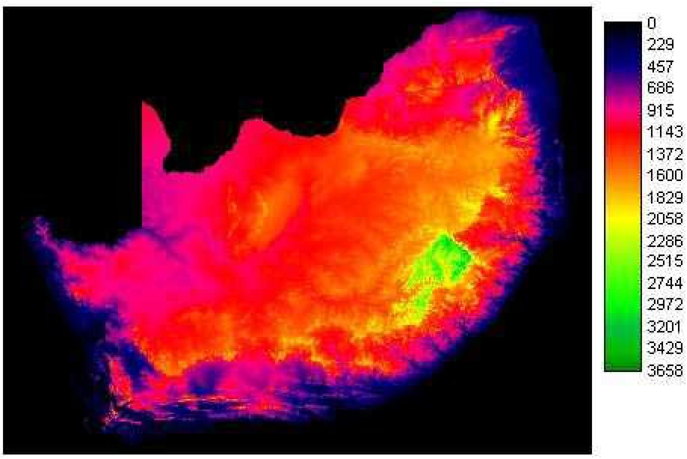
SOUTH AFRICA`S SOILS AND TOPOGRAPHY

Major topographic features

The Great Escarpment and the Drakensberg mountains provide the physical barriers which determine the climate and vegetation of much of the livestock growing regions of South Africa. In geological time, several phases of uplifting, erosion and deposition have created complex landforms determined by the underlying geology.The country comprises five main physiographic regions (Figure 2). The first is the south western fold mountains, which influence the climate and vegetation patterns of the southern Cape. The second is the coastal plain, which extends from the Namibian border, all along the coast to southern Mozambique. This narrow plain between the ocean and the Great Escarpment is the region with the most fertile soils, moderate to high rainfall and where most intensive livestock production occurs. The Great Escarpment, which forms the major barrier to moisture reaching the interior, together with and the central highveld, contains most of the high elevation grasslands. The major urban, mining and agricultural activities take place in the central highveld, which is situated at 1600-1700m. The great karoo basin occurs from 1400-1600m and contains the steppe-type vegetation associated with fertile aridosols of the semi-arid region. The Kalahari region, bordering on Namibia and Botswana, represents a very important extensive livestock producing area. The region is the southern part of the continental scale basin which is covered by sands of varying depth (sometimes >200m). Deep boring technology has enabled commercial graziers to become permanently established in the region, and to optimise livestock production. The vegetation is an arid savanna, with a carrying capacity of 30-40 ha per LSU.



Major soil types

The soils of South Africa have been classified using a hierarchical system (Soil Classification Working Group 1991), and include a large number of soil bodies which range from soil bodies black, smectitic clay on dolerite to yellow, kaolinitic clay on Beaufort sediments. The classification system contains two main levels, SOIL FORM and SOIL FAMILY. There are currently 73 SOIL FORMS, defined by the nature of the topsoil (organic, humic, vertic, melanic or orthic), and numerous diagnostic sub-soil horizons.

The relatively young South African and active geology has given rise to soils of high nutrient status. The Nama-karoo biome of the central regions comprise predominantly mudstones and sandstones of the Karoo Supergroup, which give rise to shallow (<30cm) aridosols, with a calcareous hardpan layer typically in the profile. During the Jurassic age, these sedimentary rocks were intruded by dolerites, which criss-cross the landscape in characteristic dykes. The dolerites contain plagioclase which give rise to soils of high clay content. These features contain many grasses and associated phreatic woody shrubs, and represent refugia for many desirable (to the herbivore) plant species. The dolerite sills and dykes provide summer grazing, whereas the nutrient rich calcareous plains provide abundant, high quality winter forage. The grasslands of the highveld are associated with high nutrient status soils of basalt and dolerite origin.

The savannas of the Mpumalanga Lowveld are associated with the gabbros and granities of the Bushveld igneous complex. The latter give rise to sandy soils of moderate nutrient status. The gabbros give rise to a nutrient rich Mispah rock complex.

In geological time several phases of uplifting, erosion and deposition have created complex landforms determined by the underlying geology. The Cape Fold Mountains and the Lesotho Highlands are the largest surfaces which intrude above the African plane. The Cape Fold Mountains are siliceous rocks, giving rise to immature, litholic soils. The Lesotho Highlands on the other hand are basaltic, giving rise to mollisols (Partridge 1997). The grasslands of the highveld are associated with high nutrient status soils of basalt and andesitic origin.

CLIMATE AND AGRO-ECOLOGICAL ZONES

Climate and drought

With a mean annual rainfall of approximately 450 mm, South Africa is regarded as semi-arid. There is, however, wide regional variation in annual rainfall (Figure 3), from less than 50 mm in the Richtersveld on the border with Namibia, to more than 3000 mm in the mountains of the south western Cape, however only 28% of the country receives more than 600 mm (Table 1). The uncertainty of the rainfall is best expressed by the co-efficient of variation in annual rainfall (Figure 4). The low rainfall regions have the highest co-efficient of variation. Annual rainfall distribution is skewed such that there are more below average than above average rainfall years, and the median is a more meaningful than the mean. The high seasonal variations are accompanied by high spatial variability, and the annual potential evapo-transpiration may exceed annual precipitation by ratios of up to 20:1, hence drought conditions are a common phenomenon (Schulze 1997). The declaration of drought status to a magisterial district has historically been used by the Department of Agriculture & Land Affairs to intervene in exceptional circumstances. Since 1994 this intervention has been discontinued and graziers are encouraged to plan their production system within the long-term production expectations of their farms.

Table 1. Annual rainfall distribution and climatic classification in South Africa

Rainfall (mm)	Classification	Percentage of land surface
<200	Desert	22.8
201-400	Arid	24.6
401-600	Semi-arid	24.6
601-800	Sub-humid	18.5
801-1000	Humid	6.7

<1000	Super-humid	2.8

Source: Schulze 1997

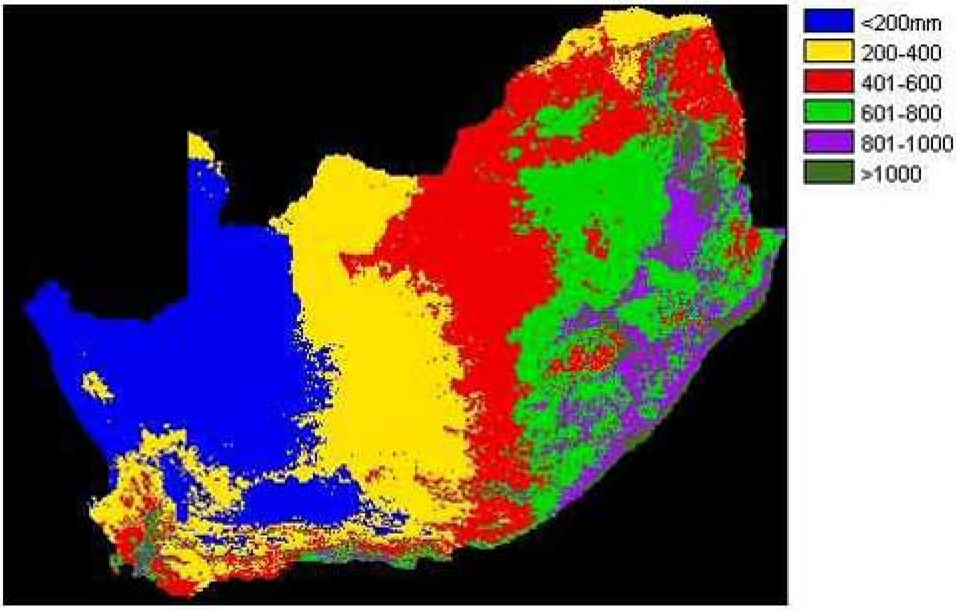


Figure 3. The median annual rainfall for South Africa
(Dent *et al*. 1987)
[Click to view full picture]

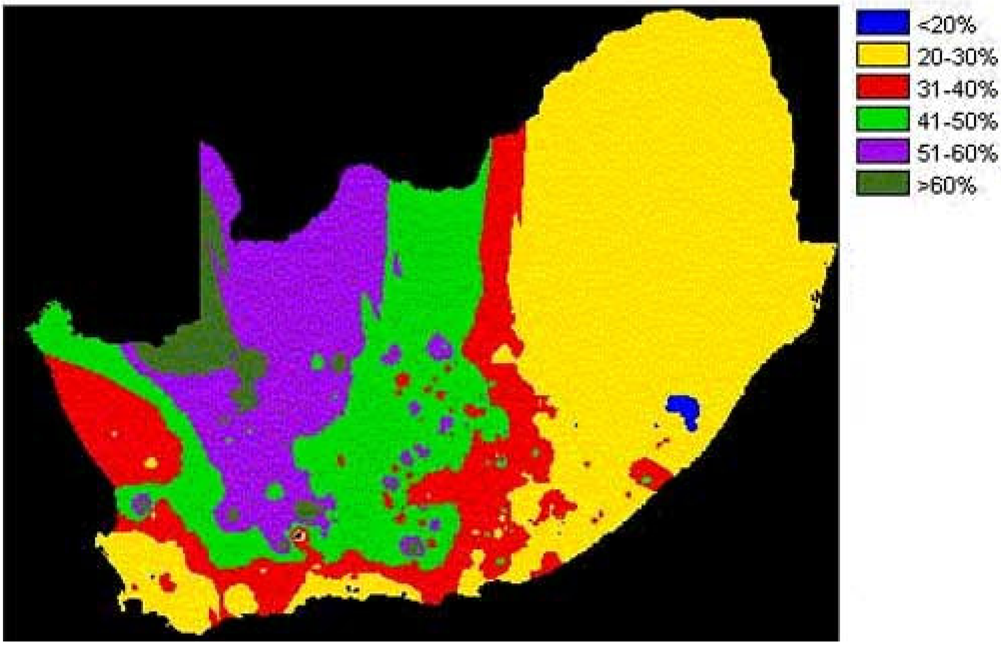


Figure 4. The co-efficient of variation in annual rainfall for South Africa. Derived from the long-term rainfall records (50 years or more data) from 1015 stations.

Seasonality of rainfall

There are three major zones within the country, namely the winter rainfall region of the western, south western and southern Cape; the bimodal rainfall region of the Eastern Cape, and the strong summer seasonality of the central highveld and KwaZulu Natal. The regions with strong summer seasonality are strongly influenced by the inter-tropical convergence which moves southwards during the southern hemisphere summer. The season of rainfall in the south western and southern coastal regions is influenced by the frontal systems developing in the southern Oceans. These frontal systems bring cool, moist air during the winter season (June - August), and promote the development of sclerophyllous and succulent floras. In general, the natural vegetation of these regions is less useful for livestock production. Because of the varying rainfall seasonality, growing periods vary throughout the country. In the north, east and along the coastal belt, summer seasonality encourages C4 grass production and the main focus is cattle and sheep production. In the semi-arid central and western regions C3 grasses and shrubs predominate, and this favours sheep and goat production.

Temperatures

The temperatures in South Africa are strongly determined by elevation and distance from the sea. The high elevation (1500-1700m) inland regions experience warm summer (January) mean daily maximum temperatures (26-28^{o}C) and cool winter (July) mean daily minima (0-2 ^{o}C), with frost during the coolest months (Schulze 1997) . These regions experience occasional snow. The warm Mozambique current on the east coast plays a strong role in ameliorating temperatures along the coastal zone between East London and Mozambique. The northern parts of the coastal zone experience warm winter daily minima (8-10 ^{o}C) and warm summer maxima (32 ^{o}C), and the climate is strongly sub- tropical. The vast interior, represented by the Kalahari basin and the Nama-karoo, experiences a more extreme climate, with low winter mean daily minima (0-2 ^{o}C) and high mean daily summer maxima (32-34^{o}C). The southern and south-western coastal zone experiences moderate winter mean daily minima (6-8 ^{o}C) as a result of the circum-polar westerlies which bring moist, cold air from the southern oceans during June, July and August. The temperatures on the west coast, from Cape Town to Port Nolloth, are influenced by the cold Benghuella current. This arid regions experiences July mean daily minima of 6-8 ^{o}C, but little or no frost, and is able to support a rich succulent flora. The cold ocean current favours the development of fog during the winter months, bringing cold, moist air onto coastal plain.

3.2 Agro-ecological zones and biomes Based on bio-climatic and growth form information, Rutherford & Westfall (1986) defined six biomes in South Africa. An improvement has been suggested by Low & Rebelo (1996), who further sub-divided the savanna biome to include the category "Thicket" which occurs predominantly in the river valleys of the eastern and south eastern coastal region (Figure 5).

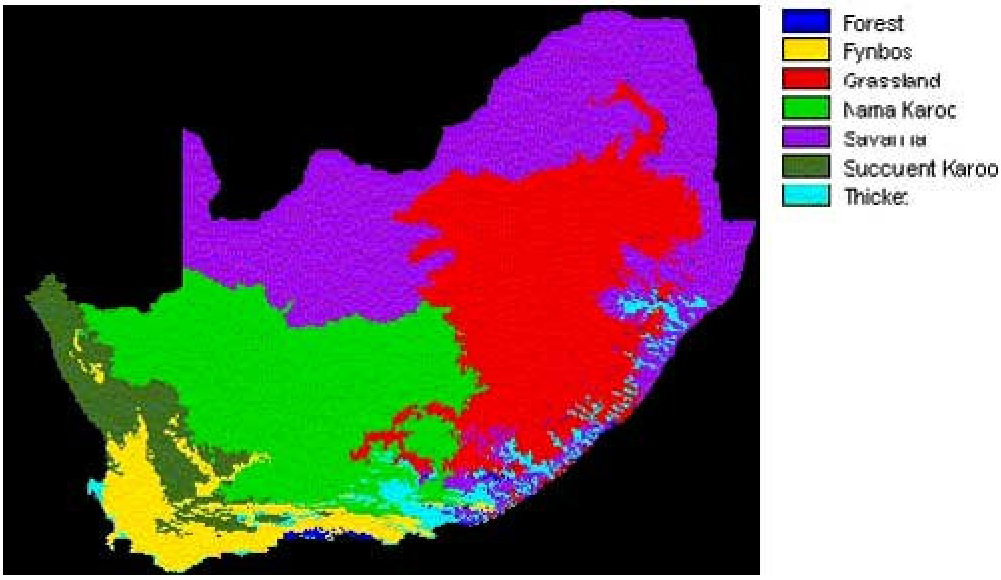


Figure 5. The biomes of South Africa
(After Rutherford & Westfall, 1986 and Low & Rebelo, 1996)
[Click to view full image]

Succulent Karoo

The succulent karoo biome occurs in the winter rainfall regions of the southern and south-western portions of South Africa. The flora of the biome comprises mainly of shrubs (0.5-1.5m) and dwarf shrubs (<0.5m) with succulent leaves and stems. The climate of the region is arid to semi-arid (100-250mm per annum), with a strong winter seasonality. The succulent karoo is well known for its high floristic diversity, part of which is a function of its proximity to the floristically rich adjacent fynbos biome. The biome, with >5000 species in 100 251km^2, has the highest species richness recorded for semi-arid vegetation, and more than 50% of the plant species are endemic to this biome (Milton et al 1997). Some of the areas with high floristic diversity (e.g Richtersveld and Namaqualand) receive a large portion of their precipitation in the form of coastal advective fog during the coolest months of the year. There are many species in two families (i.e. Mesembryanthecaceae and Crassulaceae), several unique taxa (species of the genus *Pachypodium*) and growth forms (leaf and stem succulents). This diversity has made the biome ideal for the development of an eco-tourism industry which promotes the floristic uniqueness of the region. The biome is an important small stock region, where graziers focus on the production of mutton sheep, goats and ostriches.

Nama-karoo

The Nama-karoo biome is the largest of the biomes in South Africa, comprising much of the central and western regions of the country. The biome is dominated by a steppe type vegetation, comprising a mixture of shrubs, dwarf shrubs, and annual and perennial grasses. The biome is associated with the moderate rainfall regions (250-450mm per annum) and is ideal for sheep and goat production. The summer seasonality of the rainfall in the eastern parts of the biome means that there is often abundant grass production during the growing season. Graziers are able to optimize production during this time. In the winter months, the dwarf shrubs maintain their crude protein at around 8%, providing excellent forage. The nutrient-rich substrata provided by the mudstones, sandstones and dolerites mean that this production is sustainable. There were earlier suggestions that large scale structural transformations were taking place in this biome (Acocks 1964), with the dwarf shrubs supposedly spreading into the adjoining grasslands of the central Free State. This process has not continued in the way envisaged, and the relatively high rainfall of the 1990's has promoted grass production in the eastern portions of the biome.

In the western portions of the biome, there are alarming trends in woody encroachment with two species in particular (*Acacia mellifera* and *Rhigozum trichotomum*) thickening up in regions with a long history of domestic herbivory.

Savanna

The savanna biome comprises the northern and eastern portions South Africa, with the arid savanna extending into the southern Kalahari. The flora comprises a woody layer (mainly single-stemmed, seasonally deciduous, trees and shrubs), with a ground layer of grasses and forbs. The standing biomass of shrubs and trees can be in excess of 16 tonnes per hectare. The dominant grasses are C_4 and comprise the important production component for domestic livestock. A strong summer seasonality in the rainfall encourages woody shrub production. There is strong evidence of woody shrub encroachment throughout this and other biomes (Hoffman & O'Connor 1999). A number of explanations have been suggested for the increase in woody shrub biomass, including i) a reduction of fire frequency (Trollope, 1980), ii) the removal of grass biomass by domestic herbivory with the resultant success of woody shrubs (du Toit 1967), and iii) the C_3 shrubs having a competitive advantage over C_4 grasses under elevated CO_2 conditions (Bond & van Wilgen 1996). Graziers attempt to control the woody encroachment using a number of approaches including clearing-felling; burning followed by intensive browsing by goats; and chemical control. The latter seems to be the favoured approach, with an estimated R10 million spent annually on herbicides. The biome is occupied by both commercial and communal graziers. In general, the woody encroachment problems are more severe in land under communal tenure, although multiple use ensures that wood is used for fuel, construction and traditional purposes.

Grassland

The grassland biome is situated mainly in the central, high lying regions of South Africa (Figure 5) and occupies some 350 000km^2 (O'Connor & Bredenkamp 1997). The biome spans a rainfall gradient from "ca. 400 to >1200mm yr-1, a temperature gradient from frost-free to snow-bound in winter, ranges in altitude from sea level to >3300m, and occurs on a spectrum of soil types from humic clays to poorly structured sands" (O'Connor & Bredenkamp 1997). Although the general structure is fairly uniform, there is a wide range in floristic composition, associated environmental variables, dynamics and management options. There is a strong dominance of hemicryptophytes of the Poaceae. Standing biomass is moisture dependant, and decreases with the rainfall gradient. Herbivory from domestic and wild herbivores has a decisive impact on standing biomass and species composition. The biome was originally defined on climatic factors and is limited to summer and strong summer rainfall areas with a summer aridity index between 2.0 and 3.9 (Rutherford & Westfall 1986). Frost is common and occurring for 30-180 days per annum. The most common soil in the biome, accounting for 50% of the area, is the red-yellow-grey latosol plinthic catena. This is followed by black and red clays and solonetzic soils, freely drained latosols, and black clays (Rutherford & Westfall 1986). Acocks (1953) defined thirteen pure grassland types and six "false" or anthropogenically-induced grasslands, ranging from the so-called "sweet" grasslands of the semi-arid regions of the Eastern Cape to the "sour" grasslands of the high rainfall regions of the Drakensberg. There are now six recognisable grassland floristic regions (O'Connor & Bredenkamp 1997), reflecting a topo-moisture gradient from the dry western region to the eastern mountains and escarpment (Table 5). The concepts "sweet" and "sour" refers to the palatability of the grasses, dwarf shrubs and trees to domestic livestock. Although difficult to define in strict scientific sense, these terms have retained their use throughout the farming community, being applied to both individual species and to components of the landscape. "Sweet veld" usually occurs on eutrophic soils under arid and semi-arid conditions. These soils are generally derived from the shales, mudstones and sandstones of the Karoo Supergroup. "Sour veld" is associated with the acid soils of quartzite and andesitic origin, and occurs in higher (>600mm) rainfall and high elevation (>1400m). Ellery et al (1995) have suggested that the concept is driven by the C:N ratios of the grasses, and the sweet veld has a lower C:N ratio than sour veld. In concluding their chapter on the biome, O'Connor & Bredenkamp (1997) report "that the rainfall gradient across the grassland biome is the main determinant of community composition, primary production, foliage nutrient content, nutrient cycling and attributes of species such as photosynthetic pathway, secondary chemicals and phenology. Rainfall in semi-arid regions, and hence production and nutrient cycling, is more variable than in moister regions. Indeed, rainfall regime seems to determine the distribution of the biome both directly (i.e. water balance) and indirectly through fire regime, although biotic effects of grazing can influence biome boundaries. A temperature gradient is also undoubtedly important, and is partly independant of rainfall, although this relationship has not been well investiagted. Soil type is a critical modifier of the influence of rainfall regime at a local or regional scale. Although all grasslands of the biome comprise mainly tufted perennials, it is tentatively suggested that semi-arid grassland has faster turnover of individual tufts, because of the increased frequency of drought related mortality, and therefore has the potential for rapid compositional change. In contrast, tuft turnover and change in high-rainfall regions is slow, because of the stable rainfall regime. It would appear that as a result of these different rainfall patterns, grazing has a more mmediate effect on community change in semi-arid than moist grassland. Changes in community composition can dramatically influence water balance, production, nutrient cycling, foliage quality, soil loss and fire behaviour. Community change depends on the influence of communities on the abiotic environment and on species attributes, but the response of species to environment is contextual rather than absolute.

Table 2. Regions within the grassland biome (O'Connor & Bredenkamp 1997).

Name	Dominant taxa	Geology	Soil type	Altitude(m)	Rainfall(mm)
Central inland plateau	Themeda triandra Eragrostis curvula	sandstone, shale	deep red, yellow eutrophic	1400-1600	600-700
Dry western region	Eragrostis lehmanniana E. obtusa Stipagrostis obtusa	mudstone, shale	shallow aridosols	1200-1400	450-600
Northern areas	Trachypogon spicatus Diheteropogon amplectans	quartizites, shale andesitic lava	shallow, lithosols	1500-1600	650-750
Eastern	Themeda	sandstones	deep	1600-1800	700-950

inland plateau	triandra Aristida junciformis Eragrostis plana	and shales	sand loam		
Eastern mountains and escarpment	Hyparrhenia hirta Aristida diffusa	Drakensberg complex	shallow lithosols	1650-3480	>1000
Eastern lowlands	Hyparrhenia hirta Sporobolus pyramidalis	dolerite	shallow lithosols	1200-1400	850

RUMINANT LIVESTOCK PRODUCTION SYSTEMS

There are currently (2005) about 13.8 million cattle, 25.3 million sheep and 6.4 million goats in South Africa (see Table 3a), in addition to smaller numbers of pigs, poultry and farmed ostriches. The total numbers of cattle and small stock fluctuate in response to high and low rainfall years. There are more cattle in the communal than the freehold sector (Table 3b), although the communal sector contributes minimally to formal beef sales. Nationally, beef production is the most important livestock related activity, followed by small stock (sheep and goat) production (Table 4). Most of the output from the small stock sector (wool, mohair, mutton and lamb) is exported. The combined livestock sector contributes 75% of total agricultural output (National Department of Agriculture, 1999). Since 1992 there has been a steady increase in the production of chicken meat and a general decline in beef and veal production. Total meat production has increased from 1.5 M tonnes to 1.8 M tonnes.The national output of wool has declined from 83Mt in 1992 to 44Mt in 2004. Up until 2001 South Africa imported large numbers of live cattle (100,000-200,000 per year) and continues to import large numbers of live sheep (700,000-1,000,000) per year). Beef and veal imports were 10,000 tonnes in 2003 while exports were only 4,000 tonnes. Exports of dairy products (expressed in milk equivalents) ranged between 87,000 and 232,000 tonnes over the period 1995-2003 but since 2000 imports have exceeded exports and in 2003 imports of 162,000 tonnes (exports were 87,000) cost US$ 65,180,000 while earnings for expors were US$ 36,809,000.

Table 3a. South Africa statistics for livestock numbers for the period 1996-2005

	1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004***	**2005**
Cattle nos. (,000,000)	13.0	13.4	13.7	13.8	13.6	13.5	13.6	13.5	13.5	13.8
Sheep nos. (,000,000)	28.9	29.2	29.4	28.7	28.6	28.8	26.0	25.8	25.4	25.3
Goat nos. (,000,000)	6.7	6.6	6.6	6.5	6.7	6.6	6.5	6.4	6.4	6.4
Horse nos. (,000)	250.0	255.0	260.0	258.0	270.0	270.0	270.0	270.0	270.0	270.0

Source: FAOSTAT 2006;

* Other livestock in 2004: pigs 1.7 million and poultry 146.0 million.

Table 3b. National livestock census 1999.

Tenure	Cattle	Sheep	Goats
Freehold	6 275 000	19 300 000	2 070 000
Communal	6 825 000	9 300 000	4 230 000
TOTAL	13 100 000	28 600 000	6 300 000

South Africa also possesses a rich and diverse wildlife resource, and almost 10% of the country is designated as National Parks and formal conservation areas, but a considerable proportion of the wildlife exists outside formally proclaimed conservation areas. Many livestock farmers derive some or all of their income from hunting and/or eco-tourism.

There are two widely disparate types of production system. In the freehold farms there are clear boundaries, exclusive rights for the individual properties, and commercial production objectives. Land tenure issues considerably hamper the introduction and adoption of improved management practices in the communal areas, in which there are often unclear boundaries, generally open access rights to grazing areas, and the farmers are subsistence oriented.

Table 4. Production (x 1000 Mt) statistics for beef and veal, chicken, mutton and lamb, goat and game, as well as wool and milk production for the period 1992-2005

Commodity	1992	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Beef and Veal	703	508	508	503	496	513	622	577	580	635	655	643
Chicken meat	495	600	649	692	665	706	817	893	925	900	906	919
Mutton and lamb	130	110	98	91	91	112	118	104	105	107	120	122
Goat meat	37	36	37	37	37	36	36	36	36	36	36	37
Game meat	10	10	11	13	14	15	16	16	17	17	17	19.5
Other meat*	135	132	134	131	125	129	110	117	118	133	141	n.r.
Total Meat	1510	1397	1437	1467	1428	1511	1718	1743	1781	1849	1887	1888
Wool (greasy)	83	68	62	57	53	56	53	49	48	44	44	44
Milk (total)	2350	2794	2638	2851	2968	2667	2540	2759	2685	2642	2552	2552

Source: FAO database 2006
*includes pig meat, horse, duck, goose and turkey meat

Freehold/commercial sector

The commercial farming sector is well developed, capital-intensive and largely export oriented. Commercial area livestock production accounts for 75% of national agricultural output and comes from 52% of the farming/grazing land (Table 5). The freehold area is divided into approximately 55 000 farms with an average size of 120ha., owned by about 45 000 individuals or agricultural enterprises.

Table 5. Land areas (million ha) of the major land-use types in South Africa

	Total Area	Farm land	Potential arable	Arable land used	Grazing land	Nature Conservation	Forestry	Other
Developing agriculture	17	14	2.5	N/A	11.9	0.78	0.25	1.5
Commercial agriculture	105	86	14.1	12.9	71.9	11	1.2	6.8

Source:Development Bank of Southern Africa 1991

Cattle are predominant in the eastern parts of the country where the rangelands generally have a higher carrying capacity. Beef cattle ranching is the largest contributor to commercial farming income, and the major breeds are Brahman, Afrikander and Simmentaler. Sheep are largely concentrated in the drier west and also in the south east and are mostly the Dohne merino, bred mainly for wool production, and the Dorper for meat production. Goats are more widely distributed and the main breeds are the Boergoat and the Angora. Grazing livestock are raised under extensive ranching conditions, relying on natural pasture occasionally supplemented by protein/mineral licks. Ostriches are farmed in the southern parts of the country and use natural vegetation, supplemented by fodders and concentrates.

The commercial areas are divided into fenced ranches and then further subdivided into a number of paddocks, through which some form of rotational grazing is normally practised. Compared to the communal areas, stocking rates tend to be more conservative.

Fire is applied to many of the high elevation rangelands to provide grazing during the early growing season. Fire is used primarily by commercial ranchers to remove material of low quality which remains after the winter, and to encourage the flush of short green grass during spring. In response, there has been a marked increase in game farming and eco-tourism in the commercial areas, in recognition of the difficulties and consequences of farming with mono-specific (grazer) domestic stock.

Communal/subsistence sector

The communal areas occupy about 17% of the total farming area of South Africa and hold approximately 52% of the total cattle population, 72% of the goats and 17% of the sheep (Table 3). They differ markedly from the freehold areas in their production systems, objectives and property rights (Table 5); only the cropping areas are normally allocated to individual households, while the grazing areas tend to be shared by members of a community. The communal sector has a substantially higher human population per unit area than the commercial sector, and has suffered from lower levels of state intervention. Investments in infra-structure (access roads, fences, water provision, power supply, dipping facilities) has not kept up with the commercial rangeland. The production systems in the communal areas are based on pastoralism and agro-pastoralism, and the majority of households are subsistence-based and labour intensive, with limited use of technology and external inputs. The outputs and objectives of livestock ownership are much more diverse than in commercial livestock production and include draft power, milk, dung, meat, cash income and capital storage as well as socio-cultural factors. The combination of objectives tends to be met by a policy of herd maximisation rather than turnover, hence even the large herd owners tend to sell only to meet cash needs.

Communal area livestock production contributes insignificantly to formal agricultural output and is mainly confined to the eastern and northern part of the country. However herd sizes vary considerably between and within regions, and livestock ownership is strongly skewed, with a small number of people owning large herds and the majority owning few animals or none at all.

Stock numbers tend to be less evenly distributed in communal than in commercial areas. There is a tendency for high concentrations of people and livestock near to access roads, towns and infra-structure (schools, clinics, supply stores) and permanent water. Portions of the landscape that are inaccessible (e.g. steep slopes, high mountain plateuas) or far from permanent water remain under-utilised.

Mixed livestock ownership is more common in communal than freehold areas. Cattle are the generally preferred livestock species, and are important for draft power, but economic and ecological conditions often limit the possibilities of cattle ownership. Goats and, to a lesser extent, sheep are widely distributed in the communal areas, with a few communities in the high elevation regions of the Eastern Cape focussing on sheep only. The pigs and poultry in the communal areas are mainly commercial breeds.

Cattle, sheep and goats are herded during the cropping season in cropping areas, and where there are predator or theft risks in other areas, but herding tends to be relaxed during the dry season during which animals have access to crop residues. In the communal areas of Namaqualand, herd owners have "cattle posts" away from the village and crop lands, and maintain most of their animals there. Pigs and poultry in the communal areas are generally free-ranging and scavenging, although some owners practise housing and feeding.

The exclusion of fire from the savanna regions under communal managment has encouraged bush encroachment. In the semi-arid regions, fire has generally been excluded, cutting for fuel or building has been minimal, there are fewer browsing animals and there is less mobility in response to rainfall spatial variation. Consequently, large areas of the medium rainfall savannas have become severely bush infested, to the detriment of the grazing potential for cattle and sheep. In communal areas, fire is used to stimulate grass production during the early summer, and this maintains a grassland state along the coastal region.

Table 6. A comparison of some of the major differences between communal and freehold tenure systems in a similar area (approximately 15 000 ha) of the Peddie district, Eastern Cape, South Africa (Palmer et al 1999).

Tenure system	**Communal**	**Commecial (Freehold)**
Economic orientation	**Multiple use but essentially subsistence**	**Profit (commercial)**
Human population	**56**	**3-6**

density (persons per km2)		
Livestock	**Cattle 3548 Sheep 5120 Goats 14488**	**Cattle 2028 Goats 3000**

	Total Area	**Farm land**	**Potential arable**	**Arable land used**	**Grazing land**	**Nature Conservation**	**Forestry**	**Other**
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THE PASTURE RESOURCE

The main forage resource for livestock in South Africa is rangeland grazing. In the higher rainfall zones crop residues are a very important feed supplement in the communal areas during the dry season when range grazing is scarce, while in the commercial areas some farmers plant fodder species. Irrigated fodder production is very limited owing to the lack of suitable soils and water supplies in the commercial areas. In times of drought, South Africa imports fodder from neighbouring countries.

Range grazing

The principal vegetation types of South Africa are illustrated in Figure 6 by this generalised image of the Acocks (1988) map of the Veld Types of South Africa. Acocks provided a unique perspective on the classification and distribution of the agro-economic divisions of vegetation in South Africa. This map serves to illustrate the broad floristic diversity of the South African vegetation. Acocks (1988) described the veld type as "a unit of vegetation whose range of variation is small enough to permit the whole of it to have the same farming potential", and he argued that it is possible to select relatively few species to serve as indicators of different vegetation types. The veld type concept has been used by researchers and managers to define the units within which the results of experiments and grazing trials can be applied. This has resulted in a knowledge base within each veld type, much of which is captured in the "grey" unpublished literature.

It is well recognised that rainfall is the primary determinant of forage production, and a number of workers in Africa have demonstrated linear relationships between annual rainfall and primary production within the rainfall limits experienced in South Africa. These relationships can be simplified to straightforward expressions of kilograms of annual dry matter production of forage per millimetre of annual rainfall (Le Houerou, 1984).

An above-ground biomass production model based on the concept of rain-use-efficiency has been developed (Palmer 1998) and applied to rangeland. The resultant map for commercial production is provided (Figure 7). The production may be converted to carrying capacity by assuming a daily requirement of 11.25 kg dry matter per large stock unit, and a use factor of 0.4 (Le Houerou, personal communication). The use factor may decline to 0.2 in mesic grasslands with high C:N ratios.

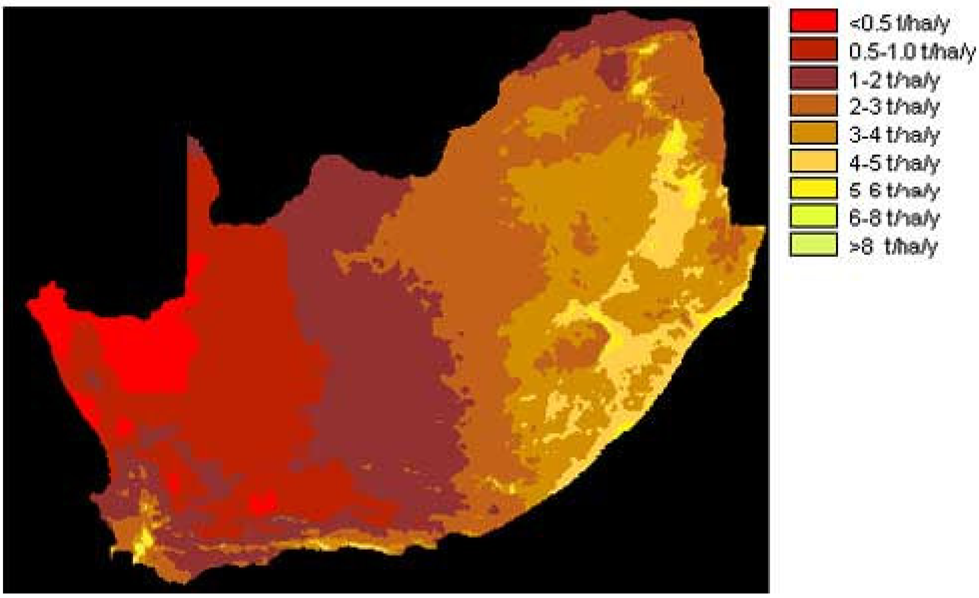

Figure 7. Rangeland production in South Africa using the model of Le Houerou *et al*. (1988) and median annual rainfall (Dent *et al*. 1987).

There have been a number of debates on range grazing in southern Africa during the past 80 years, with the focus changing from the earlier perspectives of rangeland change due to desertification to more recent debates on the role of global climate change on the rangeland resources. Instead of re-phrasing the content of these debates, we have chosen to point readers at the appropriate of published text which synthesize these debates. Wherever possible, we point the reader to an electronic copy of the original text.

Following the earlier work of Ellis and Swift (1988) on the disequilibrium/equilibrium concept, there have been numerous articles which attempt to define the processes which lead to degradation of rangeland in southern Africa (Behnke and Scoones 1993, Behnke, Scoones & Kerven 1993, Galvin & Ellis 1996).In response to this debate, Illius & O'Connor (1999) have asked "When is grazing a major determinant of rangeland condition and productivity?" and conclude "Spatial heterogeneity of resources, and particularly the seasonal separation of resource use, leads to the distinction between equilibrium and nonequilibrium areas. Equilibrium areas are those in which animals are in some sort of balance with their resources as a result of their dependance on them during the dry season. Climatic variation will cause this balance to fluctuate from year to year. Nonequilibrium areas support animals in the season of plant growth but the size of the animal population is not determined by these resources. It is on these nonequilibrium areas that variable and periodically high defoliation intensity may be imposed as a result of climatic variation causing fluctuations in the ratio of animal population size to resource abudance. Vegetation use in dry-season range is unlikely to suffer such impacts, because it is likely to be insensitive to defoliation during the dry season (Ash & McIvor 1998). Periodic intense defoliation is a consequence of climatic variation. Together with spatial localization of herbivore impacts, due to seasonal ranging behaviour and plant species and patch-level selection, this is likely to make these environments more, and not less, prone to ecological change. Ecologists and policy makers should seek to identify the characterstics of grazing systems that predispose some systems towards degradation, while others appear to be resistant" (extracted from Illius & O'Connor 1999)."

Following a detailed description of the impact of humans on the grazing resources of South Africa, Hoffman (1997) reports:

"Crop farmers first entered southern Africa along the northeastern coastal margins in or before the third century AD (Maggs 1984). Initially they survived on a mixed agricultural base of 'slash-and-burn' agriculture, hunting and marine mollusc collection augmented possibly by domestic sheep and goats (Maggs 1984; Hall 1987). At first only the vegetation around the coastal forest margins was cleared, but within a few hundred years descendants of these early farmers had moved westwards along river valleys and further southwards along the coast. The clearing of parts of the original forests and woodlands and subsequent cropland abandonment led, in the space of a few hundred years, to an increase in the extent of scrub and grassland habitats on the eastern coastal forelands and river valleys (Feely 1980). This may have facilitated the range expansion of a number of indigenous plants (e.g. many early-successional Acacia species) and animals (e.g. white rhinoceros) (Feely 1980). It also brought with it a shift in domestic livestock composition. The reliance of the Early Iron Age farmers on browsing animals such as goats changed fairly rapidly to an increasing dependence on a cattle-based economy that now thrived on the abundant grass- and scrubland mosaic created by this early slash-and-burn agriculture (Maggs 1984; Hall 1987). Recently, however, McKenzie (1989) has challenged this general model of increased grassiness following Iron Age occupation of the eastern seaboard. He argues that in the Transkei, Iron Age population densities would have been too low for their activities to have resulted in significant increases in the extent of grasslands.

Archaeological remains of Early Iron Age settlements are found almost exclusively within the savanna biome.

These farmers chose the valley bottoms to build their villages (Maggs 1984), preferring alluvial soils for their crops of sorghum, millet and cucurbits such as pumpkins, gourds and melons. Other ecological prerequisites affecting site location were an abundant supply of wood and adjacent pasturage for cattle (Maggs 1984). Although Early Iron Age agropastoralists owned livestock, they also relied on hunting to supplement their diets. Remains of hippopotamus, crocodile and especially fish are present at these early sites. Villages which generally contained a few hundred people and varied in size from 8 to 20 ha. enjoyed a high level of self-sufficiency. Village density was surprisingly high, with one located every few kilometers (Maggs 1984).

The success of Early Iron Age farmers and their impact on the savanna landscape of the time was mainly due to their use of iron for a variety of agricultural and domestic purposes. Iron axes, for example, were essential for woodland clearing and iron hoes also increased the range of tillable soils (Hall 1987). Iron tools, such as adzes and hoes increased the efficiency of tilling the soils and tending and harvesting the millet, sorghum, cow pea and cucurbit crops. In fact, these Early Iron Age farmers were so successful that Huffman (1979, 1982) has suggested, albeit in an resolved and controversial hypothesis (Hall 1987), that it was population pressure and competition for resources that precipitated the north and westward migration of farmers across the Drakensberg escarpment into savanna lowland environments during the sixth, seventh and eighth centuries.

The manufacture of iron tools requires not only a good supply of iron ore but also an abundant supply of fuelwood to fire the furnaces and iron smelters. Van der Merwe & Killick (1979) have calculated that nearly 7000 trees (mostly hardwood such as Colophospermum mopane, Combretum imberbe and Terminalia sericea) would have been required to produce the 180 metric tons of slag produced from six furnaces at a site near Phalaborwa over 'an arbitrary lifetime of 30 years'.

This extensive clearing of the bottomlands by Iron Age people for fuelwood, iron production and cultivation has left its mark on many savanna landscapes of today. In northern KwaZulu-Natal, for example as much as 70% of the area which currently forms part of the lowland nature reserve network may be derived directly from Iron Age land-use patterns (Feely 1980). The 'wilderness model' concept for these reserves has been questioned (Feely 1980; Granger et al. 1985), since a set of secondary successional pathways adequately explains the structure and composition of the contemporary vegetation. Clearing of the original closed deciduous woodland on the interfluves in the Eastern Transvaal lowveld by Late Iron Age farmers for iron smelting, construction materials and fuelwood purposes probably increased runoff and erosion rates (Feely 1980). This would have led to significant changes in the vegetation of vleis and marshes in drainage liens. The draining and subsequent runoff regimes from the interfluves, would have led to an invasion of these drainage lines by woody plants following their later abandonment (Feely 1980).

The transition from Early to Late Iron Age towards the end of the first millennium AD is marked by dramatic cultural, agricultural and economic developments with concomitant changes to the disturbance regime of the savanna and grassland biomes at both landscape and regional scales. First, settlement location shifted from bottomland sites to hilltops with a greater reliance on stone material for hut and perimeter wall construction (Maggs 1984; Hall 1989). Second, the interior, treeless grasslands, including those west of the escarpment, were colonized for the first time in the Late Iron Age. However, this spread was not uniform across the grassland biome. There were clear initial preferences for savanna/grassland biome ecotonal sizes where transhumance patterns presented a range of ecological bet-hedging strategies well suited to the agricultural economies of the time (Maggs 1984). Finally, during the Late Iron Age the earlier emphasis on self-sufficiency association of political power which currently forms part of the lowland nature reserve network may be derived directly from Iron Age land-use patterns (Feely 1980). The 'wilderness model' concept for these reserves has been questioned (Feely 1980; Granger et al. 1985), since a set of secondary successional pathways adequately explains the structure and composition of the contemporary vegetation. Clearing of the original closed deciduous woodland on the interfluves in the Eastern Transvaal lowveld by Late Iron Age farmers for iron smelting, construction materials and fuelwood purposes probably increased runoff and erosion rates (Feely 1980). This would have led to significant changes in the vegetation of vleis and marshes in drainage liens. The draining and subsequent runoff regimes from the interfluves, would have led to an invasion of these drainage lines by woody plants following their later abandonment (Feely 1980).

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The increasing importance of cattle in the agricultural economy of the Late Iron Age led to a range of ecological problems. The rise and fall, in the ninth and fourteenth centuries, respectively, of a number of particularly well-developed economic centres in the Limpopo Basin (Hall 1987), and eastern Kalahari (Denbow 1984), provides evidence for the potentially devastating impact that these early farmers could have had on southern African savanna and grassland biome landscapes. The collapse in the fourteenth century of the Limpopo Basin state centred around Mapungubwe may have been as closely related to the deterioration of the grazing lands in the eastern Kalahari as to the shift in trade networks to more northerly centres in Great Zimbabwe (Denbow 1984); Maggs 1984; Hall 1987). These authors propose that the large cattle holdings of the settlements in the eastern Kalahari were crucial for supplying and maintaining the regional political centres in the Limpopo Basin. The deterioration of the grazing lands as a result of excessive grazing pressure resulted in a reduction of cattle numbers below that which was needed to maintain the regional trade and political networks.

The impact of Iron Age settlements, kraals and iron smelters appears widespread in savanna and grassland biome landscapes (Maggs 1984; Granger et al. 1985). Evidence of these early settlements remains and their impacts have contributed significantly to the level of patchiness and productivity in modern savanna landscapes (Scholes & Walker 1993). In the eastern Kalahari, for example, the productive and palatable blue buffalo grass Cenchrus ciliaris, is consistently associated with vitrified dung deposits of Iron Age, nineteenth century and modern kraal sites (Denbow 1979). The ability of C. ciliaris to tolerate high nitrate and phosphate levels as well as its dense, mat-forming growth habit preclude the establishment of surrounding arid savanna trees on old kraal sites. These grassy sites are easily discernible as ‘bald spots’ on aerial photographs and are common especially on hilltops, where they have not been destroyed by recent cultivation. The kraals are generally 50-150 m in diameter with vitrified and semi-vitrified dung deposits up to a metre deep, providing some indication of the extent of utilization of these arid savanna landscapes by Iron Age and recent agropastoralists (Denbow 1979).

One final example of the impact of Iron Age farmers on pre-colonial landscapes concerns the Difequane (the ‘scattering’, Hall 1987). The military conquests of Shaka Zulu and others during the early part of the nineteenth century resulted in mass regional displacement and political restructuring; especially within the eastern and northern parts of the subcontinent. Although, it is rejected by Hall (1987), there remains a popular perception (Barker et al. 1988) that the region underwent a rapid increase in human and cattle populations under the favourable climatic conditions of the late eighteenth century. This led ultimately to an ecological collapse during the series of severe droughts that occurred early in the nineteenth century. In the ensuing territorial conflict, particularly over the lowlands of KwaZulu-Natal (Maggs 1984), smaller clans and tribes were amalgamated within larger groups to form more effective armies and ultimately consolidated into a broader northern Nguni society under Shaka Zulu , who died in 1828.

In the aftermath of the Difequane the European colonists entered the largely depopulated grassland and savanna biomes from the 1830s onwards, adding further to the territorial displacement of some Iron Age farming communities and to the restructuring of land-use practices in the two biomes. Within a few decades much of the subregion had been either annexed or colonized, but not necessarily controlled by Europeans, and some entirely new impacts on the vegetation of the savanna and grassland biomes were introduced."

On the role of megaherbivores in the exacerbation of the 'bush encroachment' problem, Hoffman (1997) reports:

"One of the first and most significant, albeit indirect, impact that the early colonists had on the grassland and savanna biomes was the decimation of indigenous herbivore populations and their replacement with a few species of domestic animals. Megaherbivores, such as elephant, rhinoceros and hippopotamus, and large grazing animals, such as wildebeest, hartebeest and zebra play key roles in a number of important population and ecosystem processes within the savanna and grassland biomes (Tinley 1977, Milchunas, Sala & Lauenroth 1988; Owen-Smith 1988; La Cock 1992). Their elimination is thought to have had catastrophic implications for the normal functioning of ecosystems within these two biomes (Grossman & Gandar 1989). Although Iron Age people had traded in ivory, rhinoceros horn and animal skins for centuries before the arrival of Europeans (Hall 1989), there are no indications that they had a major impact on the populations of southern Africa megaherbivores, since they lacked the weaponry suitable for mass slaughter. The colonists, however, had firearms and could draw on the hunting and tracking skills of local hunter-gatherers, pastoralists and agropastoralists (Gordon 1984) to supply the huge demand of international markets for animal products, especially ivory. Estimates suggest that there were more than 100 000 elephants in South Africa alone prior to the big-game hunter era in the late eighteenth and nineteenth centuries, but that by the end of 1920 there were fewer than 120 individuals left (Hall-Martin 1992). These were confined to just four small populations mostly in remote parts of the savanna biome. This historical removal of megaherbivores from the savanna landscape, the alteration of fire regimes, the reduced use of trees, and overgrazing, has been blamed for the general 'bush-encroachment' problem in the savanna biome today (Grossman & Gandar 1989). Of the approximately 43 million ha comprising the savanna biome in South Africa, bush encroachment has rendered 1.1 million ha unusable, threatens 27 million additional ha and has reduced the carrying capacity of much of the rest of the region by up to 50% (Grossman & Gandar 1989)."

On the subject of "overgrazing", Hoffman (1997) reports:

"Extensive livestock ranching is the most common agricultural practice in southern Africa; 84% of land in the savanna biome of South Africa is used for this purpose (Grossman & Gandar 1989). Despite the fact that, in South Africa, cattle, sheep and goat numbers during the last decade have been at their lowest level in 60 years."

As cultivation of new lands is a common practice and one which has a major impact on rangeland, it is pertinent that some of the debate is presented. Hoffman (1997) summarises the impact of human as follows: "Of all modern agricultural practices, crop cultivation probably has the greatest impact on the terrestrial biota of a region. Not only is the relatively diverse cover and composition of natural vegetation replaced by one or a few alien species, but soil destruction and water nutrient additions further transform the environment. The total area under cultivation in South Africa in 1988 was around 130 000 km2 or about 10.6% of the land surface (Anon. 1994). This is very close to the 12 to 15% estimate of total potential arable land area in South Africa (Schoeman & Scotney 1987). Data from agricultural censuses show that there has been a steady increase in the area cultivated between 1911 and 1965, but that this has levelled off in the last two decades. This suggests that most of the productive lands have already been cultivated. Thus, any agricultural expansion of croplands in the future will encroach increasingly on economically and ecologically marginal environments, where yields are lower and environmental impacts, such as wind and water erosion, probably greater. The implications of these statistics in the light of the region's 3.0% population increase are sobering.

Nearly half of the area cultivated in South Africa has been planted to maize and the savanna and grassland biomes have been most affected. Since 1985 there has been a general decrease in the area under maize. However, this decline probably reflects a shift in maize-growing areas to other, more profitable crops, and not necessarily land abandonment.

The commercial cultivation of sugarcane in KwaZulu-Natal has a long history dating to the late 1840s. By 1866 just over 3000 ha were under cultivation (Richardson 1985). There was a steady expansion of this industry until the late 1970s, whereafter the area under cultivation decreased. The greatest impact of sugarcane cultivation has been on the vegetation of the coastal lowlands of KwaZulu-Natal. No studies, however, have documented the impact of the sugar industry on these environments."
Extracted from Hoffman (1997).

Following a detailed surbvey of degradation patterns in South Africa for the National Desertification Audit, Hoffman & Ashwell (2000) conclude:

Soil degradation

The study considered both erosive and non-erosive forms of soil degradation and found that:

- The problem is substantially worse in communal areas than in commercial farming areas.
- Land use type and land tenure system are important predictors of soil degradation, although it is not necessarily the land tenure system itself which is to blame for the observed relatively high levels of degradation in the communal areas.
- Steeply sloping land in the eastern parts of South Africa, in particular land that is now used primarily for grazing, is badly affected.
- The Northern Province, KwaZulu-Natal and Eastern Cape are the provinces most badly affected by soil degradation.

Veld degradation

The study considered five main categories of veld degradation, namely, loss of cover, change in species composition, bush encroachment, alien plant invasions and deforestation. The most important findings are:

- On the whole, veld is more degraded in communal areas than in commercial farming areas. However, in contrast to the case with soil degradation, the predominant land tenure system of a district appears not to be strongly related to the level of veld degradation. Degradation encroachment and alien plant invasions are, in general, worse in commercial districts than in communal districts.
- Rural poverty and land use policies like ‘betterment’, which were only applied to communal areas, are closely correlated with veld degradation. In the first instance, poverty forces many people to rely on natural resources for their energy and food requirements, while in the second, policies such as ‘betterment’ diminished responsibility for sustainable management practices on the part of local land users.
- Veld degradation is worst in the Northern Province and in KwaZulu-Natal.
- The eastern Karoo is no longer perceived to be badly degraded by most agricultural experts. In fact, it appears to have benefitted considerably from the attention received as a result of the writings of people such as John Acocks in the middle of the 20th century.
- The rate of veld degradation is decreasing in commercial districts, largely as a result of state intervention, strategies and schemes, while it is perceived to be increasing in communal districts.

Combined soil and veld degradation

- When soil and veld degradation are considered together, communal areas are perceived to be significantly more degraded in general than commercial farming areas, although there are many exceptions.
- Overall, land degradation is most severe in the Northern Province, KwaZulu-Natal and the Eastern Cape. The problem is greatest in steeply sloping parts of the former Ciskei, Transkei and KwaZulu-Natal. On the whole, land degradation is perceived to be increasing (ie. The situation is getting worse) in communal districts.
- The Northern Cape and Western Cape are the provinces with the most degraded commercial farming areas. In general, however, land degradation is perceived to be decreasing in commercial districts.

Factors influencing land degradation

Contrary to popular belief, environmental and climatic conditions in many of the former homelands are conductive to productive agriculture. The problem of land degradation is more closely linked to a complex and interacting suite of environmental, climatic, historical, political and socioeconomic factors. Areas with steep slopes, low annual rainfall and high temperatures seem particularly susceptible to high levels of degradation. Similarly, areas with high levels of poverty also appear more degraded than those where poverty indicators are less extreme.

Workshop participants agreed on a number of additional factors that have served to increase or decrease the levels of land degradation over the last ten years.

Reasons for improvements in the quality of land

- adequate landholdings
- government interventions, e.g. legislation, schemes and subsidies
- agricultural extension services and better education
- farmer self-organization and study groups
- decrease in stock numbers
- public pressure and a growing conservation ethic and awareness
- electrification of rural and peri-urban settlements

Reasons for increased land degradation

- inadequate landholdings
- inappropriate or enforced land use planning, e.g. 'betterment'
- economic policies, e.g. the migrant labour system, tariffs, lack of incentives for farmers in commmunal areas
- high population densities in rural areas
- high stock numbers, especially when there is no control over their movement and grazing patterns
- poverty.

Recommendations
Recommendations arising from this review include the following:

- Many of South Africa's communal areas are in dire need of attention. Intervention efforts should take account of the predictor variables and priority areas identified by this study and focus attention on these areas.
- Sustainable agricultural models must be developed for South Africa's communal areas that take account of their unique histories and biophysical as well as socioeconomic environments. The imposition of models developed for the commercial farming sector, as well as those from communal areas further north in Africa, are unlikely to prove successful combating degradation.
- Research into land degradation must continue, particularly in South Africa's communal areas. Many more case studies are needed to deepen our understanding of this complex issue and to help develop locally appropriate solutions. Success stories in which local solutions to combating desertification have occurred are urgently needed.
- While ensuring redress in terms of the provision of support to the communal areas, sustainable land use practices must also be supported and maintained in the commercial farming areas in order to ensure food security for South Africa. The commercial farming sector is crucial for a productive future and should not be summarily abandoned.
- The agricultural statistical service must be received and adequately supported to provide reliable data for planning in both commercial and communal areas.
- Similarly, a strong agricultural extension service in both the communal and commercial farming areas is essential if land degradation is to be reversed. The extension service needs to be strengthened as a matter of urgency and well-trained and effective personnel need to be deployed in all areas of the country.
- Agricultural planning must take account of the potential effects of global climate change and must be able to respond to short- and long-term changes in climate and vegetation. In particular the role of drought in affecting food security and livelihoods needs to be better understood and appropriate mitigating measures adopted.
- A national review and map of the status of South Africa's freshwater resources are urgently needed. Without this knowledge, any intervention strategy arising from the National Action Program (NAP) will be severely
- constrained.
- In order to develop a NAP that remains relevant and responsive, ongoing monitoring of various aspects of land degradation is essential. Agricultural planning must be able to respond to variable changes in climate and vegetation, particularly in the light of global climate change. Specific monitoring needs to cover rainfall, soil erosion and veld degradation. The assessment of state interventions to combat desertification will provide vital direction for future action.
- Public participation must be encouraged at all levels and efforts to combat land degradation must be better coordinated. The involvement of land users in decisions about their resources is essential if intervention strategies are to be successful" (Extracted from Hoffman & Ashwell 2001)
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5.2 Introduced legumes and fodders

A number of sub-tropical pasture legumes and fodder plants have been screened at various sites from 100–700 mm annual rainfall. Probably the most successful example of introduced legumes has been the use of lucerne (*Medicago sativa*) , annual medics (*M. polymorpha and A truncatula*) and annual clover (*Trifolium* sp.) into the grain production systems of the Western Cape. Here the commercial grain producers (wheat, barley, oats) use these species as lay crops to elevate soil nitrogen every 2-3 years. These crops reduce the risk of grain production, and at the same time provide forage for the small stock industry.

Range re-inforcement is conducted on a large scale in the commercial dairy regions of the country. Favoured grass species include *Pennisetum clandestinum* (kikuyu*), Panicum maximum*, *Digitaria eriantha*, while the legumes such as silver leaf (*Desmodium* spp) are oversown into natural rangeland.

Foggage production in South Africa is important in commercial beef and dairy production systems. Graziers use a wide range of commercially available local and imported grasses and legumes. The performance of growing beef steers grazing foggaged dryland *Pennisetum clandestinum* (kikuyu) pastures and given limited access (3 h d-1) to *Leucaena leucocephala* cv. Cunningham (leucaena) was better than that of steers grazing only kikuyu foggage during autumn and early winter (Zacharias et al 1991). Animals grazing leucaena performed better and gained 24.8 kg per animal more, over 90 days, than those on kikuyu alone. There is concern about the risk of leucaena becoming an invasive alien in the humid coast, and further encouragement of the use of this and other potentially aggressive species (e.g. *Lespedeza sericea*) has been discouraged until further evaluation has been carried out.

Investigations to determine whether frosted Kikuyu could supply quality foggage than natural pasturage in sourveld area during the winter months revealed that this grass was characterised by a crude protein content of 8 - 10% in the winter months. The performance of animals grazing such frosted Kikuyu was highly satisfactory (Rethman & Gouws, 1973). Sheep performance and patterns of herbage utilization were determined in two grazing trials involving different amounts and quality of kikuyu foggage. Wether lambs maintained livemass whereas dry ewes and wether lams both lost 8-10% of their initial mass, irrespective of differences in foggage quality. Grazing capacity was proportional to the yield of foggage and some 50% of the total herbage was utilized. The estimates of quality indicated that a higher level of utilization would have resulted in poorer sheep performance (Barnes & Dempsey1993).

Dryland fodder

Dryland fodder production is only possible in the higher rainfall regions of the country. The principal form of dryland fodder is cereal crop residues, and these make an important contribution to livestock diets in communal areas during the dry season. Some communal area farmers collect and store at least part of their residues to feed to selected animals such as milk cows and draft oxen, but most of the fodder is utilised *in situ.*

The cultivation of rainfed crops in South Africa is widespread, occurring in both commercial and communal land-use systems. The most significant commercial grain producing areas are the "maize triangle" of the central highveld, the wheat growing region of the south western Cape and the maize growing regions of central Kwa-Zulu Natal. Maize is widely preferred as the staple food in the communal areas, but millet and sorghum are more reliable crops except in the highest rainfall zones. National cereal production (roughly 80% maize, 16% wheat and 4% other including millet and sorghum) fluctuates considerably from year to year according to rainfall. Production has varied from a low of 5 044 000 Mt in the drought year of 1991/92 to a record high of 15 966 000 Mt in 1993/94.

In the drier central and western farmers commonly have small areas of drought tolerant fodder crops (Table 7) as drought reserve for exceptional circumstances.

Table 7. Exotic species which are used for fodder during exceptional circumstances.

Botanical name	**Common name**	**Uses**
Agave americana	American aloe	Drought fodder in arid and semi-arid regions
Anthephora pubescens	Wool grass	Spring & summer grazing
Atriplex mueleri	Australian	Drought fodder

	saltbush	
Atriplex nummalaria	Old Man Saltbush	Drought fodder
Atriplex semibaccata	Creeping saltbush	Drought fodder
Cenchrus ciliaris	Blue buffalo grass	Tufted perennial; spring, summer and autum grazing
Opuntia spp.	Spineless cactus	Live fencing + drought fodder
Opuntia ficus-indica	Prickly pear	Live fencing + drought fodder
Vigna unguiculata	Cowpea	Undersowing maize, millet or sorghum

Irrigated fodder

There are some eighty species of commercially available species and cultivars which are used in South Africa (Klug & Arnott 2000). Lucerne (*Medicago sativa*) is the main purpose grown irrigated fodder in South Africa, and is grown under irrigation throughout the country. Ryegrass (*Lolium multiflorum and L. perenne*) is cultivated on a large scale for pastures in the dairy industry. Many other species and numerous cultivars are available commercially and are provided in detail by Bartholomew (2000).

Imported fodder

In times of drought, the South Africa government traditionally assisted farmers in obtaining fodder by providing subsidies. According to the new drought policy (National Department of Agriculture, 1997), the fodder subsidies have been terminated in order to encourage farmers to build up their own forage reserves and to discourage them from retaining excessive stock numbers. Nonetheless, it is likely that some commercial farmers, and probably the government, will continue to import fodder in extreme drought conditions.

Table 8. Commercial cereal production for South Africa from 1992-2000 (x 1000 tons).

Cereal	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Maize	3277	9997	13275	4866	10171	10136	7693	7946	10584
Wheat	1324	1983	1840	1977	2711	2428	1787	1725	2122
Green corn	266	262	278	279	280	290	292	299	300
Barley	265	230	275	300	176	182	215	90	142
Groundnuts	132	150	174	117	215	157	108	163	169
Sorghum	118	515	520	290	535	433	358	223	352

Soybeans	62	68	67	58	80	120	200	174	148
Oats	45	47	37	38	33	30	25	22	25
Total Cereals	5044	12727	15966	7491	13647	13229	10098	10024	13244

Constraints to pasture and fodder production and improvement

The principal constraints to pasture and fodder production in communal areas are:

- Low and uncertain rainfall throughout most of the country are the main constraints to the productivity of natural pastures and to the establishment of exotic pasture species.
- Concern about exotics becoming problematic limits the introduction and testing of hardy species considered suited to the environmental and utilisation rigours of the communal areas (e.g *Leucaena* sp, *Lespedeza serricea*).
- The availability and price of seeds for pasture/fodder improvement are major constraints to communal area farmers.
- Considerable portions of the savanna vegetation types in the freehold farms are severely bush infested, but the costs of thinning/clearing generally outweigh the benefits in terms of increased carrying capacity.
- The open access to rangeland grazing, at least within communities, in the communal areas necessitates broad collective agreement and cooperation in any pasture improvement venture.
- Conventionally, communal area farmers do not retain exclusive use of their unfenced croplands after harvest for their own livestock, so limiting the opportunities and incentives for undersowing or alley cropping.

The principal constraints to pasture and fodder production in commercial areas are:

- Low and uncertain rainfall.
- Salinization of irrigable soils.
- Declining water quality.

OPPORTUNITIES FOR IMPROVEMENT OF FODDER RESOURCES

There is formal certification of pasture/fodder seed in South Africa. South African seed merchants produce 16 Mt of forage seed per annum for sale locally (14.7 Mt) and export (1.3Mt). Total sales during 2000 were dominated by oats (4.4 Mt), forage sorghum (2.0 Mt), lupens (1.95Mt), triticale (1.55 Mt), annual rye grass (1.5 Mt) and teff (1.0 Mt).

With the long-term goal to preserve germplasm (in most cases, seeds) of the entire South African flora, the ARC-Range and Forage Institute's Genetic Resources Division in Pretoria focuses at present on preservation of seeds of plant species of economic importance. A wide variety of South African pasture grasses, e.g. of the genera *Anthephora, Brachiaria, Cenchrus, Cynodon, Panicum, Pennisetum, Setaria* and *Stipagrostis* are included in the current accessions.

One of the most important sources of funding for range improvement has come from the commercial sector which is involved in the rehabilitation of disturbed areas. The mining industry is required to rehabilitate dis-used mines, and have funded a number of projects to identify suitable genetic material for this purpose. The need to make these rehabilitated areas once again available for animal production has ensured that pasture species are favoured in this process. Favoured species for the selection of suitable material include members of the genera *Panicum, Eragrostis, Cynodon* and *Cenchrus*. Similarly, the revegetation of road verges, which is funded through the National Transport Commission, provides support for the collection and evaluation of grass species suitable for road verge stabilization. Although this been successful in the improvement of *Anthephora* sp. does not directly affect forage species, it does provide funds for the establishment of collections of germplasm which can be used to identify possible forage plants. A dis-advantage of this process has been that genotypes of selected species have been spread throughout South Africa, impacting negatively on the genetic integrity of the indigenous flora.

The need to satisfy the requirements of the developing farmer has encouraged the selection of multi-purpose species which are suitable for both human and animal consumption. In this instance, the cow pea (*Vigna unguiculata*), has been tested and improved to provide cultivars which are acceptable to both humans as a food source and as a valuable forage source to livestock.

The market for turf grass in South Africa has grown rapidly since the advent of democracy, as more of the national budget is spent on the provision of sport facilities for previously dis-advantaged communities. Once again the commercial sector has become a major source of funds to access and evaluate grass cultivars suitable for turf (mainly *Cynodon* and *Pennisetum*).

RESEARCH AND DEVELOPMENT ORGANIZATIONS AND PERSONNEL

Institutional structure

The National Department of Agriculture within the Ministry of Agriculture and Land Affairs is the key institution dealing with forage resources. The National Department of Agriculture is divided into five directorates, one of which deals directly with rangeland and pasture resources. The Directorate Land and Resource Management is responsible for the implementation of the Conservation of Agricultural Resources Act 43 of 1984. This act empowers the head of the directorate to intervene when the agricultural resources of the country are threatened. Prior to 1994 this act was used to subsidise the provision of fencing, erection of new water provision points, the purchase and transport of supplementary fodder during exceptional circumstances, and the clearing of all weeds (alien and indigenous).

Each of the nine provinces also has a section or directorate which deals with rangeland and pasture research.

South Africa’s National Agricultural Policy states the main objective to be improvement of research in natural resource management (Anonymous 1996). On a project basis, pasture science related programmes deal with rangeland reclamation, carrying capacity, agro-forestry and rangeland management systems. Examples of individual on-going projects related to rangeland and pasture science may be found at the ARC web site.

The National Department of Education maintains seven agricultural colleges and carries out topic-oriented, formal training courses. All courses are certified by one of the tertiary training institutions.

Botanical research relating to rangeland is also conducted by the National Botanical Institute of the Ministry of Environmental Affairs and Tourism. Outside of government, the most significant organisation involved in rangeland research is the Agricultural Research Council's Range and

Forage Institute, which conducts research on rangeland and pasture resources. Research direction in the ARC-RFI is determined by the needs of the National Department of Agriculture and Land Affairs, as well as other research clients. The Grassland Society of Southern Africa (GSSA) is the professional organization representing the discipline in South Africa. The GSSA maintains a full-time secretariat for its members, organizes an annual congress at various localities around the sub-continent, and has published a peer-reviewed journal *(African Journal of Range & Forage Science)* annually since 1966.

Personnel

The key organisations/individuals and their current areas of activity/interest with relevance to pasture science are as follows:

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Tel: +27-12-3197545

Mr Bonga Msomi, Director, Directorate Agricultural Land Resource Management: range management, bush encroachment, range rehabilitation

Department of Environment Affairs and Tourism,responsible for reporting on the state of South African rangelands for the International Conventions (Convention for the Combatting of Desertification, Biodiveristy Convention)

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Dr A. Aucamp, Director, ARC - Range & Forage Institute

Dr R. Ellis, Head, ARC-RFI Genetic Resources Division: germplasm

collection of indigenous flora and dryland crop and fodder species

National Botanical Institute
Private Bag X7, Claremont 7735 Fax: +27-21-7998800

Prof B. Huntley, Director

Prof. G. Smith, Deputy-Director: maintaining national herbarium

Dr MC Rutherford, Co-ordinator, VEGMAP Project: revising the vegetation map of South Africa

Provincial Department of Agricultura There are 9 provincial Departments of Agriculture, and each provides some support for rangeland managment and condition assessment.

Educational Institutions Graduate and post-graduate level training in rangeland science and related disciplines is provided at the following institutions:

Universities
University of the North West
University of the Orange Free State

University of Port Elizabeth
University of Pretoria (Tuks)
University of Transkei
University of Venda (UNIVEN)
University of the Western Cape
University of the Witwatersrand, Johannesburg (Wits)
University of Zululand

Technikons
Border Technikon
Cape Technikon
Eastern Cape Technikon
Mangosuthu Technikon
ML Sultan Technikon
Peninsula Technikon
Port Elizabeth Technikon
Technikon Free State
Technikon Natal
Technikon Northern Gauteng
Technikon North West
Technikon Pretoria
Technikon SA
Technikon Witwatersrand
Vaal Triangle Technikon

Agricultural Colleges

Fort Cox Agricultural College

Cedara Agricultural College
Middelburg Agricultural College
Glen Agricultural College
Elsenburg Agricultural College
Tsolo Agricultural College

Professional Organizations

Grassland Society of Southern Africa
South African Institute of Ecologists
Wildlife Management Association of South Africa

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