camel owners (Abbala) or cattle owners (Baggara) and the limited cultivation practised is to meet all or part of the household grain requirement.

The Nilotic tribes of the high rainfall Savanna and sub-humid southern Sudan are cattle raising agro-pastoralists. Their herds experience limited seasonal movements; they spend the wet season near their permanent base where they cultivate crops such as sorghum, maize and groundnuts and herds are kept in the vicinity to provide milk to the household. In the dry season males of the household move with the herd to utilize available pasture near the Nile and perennial water courses and some of the large islands along the Nile.

Systems range from those in southern Sudan that sell a few head of cattle to full commercial sales by pastoralists, agro-pastoralists and commercial producers in the north. Income from the sale of livestock is used to meet household food requirements, market goods, drugs, vaccines, salt, feeds and pay water fees and tax (El-Sammani et al, 1996). Small scale livestock raising is another traditional village-based system where a few head of goats, sheep or cattle may be kept, with goats generally being more common than other types of livestock. Grazing of range, fallow land and along irrigation canals plus house waste and crop residues are the main sources of feed.

Commercial operations include:

- commercial herds that utilize natural pastures on a year round basis with water being transported by tankers or available from privately developed watering facilities to meet dry season requirements. Sheep are the most important type of livestock in this system and supplementary feed may be provided.
- commercial herds that utilize natural pastures in wet season grazing areas then return to irrigated land to utilize crop stubble and residues. Cattle and sheep are the most important types of livestock in this system and limited supplementary feed may be provided during the dry season.

- fattening operations near urban centres utilize weaned calves and young bulls from traditional production areas, which are subsequently marketed. Feed consists of:
    - a mix of crop residues, urea and molasses;
    - cottonseed cake, sorghum grains or wheat bran and salt;
    - processed concentrates.
- commercial herds (cattle and sheep) kept in irrigated land and fed forage sorghum and alfalfa.
- modern dairy farms where irrigated fodder (forage sorghum, maize, alfalfa and Rhodes grass) and concentrates are used.
- small-scale dairy units where cattle are kept in a courtyard or fenced site and fed purchased fodder plus concentrates; common around urban centres.
- Commercial ranching as practised in USA and some African countries has not been tried in the Sudan in spite of the various studies carried out. Generally, experience has been with group ranching initiated by a government department, or a project. The Rural Development Department took the initiative to establish group ranches in Kordofan, but had very limited success in the north and failed in the west. The top-down approach, little if any participation of target communities in the planning and implementation of the trial, and lack of clear objectives and strategy to manage and develop range resources were among the main reasons for the collapse.

The Western Savanna Development Project initiated a trial in southern Darfur to settle pastoralists and reduce the need for herd mobility, through the establishment of group ranches of 4 or 5 km^2 in selected sites. Beneficiary communities participated in all operations, including: fencing, reseeding and protection from intrusion. A local act was issued to regulate and control the use of these ranches, which included the need for payment of nominal fees for maintenance and services (A.M. Taher, personal communication).

A more viable and practical approach to group grazing allotments, initiated by the Range and Pasture Administration (RPA) and expanded by the Area Development Scheme (ADS) project, is the delineation and development of unfenced grazing perimeters with the consensus and active participation of the local communities. RPA advises these communities and provides technical guidance, while the community protect, improve and control the utilization of the site. This trial offers a less costly and more socially acceptable approach to grazing management in settled communities. There is also a need to develop a suitable model that can be adopted by semi-nomadic pastoralists.

4.2 Feeding System

Free grazing of rangelands is the most common feeding system for livestock. During the short wet season grasses grow and mature rapidly producing abundant biomass. The body condition of the grazing animal is at its best during this period, but with the onset of the dry season both quantity and quality of the pasture herbage decline and fail to meet the maintenance requirement of grazing animals. In western Kordofan, where dry season grazing is composed mainly of *Cenchrus biflorus* and *Eragrostis tremula* the crude protein content of the natural forage is about 3.4%, much below the minimum required for maintenance (Jaddalla, 1994). The nutritional inadequacy of the dry season grazing imposes a major constraint on sustainable livestock production under traditional systems where grazing constitutes the only source of feed for livestock.

The non-availability of forage during the dry season affects sedentary livestock more, as they lack the advantage of mobility excercised in the transhumant and nomadic systems.

The past few years have witnessed an increase in supplementation of natural forage grazing, by collection and storage of hay, utilization of crop residues and agro-industrial by-products and irrigated fodder. The role of fodder trees and shrubs (*Acacia*, *Cadaba*, *Maerua* etc) as a dry season source of feed (pods, leaves and twigs) should not be under-estimated. They are particularly valuable in the Semi-desert and Low Rainfall Savanna zones.

The cut-and-carry feeding system is associated with small scale irrigated farms (<1-5 ha) where fodder crops (sorghum and alfalfa) are harvested to feed farm animals. Surplus green fodder is sold in nearby towns and villages to other livestock owners. Weeds and crop residues may also contribute to livestock feed in these farms.

In large scale dairy farms irrigated fodder crops such as sorghum, alfalfa and limited areas of maize, Rhodes grass, *clitoria* and lablab are produced. Mechanical harvesting (chopping) and hand cutting are both practised and green fodder is fed to the dairy herd, while any surplus may be made into hay which is baled and stored. Locally made concentrates or processed feeds are also fed to maintain high milk yield.

Crop residues are available from irrigated as well as dry land crops. They include cereal straws and stovers (wheat, sorghum, millet, maize), cereal stubble, legume haulms (groundnuts, cowpea, lablab) sugar cane tops and baggasse, and water melon residues. Agro-industrial by-products include molasses, oil seed cakes (cotton, groundnuts, sesame, sunflower), grains and by-products of cereal milling (bran). The crop residues are a strategic source of feed for livestock during the dry season, with a part grazed in situ and part transported and stored for subsequent use. However, transportation of these bulky materials of low nutritive value is a major constraint to their large scale utilization.

4.3 Integration of Livestock into Farming Systems

Traditionally most farmers, whether in irrigated or dry land farming areas, keep some kind(s) of livestock; the animals benefit from crop residues, weeds and in a few cases grown fodder crops. Hence the link between crops and livestock exists and can be developed further to increase the integration and efficiency of production systems. At present the problems that hinder larger scale integration are two fold: firstly, there is the inherent divorce between crops and animal production in the crop rotations of the mechanized farming areas (about 8 million ha) and in the major irrigated schemes of Gezira, Rahad and New Halfa (about 1.5 million ha.); and secondly, integration of livestock into farming systems is not always viewed as a complete package of socio-economic and technical factors and supporting services that should be designed and implemented in close collaboration with the target producers.

Introduction of livestock into the crop rotations of the Gezira, the largest irrigated agriculture scheme in Sudan (more than one million ha), has been attempted with the following objectives;

- ensure a source of good quality feed on an annual basis by allocating part of the rotation land to production of fodder crops, hence leading to stability of animal production within the scheme;
- grow leguminous fodder crops which fix nitrogen, with a positive impact on the soil and crops that follow in the rotation;

- improve the socio-economic conditions and nutrition of farm households;
- improve livestock types and veterinary services;
- ensure the supply of neighbouring towns with milk, milk products and other animal products (Darrag et al. 1995).

Problems faced included:

- not all farmers own livestock hence attempts were made to provide some farmers with two heads of cattle;
- 77% of the area devoted to fodder crops was allocated to forage sorghum, cv. 'Abu Sabeen' and cv. Pioneer, both of which add to soil exhaustion as the rotation includes grain sorghum and wheat;
- Good quality seed of leguminous fodders such as philipesara and lablab was not always available.

Integration of livestock in mechanized farming schemes in southern Kordofan, southern Kosti and Gedaref has recently been attempted by some owners through their own initiatives. Livestock graze during the wet season in communal areas then after crop harvest return to the scheme to utilize crop residues, chaff and other materials produced after screening of grains (Hassan, 1995). Most owners have established their own dugouts (Hafir) to provide water during the dry season. This constructive step on the part of owners has not been supported by evaluation, research and extension and marketing efforts from the concerned institutions.

Studies of the performance of grain and forage legumes under Agadi conditions (700 mm/annum) were attempted by RPA in 1974 as a step to the introduction of livestock in mechanized farming areas. Fodder plus crop residues, chaff and broken grains would form the source of feed for livestock. The trial indicated that pillipesara (*Vigna trilobata*/*Phaseolus trilobus*) velvet bean (*Stizolobium deeringianum*), Clitoria (*Clitoria ternatea*), lubia (*Lablab purpureus*) and green gram (*Phaseolus aureus*) produced 12.0, 8.5, 6.5, 5.0 and 4.0 ton green material per feddan (one feddan = 0.42 ha) from one cutting which compares favourably with their production under irrigation. Unfortunately this work was not pursued long enough to generate reliable data and develop extension packages that could be adopted by owners of mechanized schemes.

4.4 Limitations

- Biting insects are common during the wet season in the southern parts of the Low Rainfall Savanna and the High Rainfall Savanna, forcing pastoralists to move with their herds to drier areas, areas with sandy soils and higher ground where conditions are not conducive to the multiplication of the biting insects.

- Diseases of potential economic importance are Rinderpest, Haemorrhagic Septicaemia, Contagious Bovine Pleuro-pneumonia, Blackquarter, Anthrax, Trypanosomiasis, Foot and Mouth, Tuberculosis, Brucellosis, Helminthiasis, Sheep Pox, Heart Water and internal parasites. The livestock disease problem is complicated by the vast area of the country and the fact that it is bordered by nine countries. Livestock cross borders to four or five of these countries in search of grazing and water with the possibility of communicating serious diseases into the country; plans to establish border animal health check points are underway (Dept. of Animal Wealth, 1995).

- In the past animal health services were adequately organized, sufficiently supplied and reasonably operated, meeting the national herd requirements. From the mid-eighties and for various reasons these services declined and then witnessed a degree of collapse. This is attributed to the liberalization of the economy and the sudden shift from completely government sponsored to private veterinary services provided at market price (El-Sammani et al, 1996).

- A high rate of mortality prevails, particularly among young stock; this is especially true during periods of feed deficits when females are subjected to nutritional stress with the result that milk yield become low and no longer meets young animal requirements. Some sources estimate thst the overall mortality due to diseases and mal-nutrition is as high as 15% of adult and 25% of young stock. Drought periods result in higher rates of mortality (World Bank, 1993).

- Acess to improved bulls and AI services is limited to dairy herds and livestock in the vicinity of animal production research stations. These services are declining as the number and scope of activities of these stations have been cut.

- Stock water is a limitation during the dry season, particularly in areas underlain by Basement Complex rocks (non-water bearing rocks) as is the case of Butana, Hamar District, Baja and eastern Darfur. All these areas are important grazing lands where pastoralism is a major economic activity. Most pastoralists utilize these areas as wet season grazing land and move out before the surface water in natural ponds and dugouts is exhausted. In places boreholes have been drilled through cracks in the Basement Complex rocks and they furnish a limited source of water. The expansion of irrigated agriculture in the Butana (New Halfa and Rahad schemes) provides additional sources of water through the network of canals that supply crop land with irrigation water. In a few cases water is transported by tankers to meet commercial herd requirements during the dry seasons, so that livestock will be able to utilize the large quantities of dry grass available in water deficient areas.

- Some well intentioned campaigns to provide water, launched by the government and assisted by the international community in the mid-sixties and early seventies, have had some negative impacts on the environment and resources. Water was provided to meet human and livestock requirements without giving sufficient consideration to the sustainability of other resources in the areas; the result has been that more people and livestock have been attracted to these sources of water causing over-utilization of trees and grazing resources and land degradation (Zaroug, 1996).

4.5 Socio-economic Limitations

- Services geared towards pastoralists such as education, health, extension and awareness programmes, water provision in terms of both quantity and quality, and animal health services, are in general poor. The situation has been accentuated by the sudden lifting of government subsidies and the application of a self-reliance policy (El-Sammani et al, 1996).

- In southern Sudan security problems have forced some of the pastoralists to cross the borders with their livestock into Uganda; some of their herds have developed serious disease problems, which have been introduced into the Equatoria Region of Sudan. Others moved to the suburbs of Juba town causing serious land and vegetation cover degradation. Similarly and as a result of the deteriorating security situation in southern Kordofan some stock routes have been closed concentrating livestock and grazing pressure in limited areas,

resulting in over-use of the range and the spread of livestock diseases. Field observations in southern Darfur State revealed that Taisha and Beni-Helba pastoralists spend more than 6 months annually with their livestock in the Central African Republic; they pay different fees during their stay and their livestock are exposed to serious diseases.

- In the early seventies, as mentioned above, two government actions resulted in far reaching negative impacts on pastoralism and pastoral resources; these were the abolition of traditional institutions (tribal administration system) and the announcement that all unregistered land belongs to the government. As a consequence the following took place:

- a large influx of herds and farmers, who had no traditional right of access to tribal land for grazing and traditional cultivation, with serious consequences in terms of vegetation cover destruction and land degradation;
- intrusion of other uses such as dryland farming both traditional and mechanized onto rangelands;
- intensified competition for available grazing;
- pastoralists were pushed to marginal areas which were subject to more frequent drought. These actions as well as the political, socio-economic and environmental changes that took place, and the complexity of the traditional tenure system in pastoral areas, necessitates a review of the present status of land tenure and grazing rights with a view to formulating acceptable systems that take into account present day realities and meet the needs of pastoral groups.

Some government policies, particularly agricultural policies and those that encourage investment in the rain-fed sub-sector, pricing policies and different types of fees, have some negative effects on the pastoral sector; some have been identified and are being modified while others still require review to remedy their adverse impacts and to avoid further damage to the sector (Zaroug, 1996).

5.THE PASTURE RESOURCE

5.1 Description

Rangelands form an immense natural resource and the major source of feed for the national herd. The various types of grazing land vary from open grasslands to seasonal water courses, flood plains, river banks and associated islands, woodlands, hills and mountain slopes. The following description is based on the work of Harrison and Jackson (1958):

Desert Zone grazing lands consist of ephemeral herbs and grasses confined to water courses and flat low lying areas that receive runoff. The valuable ‘Gizzu’ grazing (succulent plants) is part of this zone and supports sheep and camels during the cool season without the need for drinking water.

The Semi-desert Zone grazing lands are of three main types:

- the Red Sea coast and associated hills with winter rainfall;
- range vegetation supported by sandy soils west of the White Nile and in northern Kordofan and Darfur, and
- range vegetation supported by clay soils mainly in the Butana area. Trees and shrubs provide livestock feed in the form of leaves and twigs and pods most valued during the long dry season when forage from grasses is both scarce and of low quality. Important among these woody species are *Acacia ehrenbergiana, A. tortilis* sub-species *tortilis* and sub-species *raddiana*, *Capparis decidua*, *Maerua crassifolia*,

Salvadora persica and *Ziziphus spina-christi*. Grasses include *Aristida* spp, *Schoenefeldia gracilis*, *Eragrostis* spp., *Cenchrus setigerus*, *Cymbopogon proximus*, *Lasiurus hirsutus* and *Panicum turgidum*.

The **Low Rainfall Savanna** grazing lands occur both on the undulating sandy soils of western Sudan and the dark cracking clays of central and eastern Sudan; in general the northern parts are wet season grazing while the southern parts, where water is available, are dry season grazing lands. Depending on soil type and annual rainfall, major species in this Zone are: *Acacia mellifera*, *A. senegal*, *A. seyal*, *Balanites aegyptiaca*, *Cadaba rotundifolia*, *Combretum* and the grasses *Aristida* species, *Brachiaria obtusiflora*, *Cenchrus biflorus*, *C. ciliaris*, *Cymbopogon nervatus*, *Eragrostis, Schoenefeldia gracilis*, *Pennisetum pedicellatum*, *Setaria pallide-fusca Chloris pilosa* and *Andropogon gayanus*. Among the important herbs are *Blepharis* spp, *Crotalaria* spp and *Zornia diphylla*.

In the **High Rainfall Savanna** important grasses are: *Hyparrhenia* spp, *Andropogon gayanus, Setaria*, *Brachiaria brizantha*, *Chloris gayana* and *Sporobolus pyramidalis*. Flooded areas have species such as *Echinochloa stagnina*, *Hyparrhenia rufa* and *Oryza,* that withstand some degree of inundation.

5.2 Fodder Crops

Fodder crops are grown primarily under irrigation to feed dairy cattle, small ruminants and draught animals, and a good part of the production is channeled to the local market where it is sold as green fodder. Total area is estimated at about 126, 000 ha, with almost half in Khartoum State (Zaroug et al, 1997); this area is expanding with the increased attention given to dairy production, particularly around urban centres. Normally 80-90% of the area allocated to fodder crops is devoted to annuals, mainly forage sorghum cv. 'Abu Sabeen', with limited areas under maize and lablab; the remaining area is occupied by alfalfa, the major perennial fodder.

Buffel grass, Rhodes grass, elephent grass, para grass, panicum and clitoria have been utilized to establish irrigated pastures, especially in animal production schemes and on livestock research stations. Growing fodder crops between rows of fruit trees is practised on a limited scale; crops grown are mainly alfalfa, but clitoria, pillipesara and lablab have also been tried with the aim of improving soil fertility, controlling weeds and producing good quality fodder.

5.3 Forage Species Seed Production

Quality seed of improved varieties is an essential input for fodder crop production and pasture establishment and production and collection of forage species seed is undertaken for:

- rehabilitation of degraded rangeland;
- introduction of forage legumes in fallow land or in rotation with other crops, and
- enhancing fodder crop production in order to improve animal production systems (Zaroug et al, 1997).

Production of seed and vegetative cuttings of forage species was an important activity of RPA through its nurseries, specialized seed farms and animal production research stations.

The seed of various native species has been collected in several states to meet the requirements of local range re-seeding operations and to provide a surplus which is channeled to other states (Table 4). This opportunistic harvesting of seed from improved pasture or natural grasslands is still practiced, but to a more limited extent, due to lack of sufficient funds to meet the collection costs. Fodder crop seed production is mainly undertaken by farmers, especially in Nahr En-Nil and Northern State, and farmers with small holdings play a crucial role in the informal seed supply system.

Table 4. Species Included in Seed Collection Campaigns*

Species	Origin	State of collection
Andropogon gayanus	Local	Kordofan
Aristida spp	Local	Kordofan
Blepharis edulis	Local	Kassala
Blepharis linariifolia	Local	Darfur/ Kordofan
Brachiaria	Local	Darfur
Cenchrus ciliaris	Introduced/local	Kassala
C. setigerus	Local	Kassala
Cajanus cajan	Local	Darfur
Chloris gayana	Introduced	Kassala
Crotalaria senegalensis	Local	Kassala
Chloris virgata	Local	Darfur
Clitoria ternatea	Introduced	Darfur
Dactyloctenium aegyptium	Local	Kordofan/ Darfur
Echinocloa colonum	Local	Kordofan
Eragrostis tremula	Local	Kordofan
Ipomoea cordofana	Local	Kassala
Lablab purpureus	Introduced	Darfur
Macroptilium atropurpureum	Introduced	Darfur
Panicum coloratum	Local	Kassala
Rhynchosia memnonia	Local	Kassala
Stylosanthes guianensis	Introduced	Darfur
S. hamata	Introduced	Darfur
S. scabra	Introduced	Darfur

- different sources

The National Seed Administration was involved in the production of seed of the major fodder crops alfalfa and 'Abu Sabeen' as well as Sudan grass, clitoria, lablab, pillipesara and maize; following the re-organization of the Ministry of Agriculture and Forestry these have been transferred to the recently established Arab Sudanese Seed Company.

5.4 Limitations

- lack of data on areas and types of range, seasonal changes, grazing potential and capacities of the different range types is a serious constraint to planning at national level (Dwyer, 1979).

- burning is carried out for several reasons:

- to clean the land for cultivation;
- for regrowth of perennial grasses for grazing animals;
- to bring wild game into the open;
- to drive away bees so that honey can be collected from wild hives.

Fires may also be caused accidently and by natural phenomena.

Uncontrolled burning is a serious threat to rangelands resulting in the consumption of 10-30% of the standing dry forage in different parts of the country; annually a network of fire-breaks of more than 35000 km is established to check the spread of these fires and protect dry grass.

- the expansion of both dryland and irrigated farming has occurred at the expense of range and woodlands, giving insufficient consideration to the importance of these resources to pastoralists and their herds, and without attempting integration of livestock into the developed cropping system, or creating alternative feed sources to compensate for the loss of natural grazing and browse. FAO has estimated that the annual rate of deforestation in the Sudan is approaching five hundred thousand hectares, one of the highest in Africa (FAO Project: Forestry Development in Sudan, 1993). Destruction and removal of vegetation resources by burning or cutting, beside their adverse effects in reducing available natural forage are major factors behind land degradation and desertification.

- there is lack of well-structured and long-term range research in the Sudan; the decline in activities and then collapse of the range research programme of Ghazala Jawazat Range and Livestock Station (GJ) and the termination of the Western Sudan Agricultural Research Project (WSARP) were the last major programmes. While it was operational the GJ research programme concentrated on on-station trials (Dwyer, 1979). Main factors contributing to the institutional weakness of range management/improvement programmes include:

- the lack of incentives and difficult living conditions in remote areas for staff;
- loss of qualified and experienced staff;
- weak linkages between state and federal authorities;
- the lack of overall national policies and strategies.

6. OPPORTUNITIES FOR IMPROVEMENT OF PASTURE RESOURCES

6.1 Rangeland Rehabilitation

Although there are many techniques for rehabilitation of degraded rangeland (seeding methods, soil moisture conservation techniques, water harvesting, water spreading etc.) most are rather costly compared to the likely economic returns; unless sound management is applied and controlled grazing undertaken then rehabilitation efforts may not be sustainable. Particularly important are clear land tenure arrangements that will motivate the beneficiaries to utilize rehabilitated sites in a sustainable manner.

Rangeland rehabilitation by re-seeding with or without fencing is routinely carried out by RPA using locally collected seed of desirable native forage species. Also, FAO and IDA assisted with several rehabilitation trials over the last twenty years. The FAO assisted trial was conducted in the eighties at several locations in the Semi-desert and Low Rainfall Savanna zones following the 1984 drought. Introduced species included *Cenchrus ciliaris*, *C. setigerus*, *Chloris gayana* (varieties Boma, Masaba and Mbrara), *Panicum spp* and *Stylosanthes spp*. However, results were not sufficiently well recorded and the performance of the reseeded species was not monitored over a long enough period to generate reliable results (RPA files). The limited observations available indicated that:

- in Sodari area of Northern Kordofan emergence of the re-seeded introduced species was 30-45%, and native species that grew simultaneously included *Cenchrus biflorus*, *Echinocloa colonum*, and *Dactyloctenium aegyptium*;
- in the Butana area *C. ciliaris* established and reached seed setting stage, *Stylosanthes* reached flowering stage while *C. gayana* grew only vegetatively. Native species that grew simultaneously, such as *Aristida mutabilis*, *C. biflorus*, *Dactyloctenium aegyptium* and *Rhynchosia memnonia*, were in very good condition;
- constraints that hindered the implementation of the trial included late seed delivery towards the end of the wet season and no clear role for the beneficiary communities in protection and management of the site.

The IDA assisted re-seeding trial was conducted in the nineties with a similar philosophy and approach. Species used were similar to the FAO trial with the addition of *Brachiaria ruziziensis*.

6.2 Establishment of Improved Pasture

These have been rather limited in scale and confined to internationally assisted projects or government units; currently no activities. Previous experience:

- MAFAO dairy farm near Juba (1000 mm); programme to establish improved pasture for introduced dairy cattle and their crosses with local types, under FAO executed project. Tropical pasture species were successfully established to provide good quality grazing for the dairy herd. Unfortunately the farm was destroyed during unrest in the area. The pasture enabled reasonable levels of milk production to be maintained.
- some improved pasture establishment efforts, for grazing by local herds, were made in association with water spreading and runoff harvesting trials in Kassala State (Mukram) and in Khartoum State (Abu Zuleig and Wadi El-Hurba). In Khartoum State, *C.ciliaris*, *C. setigerus* and *Vigna trilobata/Phaseolus trilobus* were successfully established using mechanical seeding (wide level disc harrow) and low contour dykes

(45cm). However, without the necessary socio-economic studies to identify managerial and user responsibilites the established pasture did not persist.

- much effort has been made by animal production research stations and projects to establish irrigated pasture for direct grazing; species as *C. ciliaris*, *Chloris gayana*, *Panicum coloratum* and *Clitoria ternatea* were used in pure stands and grass/legume mixtures for direct grazing by sheep or cattle. Surplus forage was harvested and stored as baled hay.

6.3 Integration of Forages into Farming Systems

When integrating forage crops into farming systems the focus should not only be on agronomic aspects of fodder crop production or establishment of improved pastures in the cropping sequence, but on the complete package of socio-economic and technical issues as well as on marketing of both forages and animal products. Work initiated by the Agricultural Research Corporation Forage Resources Programme, by WSARP and earlier by RPA in the mechanized farming areas should be built upon to effectively integrate forages in irrigated, traditional dryland and mechanized farming areas. ARC experimental work at Wad Medani and Hudeiba Research Stations (irrigated agriculture) should be expanded to revive the research programme initiated by WSARP, targeting traditional dryland farming in western Sudan and by RPA in Agadi, targeting mechanized farming. WSARP earlier conducted variety screening trials on local and introduced forage legumes as well as trials of the response to nitrogen and phosphorus. Stylo was introduced in fallow land to improve the soil and produce an additional source of livestock feed. These efforts should be complemented by socio-economic research, livestock management and nutrition and marketing investigations. Based on results obtained and acceptability by producers efforts should be made to make inputs available.

6.4 Tree Legumes

More coordinated efforts are required to research how native and introduced fodder and multi-purpose trees and shrubs can be utilized within farming areas and in rangelands to provide dry season feed and supplement the dry grass with nutritions browse and pods. ARC trials with Leucaena for forage production and fuelwood should be revived and extended to other areas of the country; leucaena can be utilized as an irrigated fodder or as green hedge around farms. This should be coordinated with Forestry Research in agroforestry systems using Sesbania and other fast growing trees. The efforts of the Community-Based Rangeland Rehabilitation for Carbon sequestration and Biodiversity Project, to produce and distribute seedlings of *A. senegal*, *A. albida* and *Ziziphus spina-christi* to be used in establishing windbreaks, rangeland rehabilitation, sand dune fixation, as shade trees and in agro-forestry systems, should be expanded to other zones.

7. RESEARCH AND DEVELOPMENT ORGANIZATIONS AND PERSONNEL

7.1 Key Institutions and Current Research Priorities

The following institutions are involved in forage research and development:

- Range and Pasture Administration - main focus areas include: planning conservation and development programmes, protection of rangelands against brushfires, rehabilitation of degraded rangelands and execution of national and internationally assisted projects.
- Agriculture Research Corporation - this is the lead institution in forage resources research. Present emphasis of the ARC programme is on the introduction of fodder crops in rotations on irrigated agricultural schemes and broadening the base of fodder crops utilized in different agricultural systems.
- Universities of Khartoum, Gezira and Kordofan - involved in teaching, practical training and research on rangelands and fodder crops. Many of the M.Sc. and Ph.D. research projects focus on forage resource problems from an ecological, agronomic, nutritional or economic angle.

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