CHAPTER 7

THE ARID AND SEMI-ARID AREAS : A REVIEW

7.1 INTRODUCTION

The previous chapters have concentrated only on the study area. This chapter reviews the status of other arid and semi-arid areas in order to compare the Botswana case with them. It reviews only a few aspects relating to wild and domestic animal life, vegetation and management of arid and semi-arid areas, mainly in Africa.

Deserts and semi-deserts occur worldwide and are represented on each land mass in both hemispheres. They occupy one third of the world's land surface, and they have the territories of half the world's nations lying partly or wholly inside them (Brinck 1976, UNESCO 1979). Semi-deserts occur on the fringes of deserts and are basically transition zones from moist lands to arid land.

Deserts represent the world's environmental extremes. It is in deserts where the coldest (-90° C in Antarctica) and the hottest (58° C in Arizona Desert) air temperatures have been recorded (John Bartholomew and Son Ltd 1977); where the longest days and nights are found, such as in the Arctic and Antarctic Circles; where the driest points have been recorded (Calama in the Atacama had never recorded any rainfall in living memory as up to 1963) (Grosvenor and Darley 1963), and where minimal vegetation cover is found.

Semi-deserts with their semi-arid environments have more moderate climatic conditions and have more biotic communities represented.

Wild animal species both big and small found in arid and semi-arid environments are usually those best adapted to such environments. However, only the big animals will be considered.

Vegetation in these environments is composed of plant species which, like the animals, are best adapted to the dry conditions. Most plant species, especially the herbaceous, are however, very sensitive to grazing by domestic livestock. Drought or water stress, temperature, bushfires and grazing have varying degrees of influence on vegetation in arid and semi-arid areas.

More and more arid and semi-arid areas are being settled and used for agricultural and other purposes like mining. Settlements especially in developing countries, may have deleterious impact on the environment. They may lead to over-exploitation of woody plants for fuel and poaching of wild animals. Compared to traditional land uses, some of the modern ones provide some of the most serious conflicts with conservation efforts in arid and semi-arid areas. The rate at which over-exploitation of semi-arid areas occurs has created worry about desertification and expanding desert frontiers.

The arid and semi-arid lands of Africa are represented by the Sahara Desert/Sahel complex in the northern part of Africa, and arid and semi-arid lands of East Africa including Sudan, Ethiopia and Kenya, and the Southern African arid and semi-arid lands of the Namib Desert/Kalahari complex covering Namibia, the Northern Cape in South Africa, Botswana and parts of Angola.

7.2 THE ANIMALS

7.2.1 General.

Species of domestic and wild animals have varying degrees of adaptation to arid and semi-arid conditions. However, whatever the degree of adaptation each must address itself to two main stresses: water requirements amidst its considerable scarcity and the high temperatures and heat stresses of the summers.

This section is not meant to be an exhaustive review of literature on the physiology of desert dwelling animals, but instead as a reconnaissance of some of the fundamental requirements of some of these animals. It is hoped this review will help explain other aspects of why many species of animals exist in the Kalahari.

7.2.2 Water Sources, Needs and Economy.

Outside the arid and semi-arid lands, the commonest source of water is usually perennial rivers. The majority of the arid and semi-arid lands do not have perennial rivers. Animals in these areas must therefore have alternative sources of water.

Domestic animals are usually provided for by sinking open wells or boreholes. Wild animals have to look to nature alone to provide their water needs. This may come as rain which if heavy enough may create free standing water or recharge shallow aquifers which may flow onto pans as natural springs. In some areas there are oases. Dew is one source of water. The cold night temperatures of these areas may, where relative humidity is moderately high at night, cause water to condense as dew and this becomes available to the nocturnal grazers and browsers. These are about all the sources of free water available to the wild animal.

Rainfall in these dryland areas is generally low and because of this, free standing rain-water is infrequent and the natural springs are not always flowing. Secondly, dew can only form where relative humidity is high enough. This relative humidity height is, however, dictated by how much water is being released into the atmosphere from some source. Vegetation plays a role in releasing water into the atmosphere through evapo-transpiration. However, vegetation can only play this role successfully if it has access to water. The absence of rainfall, the primary water source, means drought. In arid and semi-arid lands drought may be considered as the norm while non-drought periods are more of an exception than the rule.

Other sources of moisture for the animals in these dry environments are water-rich plant parts. Sprouting and green grass, green tree leaves, succulent fruits, bulbs and tubers, are some of the plant parts used by various species of animals as sources of water. The eland feeds mainly on leaves of several species of *Acacia* which may contain up to 58% water. These may provide up to 5.5 litres of water per 100kg body weight per day as daily water requirement for this animal in hot weather (Taylor 1969). The fruits and seeds of tsamma melon *Citrellus* species, fruits and roots of *Cucumis* species, etc. (see Chapter 2) have been identified as foods with a high water-content used by several species of animals including the eland and the gemsbok (Smithers 1971, Bramwell 1973, Morris 1980). The oryx of East Africa favours grasses and shrubs especially a shrub of genus *Disperma*. While by day the dry leaves of this shrub may contain as low as 1% water, Taylor (1969) found that, when exposed to higher relative humidity, they acquired up to 42% water content. Since the relative humidity is generally higher at night, then by browsing

Disperma at night, the oryx exploited this moisture source. The carnivores obtain their water from the body fluids of their prey.

Many species of animals in arid lands are highly mobile. This is another form of adaptation which enables these animals to exploit widely placed favourable habitat conditions. Most nomadic and/or migratory movements of these animals are mostly associated with the search for water and food (Delany and Happold 1979, Dingle 1980).

The quantity of water required by an animal varies between species under similar conditions. Taylor (1968a) found that the average minimum water requirements, the amount of water required to maintain the weight of an animal at approximately 85% of its initial weight, for several ruminants inhabiting drylands of East Africa, were in ranking order as shown in Table 7.1 The table also shows the respective sources of water.

Of the three sources of water indicated in Table 7.1, the metabolic water is water released from food oxidation during the metabolic process, and preformed water is water taken in with food, while drinking water is consumed as free water.

Macfarlane and Howard (1972) have also reported on the water turnover, the process involving water ingestion, paths through the body, its retention and ultimately release, in the kangaroo, the camel and shorthorn cattle at daily maximum temperatures from 38° C to 42° C in the Australian aridlands. Camels had the lowest water turnover at 62ml/kg/day, kangaroo next at 88ml/kg/day and shorthorn cattle the highest at 148ml/kg/day. The ranking order of water turnover was found to be maintained in shared environments irrespective of fluctuations within the environment.

Water conservation by animals in dry environments has been studied by several researchers. Taylor (1969) has investigated water conservation in the eland and the oryx. He found that these two animals under a heat load of 40° C, raised their body temperatures to slightly higher than the ambient temperature. By doing this the water that would otherwise be lost through evaporative cooling was then conserved. The difference in temperature rises were on occasion by 7° C for the eland and 6° C for the oryx. Thus by raising the body temperature relative to the air temperature, they cut off sweating and avoided moisture loss. The same pattern was reported for the camel by

TABLE 7.1 Minimum Water Requirements for Some African Animals at 22° C.

(After Taylor 1968.)

Species	Quantity Litres/100kg/day			
	Sources			Total
	Metabolic	Preformed	Drinking	
Oryx	0.40	0.18	1.30	1.88
Zebu cattle	0.24	0.10	1.61	1.95
Grant's Gazelle	0.62	0.21	1.25	2.08
Thompson's Gazelle	0.72	0.23	1.25	2.20
Wildebeest	0.53	0.23	2.23	2.99
Buffalo	0.45	0.18	2.80	3.43
Eland	0.38	0.21	3.15	3.74
Hereford Cattle	0.35	0.16	4.11	4.62

Schmidt-Nielsen (1964). The eland and the oryx also reduced water loss by breathing more slowly at low body temperatures.

Other methods of water conservation include seeking shade during a hot day, and concentration of urine and faeces. The various physiological and adaptive mechanisms, including water requirements and economy by animals in desert conditions are broadly covered for a wide range of animals by Schmidt-Nielsen (1964), Maloiy (1972) and Delany and Happold (1979).

7.2.3 Temperature Regulation.

There are three main ways "desert" animals cope with heat: evading heat, tolerating or combating it. Heat evasion is by using ground burrows, caves, tree hollows etc. Heat tolerance involves the ability to adjust the body temperature so as to exceed or stay level with the environmental temperature. Heat combating includes the process of evaporative cooling which may be by sweating or by panting. Heat combating by evaporative cooling involves loss of moisture from the body. Since water is scarce under arid and semi-arid environments, most big animals combine the vicissitudes of heat tolerance and heat combating. Success in living under dryland heat conditions by big animals, which is also a measure of their adaptation is therefore being maximally heat tolerant and maximally conservative in evaporative cooling.

The abilities of the eland, the oryx and Coke's harbebeest to cope with high temperatures under arid conditions have been reported by Taylor (1969) and Finch (1972). These animals, which may be taken as representative of the group of big animals highly adapted to arid conditions, cope with high temperatures in several ways:

(i) they reflect some of the incident radiant energy from the hair surface on their skins. Finch (1972) found that the eland and Coke's hartebeest reflected up to 22% and 42% respectively of this energy this way. Additionally Coke's hartebeest further absorbed and reradiated part of the energy from within its thicker coat of hair before such energy reached the skin surface. This additional advantage of the hartebeest made it better adapted than the eland. The hartebeest tended to seek shade less than the eland.

Elsewhere in this thesis, it has been indicated that some animals have iridescent coats. This iridescence is partly the reflected incident light off the hair of such animals. This reflected light carries with it some of the heat energy. The colour and coat hair structure therefore play an important role also in reducing heat load entering the wild animal body. This was long recognised for cattle, according to some information sources in Finch (1972).

(ii) their body temperatures are able to fluctuate with the ambient temperatures. The increases may be as much as 7^{0}C for the eland and 6^{0}C for the oryx.

(iii) beyond the 40^{0}C to 45^{0}C ambient temperature range, evaporative cooling plays a major part in keeping down the body temperatures of the three animals. However, these high temperatures are avoided by seeking shade.

7.3 THE PLANTS

7.3.1 General.

Plants, like animals, are influenced by water and temperature gradients. Soil nutrients and photoperiodism are also important factors in plant morphogenesis. The high summer and low winter temperatures, low soil moisture, and low soil nutrients and fertility in these dryland areas provide minimal requirements for plant growth. Plants found in these areas are therefore those which can grow and maintain themselves under those extreme conditions. The semi-arid areas support moderate diversity and density of plant life. However, these are highly sensitive to some uses such as uncontrolled grazing and overstocking by domestic livestock. This is examined again later in this chapter and Chapter 8.

This review, it is hoped, will explain why plants survive in the Kalahari of Western Botswana, and why they are sensitive to uses such as intensive grazing there.

7.3.2 The Effects of Drought and Water Stress on Plants.

Moisture stress suppresses such processes as nutrient up-take, photosynthesis, protein synthesis and general metabolism (Slatyer 1974). The growth suppression at the root and apex shoot system is by the suppression of the development of the primordia. This leads to a condition similar to dormancy. In this condition the plant remains in a state of suspended growth and does not contribute to the green biomass. Water stress also affects internodal growth which leads to reduced leaf size and the rate of appearance of new leaves. This in turn leads to lowered total dry matter production because of the reduced rate of the photosynthetic process. In plant species with well defined seasonal growth patterns, such as many woody perennials, bud formation may be the main drive for the next season's growth. Water stress at this stage will adversely affect bud formation and therefore growth.

In the root system, water stress leads to reduction in root elongation and thus reduces the ability of the plant to search widely for moisture and nutrients. Water stress also leads to increased root suberization, a process whereby a cork-like structure is developed around the root surface, and this suppresses the efficiency of nutrient and water uptake by the root. Suberization is most developed under severe moisture stress.

Water stress also affects the reproductive process of plants. It suppresses development of flowers, fertilization and fruit-set by causing delayed flowering and dehydration of pollen grains and ovaries. A prolonged stress will stop flowering completely. Under severe drought shoot dieback may occur. When drought breaks new tillers develop from the basal buds in the case of perennial grasses or from shoot primordia in woody plants. Residual tussocks in perennial grasses in semi-arid areas are extremely tolerant of water stress, and can persist through lengthy drought periods if not damaged by other processes such as grazing during the stress period. Woody perennials are also drought tolerant and will shed their leaves as a first step if the stress is prolonged. However, because their root system is generally deeper, they are even more tolerant than the herbaceous plants.

Another aspect of plant adaptation in arid and semi-arid areas, is the development of water storage capabilities. Some plants, for example some *Cucumis* and *Elephantorrhiza* species, have succulent root systems while others like the *Cactus* have thick succulent leaves and stem. These succulent roots and leaves provide the plant with stored moisture during periods of drought.

Leaf size is one other important adaptation mechanism. Most plants in arid and semi-arid areas have small leaves. This small size reduces the surface area over which evapo-transpiration occurs and thus reduces moisture loss.

Overall, droughts cause water stress and lower the general productivity of the habitat. In arid and semi-arid areas where drought is common, management must concentrate on evaluating the impact of this natural phenomenon on the productivity of the habitat.

7.3.3 The Effects of Temperature on Plants.

Morphogenetic changes induced by temperature include influence on the number and size of floral parts, leaf shape, seed potency and germination (Laude 1974). Although the maturation process is generally hastened by heat, especially in annual herbaceous plant species, where high temperatures prevail under moisture deficiency, plant growth is reduced. At low temperatures both plant growth and flowering may be delayed. Plants adapted to semi-arid and arid conditions can tolerate these extremes for much longer than those not adapted to such conditions. However, if the extremes of temperatures are prolonged, even these adapted plants will die.

Two other mechanisms of plant response to a combination of temperature, moisture and photoperiodism are rigor and dormancy. Plants go into a state of rigor under extreme temperatures and all growth is arrested. A prolongation of this stress leads to death of the plant. Dormancy, unlike rigor, is a seasonal phenomenon. It occurs when the length of daylight is reduced while at the same time temperatures are lowered and the moisture gradient decreases. During this state, the plants, mostly perennials, suspend growth.

Injuries commonly caused to plants by high temperatures include leaf chlorosis (loss of chlorophyll), leaf scorch, sun-scald, stem-cracks and lesions.

Grasses are most sensitive to temperature stress at the flowering stage. Very high temperatures will kill the florets. Temperature stress during seed maturity influences the germinability of such seeds upon maturity. Seedlings grown from seed produced under intolerable temperature ranges tend to be less vigorous than those produced under normal temperatures. Seeds may be killed by extreme temperatures at a younger age.

In arid areas, where temperature extremes are common, both plant diversity and density are low. This partly accounts for the low productivity in these areas. In semi-arid areas where conditions are less severe both plant diversity and density are higher.

7.3.4 The Effect of Nutrient Stress on Plants

The vigour of vegetation is also a function of soil fertility. Nitrogen (both as nitrate and ammonia) and phosphates are important soil nutrients for plant growth. The soils replenish these nutrients as dead plant material is decomposed. In areas of low fertility these nutrients are at low levels. In these areas there is also a marked surface concentration of these nutrients so that a loss of a few centimetres of top-soil may promote pasture deterioration (Friedel, Cellier and Nicolson 1980). In one case overgrazing led to the loss of vital nutrients through erosion in an arid saltbush community (Friedel *et al.* 1980).

7.4 LAND USES IN ARID AND SEMI-ARID AREAS

7.4.1 General.

Although the soils of arid and semi-arid areas are generally described as of poor quality, deficient in minerals and nutrients and of low productivity, Israel has demonstrated that these soils can be highly productive if water is supplied. Natural rainfall, rainfall enhancement and irrigation have been used on unfertilised lands there with success and reasonably good harvests obtained (UNESCO 1979, Noy-Meir and Seligman 1979). Such unfertilised lands under the traditional cropping systems have been able to yield up to 1000-1200kg per hectare of crop harvest there.

Under natural states, the soils of semi-arid areas also support moderately diverse and dense vegetation. Traditional systems of land uses were able to utilise these resources with success over long periods of time because the traditionalists' understanding of the environment was very important for their so-called subsistence living. In the case of arable farming, manure was used to replenish the nutrient deficit created by harvested crops.

If semi-arid areas are properly managed with adequate soil and land management practices provided to avoid salinisation of soils, overgrazing and soil erosion, they can provide long-term sustained production. The impact of various land-use practices on the environment isexamined below. It is hoped the review below will enable re-assessment of economic development policies relating to land uses in Western Botswana, by showing the hazards already experienced in other countries with similar environments.

7.4.2 Agriculture.

7.4.21 Pastoral: In the arid and semi-arid zones of the world about 18 million square kilometres are used for grazing large herds and flocks of various forms of domestic stock (UNESCO 1979). The traditional pastoral agriculturists comprising some 50 million people in semi-arid Africa south of the Sahara lead a nomadic or semi-nomadic life (Barnes 1979). Their movements, primarily aimed at providing the best possible natural grazing for their livestock, are normally coordinated with rainfall patterns and seasonal availability of forage and water. In this system there is no deliberate control of stock numbers nor of systematic animal production management. Herds build up during periods of good rainfall then crash during droughts. This was witnessed in the Kajiado District of Kenya where cattle herds were reduced by some 55% during the 1957 and 1961 droughts (Barnes 1979).

In the Sudan semi-arid areas, pastoralists keep camels, cattle, sheep and goats (Sorbo 1977). Camels are an important source of milk, transport and prestige. They can endure hardships like drought and subsist on relatively poor vegetation; thus they are well-adapted to the arid and semi-arid conditions. Cattle, sheep and goats provide milk, meat and skins as well as wool from sheep. Seasonal movements of these herders are determined and guided by factors such as presence of grazing, water in wells and reservoirs, and by herd composition and size. Nomadic pastoralism is the major land-use practice.

In the Sahel, the nomadic pastoralists herd and manage animals to best exploit various vegetation community types, accomplishing this by herding several species of domestic animals each with its own economic and ecological characteristics (Swift 1977). Sheep and cattle are herded together, while camels and goats are separately herded together. The former group requires more care, drink more often, eat lots of grass and sell well while camels and goats can survive very bad conditions and eat browse, but do not sell as well as sheep.

In Tanzania and Kenya, according to Talbot (1972), the Masai practised transhumance pastoralism until they were sedentarised. In the transhumance practice, the graziers and the community stayed in one place until the grazing resources were reduced although not necessarily heavily, then the area was vacated by the whole community which moved to the next area. After sedentarisation, only herdsmen and not the whole community, still continued to move from place to place typical of nomadism everywhere else.

In Botswana, the cattlepost system of pastoralism involved location of cattle "posts" at radial distances of up to 10 kilometres from a central watering point (usually in the village) where cattle, sheep and goats had to go almost every second day to drink. Once grazing conditions deteriorated around the post, then another new site (or old site revisited) about the same distance from the same central water point was chosen and occupied.

Another pastoral practice in semi-arid areas, associated with modern economic development practices is that of commercial domestic livestock ranching. In this practice, areas are fenced off, watering points provided and cattle handling facilities such as dipping, inoculating, drenching etc. for control of internal and external parasites are also provided. Breeding is controlled as well as control of predators and competitors. Under good management, including stock limitation, this system can optimise the use of the particular fenced area without causing adverse effects on the environment. However, under improper management, it can create a patch of overgrazed, and at worst bare sand patches on the area. Such a situation is exemplified by the Konga and Ilkisongo Ranching Schemes of 1946 and 1954 in East Africa, both of which by 1958 had rendered their sites bare and were then vacated (Talbot 1972).

The effects of pastoralism on semi-arid ecosystems are varied depending on the system of management practised. Under traditional nomadic practice the system is maintained in a dynamic equilibrium with the animals using it. The size of the animal population is limited and determined by the ecological carrying capacity, any excess usually dying off. Sedentarization is, however, usually accompanied by control of diseases, provision of supplementary feeds, elimination of predators and other husbandry practices. Because of this, the populations usually grow and exceed the ecological carrying capacity. This results in the excessive removal of vegetation through year-round unrelieved grazing pressure followed by soil erosion and degradation, that rapidly turns the area to desert. The environmental impact of grazing arid lands has also been reviewed recently by Heathcote (1983).

7.4.22 Arable Agriculture: Semi-arid areas usually have parts which vary from dry to moister. In moister places, some crop production, although sporadic and at a low level, may be practised (Barnes 1979). In Israel, wheat and barley have been the main crops grown in the semi-arid areas (Noy-Meir and Seligman 1979). In the southern margins of the Sahara, sorghum and millet have been the main crops (Wickens and White 1979), but under irrigation other crops such as rye, ground nuts, and tobacco are grown in Mauritania, Senegal, Mali, Niger, Nigeria, Chad and Sudan. Irrigation in Egypt dates back to Biblical times. The importance as well as the environmental effects of the irrigation waterworks in Egypt have been reviewed by George (1972), Kassas (1972) and Worthington (1972). These works increased crop production for a while but caused diminished fisheries and salin- isation of the delta soils.

The effects of arable agriculture on the environment in semi-arid areas are varied. In the traditional practice, precipitation restricts the rain-fed crops to specific localities where there is adequate moisture. Because of this specificity, the sites once cleared have to be used regularly as the option to move to another similarly suitable area does not exist. Thus the natural perennial vegetation never has a chance to re-establish itself again on such cultivated land. The natural vegetation then becomes dominated by annual herbs and grasses as the trees are removed to cultivate more land. Trees are also heavily collected for firewood by the agricultural community (Wickens and White 1979). This serious alteration of the tree cover leaves the cleared cultivated fields without adequate windbreaks. The fields become exposed to wind which removes the top soil with nutrients. Kovda (1980) attributes the increased frequency of dust storms, reinforcement of albedo, warming of climate, reduction of relative humidity, soil erosion etc. to the general deforestation, loss of humus layer and the "continuous plowing of tens and hundreds of kilometres" of the semi-arid areas (p. 101).

Irrigation causes salinisation of the soils, the most serious impact on the environment. Up to 50% of all irrigated lands throughout the world is salinised, produces lower yields or is not farmed at all (Kovda 1980). The effects of irrigation and salinisation of soils in various parts of the world have been reviewed by Kovda (1977, 1980), Gabally (1977) and recently by Heathcote (1983).

7.4.3 National Parks, Equivalent Reserves and Wilderness Areas

Land use in semi-arid areas also includes reservations of land for conservation purposes such as national parks, wildlife reserves and wilderness areas. These land uses are in harmony with the environment of semi-arid areas. Their basic policies and objectives of conservation of natural resources like soils, vegetation and animal life in as natural a state as possible facilitate the protection of the semi-arid environment. These policies do not necessarily exclude human use of such zoned nature conservation areas but instead demand that such use shall be secondary to nature conservation. Such uses, well controlled to minimise impact on the environment, are tourism and recreation. An overview of the parks, reserves and wildlife areas in the semi-arid and other parts of Africa has been given by Curry-Lindahl (1974a, 1974b).

7.4.4 Mining

Mining continues in semi-arid areas for various minerals including oil and phosphates. An account of the effect of mining oil and sand-minerals on the natural environment has been given by Frith (1973: 120). UNESCO (1979) indicates that mineral exploration in semi-arid areas is made easy because prospecting and the geology are not obstructed by heavy vegetation. Some countries in the arid and semi-arid areas subsist on one or more major mineral resources, for example Libya, Saudi Arabia and others subsist on oil. The mining sites always become settlements and naturally attract more people.

The effects of mining on the semi-arid environment are varied. In sand-mining, the top soil and vegetation have to be removed and the sand beneath then put through a processor to extract the minerals. This procedure leaves the area bare of vegetation cover and therefore the soil becomes prone to wind erosion. In some cases reclamation is made by landscaping such soil dumps and planting some vegetation on them. Open-cast mining pits are difficult to reclaim.

The establishment of settlements and increase of human population brings pressure on the local vegetation which may be collected for fuel or grazed by introduced livestock. Arable farming based on irrigation, with its related problems may even be introduced to provide food for the community, if adequate water supply is available or by use of sewage water.

7.5 MANAGEMENT OF ARID AND SEMI-ARID AREAS

The compatibility of land uses with the arid and semi-arid environment need to be considered in the management policies of such areas. Recognising and assessing the capability and suitability of these areas for specialised uses, and the incorporation of such recognition in land-use planning can ensure long-term protection of such environments.

Semi-arid areas that have been degraded can also be reclaimed. The reclamation projects, however, are very expensive. They also require prior knowledge of the ecology of the area and the optimisation of whatever benefits can be derived from the environment to re-establish itself. For instance, if trees are to be planted as a reclamation process, there is a need to know what type of tree is the best coloniser, and the conditions under which its root system performs best. In the case of the area itself knowledge must exist on how long it retains soil moisture after rains and whether the tree species chosen can optimally use that moisture.

The traditional land use practitioners recognised the fragility of the various areas and acted to minimise the adverse impact on them. The environment itself played a role in influencing such uses, for example in pastoral farming, nomadism was resorted to in response to increasing scarcity of grazing in the occupied locality. If such increasing scarcity of grazing was not immediately responded to, the increase in domestic livestock numbers was suppressed through mortalities. It appears there were no deliberate efforts made towards pasture improvement such as by growing fodder crops. This was probably because the environment itself was not suitable for such crops. Thus, moving away from the area before the grazing resources were exhausted ensured continual existence of vegetation cover and protection of the soil against erosion, stoppage of surface run-off and encouragement of downward drainage. This in turn supported high underground water tables and recharges of underground aquifers.

The traditional arable agriculture was confined to areas in the semi-arid zone where there was higher rainfall, to flood plains or to oases sites and had thus restricted impact on the environment. Such areas were not extensive and arable agriculture was therefore not a serious environmental hazard.

National parks, wildlife reserves and wilderness areas are probably the forms of land-uses that are wholly compatible with environmental protection in arid and semi-arid areas. However, the secondary activities associated with their use, such as tourism and recreation, have to be adequately managed because they can be destructive to the environment. Some of their worst impacts include collection of wood for fuel, disposal of waste, artificial manipulation of the animals' habitats for tourist attraction, developments of complex tourism road networks, operation of off-the-road vehicles, trampling, and littering the environment. Restriction of such activities to specific sites can ensure their proper control.

Modern economic planning and technology appear to be the major causes of environmental deterioration as land uses take on intensification and extensification with minimal environmental impact assessment made beforehand. Irrigation and damming schemes have been developed in semi-arid areas with consequent salinisation of soils, diminishing fisheries resources etc. Extraction of minerals from sand has been undertaken, resulting in destruction of vegetation and exposure of soils to erosion, while intensification of pastoral farming and sedentarization of nomadic pastoralists have led to overgrazing, soil erosion, surface run-off and the subsequent results of desertification, sand-storms, droughts and famine.

Desertification can be fought by trying to halt or reverse degradation of the land. This process, called de-desertification (Le Houerou 1976), includes activities such as establishment of green belts, sand-dune stabilisation and desalinisation of soils, which have all been suggested and tried. However, all those activities are very expensive to undertake although they are very helpful in improving the functioning and recovery of the deteriorated ecosystems.

Generally there are three types of recovery:

(i) natural recovery: in which the natural process of colonisation through to climax communities occurs uninterrrupted and unassisted by man;

(ii) semi-natural recovery: in which natural recovery may be speeded up by artificial measures such as contour terracing and over-sowing, with a view to helping natural vegetation and other biological recovery;

(iii) artificial recovery: which involves the transformation of the whole ecosystem artificially. This includes planting of drought resistant trees for fuel, sand-dune stabilisation, creation of windbreaks, shelterbelts and greenbelts, as well as reclamation of salinised soils (Le Houerou 1976).

However, the best management of land use and fight of desertification in arid and semi-arid areas should be by:

(i) adopting those development schemes that do not seriously disturb the vegetation and soil;

(ii) education of the public on conservation measures;

(iii) and the continuous monitoring, evaluation and appraisal of the so-called development projects that have inherent impact on the environment. But perhaps the simplest method of fighting desertification is by fighting its causes before it is initiated, i.e. forestalling it by avoiding it.

The interrelationships of economic development, land use and ecological conservation, require recognition at the outset if disasters such as desertification, drought and famine are to be avoided. These interrelationships have been addressed recently by the new concept of "ecodevelopment". Ecodevelopment is a concept that focusses more attention on the importance of considering the environment and conservation of natural resources in economic development planning. Arguing the case for ecodevelopment, Riddell (1981) says environmental balance in a human ecosystem ensures a future for that society's needs that can last almost indefinitely. Environmental degradation and over-exploitation of natural resources now, means human misery in future. Thus a need to plan for a sustained use of natural resources and the protection of the environment requires incorporation in any economic development planning process. Put simply, ecodevelopment is a concept of growth development with progressive and systematic consideration of environmental protection and resource conservation to achieve maximum sustained benefits from the land. Miller (1978) and Selman (1981) have reviewed this concept in relation to national parks planning and ecological planning respectively.

Land is an invaluable resource as long as it is managed sensibly. In arid and semi-arid environments its use calls for a prior understanding of the ecology of natural ecosystems, for the problems of recovery and/or reclamation of damaged ecosystems in these areas are much more difficult than elsewhere.

7.6. SUMMARY

Wild animal species utilising arid and sem-arid areas, having evolved and adapted themselves to such environments, must be viewed as the best users of such areas. Invariably domestic animals have occupying those areas depend on man to manipulate the environment to some extent, to make it suitable for their upkeep. This has been mainly by creating artificial water points to supply the high demands of these less arid-adapted animals. The results of these activities by man have been catastrophic in some cases. Yet not all uses of these areas by domestic stock need necessarily lead to catastrophes. The traditional utilisation patterns of nomadic pastoralism were less destructive.

The main area of management emphasis, for the more adapted and least destructive wild animal life of these areas, should basically be recognition that they need extensive areas of land over which to seek water and food. They require no water or food supplementation from the manager if the area over which they roam is unrestricted. Thus provision of adequate and properly sited conservation areas, such as national parks, wildlife reserves, wildlife management areas and wilderness areas, and unobstructed migration routes are almost all that the wild animal requires to survive. The capital and husbandry costs are almost non-existent for the management of the wild animal under such conditions.

Conservation of vegetation ensures protection of the soil and a check against desertification. Its destruction leads to alteration of soil structure, ease of wind or water erosion and general degradation of the surface environment. The disappearance of vegetation also means the disappearance of fauna that utilise it. Thus there is a chain reaction when the dynamic equilibrium of these areas is upset. The main causes of such upsets have in most cases been poor management of the grazing system, and also ignoring of environmental considerations in economic planning. The examples are locating of farms in semi-arid areas where grazing resources are sensitive to unrelieved prolonged use.

Land use in arid and semi-arid areas should be based on land capability and suitability assessment. The fragility of these zones makes this prior assessment especially necessary. Range management, including the monitoring of the range's response to various factors like land uses, droughts, fires etc. is an especially important tool in managing the arid and semi-arid environments.

Having reviewed the main biotic components, basic dynamics, management and utilisation of arid and semi-arid areas above, Chapter 8 examines some of Botswana's natural resources management policies relating to the Western Kalahari for comparison with this chapter's review.

CHAPTER 8

MANAGEMENT OPTIONS FOR LAND RESOURCES OF WESTERN CENTRAL KALAHARI

8.1 SUMMARY OF, AND CONCLUSIONS FROM FINDINGS

8.1.1 Animal Abundance, Productivity and Seasons.

In this study, there were higher densities of most animal species in the study area between November 1983 and June 1984 (see Section 6.2.3). The animals apparently move in and out of the study area depending on the status of the habitat. The habitat conditions were optimum during this time. Almost all the species considered have peak breeding period during this time (see Section 2.6.2). This was the time when productivity as measured by levels of greenness was highest. Trees and herbaceous plant layer were generally green, and according to information from APRU (1980) some of the trees and grasses have high nutritive value at this time as measured by their phosphorus, calcium and crude protein content levels. This was also the period with highest rainfall.

It may thus be concluded that animal abundance in the study area is probably influenced by availability of rains which improve the productivity levels of the vegetation. There is however, a need to do a long term study of this apparent relationship so that a comparison between years and not only between a few seasons in one year, can also be made.

8.1.2 Animal Distributions.

8.1.21 Animal Distribution in Relation to Farms, Settlements and Communal Areas: Fenced farms, most permanent settlements and communal cells are avoided by wild animals. The communal area around Ohe was however tolerated. The avoidance of the permanent settlements and communal cells is in terms of occupancy since there is evidence indicating animals, especially hartebeest and wildebeest, apparently use those areas in transit. The gemsbok showed definite avoidance of fenced farms and communal cells.

Unfenced and unoccupied farms are tolerated by wild animals. Several species were found in the TGLP unfenced farms east of Tshane. The same tolerance is shown of temporary settlements.

As could be expected, domestic animals studied, cattle, horse and donkey, occupied the farms, permanent settlements and communal areas. It would appear during the rainy period especially when there is water in pans, the domestic animals spread out into the wildlife management areas to exploit this water source.

Wild animals as could be expected occupied conservation areas - the national park and wildlife management areas.

From the foregoing, it may be concluded that settled areas, both communal areas and fenced farms have displaced wildlife from such settled locations. Wild animals can no longer occupy such areas. A further conclusion drawn from this is that as these settled areas expand, they will accordingly displace wild animals from the areas such wild animals now occupy.

8.1.22 Animal Distribution in Relation to Physiographical factors: Various species of wild animals use at various times of the year, the various physiographical features found in the study area. Notwithstanding the above general observation, some animal species seemed to have stronger preferences for some of the factors. Gemsbok for example, showed generally strong preference for old drainage valleys, hartebeest for areas below 1120 metres above sea level and wildebeest for low sand-dune fields and mixed soils with high white pan soil content. Although not strongly reflected in the quantification of associations, field observation showed that springbok seemed to favour mixed soils with high white pan soil content throughout the study period.

No outstanding association was noticed of the influence of big pans on animal distributions although the presence of big pans in areas of mixed soils with high pan soil content must have influenced the associations found in those areas.

It may be concluded from the foregoing that the physiography of the study area does not generally have a strong influence on the distribution of the wild animals, although as can be expected, local preferences by certain species for certain factors occur at certain times of the year.

8.1.23 Animal Distribution in Relation to Vegetation types and Habitat Condition: No distinctive cases of the influence of vegetation types on animal distributions have been observed. Like the physiographic factors, various species of wild animals used the various vegetation types at different times of the year. The only exception was for the area of dense woodland around the Matsheng Village area which was not occupied by wild animals but only used in transit. Field observations showed that springbok were confined in the western part of the study area, to mainly the park woodland sites.

Vegetation condition ie. productivity and herbaceous plant cover did not seem to have strong influences on distribution of animals over the study area, although there was a tendency for animal occurrences to be greatest in the southern parts where there was lesser cover. There is, however, no adequate information tying such distributions to herbaceous plant cover. The poor herbaceous plant cover in the southern part of the study area seems to be accountable to the action of harvester termite *Hodotermes mossambicus*. Field observations indicated springbok seemed to have greater preference for the sparsely covered areas.

No significant influence of surface water availability on distributions of wild animals has been observed. This finding is not conclusive enough for several reasons. Firstly surface water was observed in only two aerial surveys. No definite conclusion can be drawn from a sample that small. Secondly the design of the present study is not considered by the author to have been suitable for investigating that relationship. A better design would be to make a twenty-four hour surveillance of animal arrivals and departures from such water points. On a few occasions a few animals were found at these surface water sites though. There is therefore inadequate information about this factor in the Kalahari to enable a definite conclusion to be drawn. The importance of water or moisture to animals in semi-arid environments has been illustrated in Chapter 7. There is thus a need to study its importance more with regard to the semi-arid Central Western Kalahari ungulates.

8.1.3 Land Use and Grazing Resources.

The grazing conditions around permanent settlements and Ncojane ranches are poor. In the permanent settlement areas there are bare areas, a result of overgrazing by domestic livestock. In the Ncojane ranches overgrazing signs are beginning to show. In both permanent settlements and Ncojane ranches there is uncontrolled grazing. It is expected the TGLP ranches in the study area will be run along the same lines and will therefore experience the same problems of overgrazing.

In the conservation areas there are also signs of overgrazing. This appears to be accountable to harvester termites action with minor contributions from bush-fires and wild animal grazing.

Overgrazing in Matsheng Village area has led to bush encroachment. It is only in this area where dense woodland has been noted and related to the grazing practice. It can be assumed that with more overgrazing occurring over the study area, then more areas will be lost to bush encroachment.

Bush encroachment combined with land uses not tolerated by wild animals may together in the long run cause local extinction of the wild animal species not tolerant of them. These will include the springbok, wildebeest and hartebeest. Secondly, the ultimate absence of an herbaceous plant layer will lead to a situation where trees are felled to provide fodder for animals and this process will in turn lead to ultimate denudation of the vegetation. Tree felling for fodder is one of the serious deforestation threats facing many semi-arid areas in especially the West African Sahelian region. There is thus a need to take action against overgrazing immediately.

8.2 MANAGEMENT OF LAND, WILDLIFE AND OTHER LAND RESOURCES OF WESTERN CENTRAL KALAHARI

8.2.1 General.

Management of land resources is a complex exercise. Land resource here refers to biological, physical and chemical elements of the land, and in this respect includes those elements that occur both above the surface and beneath the earth's surface. However, the discussions here will be restricted to a few surface land resources selected from the spectrum of those discussed in the preceding chapters of this thesis. Management of land resources requires production of a plan that will show how the various resources are related, where there are mutual tolerances and conflicts and in the final analysis have an integrated programme of managing all. Without doubt, compromises have to be made in cases where there are conflicts. It is at this stage of what resources have to be compromised that the attitude and preferences often called priorities, of the ultimate decision-maker are expressed. This is where the destiny of a resource is determined. Having reviewed the findings of this study above (section 8.1), some of the land resources management policies and plans applicable to the study area are reviewed.

8.2.2. Land Management.

8.2.21 General: The definition of land adopted here is generally as given by the Australian Department of National Development (1979). Land comprises the physical and biological environment. This includes climate, relief, soils, hydrology vegetation and fauna and the extent that they influence potential for land use. It also includes the results of past and present human activities, such as reclamation of areas previously unavailable as well as degradation results. In this respect land is therefore a resource that requires specific management objectives as distinct from management of specific land uses. The major land guiding constituent of a land management strategy would be a land management policy. The policy would provide for conditions under which land will be used, prescribe precautions to be taken by the various users to avoid land degradation, and provide reclamation strategies for degraded lands. However, these would require fore-knowledge of the status of the land and its limitations, as well as the status and categories of land under various uses. Basically the policy would provide for inventory of land status or capability and suitability assessment, planning the uses, implementing the plan and monitoring the effects of the uses under the plan. And finally there should be a specific authority to oversee the application of the policy.

Botswana, in the above context has no land management policy. Land is used as and when some organisation wants to do something where it considers appropriate. Thus it is the users who decide how land is used. Land zoning plans are thus user-dictated rather than being dictated by whether land is actually suitable for the purpose, that is, it is not land capability or suitability assessments that dictate the nature of use but user demand. The zoning or allocation is thus to satisfy the demands of the various users. This state has led to a situation where only land use policies specific to some use are enunciated, often carrying in themselves various degrees of conflicts with other uses and elements of environmental degradation. One example of this situation is the 1975 grazing policy formulated as the Tribal Grazing Land Policy (TGLP) (Botswana Government 1975).

The shortcomings, including conflicts with resources like wildlife, of this policy are discussed later. However, one major advantage brought about by this policy was the realisation that there was a need to coordinate land use. The establishment of the Land Development Committee brought into existence a reference body to oversee land use zoning. The shortcoming of this body is that it was only advisory and it had no specific executive functions. In this respect the body would not direct how the land should be used, nor be in a position to go into land research. From mid-1983 the committee was redirected to take on responsibility of general land use planning. However, without it being executive, there is little that the committee can do in really deciding how land should be used or policing land utilisation, thus its advisory coordinative role will in essence remain generally less effective. The Land Boards only allocate land and settle disputes and are hitherto ineffective in policing or directing how land should be maintained [see also Machacha (1981) and Mathuba (1982), about the various problems of the local land boards].

In discussing the land management and use issues in an interview with the senior personnel of the Botswana Ministry of Local Government and Lands and Ministry of Agriculture, it was clear to the author that unless a different strategy is adopted for the management of land in the country, there is no way the current problems of land or environmental degradation arising mainly from grazing, as well as land use conflicts, can be easily resolved. A suggestion was even advanced from a member of the Ministry of Agriculture that neither Ministry of

Agriculture nor Local Government and Lands as presently structured were capable of taking on the responsibility of land management as suggested by the author.

One major problem that prevails because of lack of a land or environmental management policy is the opening up of the western Kalahari to more grazing of livestock and the resulting expansion of overgrazed and denuded land, displacement of wildlife and other environmental problems discussed in previous chapters. The desertification process has been initiated in the Western Kalahari. One needs to look at what is happening in the Bokspits area further south-west of the study area to understand the seriousness of the threat.

8.2.22 Land Management Recommendation: It is recommended that a land management policy be adopted for Botswana in order to streamline and ensure environmental protection of the fragile ecosystems. Western Botswana, the heart of the Kalahari, requires special consideration under the recommended land management policy. Chapters 5 and 6 and section 8.1.3 have identified the nature of this area and it is the view of the author that only a sound land management policy administered by an executive authority can forestall the threat of desertification being currently set in motion there and indeed in other parts of the country (see also section 8.2.4).

The land management policy recommended should provide for:

(i) Research: This should entail land capability and suitability assessment. Land capability is a measure of the potential of the particular area for a particular use such as for example grazing, cultivation, tourism, nature conservation etc. The process of measuring the potential of course involves collation and integration of biophysical information. Since land use is a dynamic process, the need to monitor the effects of the use opted for, or the use land was previously put to, becomes part of the information gathering exercise. However, the land attributes chosen for investigation must be such that they will provide adequate information about the maximum potential that long term and permanent sustained production of the land can be based on. The thrust of the policy here simply is: assess the potential of the land by first inventorying all its resources. This step is followed by land capability classification which basically is a blue-print for land zoning.

Land suitability is a measure of the desirability of the use contemplated for an area. While the land may be capable of sustaining a certain use, it does not necessarily mean that that use is desirable for the area. For example, some good grasses located in an arid environment may be capable of sustaining short term grazing but it would be undesirable to graze the area because it could become easily overgrazed and denuded. Suitability assessment is in other words based on the capability of the land to provide long term sustenance in so far as that strategy provides the long term socio-economic benefits. Thus the long term socio-economic implications must also be assessed before-hand.

The land capability and suitability assessment strategies as well as the related land inventory and classifications have been practised in Canada [Lacate 1969, Canada Land Inventory (CLI) 1970], and the United States (Dept. of National Development 1979) now for some time (see also Wiken and Ironside 1977). One of the main advantages of the strategy is that by the time allocation of land is made, information on all competing or existing land resources is known.

(ii) Land Zoning: Once land capability and suitability assessments have been made and land classification determined, the exercise of zoning would be commenced. It is here that actual delineations are determined for the various uses, and alongside this, the actual terms of allocation including accountability for degradation or abuse, are spelt out.

(iii) Implementation and Monitoring of the Zoning Plan: The land zones may then be used in accordance with the terms of allocation, and the impact of such uses monitored, and where appropriate such uses changed.

A land management policy of this nature would ensure there was no prejudice in land resource allocation since the zoning would have been independent of specific user demands. Secondly, land use conflicts would be rationally resolved as there would be available information on all aspects of the resources of the area.

8.2.3 Wildlife Management.

8.2.31 General: Chapters 5 and 6, and section 8.1 above have identified the big wild animals of Western Central Kalahari as very mobile. This is shown by both the seasonal distributions and the fluctuating abundance values, again tied to seasonal changes. The whole area is used by animals in one way or another over the whole year. These distribution characteristics make the management objective basic and easier - big areas of land must continue to be provided for exclusive wildlife use.

The present Botswana policy on wildlife conservation is basically that while wildlife should be protected, it should also play an important role in the socio-economic field and in this respect a sub-policy of wildlife utilisation has been adopted in the country. In recognition of this stated policy, areas have been or are being set aside as national parks, game reserves and wildlife management areas. The former two are preservation areas where consumptive utilisation is prohibited, but instead "photographic" tourism is tolerated. In the wildlife management areas hunting is allowed. It is here where the wildlife benefits accrue to the rural majority poor. Wildlife management areas, like national parks and game reserves, are a land use form where wildlife conservation, according to the prescribed policy on them is considered as a priority above other uses. In practice though, the picture is somewhat different and gloomier. They are practically being looked upon as reserved areas for future use as grazing areas. Thus the plight of wildlife remains.

In Western Central Kalahari, according to this study, approximately 10,000 eland, 29,000 gemsbok, 98,000 hartebeest, 72,000 wildebeest, 115,000 springbok etc. occupy the area. The total area available to them as conservation areas is about 80%, of which about 77% is wildlife management areas and the rest a national park. The rest of the study area, about 20%, is communal cells and farms. If these respective percentages were maintained at these levels indefinitely, and no further developments reduced the 77% available as wildlife management areas now, then the future for wildlife of the study area would be bright.

Unfortunately, several problems face wildlife in this area. The TGLP farms are continuing to be planned for parts of areas now zoned as wildlife management areas. Secondly, mineral prospecting is taking place in these same areas. Prospects are high for valuable minerals and if that leads to mining, then the wildlife management areas will be further reduced and movements of animals further restricted. Thirdly while movement to the south of the study area is unrestricted, this is not so for movements to the east and north-west. Both have many settlements. However, there are still outlets in the north and north-east out of the study area. But, there is a current strong move by Ghanzi cattle farmers to establish farms here. The Okwa Valley is already occupied by cattle under the cattle-post system. These areas are supposedly also wildlife management areas. Fourthly, it is the view of the author that hunting pressure is building up as there is now an increase in motorised transport and hunter movement is facilitated by prospecting traverse lines.

8.2.32 Recommended Wildlife Management Strategy: The present policy on wildlife conservation is sound. Wildlife should be used just as other resources are used. Being a renewable resource, with good management it can be used on a sustained yield basis indefinitely. Good management here refers to recognition of all pressures that could threaten wildlife survival and removing such pressures or threats. It also includes setting and regulating hunting quotas based on adequate information and continuous research.

For Western Central Kalahari therefore, the management strategy should entail the following:

(i) Research: This study and other preceding studies have identified certain aspects of the ecological dynamics of the area. This study has especially attempted to show the close relationships between wildlife and other land resources and land uses emphasising the need to unequivocally accept it as an equally important land resource. This was meant to provide an integrated picture that should form the basis for future research. Therefore research must be stepped up in this area. The specific fields that require immediate investigation are movement patterns, the feeding and breeding characteristics of the various species, the detailed study of the importance or otherwise of pans to wildlife in this area as well as the actual study of animal population dynamics.

Provision of artificial water points for Kalahari wildllife has been contemplated by various Botswana authorities. This is a sound idea provided the effect of such a step can even if vaguely, be anticipated. This calls for further investigations into the extent to which animals here rely on surface water. This study has found no significant correlation between any species of wild animals observed and availability of rain water in pans. However, only two instances of such surface water were observed. This is grossly inadequate to draw any definite conclusions from. Besides the method- ology is not considered to have been suitable for observing this particular behaviour. It is considered the method used by especially Weir and Davison (1965) would be ideal for investigating this aspect.

(ii) Wildlife Utilisation; The majority of people in Western Central Kalahari and indeed in other parts of the country, subsist on game meat and sell the various artefacts made from game products. This is an important socio-economic contribution by wildlife. The policy of wildlife utilisation is therefore perhaps even more important here, more especially that there are even fewer economic opportunities here. Hunting by safari operators also is undertaken in this area. Revenue from this activity has been substantial.

While the policy of wildlife utilisation should continue, there should be more vigilence exercised over illegal hunting by both subsistence and commercial (safari) hunters. Tourism also should be encouraged in this area.

(iii) Wildlife and Land Use; This study has established that fenced farms and communal areas are least tolerated by wildlife. Unfenced and unoccupied farms are used by wildlife. It can be expected that as soon as these farms are occupied and fenced, animals will move away. Management efforts should thus be also concentrated on directing locations of any planned farms such that their impact on wildlife distributions can be minimised. This study has clearly shown that animals in this area do use practically the whole area. There should therefore be no illusion that any proposed sites indicated as of little conflict can actually be sites of no conflict.

The present respective sizes of conservation areas should be maintained. The animal distribution maps show that any alteration of these by taking away part of them will be taking some part valuable to several species. The maintenance of these conservation areas at their present sizes may only be achieved by accepting wildlife as a resource with specific land requirements, at all levels of economic planning.

8.2.4 Management of Grazing Resources.

8.2.41 General: The grazing resources of Western Central Kalahari have been summarised in Section 8.1.3. They are heavily depended upon by domestic livestock, wild animals and harvester termites. Here grazing resources are defined mainly in terms of herbaceous plant layer but may also include tree foliage. Around permanent settlements the palatable herbaceous plants have been overgrazed and bare areas are common. In communal cells grazing with respect to palatable herbaceous plants is also poor but overgrazing by domestic livestock becomes less severe with distance away from settlements.

Signs of overgrazing also show at Ncojane farms again through cattle grazing, and in conservation areas through mainly harvester termite action, apparently some wildlife grazing and fire.

There is no management of grazing around settlements and in communal areas. This is common over the whole country. There should be management of grazing inside farms but as observed in the Ncojane farms, no such management exists. The farms are grazed the same way as communal areas. The occupied TGLP farm east of Tshane is also grazed in this manner.

That cattle, sheep and goats have a significant deleterious impact on grazing resources and soils in various ranges including arid and semi-arid, has been emphasised by various investigators in Australia (see Perry 1974, Barker 1976, Christie 1978, Graetz 1980, Friedel et al. 1980, Wilson and Mulham 1980). It is assumed here that arid and semi-arid conditions in Australia are likely to be generally similar to those elsewhere including Botswana. Overgrazing leads to changes in plant community composition as well as soil erosion and depletion of surface soil nutrients. Invertebrates on the other hand have been observed to also cause considerable grazing deterioration (see section 6.3.32) and Bayliss (1983 pers. comm.) observed a 50% reduction in the Saltbush (*Atriplex* spp.) productivity in the Kinchega National Park, New South Wales, as accountable to invertebrate action.

In 1975, in recognition of the adverse effects uncontrolled grazing was having on grazing resources in communal areas, The Tribal Grazing Land Policy (Botswana Government 1975) was adopted. The aims of the policy were noble but the policy overlooked several important matters.

8.2.42 The Tribal Grazing Land Policy (TGLP): This policy recognised the problems of overgrazing and degradation of the range by the traditional grazing methods and one of its aims was to stop this. Specifically on range deterioration the policy stated "increased herds, under the system of uncontrolled grazing, have led to serious overgrazing around villages, surface water sources and boreholes. Overgrazing has led to sheet erosion and bush encroachment which reduces the amount of good grazing," and "As the number of people and their cattle increase year by year, good grazing becomes scarcer. It therefore becomes more important to ensure that the available grazing is properly used and equitably distributed" (p. 3). Thus the policy wished to make grazing control, better range management and increased productivity possible.

The policy therefore directed the land should be zoned into three groups - commercial grazing land, communal grazing land and reserved land. In commercial farming areas groups and individuals with large numbers of cattle would lease land, fence it, reticulate water, cut firebreaks and apply other ranch management techniques. This would then relieve the communal grazing areas of heavy grazing pressure and enable small stock-owners to have adequate grazing. In zoning the communal areas, where it was found the areas had become overcrowded, such areas would be made bigger.

Reserved areas were to be areas set aside for the future, being safeguards for the poorer members of the community. The other uses to be considered for reserved areas would be wildlife, mining and cultivation.

The overall aims of the policy were far-sighted. However, the following were overlooked by the policy:

(i) That there was no unutilised land. The policy presumed there were areas which were unutilised and could be put to commercial cattle ranching. This presumption is understandable for the policy was on grazing of domestic livestock. However, wildlife which was another grazer with land requirements, it was soon found, occupied and utilised areas that had been presumed unoccupied and unutilised. So the question of unutilised land changed to one of deciding economic planning priorities for allocation of available land, not unutilised land. Parts of the land occupied by wildlife were thus zoned commercial farming areas.

(ii) By placing wildlife under areas reserved for future use, inadequate provision was made for it at policy level, leaving room for potential underrating of this resource by planners.

(iii) The oversight above was due to lack of integrated land capability and suitability assessment and land classification information obtained beforehand. This information would have guided the zoning directives in the policy.

(iv) By removing excess numbers of cattle from communal cells meant more food resources would become available to those remaining and their numbers would swell rapidly again. This would never allow recovery of grazing in the communal areas.

(v) Because prospective lessees of commercial farms had no knowledge of ranch and range management, the farms would end up being put to uncontrolled grazing like communal areas.

(vi) Big cattle-owners occupying the commercial farms could split their big herds so that part remained in communal areas while others were taken to the farm. This would ensure the farm was not overstocked, but would not greatly relieve the communal area grazing. In fact there was no prohibition of cattle moving out of the degraded farm back to communal areas, nor of compulsion of lessees to take occupation immediately.

(viii) Not all parts of the country were the same, and could not all be put to commercial cattle ranching. This would also have been resolved beforehand by capability and suitability assessment and land classification.

In Western Central Kalahari, the results of the foregoing oversights have been:

(i) TGLP commercial farms have been placed in areas utilised by wildlife (see Chapter 5). More are still considered for the area. Thus although wildlife management areas have been identified, parts of them will be taken over by planned commercial ranching areas. Thus areas available to wildlife will continue to be constricted. This, it is the view of the author, is perhaps one of the most serious oversights in not specifying, in clear terms, in the main policy, the specific requirements of wildlife.

If the experiences at Ncojane farms and Phuduhudu ranch are to go by, as soon as fences are put up animals will break them and thus exacerbate their own (animal's) demise as attitudes against them harden.

(ii) Of the eight TGLP ranches allocated east of Tshane, one is now occupied, two are being prospected for water while the rest are lying unattended now for over five years. There is nothing compelling the occupiers to take their occupation. Thus the problem of overgrazing in communal areas remains unsolved.

(iii) The occupied TGLP farm east of Tshane is unfenced and is being grazed under an uncontrolled system similar to communal areas. Again a comparison with Ncojane farms leads one to draw the conclusion that as long as occupiers of these farms are not compelled to practise proper grazing controls, the TGLP farms here will degenerate into cattle-post holdings with the dignified title of farm.

(iv) Almost all these TGLP farms are on areas already infested by harvester termites. Rapid degradation can therefore be expected.

Overall, TGLP in Western Central Kalahari has not yet solved the problem of overgrazing. Indeed it is encouraging the rapid and wide distribution of degradation.

8.2.43 Recommendations on Grazing Resources Management: It is necessary that Western Central Kalahari be recognised as requiring special attention in range management. As already shown soils are not that fertile, rainfall is low, temperatures high etc. and therefore herbaceous plant productivity is generally low. This creates a very fragile grazing environment. To ensure protection of the grazing resource:

(i) the TGLP farm lessees should be compelled to take their occupation and immediately apply the farm management practices required for ensuring sustained grazing.

(ii) Since these management practices require heavy capital expenditure, government should be prepared to subsidise them.

(iii) In both communal areas and commercial farms stock limitations should be imposed.

(iv) The ecology and behaviour of the harvester termite should be studied in order to determine whether the insect should be controlled or not. However, areas infested by harvester termite should not be put to grazing by domestic stock because that can only mean destabilising the already exposed soils and creating even more conditions for suppression of herbaceous plant growth.

(v) Wildlife management areas should not be reduced any further. If they must, then ranching should be on the periphery of the communal areas where wildlife is in any case already disturbed. Wildlife management areas do not only protect wildlife but protect the overall range resources.

(vi) Before farms are actually sited, the movement patterns of the animals in the area should first be studied so that the alignment of individual farms can take into consideration such movement patterns e.g. to enable alignment of corridors between farms.

(vii) As Chapter 7 shows, management of grazing resources in semi-arid environments is a complicated exercise. It is suggested study visits be made to those African and other countries that have been longer at applying the techniques that Botswana is now adopting.

8.2.5 Concluding Remarks on Management of Land Resources of Western Botswana.

The present study has identified some areas that require immediate attention. These are the development of a land management policy based on biophysical attribute evaluation and a new focus on management of wildlife and grazing resources in the Kalahari.

Western Central Kalahari, or indeed Western Botswana, needs a management plan, not only a land use plan showing the present state but a plan showing how the local land resources should be managed in future.

The present study has identified four land regions in the study area - Flatland, Undulating Land, Low Sand-dune Fields and High Sandhills and Sandridges. Other than the preliminary observations made on distribution of animals and other resources within these regions, their detailed ecology remains unknown. Since land use strategies proposed here emphasise prior ecological (biophysical) knowledge, there is need to study these regions individually and develop their uses depending on their individual (region's) uniqueness. Basically this is a call for land capability/suitability assessment on individual land regions.

Integration of research in Western Botswana is necessary if an integrated management plan is to be produced for the area. An integrated management plan should be based on the concept of ecodevelopment (see Section 7.5). This would produce a balanced plan and ensure the vulnerable resources like wildlife and grazing are utilised on a sustained yield basis. This would produce a plan that will check against desertification.

REFERENCES

Andersson, R. J. F. 1969. Climatic Factors in Botswana *Botswana Notes and Records* **2**: 75-78.

Andersson, R. J. F. 1971. Insolation as a Factor in Rainfall Distribution and Retardation. In Botswana Society (eds.) "Proceedings of a Conference on Sustained Production from Semi-Arid Areas". *Botswana Notes and Records*, **Sp. Ed. No. 1**: 315-316.

Animal Production Research Unit (APRU) 1980. *Ten Years of Animal Production and Range Research in Botswana.* Animal Production Research Unit, Ministry of Agriculture, Gaborone, Botswana.

Baillieul, T. A. 1975. A Reconnaissance Survey of the Cover Sands in the Republic of Botswana. *J. Sed. Pet.* **45(2)**: 494-503.

Baker, R. R. 1982. *Migration - Paths Through Time and Space.* Hodder and Stoughton, London.

Barker, S. 1976. Effects of Sheep Stocking on the Population Structure of Arid Shrublands. *Aust. Rangel. J.* **1(2)**: 87-94.

Barnes, D. L. 1979. Cattle Ranching in the Semi-Arid Savannas of East and Southern Africa. In Walker, B. H. (ed.), *Management of Semi-Arid Ecosystems*, Elsevier Scientific Publishing Company, Amsterdam.

Bayliss, P. 1980. *Kangaroos, Plants and Weather in the Semi-Arid.* Unpublished M. Sc. Thesis, University of Sydney, Australia.

Bigalke, R. C. 1958. On the Present Status of Ungulate Mammals in South West Africa. *Mammalia*, **22**: 478-497.

Bofinger, V. J. 1975. An Introduction to Some Multivariate Techniques with Applications in Field Experiments. In Bofinger, V. J. and J. L. Wheeler (eds.), *Developments in Field Experiment Design and Analysis, Ch. 6.* Commonwealth Agricultural Bureaux. Farnham Royal.

Bothma, J. du P and M. G. L. Mills 1977. Ungulate Abundance in Nossob River Valley, Kalahari Desert.. *XIII Congress of Game Biologists*: 90-102.

Boocock, C. and O. J. van Straten 1962. Notes on the Geology and Hydrogeology of the Central Kalahari Region. Bechuanaland Protectorate. *Trans. Geol. Soc. S. Afr.* **65.**: 125-171.

Botswana Government 1975. National Policy on Tribal Grazing Land, Government Paper No. 2 of 1975. Government Printer, Gaborone.

Botswana Society (Ed.) 1971. Proceedings of the Conference on Sustained Production from Semi-Arid Areas. *Botswana Notes and Records* **Sp. Ed. No. 1.** Botswana Society Gaborone.

Bramwell, M. (ed.) 1973. *The Atlas of World Wildlife.* Purnell and Sons (S.A.) Pty. Ltd. Cape Town.

Brinck, P. 1976. Preface. In Rapp A., H. H. Le Houerou and B. Lundholm (eds.), *Can Desert Encroachment be Stopped?* Swedish Natural Science Research Council, Stockholm.

Brown, R. C. 1974. Climate and Climatic Trends in the Ghanzi District, *Botswana Notes and Records,* **6**: 133-146.

Campbell, A. and G. Child, 1971. The Impact of Man on the Environment of Botswana. *Botswana Notes and Records* 3: 91-110.

Canada Land Inventory (CLI) 1970. Objectives, Scope and Organisation *CLI Rep. No.1,* Queens Printer, Ottawa.

Carr, A. 1964. *The Land and Wildlife of Africa.* Time-Life Books, Alexandria, Virginia.

Carr, J. D. 1976. *The South African Acacias.* Conservation Press, (Pty.) Ltd. Johannesburg.

Caughley, G. 1974. Bias in Aerial Survey *J. Wildl. Manage.* **38(4)**: 921-933.

Caughley, G. 1977a. *Analysis of Vertebrate Populations.* Wiley, London.

Caughley, G. 1977. Sampling in Aerial Survey. *J. Wildl. Manage.* **41(4)**: 605-615.

Caughley, G. 1979b. Design for Aerial Censuses. In *Aerial Surveys of Fauna Populations, Proceedings of a Workshop.* p.15-19. Australian Government Publishing Service, Canberra.

Caughley, G. and G. C. Grigg 1981. Surveys of the Distribution and Density of Kangaroos in the Pastoral Zone of South Australia and their Bearing on the Feasibility of Aerial Survey in Large and Remote Areas. *Aust. Wildl. Res.* 8: 1-11.

Caughley, G., R. Sinclair and D. Scott-Kemmis 1976. Experiments in Aerial Survey. *J. Wildl. Manage.* **40(2)**: 290-300.

Caughley, G., R. Sinclair and G. R. Wilson 1977. Numbers, Distribution and Harvesting Rate of Kangroos on the Inland Plains of New South Wales. *Aust. Wildl. Res.* **4**: 99-108.

Child, G. and J. D. Le Riche 1969. Recent Springbok Treks (Mass Movements) in South Western Botswana, *Mammalia,* **33**: 499-504.

Christie, E. K. 1978. Herbage Condition Assessment of Australian Infertile Grassland Based on Site Production Potential. *Aust. Rangel. J.* **1(2)**: 87-94.

Coaton, W. G. H. 1958. The Hodotermitid Harvester Termites of South Africa. *Dept. of Agric. Union of South Africa, Bull.* **375** Ent. Ser. 43.

Coaton, W. G. H. 1963. Survey of the Termites (Isoptera) of the Kalahari Thornveld and Shrub Bushveld of the R.S.A. *Koedoe,* **6**: 38-50.

Cochran, W. G. 1977. *Sampling Techniques,* John Wiley and Sons, New York, 3rd Edition.

Cooke, H. J. 1978b. Botswana's Present Climate and the Evidence for Past Change. In Hinchey, M. T. (ed.), *Proceedings of the Symposium on Drought in Botswana.* Botswana Society, Gaborone.

Cooke, H. J. and T. Baillieul 1974. The Caves of Ngamiland: An Interim Report on Explorations and Fieldwork 1972-1974. *Botswana Notes and Records,* **6**: 147-156.

Crowe, T. M., J. C. Schijf and A. A. Gubb 1981. Effects of Rainfall Variation, Fire, Vegetation and Habitat Physiognomy on a Northern Cape Animal Community. *S. Afr. J. Wildl. Res.* **11(3)**: 87-104.

Curl, S. E. and J. L. Schuster 1971. Ecological and Physiological Constraints of Practical Sustained Livestock Production, in the Sub-desert Environment. In Botswana Society (ed.), "Proceedings of the Conference on Sustained Production from Semi Arid Areas", *Botswana Notes and Records,* **Sp. Ed. No.1**: 140-152.

Curry-Lindahl, K. 1974a Conservation Problems and Progress in Equatorial African Countries, *Environmental Conservation,* **1(2)**: 111.

Curry-Lindahl, K. 1974b. Conservation Problems and Progress in Northern and Southern Africa. *Environmental Conservation,* **1(2)**: 263.

Delany, M. J. and D. C. D. Happold 1979. *Ecology of African Mammals* Longman, London.

Department of National Development 1979. *Towards a National Approach to Land Resource Appraisal, Report No. 2.* Australian Government Publishing Service, Canberra.

Devitt, P. 1971. Man and His Environment in the Western Kalahari, or A Little Technology is a Dangerous Thing. In Botswana Society (ed.) "Proceedings of a Conference on Sustained Production from Semi Arid Areas". *Botswana Notes and Records,* **Sp. Ed. No.1**: 50-56.

DHV 1980. *Countrywide Animal and Range Assessment Project, (Botswana), Final Report* (7 Volumes). Dept. of Wildlife and National Parks, Gaborone.

Dingle, H. 1980. Ecology and Evolution of Migration. In Gauthreaux, S. A. Jr. (ed.), *Animal Migration, Orientation and Navigation*. Academic Press, New York.

Dixon, W. J., M. B. Brown, L. Engelman, J. W. Frame, M. A. Hill, R. I. Jennrich and J. D. Toporek (eds.), 1983. *BMDP Statistical Software*. University of California Press, Los Angeles.

Dougenik, J. A. and D. E. Sheehan 1976. *SYMAP - User's Reference Manual*. Laboratory for Computer Graphics and Spatial Analysis Harvard University, Cambridge, Massachusetts.

Eldridge, D. J. and C. G. Bulawa 1978. Soils of Matsheng, Kgalagadi, Unpubl. Map: Division of Land Utilisation, Gaborone.

Eloff, F. C. 1959. Observations on the Migration and Habits of the Antelopes of the Kalahari Gemsbok Park. I and II, *Koedoe*, **2**: 1-51.

Eloff, F. C. 1961. Observations on the Migration and Habits of the Antelopes of the Kalahari Gemsbok Park. III, *Koedoe*, **4**: 18-30.

Eloff, F. C. 1962. Observations on the Migration and Habits of the Antelopes of the Kalahari Gemsbok Park. IV, *Koedoe*, **5**: 128-136.

Farr, J. L., C. S. Cheney and J. H. Baron 1981. *Evaluation of Underground Water Resources (Botswana) -Final Report GSIO Project*. Department of Geological Survey, Lobatse, Botswana.

Field, D. I. 1976. *Common Grasses in Botswana*. Ministry of Agriculture, Gaborone, Botswana.

Finch, V. A. 1972. Energy Exchanges with the Environment of Two East African Antelopes, The Eland and the Hartebeest. In Maloiy, G. M. D. (ed.) *Comparative Physiology of Desert Animals*. Zoological Society of London, London.

Friedel M. H., K. M. Cellier, K. P. Nicolson 1980. Nutrient Deficiencies in Central Australian Semi-desert Rangeland with Reference to Decline in Range Condition. *Austr. Rangel. J.* 2(2): 151-161.

Frith, H. J. 1973. *Wildlife Conservation*. Australian National Science Library.

Gabally, M. M. 1977. Problems and Effects of Irrigation in the Near East Region. In E. B. Worthington (ed.), *Arid Land Irrigation in Developing Countries*. Pergamon Press, Oxford.

George, C. 1972. The Role of Aswan High Dam in Changing the Fisheries of the South Eastern Mediterranean. In Farvar, T. R. and J. P. Milton (eds.), *The Careless Technology*. The Natural History Press, London.

Global Navigation Inc. 1975. *GNS 500A, Operators Manual Report No. 1023.* Global Navigation Incorporated, U.S.A.

Graetz, R. D. 1980. The Influence of Grazing by Cattle and Sheep on Population Dynamics of Bladder Saltbush (*Atriplex vesicaria*) and White Top (*Danthonia caespitosa*). *Aust. Rangel. J.* **2(2)**: 208-213.

Grove, A. T. 1969. Landforms and Climatic Change in the Kalahari and Ngamiland. *Geogr. J.* **135(2)**: 191-212.

Grosvenor, B. and J. Darley (eds.) 1963. *The National Geographic Atlas of the World.* National Geographic Society, Washington.

Gwynne, M. D. and H. Croze 1979. The Concept and Practrice of Ecological Monitoring Over Large Areas of Land: The Systematic Reconnaissance Flight (SRF). In Ajayi, S. S. and L. B. Halstead (eds.), *Wildlife Management in Savannah Woodland.* Taylor and Francis Ltd., London.

Hanks, J. 1974. *Mammals of Southern Africa.* McGraw-Hill Book company, Johannesburg.

Hanson, M. G. 1980. *ASPEX - User's Reference Manual.* Laboratory for Computer Graphics and Spatial Analysis, Harvard University, Cambridge, Massachusetts.

Heathcote, R. L. 1983. *The Aridlands: Their Use and Abuse.* Longman, London.

Hitchcock, R. K. (ed.) 1982. *Proceedings of the Symposium on Botswana's First Livestock Development Project and its Future Implications.* National Institute of Research, Gaborone, Botswana.

Hone, J. 1981. *Theoretical and Practical Aspects of Estimating Animal Abundance by Transect Counts.* Unpubl. M.Sc. Thesis, University of Sydney.

Hyde, L. W. 1971. Ground Water Supplies in the Kalahari Area, Botswana. In Botswana Society (eds.) "Proceedings of the Conference on Sustained Production from Semi-Arid Areas". *Botswana Notes and Records.* **Sp. Ed. No.1**: 77-87.

Jarman, P. J. 1972. Seasonal Distribution of Large Mammal Populations in the Unflooded Middle Zambesi Valley. *J. Appl. Ecol.* **9**: 283-299.

Jarman, P. J. 1979. The Types of Information Available from Aerial Surveys, and Their Applicability to Management. In *Proceedings of a Workshop on Aerial Surveys of Fauna Populations,* p. 107-113. Australian Government Publishing Service, Canberra.

Jennrich, R. and P. Sampson 1983. Stepwise Discriminant Analysis, In Dixon W. J. *et al.* (eds.) *BMDP Statistical Software*. University of California Press, Los Angeles.

John Bartholomew and Son Ltd. 1977. *The Times Atlas of the World*. Plate 5, Times Books, London.

Jolly, G. M. 1969a. Sampling Methods for Aerial Censuses of Wildlife Populations. *E. Afr. Agric. For. J.* **34 (Special Issue)** :46-49.

Jolly, G. M. 1969b. The Treatment of Errors in Aerial Counts of Wildlife Populations. *E. Afr. Agr. For. J.* **34 (Special Issue)**: 50-55.

Joubert, E. and P. K. N. Mostert 1975. Distribution Patterns and Status of Some Mammals in South-West Africa. *Madoqua*, **9**: 5-44.

Kassas, M. 1972. Impact of River Control Schemes on the Shoreline of the Nile Delta. In Farvar, T. A. and J. P. Milton (eds.), *The Careless Technology*. The Natural History Press, London.

Kok, O. B. 1975. Behaviour and Ecology of the Red Hartebeest (*Alcelaphus buselaphus caama*). Orange Free State Provincial Administration Publication No. 4, 1975. Bloemfontein.

Kovda, V. A. 1977. Arid Land Irrigation and Soil Fertility: Problems of Salinity, Alkalinity, Compaction, in Worthington, B. (ed.) *Arid Land Irrigation in Developing Countries*. Pergamon Press Oxford.

Kovda, V. A. 1980. *Land Aridisation and Drought Control*. Westview Press, Boulder.

Kuper, A. 1970. *Kalahari Village Politics: An African Democracy*. Cambridge University Press, London.

Kutiliek, M. J. 1974. The Density and Biomass of Large Mammals in Lake Nakuru National Park, *E. Afr. Wildl. J.* **12**: 203-212.

Lacate, D. S. (compiler) 1969. Guidelines for Biophysical Land Classification. Subcommittee on Biophysical Land Classification *Can. For. Serv. Publ.* **1204**, Queens Printer, Ottawa.

Lancaster, I. N. 1974. Pans of the Southern Kalahari. *Botswana Notes and Records*, **6**: 157-169.

Lancaster, I. N. 1978. Pans of the Southern Kalahari, Botswana. *Geogr. J.* **144**: 81-98.

Laude, H. M. 1974. Effects of Temperature on Plant Morphogenesis. In Kreitlow, K. W. (Coord.), *Plant Morphogenesis as a Basis for Scientific Management of Range Resources*. (p. 25-33). Agricultural Research Service, U.S. Department of Agriculture, Washington, D.C.

Lee, K. E. and T. G. Wood. 1971. *Termites and Soils*. Academic Press London.

Le Houerou, H. N. 1976. Rehabilitation of Degraded Arid Lands. In Rapp, A., H. N. Le Houerou and B. Lundholm (eds.), *Can Desert Encroachment Be Stopped?* Swedish Natural Research Council, Stockholm.

Leistner, D. A. 1967. The Plant Ecology of the Southern Kalahari. *Bot. Surv. Memoir*, **No.38**, Government Printer, Pretoria.

Litherland, M. 1982. *The Geology of the Area Around Mamuno and Kalkfontein, Ghanzi District, Botswana*. Geological Survey Department District Memoir 4, Government Printer, Gaborone.

Macfarlane, W. F. and B. Howard 1972. Comparative Water and Energy Economy of Wild and Domestic Mammals. In Maloiy, G. M. D. (ed.), *Comparative Physiology of Desert Animals*, Zoological Society of London, London.

Machacha, B. N. 1981. *Landboards as Land Management Institutions*. Unpubl. M.S. Thesis, University of Wisconsin - Madison.

Maloiy, G. M. C. (ed.) 1972. *Comparative Physiology of Desert Animals*. The Zoological Society of London. London.

Mathuba, B. M. 1982. *Customary and Modern Land Tenure Systems in Botswana*. Unpubl. M. S. Thesis, University of Wisconsin - Madison.

Melton, D. 1978. Undercounting Bias of Helicopter Censuses in Umfolozi Game Reserve. *The Lammergeyer*, **26**: 1-6.

Mence, A. J. 1969. Psychological Problems of Conducting Aerial Censuses from Light Aircraft. *E. Afr. Agr. For. J.* **34 (Special Issue)**: 44-45.

Miller, K. R. 1978. *Planning National Parks for Ecodevelopment Vol. I and II*. University of Michigan.

Mills, M. G. L. and P. F. Retief, In Press. The Response of Ungulates to Rainfall Along the River-beds of the Southern Kalahari 1972-1982. *Koedoe*.

Ministry of Finance and Development Planning (MFDP) 1980. *National Development Plan 1979-1985*, Government Printer, Gaborone.

Morris, J. 1980. *South African Wildlife*. Howard Timmins Publishers, Cape Town.

Ngwamotsoko, K. T. 1982. Lessons for Future Livestock Development Projects in Botswana: Wildlife Resources Considerations. In Hitchcock, R. K. (ed.), *Proceedings of the Symposium on Botswana's First Livestock Development Project and its Future Implications*. National Institute of Research, Gaborone.

Nie, N. H., C. H. Hull, J. G. Jenkins, D. H. Bent, K. Steinbrenner, (eds.), 1970. *SPSS - Statistical Package for the Social Sciences*, 2nd Edition. McGraw-Hill Book Company, New York.

Norton-Griffiths, M. 1975. The Numbers and Distribution of Large Mammals in Ruaha National Park, Tanzania. *E. Afr. Wildl. J.* **13**: 121-140.

Norton-Griffiths, M. 1978. *Counting Animals, Handbook No. 1., 2nd Ed.* African Wildlife Leadership Foundation. Nairobi.

Noy-Meir, I. and N. G. Seligman 1979. Management of Semi-arid Ecosystems in Israel. In Walker, B. H. (ed.), *Management of Semi-arid Ecosystems*, Elsevier Scientific Publishing Company, Amsterdam.

Odell, M. L., 1980. *Botswana's First Livestock Development Project - An Experiment in Agricultural Transformation.* Government Printer, Gaborone.

Palgrave, K. C. 1977. *Trees of South Africa.* C. Struick Publishers, Cape Town.

Palmer, E. 1977. *A Field Guide to the Trees of Southern Africa.* Collins, London.

Parris, R. 1971. The Ecology and Behaviour of Wildlife in the Kalahari. In Botswana Society, (eds.) "Proceedings of the *Botswana Notes and Records.* **Sp. Ed. No. 1**: 96-101.

Parris, R. 1976. *A Study of the Major Components of the Kalahari Pan Ecosystem.* Unpubl. M.Sc. Thesis, University of Pretoria, South Africa.

Pennycuick, C. J. 1969. Methods of Using Light Aircraft in Wildlife Biology. *E. Afr. Agric. For. J.* **34**: (Special Issue), 24-29.

Pennycuick, C. J. and D. Western 1972. An Investigation of Some Sources of Bias in Aerial Transect Sampling of Large Mammal Populations. *E. Afr. Wildl. J.* **10**: 175-191.

Pennycuick, C. J., J. B. Sale, M. Stanley-Price and G. M. Jolly. 1977. Aerial Systematic Sampling Applied to Census of Large Mammal Populations in Kenya. *E. Afr. Wildl. J.* **15**: 139-146.

Perry, R. A. 1974. Strategies Available for Managing Multi-specific Communities in Australia. In Kreitlow, K. W. (compiler), *Plant Morphogenesis as the Basis for Scientific Management of Range Resources.* p. 124-137. Agricultural Research Service, United States Department of Agriculture, Washington, D. C.

Pike, J. G. 1971. Rainfall Over Botswana. In Botswana Society, (eds.) Proceedings of a Conference on Sustained Production from Semi Arid Areas. *Botswana Notes and Records.* **Sp. Ed. No. 1**: 69-75.

Richason Jr., B. F. 1978b. Landsat Platforms, Systems, Images and Image Interpretation. In Richason Jr. B. F. (ed.), *Introduction to Remote Sensing of the Environment*. Kendall/Hunt Publishing Co., New York.

Riddell, R. 1981. *Ecodevelopment*. Gower Publishing Company, Hampshir_.

Rose, T. 1982. Economics of Ranching in the Western Statelands [Botswana]. In Hitchcock, R. K. (ed.), *Proceedings of the Symposium on Botswana's First Livestock Development Project and its Future Implications*. National Institute of Research, Gaborone.

Schmidt-Nielsen, K. 1964. *Desert Animals, The Physiological Problems of Heat and Water*. Oxford University Press, London.

Seber, G. A. F. 1979. General Mathematical Principles and Theory of Fauna Sampling. In *Aerial Surveys of Fauna Populations*. p.1-7. Australian Government Publishing Service, Canberra.

Seber, G. A. F. 1982. *The Estimation of Animal Abundance*, 2nd Ed., Ch. 12. Charles Griffin and Company Ltd., London.

Selman, P. H. 1981. *Ecology and Planning*, George Godwin Ltd. Sydney.

Seitshiro, G. 1982. Range Ecology in Western Botswana. In Hitchcock R. K. (ed.), *Proceedings of the Symposium on Botswana's First Livestock Development Project and its Future Implications*. National Institute of Research, Gaborone.

Shortridge, G. C. 1934. *The Mammals of South West Africa Vol. I and II*. Heinemann, London.

Skarpe, C. 1981. *A Report on the Range Ecology Project Western Kalahari*. Animal Production Research Unit, Ministry of Agriculture, Gaborone, Botswana.

Slayter, R. O. 1974. Effects of Water on Plant Morphogenesis. In Kreitlow, K. W. (coord.), *Plant Morphogenesis as the Basis for Scientific Management of Range Resources*. (p.3-13). Agricultural Research Service, U.S. Department of Agriculture, Washington, D. C.

Smithers, R. H. N. 1968. *A Checklist and Atlas of the Mammals of Botswana*. The Trustees of the National Museum of Rhodesia, Salisbury.

Smithers, R. H. N. 1971. *The Mammals of Botswana Museum Memoir No. 4*, Trustees of the National Museums of Rhodesia, Salisbury.

Sorbo, G. M. 1977. Nomads on the Scheme - A Study of Irrigation Agriculture and Pastoralism in Eastern Sudan. In O'Keefe, P. and B. Wisner (eds.), *Land Use and Development*. International African Institude, London.

Strahler, A. H. 1978. Binary Discriminant Analysis: A New Method for Investigating Species - Environment Relationships *Ecology*, **59(1)**: 108-116.

Surveys and Lands. 1982. Map - Republic of Botswana 3rd Ed. Scale 1:1500000. Government Printer, Gaborone.

Swift, J. 1977. Desertification and Man in the Sahel. In O'Keefe, P. and B. Wisner (eds.), *Land Use and Development*. Internation- al African Institute, London.

Tanner, J. T. 1978. *Guide to the Study of Animal Populations*, University of Tennessee Press, Knoxville, U.S.A.

Talbot, L. M. 1972. Ecological Consequences of Rangeland Management in Masailand East Africa. In Farvar, T. A. and J. P. Milton (eds.), *The Careless Technology*. The Natural History Press, London.

Taylor, C. R. 1968a. The Minimum Water Requirements of Some East African Bovids. *Symp. Zool. Soc. Lond.* **21**:195-206.

Taylor, C. R. 1969. The Eland and the Oryx. *Sci. Amer.*, **220**: 88-95.

Timberlake, J. 1980. *Botswana Acacias*. Ministry of Agriculture Gaborone, Botswana.

Townshend, J. R. G. 1981a. An Introduction to the Study of Terrain. In Townshend J. R. G. (ed.), *Terrain Analysis and Remote Sensing*, George Allen and Unwin, Sydney.

Townshend, J. R. G. 1981b. Regionalisation of Terrain and Remotely Sensed Data. In Townshend, J. R. G. (ed.), *Terrain Analysis and Remote Sensing*. George Allen and Unwin, Sydney.

Tracor, Inc. 1982. *The 7800 Omega/VLF Navigation System, Pilot Guide* Tracor Inc. Texas, U.S.A.

Tyson, P. D. 1978. Southern African Rainfall: Past, Present and Future. In Hinchey, M. T. (ed.), *Proceedings of the Symposium on Drought in Botswana*. Botswana Society, Gaborone.

UNESCO 1979. Trends in Research and in Application of Science and Technology for Arid Zone Development, *MAB Technical Notes, 10*, UNESCO.

Van Zyl, J. H. M., 1965. The Vegetation of the S. A. Lombard Nature Reserve and its Utilisation by Certain Antelopes. *Zool. Afric.* **1**: 55-72.

Warwick, P. V. 1970. Canonical Correlation Analysis: Subprogram CANCORR. In Nie, N. H. *et al.* (eds.), *SPSS - Statistical Package for the Social Sciences*, 2nd Ed. Ch. 25. McGraw-Hill Book Company, New York.

Wayland, E. J. 1953. More About the Kalahari, *Geogr. J.* **119(1)**: 49-56.

Wayland, E. J. 1954. Outlines of Prehistory and Stone Age Climatology in the Bechuanaland Protectorate. *Mem. Acad. R. Sci. Colon., Sci. Nat. Med.* 25, 47.

Weare, P. R. and A. M. Yalala. 1971. Provisional Vegetation Map of Botswana. *Botswana Notes and Records.* **3**: 131-147.

Weir, J. and E. Davison. 1965. Daily Occurrence of African Game Animals at Water Holes During Dry Weather. *Zool. Afric.* **1(1)**: 353-368.

Western, D. 1976. *The Distribution of Animals in Relation to Resources Handbook No. 2.*, African Wildlife Readership Foundation, Nairobi.

White, R. 1982. Ranch Development and Land Use Planning in Western Botswana. In Hitchcock, R. K. (ed.) "Proceedings of the Symposium on Botswana's First Livestock Development Project and its Future Implications". National Institute of Research, Gaborone.

Wickens, G. E. and L. P. White. 1979. Land Use in the Southern Margins of the Sahara. In Walker, B. H. (ed.), *Management of Semi Arid Ecosystems.* Elsevier Scientific Publishing Company, Am- sterdam.

Wiken, E. B. and G. Ironside. 1977. The Development of Ecological (Biophysical) Land Classification in Canada. *Landscape Planning.* **4**: 273-275.

Wilson, A. D. and W. E. Mulham 1980. Vegetation Changes and Animal Productivity Under Sheep and Goat Grazing on Arid Belah (*Casuarina cristata*) Rosewood (*Heterodendrum oleifolium*) Woodland in Western New South Wales. *Aust. Rangel. J.* **2(2)**: 183-188.

Worthington, B. E. 1972. The Nile Catchment - Technological Change and Aquatic Biology. In Farvar, T. R. and J. P. Milton (eds.), *The Careless Technology.* The Natural History Press, London.

Zumer-Linder, M. 1976. Botswana. In Rapp A., H. N. Le Houerou and B. Lundholn (eds.), *Can Desert Encroachment be Stopped? A Study With Emphasis on Africa.* Ch.8.7. United Nations Environment Program/Secretariat for International Ecology, Stockholm, Sweden.

APPENDIX 1

NOTES ON SOME COMMON TREE AND BUSH SPECIES STUDIED IN WESTERN CENTRAL KALAHARI.

(a) ***Acacia erioloba*** (E Meyer)

Description: The tree usually has a single stem. On average the tree grows to a height of about 7 metres, with a canopy spread of up to 22 metres across with a wide flattish spreading crown, (Carr, 1976, Palgrave 1977, Palmer 1977). It has straight greyish thorns which are about 5cm long. Trees can grow to be very old. One specimen in Lehututu was aged at 300 years old (Timberlake 1980).

Distribution: *A. erioloba* was found to be distributed throughout the study area. However major predominances are in the park woodland and in a small pocket about 20 km southwest of Kokong, where in each it forms about 90% of the tree species. In the rest of the study area it occurs in varying associations with other tree species.

Leafing and flowering: In 1983, *A. erioloba* started leafing and flowering in October and by November was green. It stayed green until June 1984. It shed leaves from July 1984 the last of the *Acacias* to do so at that time, and by August 1984 was completely defoliated and remained so until early October 1984. Leafing and flowering was again observed to start occurring from around early October 1984 and by early November 1984, was predominantly green.

The fruit of *A. erioloba* is a thickened, half-moon shaped, non-dehiscent pod with dark brown hard seeds. The fruit was mature and dry by June (1984) when it started dropping to the ground.

Uses: This tree species like a few other discussed later, has a wide variety of uses and is of some ecological and economical importance.

(1) The leaves and pods are heavily browsed by cattle and goats in settled areas. Kudu, springbok, eland and gemsbok also browse these (Timberlake 1980). The

crude protein, phosphorus and calcium content of some parts of this tree are given in Table 5.10.

(2) The branches of this tree are locally used for fencing ploughing fields and cattle corrals. The thorns make them especially effective in this respect.

(3) The stems of trees of various ages are used as rafters in building, construction of corrals and fence posts. Because the sapwood is hard and the heartwood is heavy and strong the poles and branches of this tree can last for a long time.

(4) The wood is also used for fuel. It makes a very hot fire and burns slowly thus providing some sustained energy source.

(5) The tree produces edible brownish viscous gum which is also sometimes used locally as glue for home-made chairs.

(6) The canopy of the mature tree provides good dense shade and in full leaf almost excludes sun-rays completely. Animals therefore use it to escape from the sun. Even where it occurs with other tree species, it would appear there is a preference for using it.

(b) ***Acacia fleckii*** (Schinz)

Description: *A. fleckii* is a tree, mainly multi-stemmed growing up to an average of 4 metres and above (Palgrave 1977, Timberlake 1980). It has sharp, strong and hooked prickles.

Distribution: *A. fleckii*, unlike *A. erioloba*, has no marked predominance anywhere in the study area. It occurs in low densities almost throughout the study area although it is more abundant north of Hukuntsi Village in the Matsheng Village area, as well as in the sand-hill area in the east of the study area. In the Matsheng Village area some trees are up to 10 metres high.

Leafing and Flowering: In 1983 and 1984, leafing and flowering started about November and by January (1984 only) straw coloured, flattish dehiscent pods were fully mature and dry. Flowering preceeded leafing by about one week. The plant remained green until May (1984) when it started shedding its leaves and remained defoliated until November (1984).

<u>Uses:</u> The tree is used for fencing crop fields and corrals, and as rafters in traditional buildings. The thinner stems are used for making traditional chairs and as firewood. The leaves and pods are heavily browsed by goats and cattle and, according to Timberlake (1980) also by gemsbok and springbok. The tree produces edible gum and provides good shade during hot summers.

(c) ***A. hebeclada*** var. *hebeclada* (DC)

<u>Description:</u> The *hebeclada* variety of *A. hebeclada* is a bush that grows up to about 3 metres and was the only one found in the study area. It branches up from near ground level and at times the lower parts of the branch stems are covered by soil.

In grassy areas the bush generally grows very low.

<u>Distribution:</u> The bush was found throughout the study area. It appeared to be more predominant in settled areas where individual bushes were up to more than 10 metres across the base. In these areas the bushes seemed to act as windbreaks and had a lot of sand trapped against them, showing the bush's good quality of being a sand-stabiliser.

<u>Leafing and Flowering:</u> In 1984 the bush started developing leaves and flowers from early July in settled areas while the bushes in the "wild" were still defoliated. The pods were well developed by October. Those in the wild developed leaves from around late September (1983 and 1984) and all were fully green by October. They all shed leaves by May (1984).

<u>Uses:</u> The branches are used for fencing of crop fields and corrals but because it is so dense and difficult to get to the base of branches without being scratched by its many thorns, it is not a common choice for this purpose. The leaves and pods are eaten by goats and springbok.

Of the *Acacias* found in the study area, it has the highest concentrations of crude protein and phosphorus in its leaves and pods (APRU 1980, Timberlake 1980). These qualities make the bush a very important browsing plant, more especially that it also goes into leaf and flower almost earlier than other tree and bush species.

(d) ***A. luederitzii*** var. *luederitzii* (Engl.)

<u>Description:</u> The trees of this species are tall, reaching

about 7 metres to 10 metres. It has thorns that grow almost straight and are up to 7cm long.

Distribution: This tree species, like *A. erioloba*, was spread throughout the study area. No specific areas could be identified with its predominance, but it was otherwise abundant in the whole area.

Leafing and Flowering: In 1983 the trees started leafing and flowering from about November and by February the pods were ripe. The fruit is a short, flattish, brownish pod. They shed leaves from May (1984) and were defoliated by the end of this month. They remained defoliated until about mid-November (1984).

Uses: It is also used for building, for fencing crop fields and corrals, and for firewood. The tree produces edible viscous gum which is at times also used locally as glue. The dark brown bark is at times used for tanning.

The leaves and pods are eaten by goats, and Timberlake (1980) reports the consumption of pods by eland.

(e) ***A. mellifera*** var. *detinens* (Vahl) (Benth)

Description: This is a tree of between 5 metres and 8 metres (Palgrave 1977) but in grassy areas remains a shrub. The thorns are short and curved and have led to it being called a wait-a-bit tree.

Distribution: *A. mellifera detinens* occurs throughout the study area in association with other tree species. It is more predominant in the clumped woodland community type where it accounts for over 90% of the clumped thickets, especially in the northwest. It seems to constitute most thickets on pan sand-dunes. It is otherwise one of the most conspicuous tree species in the study area.

Leafing and Flowering: In 1983 and 1984 it was observed to start leafing and flowering from late September and by January (1984 only) had mature pods. The pods are dehiscent and split as soon as they dry up. Flowering preceeded leafing by more than a week. Leaves were shed from mid-May and by June the tree was defoliated, remaining so until late September (1984).

Uses: Its timber is used for a variety of purposes: building, axe and pick handles, in manufacture of traditional chairs and fencing poles. The branches are used for fencing in of crop fields and corrals, while wood is collected as firewood. The leaves and pods are browsed by both cattle and goats, and according to Timberlake (1980) by kudu, springbok, gemsbok and eland.

The tree also produces edible gum.

(f) ***Boscia albitrunca*** (Burch) (Gilg and Benedict)

Description: This tree species grows to an average of about 4.5 metres high (Palgrave 1977, Palmer 1977). It has a stout, smooth greyish trunk with relatively soft bark. It has no thorns.

Distribution: This species was also found distributed over the whole study area. No predominance was observed in any area except in the south of the Matsheng Villages where it was the second most abundant in association with *A. mellifera*.

Leafing and Flowering: In 1983 and 1984 *B. albitrunca* maintained greenness throughout the study period and throughout the study area. However there appeared to be a difference between the big, and obviously mature trees, and the medium to small trees. The mature trees remained green throughout while the medium to smaller trees shed leaves from June to July (1984) and remained defoliated until October when they started leafing and flowering again. This leafing and flowering was also observed at the same time in 1983. By mid-December (1983) the succulent yellow fruit was ripe.

Uses: Being an evergreen tree, it provides year round browse for domestic stock and potentially for the wild animal browsers, although no wild animal species was identified in this study as browsing this tree species. The ostrich eats the fruits. The leaves and bark are succulent and must provide some moisture to those animals that feed on them. Old trees sometimes have hollow trunks which trap rain water which may be used by both animals and people. Various parts of this tree are used for several purposes:

(1) the roots when dried are pounded and brewed as coffee substitute;

(2) the flesh of the fruit is edible, making sweet heavy fruit juice;

(3) the trunk is used for building sledges, for making watertroughs, grain mortars, wooden basins and other household utensils.

(g) ***Grewia flava*** (DC)

Description: *G. flava* is a bush that grows to an average height of about 2 to 3 metres. It has no thorns and the multiple stems all grow from the one base.

Distribution: This bush is spread throughout the study area. While there are many other species of *Grewia* occurring in the study area and also recorded by other researchers (DHV 1980, APRU 1980), this particular one was noted because it appeared the most abundant. In the settled areas it was found to be in greater abundance than even *A. hebeclada*.

Leafing and Flowering: In 1983 and 1984 this bush started leafing and flowering in October and by December (1983 observation only) the fruits were mature. The leaves are medium size between broad leaved and small-leaved. Leaves were shed from mid-May and the bush remained defoliated until late September (1984).

Uses: Different parts of this bush are used for various purposes. Leaves and twigs are heavily browsed by cattle and goats. No wild animal species has been identified in this study with browsing leaves of this bush although the ostrich eats the fruit of the bush. The occurrence of this bush in settled areas means it is able to provide considerable forage for domestic stock, especially cattle which otherwise have to travel considerable distances to reach grass pastures. Its moderate crude protein content with moderate digestibility make it a valuable forage plant.

In the households, the stems of young and immature twigs are used for weaving baskets while the fruits are edible and when dried can last for up to a year without deteriorating greatly in quality. The fruits are also used for brewing traditional alcoholic drinks.

(h) ***Lonchocarpus nelsii*** (Schinz)

Description: The tree grows to an average height of about 4 metres but may reach up to 7 metres under favourable conditions (Palmer 1977, Palgrave 1977). The bark is smooth and yellowish grey. The tree has no thorns.

Distribution: This tree species is restricted to the northeastern and northern part of the study area as far west as the Ncojane Ranches. The distribution belt runs approximately from

Morwamosu Village in an inverted curve through south of Phuduhudu Ranches north of Ohe Village to Ncojane Ranches. South of this curve the species does not occur. The species seems to favour sand-dune tops.

Leafing and Flowering: In 1983 and 1984 this tree species was observed to start flowering and leafing in September. The fruit is a small flattish pod. The leaves are broad and it is the only broad leaved tree species observed in the study area. Leaves were shed from mid-May and the tree remained defoliated until the end of September.

Uses: Leaves are browsed by livestock. No wild animal species has been identified in the study area browsing this tree species. The human uses include its use for making axe and pick handles and traditional chairs.

(i) ***Terminalia sericea*** (Burch ex DC)

Description: It is a small to medium tree growing to between 4 and 6 metres high. In grassed areas it remains stunted and a bush generally no taller than 2.5 metres. Where other trees are cleared around it such as in crop fields where they are left as shade trees, it grows into a large tree reaching up to about 10 metres. The plant has no thorns.

Distribution: This plant species was found throughout the study area. It formed the predominant bush intermix in grassland areas where it appeared never taller than 2.5 metres. It was also abundant in the scrubland community in the southwest of the study area. It is the most dominant tree species in the open woodland community within the Matsheng Village quadrangle.

Leafing and Flowering: In 1983 and 1984 this tree species was observed to come into leaf and flower at the end of September and by December (1983) the fruits, the reddish brown flattish pods had matured. The leaves of this tree are silvery grey instead of green. They are bigger than those of the *Acacias* but smaller than those of *L. nelsii*. They were shed from the end of May.

Uses: This is one of the tree species with a variety of uses. The leaves are browsed by domestic livestock. No wild animal species has been identified in the study area as browsing this tree species. The domestic uses include:

(1) use of root bark as lathe in hut roofs and for strapping together wooden courtyards;

(2) the stems are used as rafters and as fence around huts;

(3) the stems are also used as droppers and standards in wire fencing;

(4) the household items made from the tree include traditional chairs, wooden spoons, grain mortars and pole props;

(5) the bark of root and stem is used for tanning;

(6) the tree also produces edible gum.

(j) ***Ziziphus mucronata*** (Willd)

Description: It is a tree which may grow up to 9 metres but on average is about 6 metres. It has thorns which usually have one curved while the other is almost straight.

Distribution: It is widespread throughout the study area. No predominance was observed for this tree species anywhere in the study area. It occurred in association with all other trees without any obvious preference for any localities. Its root system is apparently hardy enough to allow the tree to establish itself on the compacted hard pan soils where many big trees were observed near mudpools. Only the non-saline pans supported this tree species. Almost every non-saline pan had one or two trees of this species growing on them and nothing else except the *A. hebeclada* bush which also seemed to easily establish itself on these soils.

Leafing and Flowering: In 1983 and 1984 this tree species was observed to flower and develop leaves from October and by March (1984 only) the reddish-brown fruits were mature. The leaves are medium sized and were shed from mid-May with the tree staying defoliated until the end of September.

Uses: The leaves are browsed by cattle, goats and kudu. The fruits are eaten by ostrich and human beings. The fruits are often roasted, ground and brewed as a substitute for coffee.

The timber is used for a variety of purposes. The main use is in making traditional chairs as the timber is strong and chairs made from it outlast those made from other trees. It is also used in buildings.

Appendix 2

DATA SHEET

SURVEY .... (WCK App

DATE: 10/4/84 NAVIGATOR ONS | VLF HEIGHT 91.4

A/C : C210 OBSERVER KN SPEED 160 K/H

PILOT: DP SIDE OF A/C F/R Recording STRIP WIDTH 200

LEFT OBS. KP RIGHT OBS. ML

GROUND TEMP. START: 16 °C WIND DIR ST. Calm SKY COND. ST. Clear A/S T/O HVK TIME T/O 0740

GROUND TEMP. FIN. 28 °C WIND DIR FIN. Calm SKY COND. FIN. Clear A/S LAND HVK TIME LAND 1215

TR.	S/U	Time	Cardin. Points Coordinates	Animal Count Left	Animal Count Right	Air-Temp/ Cab. Temp	Wind dir. and Strength	Other Info.
10	1	803	2430	44	05	16/26		Clear
				115				Grassland/scatt
								cover sparse
								Trees green Grass F/g
	2	805	2427	43	02			Scattered trees
				61				Cover mod
								H6 / Trees g
								Grass F/g
	3	807	2424					Trees green
								Scattered t Cover mod
								Grass F/g
	4	809	2421	82	91			Scattered t
								Trails mult
								Trees green
								Grass F/g Cover sparse
	5	811	2418					Trees gre
								Open woods
								Grass green cover sparse
	6	812	2415	417				Trees green
								Scattered tr Cover good
								Grass green
	7	814	2412		91			Open woods // Trails multiple / Cover sparse

APPENDIX. 3. TSHANE CLIMATIC DATA

(a) TSHANE - Long Term Climatic Data (Botswana Dept. of Meteorological Services Unpubl. Data)

Month	Precipitation Mean (mm) (1958-1980)	Evaporation Open Tank Mean (mm)	Relative Humidity Mean (%) (1965-1979)		Temperature (°C)			Wind Speed Mean (km/hr) (1959-1980)
			0800 hrs (LT)	1400 hrs (LT)	Mean Max.	Mean Min.	Mean Mean	
July	1.1	186.0	66.0	32.0	22.2	3.5	12.9	8.3
Aug.	0.5	220.0	58.0	30.0	25.2	6.0	15.6	9.8
Sept.	2.8	294.0	49.0	26.0	29.4	11.2	20.3	11.2
Oct.	16.0	325.0	51.0	28.0	31.6	14.2	22.9	12.0
Nov.	30.4	321.0	53.0	31.0	33.0	16.9	25.0	12.3
Dec.	33.8	369.0	57.0	32.0	33.7	18.3	26.3	12.2
Jan.	86.0	378.0	65.0	42.0	33.3	19.3	26.3	11.8
Feb.	72.3	303.0	72.0	43.0	32.0	18.6	25.3	10.4
March	68.5	287.0	71.0	42.0	30.6	17.1	23.9	9.9
Apl.	34.8	253.0	74.0	43.0	27.6	13.0	20.3	8.5
May	7.4	225.0	70.0	35.0	24.5	7.0	15.8	7.8
June	3.6	187.0	70.0	35.0	21.6	3.9	12.8	7.8
Annual	357.2	3348.0	63.0	35.0	28.7	12.4	20.6	10.2

(b) TSHANE - 1983/1984 Climatic Data (Botswana Dept. of Meteorological Services - Unpubl. Data)

Month	Rainfall (Mean)	Relative Humidity (Mean) (%)		Number of Days with Cloud	Temperature (°C)		
		0800 hrs (LT)	1400 hrs (LT)		Mean Max.	Mean Min.	Mean Mean
Sept. 1983	0.0	42.0	23.0	1	31.4	10.9	21.2
Oct.	23.8	51.0	28.0	6	31.5	15.2	23.4
Nov.	55.9	56.0	33.0	8	33.5	17.2	25.4
Dec.	65.6	66.0	45.0	13	32.7	17.8	25.3
Jan. 1984	16.2	53.0	30.0	7	36.5	21.2	28.9
Feb.	6.0	47.0	25.0	5	36.5	21.2	28.9
March	39.2	63.0	39.0	5	32.5	18.0	25.3
April	15.5	74.0	43.0	7	27.7	14.1	20.9
May	15.7	68.0	30.0	4	24.6	8.5	16.6
June	0.0	68.0	32.0	0	21.3	3.0	12.2
July	1.1	64.0	31.0	2	22.7	3.3	13.0
Aug.	0.0	53.0	24.0	-	26.9	6.6	16.8
Sept.	3.4	41.0	18.0	-	30.7	10.3	20.5

(c) TSHANE - Percent Rainfall Departures from Normal 1973/74-1983/84

Year	1973/74	1974/75	1975/75	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84
Percent Departure	123	29	98	-12	15	-39	46	-14	-17	-9	-34

APPENDIX 4

CORRELATION EVALUATION TABLES

TABLE 6.3 Animals and Herbaceous Layer Cover and Condition

Animal Species	Time of Occurrence (Date of Survey)	Association with: Herbaceous Layer Cover and Condition: Canon. Correl. Coeff.	Probability p	Group	Opinion
Gemsbok	April 1984	- 0.49	< 0.01	Sparce and fawn	Preference
Hartebeest	June 1984	0.39	< 0.001	Moderate and fawnish green	Preference
Springbok	June 1984	- 0.26	< 0.01	Sparse and green	Preference
	Aug. 1984	- 0.35	< 0.001	Sparse and green	Preference
	Sept. 1984	- 0.26	< 0.001	Sparse and green	Preference
Kudu	Sept. 1984	0.41	< 0.001	Moderate and green	Preference
Harvester termite	Aug. 1984	- 0.76	< 0.001	Sparse and fawn	Preference
	Sept. 1984	- 0.76	< 0.001	Sparse and fawn	Preference
Gemsbok (- 0.36) Wildebeest (- 0.84) Springbok (- 0.38) Donkey (- 0.35)	Jan. 1984	0.27	< 0.001	High	Avoidance
Eland (- 0.65) Gemsbok (- 0.41) Wildebeest (0.43)	Jan. 1984	- 0.36	< 0.005	Low	Preference
Gemsbok (- 0.39) Wildebeest (0.64) Springbok (- 0.40) Kudu (0.34)	April 1984	0.30	< 0.001	High	Preference
Gemsbok (- 0.29) Wildebeest (-0.50) Ostrich (- 0.41) Donkey (- 0.64)	April 1984	0.44	< 0.05	High	Avoidance
Hartebeest (0.77) Springbok (- 0.27) Ostrich (- 0.27) Donkey (- 0.37)	June 1984	0.61	< 0.001	High	Avoidance
Wildebeest (- 0.43) Springbok (- 0.70)	Aug. 1984	0.55	< 0.001	High	Avoidance
Springbok (0.59) Horse (- 0.52) Donkey (0.41)	Sept. 1984	- 0.31	< 0.001	Low	Preference

Note: Low= Sparse and green, sparse and fawnish green, sparse and fawn, moderate and fawn.
High = moderate and fawnish green, moderate and green, good and fawn, good and fawnish green, good and green.

TABLE 6.4 Animals and Bushfire Occurrences

Animal Species	Time of Occurrence (Date of Survey)	Extent of Association with Bushfire			Opinion
		Canon. Correl. Coeff.	Probability p	Group	
Hartebeest	June 1984	0.53	< 0.001	Old fire scar	Preference
Hartebeest (0.78) Springbok (- 0.36) Donkey (0.31)	November 1983	0.30	< 0.001	High	Preference

Note: High = Old fire scar, burning fire.

TABLE 6.5 Animals and Vegetation Types

Animal Species	Time of Occurrence (Date of Survey)	Extent of Association with Vegetion Types			Opinion
		Canon. Correl. Coeff.	Probability p	Group	
Springbok	November 1983	0.42	< 0.001	Park Woodland	Preference
Gemsbok	January 1984	0.40	< 0.05	Park Woodland	Preference
	June 1984	- 0.26	< 0.005	Grassland	Preference
Springbok (- 0.56) Ostrich (- 0.37) Donkey (- 0.40)	November 1983	- 0.47	< 0.001	Low	Preference
Hartbeest (0.78) Springbok (- 0.36) Donkey (0.31)	November 1983	- 0.26	< 0.001	Low	Preference
Gemsbok (- 0.36) Hartebeest (0.73) Wildebeest (- 0.84) Springbok (- 0.38) Donkey (- 0.35)	January 1984	- 0.54	< 0.001	Low	Preference

Note: Low = Scattered trees, Scrubland, Grassland

TABLE 6.6 Animals and Settlement Types

Animal	Time of Occurrence (Date of Survey)	Extent of Association with Settlement Types			Opinion
		Canon. Corr. Coeff.	Probability p	Group	
Donkey	September 1984	0.66	< 0.001	Permanent settlement	Preference
	November 1983	0.55	< 0.001	Permanent settlement	Preference.
	January 1984	0.28	< 0.001	Permanent settlement	Preference
	September 1984	0.58	< 0.001	Permanent settlement	Preference
Horse	November 1983	- 0.39	< 0.001	No Settlement	Avoidance
Cattle	September 1984	0.45	< 0.001	Permanent settlement	Preference
Cattle (0.30) Donkey (0.88)	September 1983	0.61	< 0.001	High	Preference
Cattle (0.35) Donkey (0.75)	November 1983	0.58	< 0.001	High	Preference
Cattle (0.41) Donkey (0.76)	September 1984	0.62	< 0.001	High	Preference
Cattle (- 0.80) Horse (- 0.30) Donkey (0.52)	September 1983	0.59	< 0.001	High	Avoidance
Springbok (- 0.36) Hartebeest (0.78) Donkey (0.31)	November 1983	0.29	< 0.001	High	Tolerance
Springbok (- 0.56) Ostrich (- 0.37) Donkey (- 0.40)	November 1983	- 0.39	< 0.001	Low	Tolerance
Gemsbok (- 0.29) Wildebeest (- 0.50) Ostrich (- 0.41) Donkey (- 0.64)	April 19..	0.38	< 0.05	High	Avoidance

Note High = Permanent Settlement and Temporary Settlements;
Low = No settlements

TABLE 6.7 Animals and Communal Cells

Animal Species	Time of Occurrence (Date of Survey)	Extent of Association with Communal Cells: Canon. Correl. Coeff.	Probability p	Group	Opinion
Cattle	September 1983	0.31	< 0.001	Present	Preference
	April 1984	0.59	< 0.001	Present	Preference
	June 1984	0.50	< 0.001	Present	Preference
	September 1984	0.48	< 0.001	Present	Preference
Donkey	September 1983	0.36	< 0.001	Present	Preference
	April 1984	0.63	< 0.001	Present	Preference
	June 1984	0.55	< 0.001	Present	Preference
	September 1984	0.32	< 0.001	Present	Preference
Horse	November 1983	0.44	< 0.001	Present	Preference
	April 1984	0.48	< 0.001	Present	Preference
	August 1984	0.69	< 0.001	Present	Preference
Eland	September 1983	0.28	< 0.001	Present	Tolerance
Gemsbok	September 1983	- 0.27	< 0.001	Absent	Avoidance
	April 1984	- 0.70	< 0.005	Absent	Avoidance
	June 1984	- 0.32	< 0.005	Absent	Avoidance
	August 1984	- 0.44	< 0.005	Absent	Avoidance
	September 1984	- 0.32	< 0.001	Absent	Avoidance
Ostrich	June 1984	- 0.33	= 0.05	Absent	Avoidance
Cattle (0.30 Donkey (0.88)	September 1983	0.47	< 0.001	Present	Preference
Cattle (0.35) Donkey (0.75)	November 1983	0.44	< 0.001	Present	Preference
Cattle (0.39) Donkey (0.61)	January 1984	0.34	< 0.001	Present	Preference
Cattle (0.59) Donkey (0.49)	April 1984	0.86	< 0.001	Present	Preference
Cattle (0.61) Donkey (0.42)	June 1984	0.72	< 0.001	Preswent	Preference
Cattle (0.41) Donkey (0.76)	September 1984	0.48	< 0.001	Present	Preference
Eland (0.77) Springbok (0.38) Ostrich (- 0.60) Horse (- 0.29)	September 1983	- 0.45	< 0.01	Absent	Avoidance
Hartebeest (- 0.75) Wildebeest (- 0.35) Ostrich (0.32)	August 1984	0.33	< 0.001	Present	Avoidance
Wildebeest (- 0.44) Springbok (- 0.70)	August 1984	0.63	< 0.001	Present	Avoidance
Eland (- 0.77) Donkey (- 0.54)	August 1984	0.62	< 0.01	Present	Avoidance
Eland (0.41) Hartebeest (0.38) Horse (0.54) Wildebeest (0.58)	September 1984	- 0.42	< 0.01	Absent	Avoidance

TABLE 6.8 Animals and Farms

Animal Species	Time of Occurrence (Date of Survey)	Extent of Association with Farms: Canon. Correl. Coeff.	Probability p	Group	Opinion
Cattle	September 1983	0.52	< 0.001	Present	Preference
	April 1984	0.44	< 0.001	Present	Preference
	June 1984	0.30	< 0.001	Present	Preference
	August 1984	0.48	< 0.001	Present	Preference
	September 1984	0.31	< 0.001	Present	Preference
Horse	September 1983	0.32	< 0.001	Present	Preference
	June 1984	0.29	< 0.001	Present	Preference
	September 1984	0.36	< 0.001	Present	Preference
Gemsbok	November 1983	0.37	< 0.05	Present	Tolerance
	January 1984	- 0.88	< 0.05	Absent	Avoidance
	April 1984	- 0.68	< 0.005	Absent	Avoidance
	June 1984	- 0.42	< 0.005	Absent	Avoidance
	August 1984	- 0.45	< 0.005	Absent	Avoidance
	September 1984	- 0.32	< 0.001	Absent	Avoidance
Harvester termites	September 1984	0.31	< 0.001	Present	Preference
Cattle (- 0.80) Horse (- 0.30) Donkey (0.52)	September 1983	- 0.72	< 0.001	Absent	Preference
Cattle (0.34) Donkey (0.75)	November 1983	0.32	< 0.001	Present	Preference
Cattle (- 0.40) Donkey (- 0.61)	January 1984	- 0.32	< 0.001	Absent	Preference
Cattle (- 0.59) Donkey (-0.49)	April 1984	- 0.31	< 0.001	Absent	Preference
Cattle (- 0.59) Donkey (- 0.42)	June 1984	- 0.49	< 0.001	Absent	Preference
Cattle (0.41) Donkey (0.76)	September 1984	0.27	< 0.001	Present	Preference
Eland (0.77) Springbok (0.38) Ostrich (- 0.60)	September 1983	- 0.39	< 0.01	Absent	Avoidance
Hartebeest (0.78) Springbok (- 0.36) Donkey (0.31)	November 1983	0.33	< 0.001	Present	Tolerance
Gemsbok (- 0.29) Wildebeest (- 0.64) Ostrich (- 0.41) Donkey (- 0.64)	April 1984	0.48	< 0.05	Present	Avoidance
Eland (- 0.77) Donkey (- 0.54)	August 1984	0.85	< 0.01	Present	Avoidance
Springbok (0.59) Ostrich (0.51) Horse (- 0.52) Donkey (0.41)	September 1984	- 0.56	< 0.001	Absent	Avoidance

TABLE 6.9 Animals and Conservation Areas

Animal Species	Time of Occurrence (Date of Survey)	Extent of Association with Conservation Areas			Opinion
		Canon. Correl. Coeff.	Probability p	Group	
Eland	September 1983	0.43	< 0.001	National Park	Preference
	November 1983	<u>0.26</u>	< 0.001	W.M.A.	Preference
Gemsbok	November 1983	0.45	< 0.001	W.M.A.	Preference
	January 1984	0.95	< 0.001	National Park	Preference
	April 1984	0.52	< 0.005	National Park	Preference
Springbok	June 1984	0.35	< 0.001	W.M.A.	Preference
	August 1984	0.39	< 0.001	W.M.A.	Preference
Ostrich	September 1984	<u>0.27</u>	< 0.05	W.M.A.	Preference
Horse	April 1984	- 0.30	< 0.001	Non Conservation areas	Preference
Harvester termites	August 1984	0.53	< 0.001	W.M.A.	Distribution
	September 1984	0.51	< 0.001	W.M.A.	Distribution
Eland (0.77) Springbok (0.38) Ostrich (- 0.60) Horse (- 0.29)	September 1983	- 0.71	< 0.01	Low	Tolerance
Wildebeest (- 0.44) Springbok (- 0.70)	August 1984	- 0.66	< 0.001	Low	Preference
Eland (- 0.77) Donkey (-0.54)	August 1984	0.89	< 0.01	High	Avoidance
Eland (0.41) Hartebeest (0.38) Wildebeest (0.58) Horse (0.54)	September 1984	- 0.48	< 0.005	Low	Tolerance

Note: High = Wildlife management areas (W.M.A.), National Park,
Low = Non-conseration areas.

TABLE 6.10 Animals and Mineral Prospecting Areas

Animal Species	Time of Occurrence (Date of Survey)	Extent of Association with Mineral Prospecting Areas			Opinion
		Canon. Correl. Coeff.	Probability p	Group	
Springbok	September 1983	- <u>0.27</u>	< 0.001	Absent	Avoidance
Hartebeest	November 1983	0.37	< 0.001	Present	Tolerance
	August 1984	0.45	< 0.001	Present	Tolerance
Ostrich	September 1984	- 0.44	< 0.05	Absent	Avoidance
Harvester termites	September 1984	0.36	< 0.001	Present	Tolerance
Hartebeest (0.73) Springbok (-0.36) Donkey (0.31)	November 1983	0.54	< 0.001	Present	Tolerance
Eland (- 0.60) Gemsbok (- 0.41) Wildebeest (0.43) Donkey (- 0.27)	January 1984	<u>0.27</u>	< 0.005	Present	Avoidance
Hartebeest (- 0.75) Wildebeest (- 0.35) Ostrich (0.32) Donkey (0.28) Cattle (- 0.26)	August 1984	- 0.42	< 0.001	Absent	Tolerance

TABLE 6.11 Animals and Big Pan Occurrence

Animal Species	Time of Occurrence (Date of Survey)	Extent of Association with Big Pans			Opinioin
		Canon. Correl. Coeff.	Probability p	Group	
Gemsbok	November 1983 June 1984	- 0.26 - 0.31	< 0.05 < 0.005	Absent Absent	Avoidance Avoidance
Horse	April 1984	- 0.26	< 0.001	Absent	Avoidance
Ostrich	August 1984	0.28	< 0.01	Present	Preference
Eland (- 0.65) Gemsbok (- 0.41) Wildebeest (0.43) Donkey (- 0.27)	January 1984	0.31	< 0.005	Present	Avoidance
Hartebeest (- 0.75) Wildebeest (- 0.35) Ostrich (0.32) Donkey (- 0.28)	August 1984	0.34	< 0.001	Present	Avoidance
Eland (0.77) Donkey (- 0.54)	August 1984	- 0.47	< 0.01	Absent	Avoidance
Eland (0.41) Hartebeest (0.38) Wildebeest (0.56) Horse (0.54)	September 1984	- 0.26	< 0.005	Absent	Avoidance

TABLE 6.12 Animals and Soil Types

Animal Species	Time of Occurrence (Date of Survey)	Extent of Association with Soil Types			Opinion
		Canon. Correl. Coeff.	Probability p	Group	
Wildebeest	June 1984	0.29	< 0.001	3	Preference
	August 1984	0.48	= 0.05	3	Preference
Springbok	August 1984	0.27	< 0.001	3	Preference
	September 1984	0.32	< 0.001	2	Preference
Ostrich	June 1984	0.34	= 0.05	3	Preference
	September 1984	0.38	< 0.05	2	Preference
Eland (0.77) Springbok (0.38) Ostrich (-0.60)	September 1983	0.33	< 0.01	Hard	Preference
Eland (- 0.65) Gemsbok (- 0.41) Wildebeest (0.43)	January 1984	- 0.26	< 0.005	Soft	Preference
Gemsbok (- 0.39) Wildebeest (0.64) Springbok (-0.40) Kudu (0.34)	April 1984	- 0.37	< 0.001	Soft	Preference
Wildebeest (-0.44) Springbok (- 0.70)	August 1984	- 0.53	< 0.001	Soft	Preference
Springbok (0.59) Ostrich (0.51) Horse (- 0.52) Donkey (0.41)	September 1984	0.51	< 0.001	Hard	Preference
Eland (0.41) Hartebeest (0.38) Wildebeest (0.58) Horse (0.54)	September 1984	0.69	< 0.005	Hard	Preference

Note: Hard = Group 2 upwards, Soft = Group 1

TABLE 6.13 Animals and Drainage Valleys

Animal Species	Time of Occurrence (Date of Survey)	Extent of Associations with Drainage Valleys			Opinion
		Canon. Correl. Coeff.	Probability p	Group	
Springbok	September 1983 September 1984	- 0.27 - 0.27	< 0.005 < 0.001	Absent Absent	Avoidance Avoidance
Eland	November 1983	- 0.29	< 0.005	Present	Preference
Gemsbok	November 1983 January 1984 June 1984	0.43 0.45 0.38	< 0.05 < 0.05 < 0.005	Present Present Present	Preference Preference Preference
Wildebeest	April 1984	0.33	< 0.005	Present	Preference
Hartebeest	June 1984 August 1984	- 0.32 - 0.37	< 0.001 < 0.001	Absent Absent	Avoidance Avoidance
Ostrich	June 1984	- 0.31	= 0.05	Absent	Avoidance
Springbok (- 0.56) Ostrich (- 0.37) Donkey (-0.47)	November 1983	- 0.54	< 0.001	Absent	Preference
Gemsbok (- 0.36) Hartebeest (0.73) Wildebeest (- 0.84) Springbok (- 0.38) Donkey (- 0.35)	January 1984	- 0.27	< 0.001	Absent	Preference
Eland (- 0.65) Gemsbok (- 0.41) Wildebeest (0.43)	January 1984	- 0.74	<0.005	Absent	Preference
Gemsbok (- 0.39) Wildebeest (0.654) Springbok (- 0.40) Kudu (0.34)	April 1984	0.28	< 0.001	Present	Preference
Hartebeest (0.77) Donkey (- 0.37)	June 1984	- 0.35	< 0.001	Absent	Avoidance
Springbok (0.59) Ostrich (0.51) Horse (- 0.52) Donkey (0.41)	September 1984	- 0.42	< 0.001	Absent	Avoidance
Eland (0.41) Hartebeest (0.38) Wildebeest (0.58) Horse (0.54)	September 1984	- 0.29	< 0.005	Absent	Avoidance

TABLE 6.14 Animals and Altitude

Animal Species	Time of Occurrence (Date of Survey)	Extent of Association with Altitude Variation: Canon. Correl. Coeff.	Probability p	Group	Opinion
Horse	September 1983	0.34	< 0.001	High	Preference
	September 1984	0.29	< 0.001	High	Preference
Eland	November 1983	- 0.27	< 0.005	Low	Preference
Gemsbok	November 1983	- 0.34	< 0.05	Low	Preference
Hartebeest	November 1983	- 0.35	< 0.0001	Low	Preference
	June 1984	- 0.49	< 0.001	Low	Preference
	August 1984	- 0.33	< 0.001	Low	Preference
	September 1984	0.26	< 0.001	High	Preference
Wildebeest	January 1984	0.28	< 0.001	High	Preference
	April 1984	0.86	< 0.005	High	Preference
Springbok	September 1983	- 0.29	< 0.005	Medium	Preference
Eland (0.77) Springbok (0.38) Ostrich (- 0.60)	September 1983	- 0.82	< 0.005	Low	Preference
Cattle (0.35) Donkey (0.75)	November 1983	0.29	< 0.001	High	Preference
Hartebeest (0.78) Springbok (- 0.36) Donkey (0.31)	November 1983	- 0.32	< 0.001	Low	Preference
Gemsbok (- 0.36) Horse (0.73) Wildebeest (- 0.84) Springbok (- 0.38) Donkey (- 0.35)	January 1984	- 0.56	< 0.001	Low	Preference
Eland (- 0.65) Gemsbok (- 0.41) Wildebeest (0.43)	January 1984	0.56	< 0.005	High	Avoidance
Gemsbok (- 0.39) Wildebeest (0.64) Springbok (- 0.40) Kudu (0.34)	April 1984	0.68	< 0.001	High	Preference
Wildebeest (- 0.50) Ostrich (- 0.41) Donkey (- 0.64)	April 1984	- 0.48	< 0.05	Low	Preference
Hartebeest (0.77) Donkey (- 0.37) Gemsbok (- 0.30)	June 1984	- 0.34	< 0.001	Low	Preference
Hartebeest (- 0.75) Wildebeest (- 0.35) Ostrich (0.32)	August 1984	0.32	< 0.001	High	Avoidance
Eland (0.41) Hartebeest (0.38) Wildebeest (0.58) Horse (0.54)	September 1984	0.46	< 0.005	High	Preference

TABLE 6.15 Animals and Land Regions

Animal Species	Time of Occurrence (Date of Survey)	Extent of Association with Land Regions			Opinion
		Canon. Correl. Coeff.	Probability p	Group	
Wildebeest	April 1984	- 0.26	< 0.005	Undulating	Preference
	June 1984	0.29	< 0.001	Low sand dune	Preference
	August 1984	0.65	= 0.05	Low sand dune	Preference
Hartebeest	August 1984	0.38	< 0.001	Sandhill	Preference
Springbok	August 1984	0.36	< 0.001	Low sand dune	Preference
Ostrich	September 1984	- 0.48	< 0.05	Undulating	Preference
Gemsbok (- 0.37) Hartebeest (0.73) Wildebeest (- 0.84) Springbok (- 0.38) Donkey (- 0.35)	January 1984	0.28	< 0.001	High	Avoidance
Gemsbok (0.41) Eland (- 0.65) Wildebeest (0.43)	January 1984	- 0.28	< 0.005	Low	Preference
Wildebeest (- 0.50) Ostrich (- 0.41) Donkey (- 0.64)	April 1984	0.31	< 0.05	High	Avoidance
Hartebeest (- 0.75) Wildebeest (- 0.35) Ostrich (0.32)	August 1984	- 0.55	< 0.001	Low	Preference
Wildebeest (- 0.44) Springbok (- 0.70)	August 1984	- 0.54	< 0.001	Low	Preference
Springbok Ostrich (0.51) Horse (- 0.52) Donkey (0.41)	September 1984	- 0.45	< 0.001	Low	Preference
Eland (0.41) Hartgebeest (0.38) Wildebeest (0.58)	September 1984	0.46	< 0.005	High	Preference

TABLE 6.16 Animals and Surface Water Occurrence

Animal Species	Time of Occurrence (Date of Survey)	Extent of Association with Surface Water Occurrence			Opinion
		Canon. Corr. Coeff.	Probability p	Group	
Cattle	April 1984	0.31	< 0.001	Present	Preference
Donkey	April 1984	0.30	< 0.001	Present	Preference
Cattle (- 0.59) Donkey (- 0.50)	April 1984	- 0.40	< 0.001	Present	Preference

TABLE 6.17 Animals and Harvester Termite Infestation

Animal Species	Time of Occurrence (Date of Survey)	Extent of Association with Harvester Termite Infestation			Opinion
		Canon. Correl. Coeff.	Probability p	Group	
Hartebeest	August 1984	- 0.36	< 0.001	Light	Preference
Springbok	August 1984	0.29	< 0.001	Heavy	Preference
Ostrich	August 1984	0.34	< 0.01	Heavy	Preference
Cattle	September 1984	- 0.26	< 0.001	No termite	Preference
Cattle (0.74) Horse (0.28)	August 1984	- 0.45	< 0.001	Low	Preference
Hartebeest (- 0.75) Wildebeest (- 0.35) Ostrich (0.32)	August 1984	0.39	< 0.001	High	Avoidance