

# **Geo-Information for Sustainable Rangeland Management**

## **A Case Study of the Arid and Semi-Arid Lands in Kenya.**

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### **1. Abstract**

This paper analyses the historic changes in the populations of Kenyan large herbivore species and presents data on the encroachment of agriculture into the Kenyan ASAL zone during the period 1970's - 1990's. It further investigates the change in the ratio of people to livestock.

The data show a significant decline between the late 1970's and the late 1980's of the populations of 13 out of 18 large herbivore species. Further analysis revealed that the majority of almost all species resides outside the protected area system, where they are subjected to the impact of a changing land use. During the study period agriculture encroached the rangelands with the relatively more favorable climatic conditions. The ratio of people over livestock exceeds in most divisions the threshold value above which livestock fails to provide the food resources required by the human population.

It is argued that sustainable conservation of Kenyan wildlife resources should be based on the recognition that the majority of wildlife resides outside protected areas. Because of this we plea for development of a legislation which promotes the sustainable exploitation of wildlife resources.

In the final paragraphs we describe the mandate and activities of DRSRS in the fields of land use planning and the formulation land use policy for sustainable land management.

## 2. Introduction

Kenya is renowned for its unique assemblage of wildlife species. The tourism industry, which accounts for 11% of Kenya's GDP and 18% of all wage employment, depends mainly on wildlife attractions. However, over 70% of Kenya's wildlife resources, reside outside protected areas, where wildlife has to compete for resources with other forms of landuse.

Pastoralism was for many years the traditional land use in the Arid and Semi-Arid Lands (ASAL) zone of Kenya. These rangelands comprise about 85% of the country and accommodate around 28% of the total human population. Livestock products form the primary source of food for these pastoral populations. However, with a steady increase of the human population livestock will no longer be able to fully meet these food requirements and pastoral communities are forced to transform their land use in the direction of agro-pastoralism. In addition, people from the densely populated uplands migrate into the ASAL zones opening up the land for agriculture. Together these land use changes put the rangeland ecosystem under stress and exert a negative impact on wildlife.

To develop appropriate policies to counteract these negative developments one needs to identify the processes responsible for this decline. So far no detailed analysis has been done to investigate whether the decline in wildlife populations may be attributed to encroachment of agriculture or transformation of traditional pastoral systems in the direction of agro-pastoralism. In addition, there is no information on how and where these processes have been affecting or will affect wildlife resources in the future.

The Department of Resource Surveys and Remote Sensing (DRSRS) in Nairobi has been collecting data on livestock and wildlife populations as well as other environmental factors in the Kenyan rangelands. In this study these long-term environmental databases will be applied to address a number of questions relevant for the management of our wildlife resources. The following questions will be addressed: (i) to what extent have wildlife populations declined in the Kenya Rangelands between the late 1970's and the late 1980's; (ii) where have ratios of people over livestock exceeded the level where livestock fails to meet the food requirements of the human population, and (iii) where has agriculture encroached in the arid and semi arid lands areas between the late 1970's and the late 1980's and how it relates to wildlife numbers and distribution. In addition we will describe the mandate and activities of DRSRS in more detail.

## 3. Methods

The results presented in this study are based on aerial census data collected by the Department for Resource Surveys and Remote Sensing (DRSRS) in Nairobi. Population densities of large herbivore species and livestock were recorded according to the systematic reconnaissance flight method (Norton Griffiths 1978). The aircraft flew along parallel flight lines or transects 2.5, 5 or 10 km apart. Each transect was sub-divided in sub-units of 5 or 10 km length. Two observers seated at the rear of the plane counted the number of animals per sub-unit. Herds exceeding 10 animals were photographed to allow more accurate counting in the laboratory. The presence or absence of agriculture in every sub-unit was recorded by an observer located at the front seat. In addition we

used information on human population density per division reported in the national population censuses of 1979 and 1989 respectively (CBS 1982, 1994).

Systematic reconnaissance flights as described above have been executed for the ASAL districts since the late 1970's (Grunblat et al. 1995, 1996). The available census data were split into two groups, corresponding to the dates of the human population census (1979 and 1989). The first one was centered around 1979 (1977 - 1984) and the second around 1989 (1985 - 1994). We then compared the population estimates of wild herbivore species for these two periods and tested for significant differences between the periods, using a z-test.

Declines in wildlife populations might be the result of increased competition for resources with livestock, encroachment of agriculture, poaching and a number of other factors. In this study we analyze the changes in agriculture and pastoral ecosystems.

We first investigated whether the amount of livestock would be sufficient to sustain the human population. For this purpose we used the ratio of metabolic weight of people over livestock. Pastoral people need a minimum amount of livestock to meet their food requirements. According to Prins (1992) an average family of 8 people consumes 6,600 liters of milk and 700 kg. of meat per year and need 35 to 40 head of cattle. Lamprey (1983) suggests that in order to sustain livelihood during periods of drought and disease, an additional 50% of cattle appear reasonable. Therefore the ideal theoretical ratio between the metabolic weight of people to that of livestock is 0.045 (Prins, 1992). When applied to an individual family this ratio may indicate whether there is enough livestock to sustain them. A somewhat higher ratio, however, does not necessarily mean that there is not sufficient livestock, since the ratio is based on an additional 50% to overcome drought years. In addition systematic reconnaissance flights tend to underestimate the true livestock population density by 10 to 15% (Stelfox, 1981, Peden et al., 1979). Moreover, we executed the analysis at the level of divisions. Although the ASAL zone is dominated by pastoral people, there will be a fraction of the population which does not directly depend on livestock. These include traders, government and NGO officials etc. Because of this we argue that a threshold value of 0.045 applied at the divisional level would be too low to indicate whether the livestock resource base satisfies the food requirements of the pastoral population. We therefore subjectively decided to produce maps using the original threshold value (0.045) proposed by Lamprey (1983) as well as a value 3 times as high (0.135). Metabolic weight ratios were calculated for the periods around 1980 and 1990. Livestock data were calculated at the level of the division using the procedures described by Jolly (1969). For each period a weighted average of the various censuses was calculated according to Norton-Griffiths (1978).

We then addressed the question how these metabolic weight ratios would evolve in the decades to come. For this purpose we calculated the ratios in the year 1999 and 2009, assuming a 3.3% increase of the human population and a constant livestock population.

We then analyzed where and to what extent agriculture had encroached in the ASAL zone. For this purpose we used crop information gathered by the front seat observer (FSO) during the aerial census flights. We mapped all areas under crops for the two time periods around 1980 and 1990. The data sets were composed from all the census in a particular period picking the highest recorded value in a given survey unit of 5 by 5 km.

Encroachment by agriculture will not occur all over the ASAL zone but will be restricted to the climatically more favored parts. To test this hypothesis we compared the percentage of sub-units where agriculture had been recorded for each of the agro-climatological zones (KSS, 1982) in Kenya. Finally we hypothesized that encroachment of agriculture would not affect all species equally, because some species prefer areas unsuitable for agriculture while others occupy the more suitable territories. We therefore investigated the distribution of the various wildlife species over the seven agro-climatological zones.

## 4. Results and Discussion

### 4.1 Change in wildlife and livestock populations

Table 1 (Grunblatt *et al.*, 1995) reveals that the population size of 13 out of 18 large herbivore species showed a significant decline between the late 1970's and the early 1990's. These species are eland, elephant, Grant's gazelle, Thomson's gazelle, gerenuk, giraffe, greater kudu, impala, kongoni, lesser kudu, oryx, waterbuck and Grevy's zebra. The population of greater kudu (45) reached a level where one might question the persistence of these species in Kenya.

**Table 1. Population estimates (PE) and standard errors (SE) for 18 wildlife species in the late 1970's and the early 1990's as well as the absolute and percentage decline (Grunblatt *et al.* 1995). Flag = significant changes at  $p < 0.01$ .**

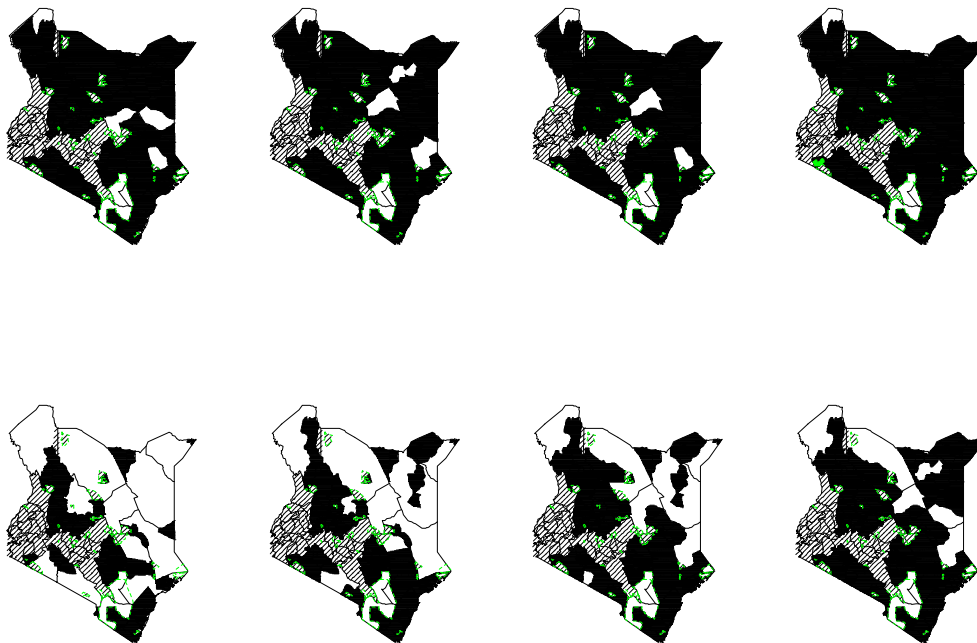
Wildlife	PE 70s	SE 70s	PE 90s	SE 90s	Decline	Decl %	Flag
Buffalo	35,453	6,060	30,187	4,197	-5,266	-15%	
Eland	25,775	3,376	19,123	1,242	-6,652	-26%	-
Elefant	39,108	6,008	14,923	1,808	-24,185	-62%	-
Gazelle Grants	247,491	12,407	103,208	3,915	-144,283	-58%	-
Gazelle Thomsons	87,086	14,766	31,259	4,269	-55,827	-64%	-
Gerenuk	42,918	1,820	21,418	1,282	-21,500	-50%	-
Giraffe	62,255	2,808	50,080	2,337	-12,175	-20%	-
Greater kudu	233	99	45	25	-188	-81%	-
Impala	116,177	8,930	67,934	3,194	-48,243	-42%	-
Kongoni	29,606	2,533	18,521	1,054	-11,085	-37%	-
Lesser kudu	17,468	1,214	7,751	710	-9,716	-56%	-
Oryx	53,653	3,571	25,824	1,950	-27,929	-53%	-
Ostrich	25,716	1,772	33,871	2,798	8,154	32%	+
Topi	93,822	10,977	92,934	18,139	-888	-1%	
Waterbuck	12,309	1,476	5,260	733	-7,049	-57%	-
Wildebeest	224,404	49,582	173,654	38,919	-51,050	-23%	
Zebra Burchell	138,448	12,643	146,093	9,549	7,645	6%	
Zebra Grevy	10,364	1,355	4,868	871	-5,496	-53%	-

With reductions continuing at the current rate the populations of Grevy's zebra, waterbuck, lesser kudu and Hunter's hartebeest may rapidly reach a similar level within a few decades. The latter species is not shown in the table; its current population size has been estimated 2175 individuals (Wargute and Aligula, 1977). No significant changes could be detected for the populations of buffalo, topi, wildebeest and Burchell's

zebra. Ostrich was the only species showing a significant increase in population size, most likely as a result of ostrich farming.

#### 4.2 Co-existence between wildlife and pastoralists

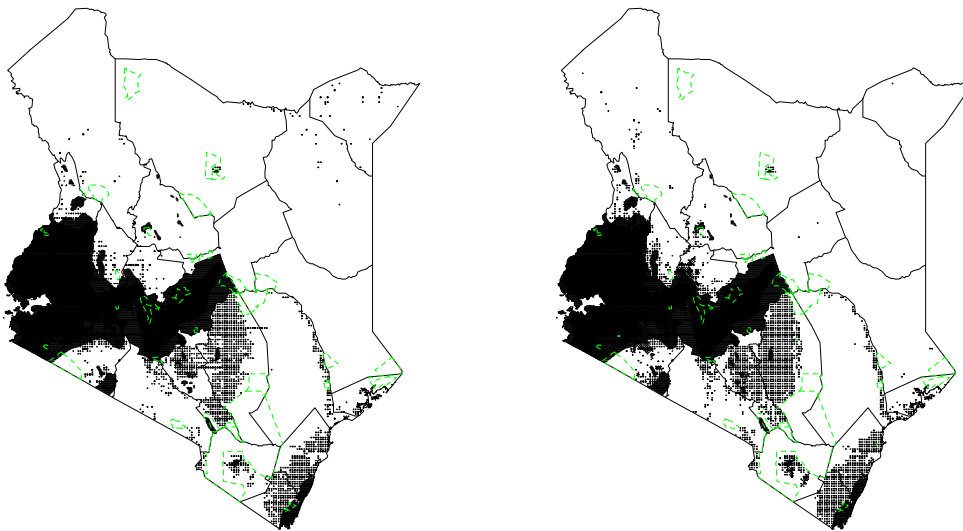
Figure 1 shows that the metabolic weight of people over that of livestock exceeded the threshold value of 0.045 (Lamprey 1983) in almost all ASAL divisions both in the late 1980's as well as the late 1970's. In these periods the ratio exceeded the higher threshold value of 0.135 in many divisions closer to the coast and adjacent to the highlands. Several divisions in southern Kenya and the north have not yet attained this level. The projections however indicate that a metabolic weight ratio will be attained in the decades to come. An exception is formed by the rangelands in the extreme north, here the predicted ratio will remain between 0.045 and 0.135.



**Figure 1.** Map showing the ratio of metabolic weight of people (kg/ha) over the metabolic weight of livestock (kg/ha) for the divisions in ASAL zone of Kenya. Hatched = high potential areas and divisions with insufficient information. Black areas indicate the divisions where metabolic weight ratio exceeds 0.135 (upper row) and 0.045 (lower row) respectively. The two figures to the left display the observed ratio in 1979 and 1989, while the two maps to the right show the predicted ratios in 1999 and 2009 respectively.

### 4.3 Encroachment of Agriculture

The number of aerial census sub-units where agriculture has been recorded increased from 1449 in the late 1970's to 3,190 in the late 1980's. Since the late 1970's agriculture has encroached rangeland in central and southern Machakos district, western Kitui district, in Kwale district, the footslopes of the Taita hills and the Kilimanjaro, in the Loita hills and plains in Narok district, as well as the southern parts of Laikipia, Baringo, West-Pokot and Samburu district.



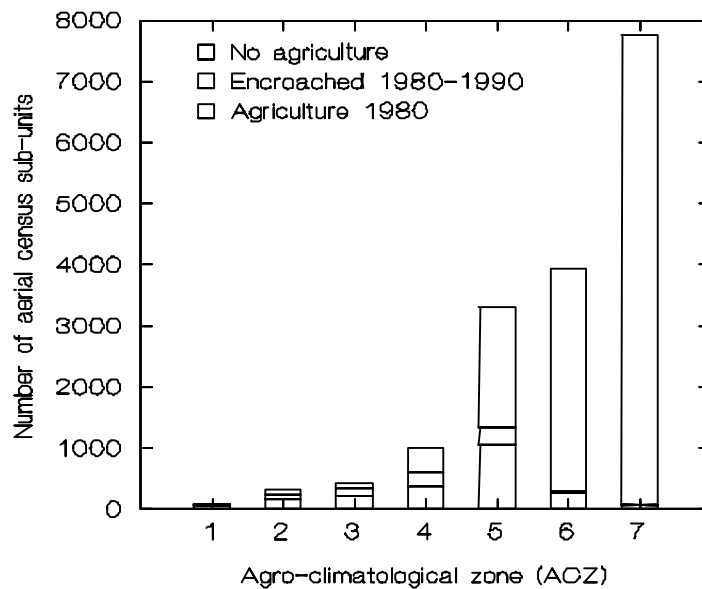
**Figure 2.** Distribution of agriculture in the Kenyan ASAL zone in the late 1970's (left) and the late 1980's (right). Dots = agriculture recorded by front seat observer; black = high potential areas (not surveyed), continuous lines = district boundaries, interrupted lines = protected area boundaries.

### 4.4 Agro-climatological zone and encroachment

Kenya can be divided into 7 major agro-climatic zones (Table 2). Zones 1, 2 and 3 have a very high to high-medium potential for cropping. The risk for maize failure is low to very low. These zones represent about 12% of the total land area but contain 72% of the total population. Zones 4 and 5 have a medium to marginal potential to grow crops. The risk for maize failure is higher particularly in zone 5. These are sparsely populated areas representing 21% of the total land area but being home to 23% of the total population. The arid zones 6 and 7 are not suitable for rain-fed agriculture. They represent 67% of the total land area and supports only 5% of the total population.

**Table 2. Agro-climatic zones of Kenya Adapted from KSS (1982); r/Eo represents ratio between rainfall and evapo-transpiration**

ACZ	r/Eo	Climate	Annual Rainfall mm	Potential for Plant Growth	Risk for maize failure
1	>80	Humid	1100-2700	Very High	Extremely low 0-1%
2	65 - 80	Sub-Humid	1000-1600	High	Very Low 1-5%
3	50 - 65	Semi-Humid	800-1400	High - Medium	Fairly Low 5-10%
4	40 - 50	Semi-humid to semi-arid	600-1100	Medium	Low 10-25%
5	25 - 40	Semi-arid	450-900	Medium - Low	High 25-75%
6	15 - 25	Arid	300-550	Low	Very High 75-95%
7	<15	Very arid	150-350	Very Low	Extremely High 95-100%



**Figure 3. Bar diagram displaying the number of aerial census sub-units where agriculture was recorded both in the late 1970's and 1980's (Agriculture 1980), in the late 1980's only (Encroached 1980- 1990), as well as the number of sub-units without agriculture (No agriculture) for the seven agro-climatological zones described in table 2.**

Figure 3 shows the number of aerial census sub-units where agriculture was recorded in the late 1970's and the late 1980's. Note that this figure includes the ASAL zone only, since aerial census data were not available for the high potential districts. The figure shows that a high and increasing fraction of the sub-units was reported to be under



agriculture in zones 1, 2 and 3. The percentage of sub-units with agriculture in zone four increased from 38% in the late 1970's till 60% in the late 1980's, leaving little land free of agriculture in this zone. Similarly in zone five the percentage of sub-units with agriculture increased from 32 to 41%. The graph shows no increase of the number of sub-units where agriculture was recorded in ACZ 6 and 7.

Table 3 shows the distribution of the populations of the various wildlife species over the seven agro-climatic zones. Some species are restricted to particular agro-climatological zones. Hunter's hartebeest and gerenuk for instance occur almost exclusively respectively mainly in zone 7. Other species, such as impala, occur over a wide range of agro-climatological zones.

The table shows as well the fraction of a population in a particular ACZ, which was recorded in protected areas. Since the data were collected in the non-migratory season, it gives a biased result for wildebeest and Burchell's zebra. For other species, however, it indicates that a large fraction of the population resides outside protected areas. The aerial census data revealed that almost the complete population of Hunter's hartebeest was located outside protected areas, while only 25% of the greater Kudu population was observed inside. Similar figures were observed for many other less endangered species.

A number of species are predominantly concentrated in the ACZ's with a high to moderate potential for agriculture. Potentially these species could be affected by the consequences of encroachment by agriculture, particularly those species with the majority of their population residing outside protected areas. The table shows that the following species have a large fraction of their population outside protected areas in these ACZ's: waterbuck, topi, impala, kongoni and Burchell's zebra. The data provided by the table suggests that majority of the wildebeest population resides inside the conservation areas. It should be borne in mind however, that wildebeest is a migratory species, which resides outside protected areas part of the year.

The last column of table 3 shows for every species the fraction of the total Kenyan population residing inside protected areas. This fraction ranges from 66 and 41% for wildebeest and buffalo, to 2% in the case of Hunter's hartebeest. This indicates that the vast majority of almost all species is to be found outside the protected area system.



**Table 3: Distribution of the populations of 20 wildlife species over the seven agro-climatological zones (%Z), expressed as percentage of the total population of a species residing in a particular ACZ and the percentage of the population in that particular ACZ which resides in protected areas (%P). The final column (Total population; %P) indicates the fraction of the total Kenyan population, which was recorded inside protected areas.**

Species	ACZ 1		ACZ 2		ACZ 3		ACZ 4		ACZ 5		ACZ 6		ACZ 7		Total population	
	%Z	%P	%Z	%P	%Z	%P	%Z	%P	%Z	%P	%Z	%P	%Z	%P	Total %	%P
Wildebeest	-		10	9	39	88	36	81	9	0	6	18	-		100	66
Thomson's gazelle	-		<1	0	10	58	45	44	37	0	7	0	-		100	26
Waterbuck	1	0	3	0	2	0	26	1	31	0	34	22	3	9	100	8
Burchell's zebra	-		4	3	3	58	22	57	34	0	30	19	7	42	100	23
Impala	-		3	3	6	37	36	21	39	0	15	22	1	49	100	14
Topi	-		1	0	1	50	50	11	7	15	35	1	7	2	100	7
Kongoni	-		1	0	2	0	11	12	51	0	32	78	4	96	100	30
Warthog	-		<1	100	2	6	12	23	15	0	36	11	35	5	100	9
Buffalo	-		-		1	0	16	53	22	1	46	51	15	63	100	41
Ostrich	-		-		-		1	9	25	0	15	16	59	6	100	6
Eland	-		-		-		5	26	26	0	62	33	6	91	100	28
Elephant	-		<1	67	1	100	4	8	10	41	67	58	17	63	100	56
Grant's gazelle	-		-		1	0	7	16	24	0	22	20	45	7	100	9
Giraffe	-		<1	0	<1	0	5	12	15	5	31	20	49	8	100	11
Gerenuk	-		-		-		<1	0	3	11	20	14	76	6	100	8
Greater kudu	-		-		-		-		4	0	57	44	39	0	100	25
Lesser kudu	-		-		-		1	0	7	5	52	25	40	11	100	18
Oryx	-		-		-		-		5	0	20	23	75	12	100	14
Grevy's zebra	-		-		-		1	0	5	0	38	6	56	9	100	8
Hunters hartebeest	-		-		-		2	0	-		98	2	1	100	100	2

#### 4.5 Discussion and conclusions

The results presented in this paper show a significant decline of the population of 13 out of 18 wild herbivore species. A few species among these are endangered (e.g. greater kudu and Hunter's hartebeest), others may become endangered when the current trend continues.

The results revealed as well that the majority of wildlife species resides outside protected areas. Here they are subjected to the impact of land use changes. Land use changes were apparent in the form of the strong encroachment of agriculture in the climatically more favoured parts of the Kenyan rangelands. Increased livestock stocking rates might be another land use change that could lead to a decline of wildlife resources. However, no significant change in the metabolic weight of livestock could be detected between the 1970's and the 1990's (De Leeuw, unpublished data). This is surprising,

given the fact that human populations increased by 3.3% in most ASAL districts. In a situation of sufficient availability of rangeland resources one would expect increased stocking densities to satisfy the food requirements of the increasing pastoral population. Our data show that this has not happened. The observation of stable livestock populations in combination with the elevated ratios of metabolic weight of people over livestock suggests that the environment controls and limits the possibilities to further increases of stocking rate. This implies that rangeland resources are intensively exploited by livestock. Hence, wildlife will experience severe competition for resources.

The land use changes described above will in the near future continue to operate in the Kenyan ASAL zone given the rapid increase of the human population. People and their livestock will increasingly exploit resources previously utilized by wildlife. This may ultimately lead to the decimation and extinction of wildlife through competition for resources (Prins 1992) or other factors associated with the presence of people and their animals such as transfer of diseases.

Under the current conditions land use will continue to intensify and lead to a reduction of the opportunities for wildlife populations. We argue that solutions aiming at sustainable conservation of Kenyan wildlife resources should be based on the recognition that the majority of wildlife resides outside protected areas. Solutions therefore should address the question how to stimulate individual land owners to protect the wildlife on their land. We believe that this can be achieved when the land owners benefit from the wildlife residing on their land. A number of initiatives aim to improve the benefits to the local land user. However, the impact of such efforts remains ephemeral when not supported by adequate legislation. What is urgently needed are legal systems that promote the sustainable exploitation of wildlife resources. This could be in the form of a land use policy which recognizes wildlife exploitation as a form of sustainable land use which is capable of yielding high economic returns. Meanwhile wildlife will systematically be decimated, unless these issues are tackled.

#### **4.6 Role of DRSSRS in Sustainable Landuse Planning and in the formulation of Landuse Policy in Kenya**

The Department of Resource Surveys and Remote Sensing (DRSSRS) was established in 1976 as the Kenya Rangeland Ecological Monitoring Unit (KREMU). The overall objective of DRSSRS is to gather and analyze data and information regarding the natural resources of Kenya and to provide interdisciplinary analysis of such information as it relates to natural resources development planning, management and policy formulation at a national, regional and district level. In its role as a survey-oriented organization, DRSSRS primarily employs aerial survey methods in its data gathering efforts. Additionally, ground surveys are undertaken primarily as a method for ground-truthing. Other modern technology are used including satellite images (NOAA, Landsat and Spot) and Geographic Information System (GIS) that facilitate development and the use of database of natural resources.

The role of the department as an agency for taking inventories on various natural resource attributes, as well as monitoring will continue to play an important role through provision of necessary data for land-use planning. This will help in characterization and indication of suitable land for various competing uses and will help managers work

towards the best use of land. This can be achieved via a process of integrating socio-economic, bio-physical and technological data set e.g. agronomy, soils, climate, biodiversity, etc. The GIS enables integrated analysis of the data-sets, resulting in options that can assist managers to formulate viable and sustainable development alternatives. Decision-makers can then choose between alternatives that optimize for both individual land owners and to the community as a whole. Indeed DRSRS can play a major role in integrated resources planning as areas of avoiding conflicts in land-use. Integrated planning will further develop a perspective, to conceptualize interpretation and to evaluate interrelationship and conflicts between resource uses.

In order to effectively contribute to sustainable environmental planning and national development, DRSRS has focused existing resources to provide timely, and effective data products and some of its activities includes:

- Cooperative work with Kenya Wildlife Services on the following:
  - Hirola (Hunters Hartebeest) trans-location project
  - The elephant programme (especially now after the lift of ivory ban more and stringent monitoring of elephant population and deaths are required)
  - Masai Mara management plan (a cooperative programme between the Masai pastolist, KWS, African Centre for Conservation and other NGO's)
- Creation of the biodiversity ecological viable conservation regions; as opposed to original protected areas.
- Assisted Shelter Afrique and Economic Commission for Africa (ECA) in setting up a Desktop GIS containing human settlements condition in Africa. This document was presented in HABITAT II conference in Istanbul in 1996.
- The joint UNEP/GOK National land degradation assessment and mapping project. The programme is to facilitate implementation of a plan of action to combat land degradation through the formulation and development of efficient and effective strategies for conservation of land resources. Also to facilitate Kenyas participation in the implementation of the African Ministerial Committee in Environment (AMCEN) Sub-programme on the environmentally sound management of terrestrial ecosystems and their resources.
- The Kajiado District ASAL projects represent a local application of GIS capabilities in arid lands assessment.

DRSRS must carefully now assess its capabilities and user requirements to develop satisfactory future collaboration with specialized support and capacity building from institutions like ITC, Wageningen Agricultural University (WAU) and the Groupement pour le Developpement de la Teledetection Aerospatiale (GDTA). Indeed technical backstopping from these institutions should assist the departments endeavor in sustainable resource planning and management of natural resources in Kenya.

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