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Land Use and Development in the Chyulu Area of Kenya

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ABSTRACT AND KEYWORDS

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PART 1 - INTRODUCTION AND SCOPE

1.1 Introduction

1.2 Summary

1.3 Acknowledgements

CHYULU HILLS WATER RESOURCES PROJECT

PART 2 - NATURAL RESOURCES

2.1 Climate

2.2 Geology and landform

2.3 Soils

2.4 Vegetation

2.5 Wildlife

LAND USE AND DEVELOPMENT IN THE CHYULU AREA OF KENYA

PART 3 - LAND EVALUATION

3.1 Land potential

3.2 Land allocation

M J MAKIN & D J PRATT

PART 4 - ENVIRONMENTAL CONSIDERATIONS

4.1 Environmental objectives

4.2 Present land use

4.3 Options for the future

PART 5 - THE MARCH OF AGRICULTURE IN URBAN AREAS

5.1 Historical background

5.2 Present land use

5.3 Options for the future

Project Report 135
KENYA-05-1/REP-135/84

PART 6 - CONSERVATION IN THE CHYULU HILLS AND THE CHYULU HILLS

6.1 Environmental objectives

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Surbiton, Surrey, England KT6 7DY

1984

CONTENTS

	Page
ABSTRACT AND KEYWORDS	v
ABBREVIATIONS	vi
PART 1 BACKGROUND AND SUMMARY	1
1.1 Introduction	1
1.2 Summary	3
1.3 Acknowledgements	5
PART 2 NATURAL RESOURCES	7
2.1 Climate	7
2.2 Geology and landform	12
2.3 Soils	13
2.4 Vegetation	17
2.5 Wildlife	23
2.6 Water availability	25
PART 3 LAND EVALUATION	29
3.1 Land potential	29
3.2 Land allocation	33
PART 4 PASTORALISM IN KAJIADO MAASAILAND	37
4.1 Historical perspective	37
4.2 Present land use	39
4.3 Options for the future	41
PART 5 THE MARCH OF AGRICULTURE IN UKAMBANI	45
5.1 Historical perspective	45
5.2 Present land use	46
5.3 Options for the future	52
PART 6 CONSERVATION IN TSAVO WEST AND THE CHYULU HILLS	57
6.1 Historical perspective	57
6.2 Present land use	57
6.3 Options for the future	60

	Page
PART 7 FUTURE TRENDS AND WATER REQUIREMENTS	63
7.1 Kajiado District	63
7.2 Machakos District	64
PART 8 FURTHER INVESTIGATIONS	67
8.1 Meteorological recording	67
8.2 Soil/water relations	70
8.3 Ecological monitoring and resource evaluation	72
PART 9 REFERENCES	73
APPENDIXES	
1. Measured areas on Maps 1 and 3	75
2. Village data east of the Chyulus	77
TEXT MAPS	
1. Location	following page
2. Land tenure	2
3. Block boundaries and water distribution system - Kiboko National Range Research Station	34
4. Water distribution and stock movement patterns on Mbirikani and Kuku ranches	40
SEPARATE MAPS (in map folder at the back of this report)	
1. Land Use - Machakos District, 1983 (scale 1:50 000)	
2. Land Potential (scale 1:125 000)	
3. Vegetation in the Kibwezi Forest (scale 1:20 000)	

ABSTRACT AND KEYWORDS

ABSTRACT

This input to the Chyulu Hills Water Resources Project assesses present and future land use patterns, as a guide to possible changes in groundwater recharge and as a basis for planning local domestic water supplies. Details of climate, soils, vegetation, cropping and surface water availability are set out and maps are presented to give an overview of land potential and land tenure, and of land use east of the Chyulus. Although lack of domestic water, rocky soils and erratic rainfall all act as limitations to settlement, developments overall are essentially based on current patterns of land allocation. Future prospects are discussed, therefore, against the historical perspective of development within the three contrasting Districts into which the study area is divided. Changes are proposed to the boundaries of the Chyulu extension to Tsavo National Park. Means for intensifying the meteorological network are set out and a proposal is made for semi-detailed soil survey of the upper Chyulus. Intensified cropping is unlikely to influence adversely the overall levels of recharge to groundwater, nor increase significantly losses due to surface runoff, but increasing local population can be expected to generate a rising demand for water supplies as enumerated in the report.

SUGGESTED KEYWORDS

Agricultural development, climate, conservation, cropping, ecoclimatic zone, groundwater, irrigation, land capability, land resource, land settlement, land tenure, land use, livestock, migration, National Park, population, rainfall, range management, soil description, soil survey, soil water, vegetation distribution, water supply, wildlife, Kenya.

ABBREVIATIONS

API	Airphoto interpretation
BGS	British Geological Survey, formerly the Institute of Geological Sciences, UK
CEC	Cation exchange capacity
ECZ	Ecoclimatic zone
ha	Hectare
ILCA	International Livestock Centre for Africa
IRR	Internal rate of return
km	Kilometre
KREMU	Kenya Rangeland Ecological Monitoring Unit
KSh	Kenya shilling
LRDC	Land Resources Development Centre, UK
m	Metre
MCM	Million cubic metres
me/100g	Milliequivalents per 100 grams
mm	Millimetre
/umhos/cm	Millimhos per centimetre
MW	Megawatts
RAF	Royal Air Force, UK
sp.	species
spp.	
t	Tonne
TAARDA	Tana and Athi Rivers Development Authority
UK	United Kingdom
vol.	Volume

PART 1 BACKGROUND AND SUMMARY

1.1 INTRODUCTION

The Chyulu Hills Water Resources Project is being executed jointly by the Water Resources Department of the Kenya Ministry of Water Development and by the British Geological Survey, on behalf of the UK Overseas Development Administration. This contribution, relating to land use and development prospects in the Chyulu area, is provided by the Land Resources Development Centre (LRDC).

The purpose of the main Project is to quantify the sustainable long-term groundwater resources of the study area (shown on Text Map 1) as a contribution to planning the development of domestic water supplies, locally and along the Kenya coast. The present study area is bordered in the north and east by the Kiboko and Athi rivers, in the west by the Loitokitok-Sultan Hamud pipeline and in the south by the Tsavo River. The Chyulu Hills and their volcanic deposits comprise the central axis and principal focus of interest. This axis also forms an administrative boundary between the Maasai pastoral area of Kajiado District in the west and the Akamba settlements and grazing areas of Machakos District in the east. Taita District and Tsavo National Park extend into the study area from the south.

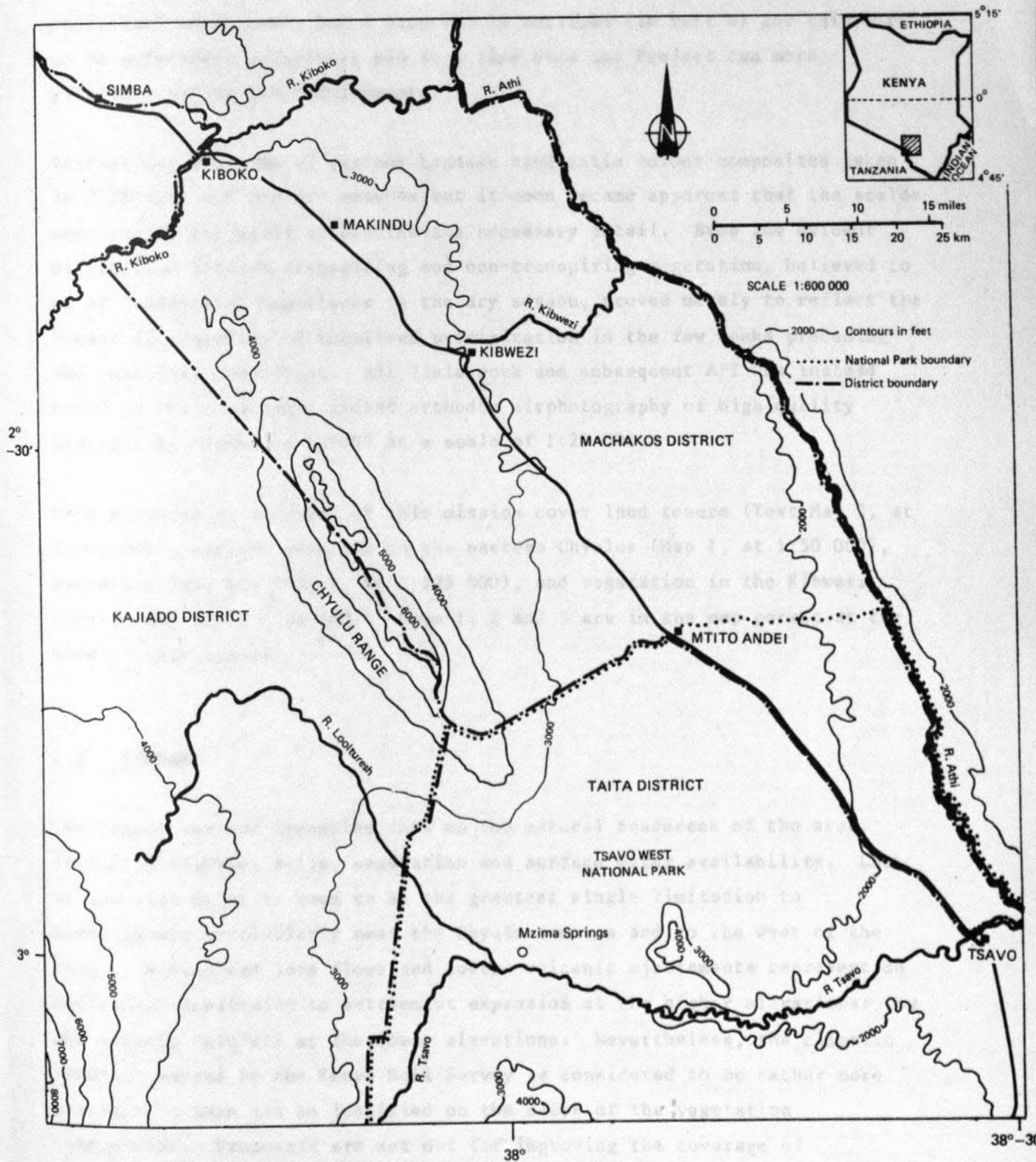
Apparently much of the groundwater accumulating beneath the 80 km length of the Chyulu Hills flows underground to emerge at the Mzima Springs, some 20 km south of the Chyulus and lying within the Tsavo West Park. Mzima Springs not only provide essential baseflow for the Tsavo and Athi rivers, but also currently constitute the main water supply by pipeline for Mombasa. Proposals exist for further abstraction from these springs. Hence the crucial importance of establishing the sustainable long-term supply from Mzima, in the light of changing patterns of land use both on and around the catchment, and the need to make more precise analysis than hitherto regarding the catchment characteristics and the associated water balance. Moreover, future planning of water supplies for the Coast may have to take account of the needs of the expanding population in proximity to the Chyulu Hills.

It has been the aim of this input to contribute to the overall assessment of the effect on groundwater resources of present and projected land use in the Mzima Springs catchment by:

1. Establishing and mapping major agro-ecological divisions, with reference to landform, soil, vegetation and land use
2. Assessing future intensities and forms of land use by reference to land potential and population pressure, indicating where control or change of present trends is needed
3. Assisting in estimating future water requirements.

To these ends, some preliminary work was undertaken early in 1983 (at LRDC expense), aiming at a field mission in May/June. In the event, approval was delayed by nine months and, owing to problems over staff timing, the mission was eventually mounted without the planned eight-week desk study. Moreover, ordering of the airphotography had to be delayed until project approval was forthcoming; the photographs were not therefore collected from Geosurvey in Nairobi until November 22 immediately prior to the first field reconnaissance, thereby effectively preventing any preliminary airphoto interpretation (API). Notwithstanding these problems, field visits were undertaken more or less as planned. The principal input was provided by M J Makin who was operational in Kenya from November 19 until December 20, supported on a first field reconnaissance (November 24-27) by D J Pratt who was in Kenya on other business. Subsequent API and map preparation were undertaken in the UK between mid-January and the end of February 1984, leaving March for reporting.

Given the broad terms of reference set out above and the extensive and diverse nature of the study area, field survey could have extended over several months with commensurate improvement in the range and detail of the resulting analysis. With relatively limited funding however (£12 000), it was important early in the assignment to define priority activities that were both attainable in the time available and likely to yield information of direct value for achieving project objectives. It became evident early in the assignment that (a) the existing 1:250 000 scale reconnaissance soil maps of the study area were insufficiently detailed for the purposes of the Project, and (b) undertaking more detailed soil survey would not only absorb



TEXT MAP 1. Location

more time than was available but could only be carried out at the expense of other relevant investigations. Consequently, no effort was invested in additional soil survey but a proposal is outlined (in Part 8) for this work to be undertaken separately and at a time when the Project can more precisely define its requirements.

Initial use was made of various Landsat band ratio colour composites taken in different wet and dry seasons but it soon became apparent that the scales were really too small to provide the necessary detail. Even the evident distinction between transpiring and non-transpiring vegetation, believed to be of fundamental importance in the dry season, proved merely to reflect the recent distribution of localised precipitation in the few weeks preceding the satellite overflight. All field work and subsequent API was instead based on the relatively recent orthodox airphotography of high quality provided by Geosurvey (1978) at a scale of 1:20 000.

Maps prepared as a result of this mission cover land tenure (Text Map 2, at 1:500 000), current land use in the eastern Chyulus (Map 1, at 1:50 000), potential land use (Map 2, at 1:125 000), and vegetation in the Kibwezi Forest (Map 3, at 1:20 000). Maps 1, 2 and 3 are in the map pocket at the back of this report.

1.2 SUMMARY

The report reviews assembled data on the natural resources of the area, including climate, soils, vegetation and surface water availability. Lack of domestic water is seen to be the greatest single limitation to development, particularly near the Chyulu summits and to the west of the range. Widespread lava flows and coarse volcanic ejectamenta represent an additional constraint to settlement expansion at the higher elevations: low and erratic rainfall at the lower elevations. Nevertheless, the climatic zonation mapped by the Kenya Soil Survey is considered to be rather more pessimistic than can be justified on the basis of the vegetation composition. Proposals are set out for improving the coverage of meteorological recording stations. Both the lava flows and the associated volcanic deposits, though of low moisture holding capacity, have high infiltration and permeability; consequently, there is no runoff. On the Basement soils however, some degree of surface runoff may be experienced.

Change from perennially-transpiring forest or bush to seasonally-transpiring crops or grassland can only increase overall levels of groundwater recharge. Phreatophytic vegetation was found to be of only very localised occurrence.

Land potential is considered against a background of historical developments and increasing population pressure. All but the most arid zone east of the Chyulus has to be regarded as suitable for settlement since a significant proportion of the area is already farmed, albeit with a high seasonal risk of crop failure; this risk becomes greater with distance from the Hills. Settlement pressures are such that continuing expansion of farming can be anticipated east of the Chyulus; details are presented of the crops and cropping patterns together with possible alternatives. In moister pastoral areas in the west Chyulus, there is expected to be some increase in cropping. Elsewhere to the west, however, lack of domestic water, combined with the aridity of the climate and extensive unsuitable clay soils, will limit development to an intensification of livestock production. Only irrigation can sustain high population densities in arid areas and the prospects for an eventual irrigation scheme on 13 000 ha west of the Athi may help relieve population pressures, though only temporarily. Otherwise, at least in the east Chyulus, priorities will need to be given to employment-generating rural enterprises, including (sesame) oil pressing, cotton ginning and vegetable packing, processing and seed production.

So far as wildlife conservation is concerned, we can see only a picture of accelerating pressures as land hunger intensifies. The future of Tsavo Park should be secure, sustained by increasing revenues from tourism and by international opinion, but the Park authorities should bow to the inevitable so far as most Park extensions are concerned. This means abandoning both the proposed extension east of Nooka and the Ngai Ndethya National Reserve, now thoroughly infiltrated by settlers, and also the existing extension to the west similarly under threat, and concentrating instead on saving the fauna and flora of the Chyulu summits - important from the standpoint of conservation and as a potential scenic tourist attraction. Kibwezi Forest should also be preserved.

Elsewhere, to the north of Tsavo, the gross patterns of land tenure have already been established. Whether as group ranches, State reserves, research stations, settlement schemes or private estates, the die has largely been cast and we do not anticipate any profound changes. Thus the

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future will be governed as much by historical accidents of land allocation as by appraisal of land 'capability'.

To the east of the Chyulus, it is assumed that immigration will continue until the land remaining has 'filled up', including farming 10% of the land on lava flows. On the basis of a number of assumptions regarding average farm size in different ecological zones, it is projected that the total human population west of the Nairobi/Mombasa road will reach some 43 600 by the year 2010 with a daily water requirement of about half a million litres. Stock projections indicate about 20 000 cattle and 100 000 smallstock in the area by that time; the watering of this number of animals would require a further daily supply of one million litres. West of the Chyulus, settlement will only be discontinuous and the increased population will still be largely dependent on livestock. On the basis of an increase in stock numbers of 50% by 2010 and a doubling of the human population, total daily water requirements (humans plus stock) in the vicinity of the west Chyulus could approach one million litres.

It is concluded that more detailed land use assessments in the Chyulus would not in general be justified since the future course of development seems more likely to reflect social and political pressures than technical considerations. One exception is the proposal for a semi-detailed soil survey of the upper Chyulus to determine the distribution of the different textural materials from which the overall contribution to recharge from deep percolation may be calculated. Such a survey will require 17 man-weeks at a total cost of £12 000.

1.3 ACKNOWLEDGEMENTS

Short term assignments of this nature promise the maximum of disruption at the receiving end for a minimum of return. Much gratitude is therefore due to all those in Kenya who assisted this preliminary mission, in particular

F R Kombonyo, District Officer, Kibwezi

G Mbuvi, Agricultural Officer, Kibwezi

Osore Chahilu, Officer-in-Charge, Kibwezi Forest Research Station

P M Muange, Chief Warden, Tsavo West National Park

Bill Woodley, Senior Warden (and long-term resident, Tsavo National Park)

Advice and assistance were also generously provided by F Muchena, Head of the Kenya Soil Survey; H Epp, Resource Ecologist, KREMU; Christine Kabuye, Officer-in-Charge of the Kenya Herbarium; J Kimani, Director, Athi River Development, TAARDA; E C Trump, formerly Ecologist, Wildlife Planning Unit; C N Maina, District Agricultural Officer, Machakos. Particular support was forthcoming from the Survey of Kenya, the Meteorological Department, the Forest Department, the Lands Department, the Tana and Athi Rivers Development Authority, and from Lindsay Penny of the British High Commission who successfully supervised all administrative arrangements in connection with our visit.

Map production in the UK was undertaken jointly by the British Geological Survey, the Directorate of Overseas Surveys and the Cartographic Section of the Land Resources Development Centre; Maps 1 and 3 were prepared by R Shepcar.

PART 2 NATURAL RESOURCES

2.1 CLIMATE

Temperature, cloud cover, and hence evaporation, all tend to vary in the Chyulu area with altitude, though there are no measurements to confirm this. Nevertheless, the chief climatic variable, annually and seasonally, is undoubtedly rainfall and it is this parameter that is chiefly discussed herein while acknowledging the importance of evapotranspiration to plant growth. A major problem in discussing patterns of rainfall however is the maldistribution of raingauges, such that the vast majority of stations lie to the east of the Chyulu Hills and principally in proximity to the Nairobi/Mombasa road and railway alignments. There are no reliable records from the main Chyulu range, nor are there any data from the Lolturesh Valley beyond.

From the rainfall data that are available (selected data presented in Table 1), it would seem that proximity to the orographic effect of the Chyulu Hills rather than elevation per se is the principal determinant of mean annual totals. The highest rainfall can be expected along the northwest/southeast trending axis of the Chyulu Range itself, with the vegetation patterns indicating relatively moister conditions at the southeast end, i.e. in proximity to Chyulu 2. Though evidently unreliable and of too short a duration normally to be acceptable, the records for Oltiasika and Chyulu I (perhaps averaged together!) may nevertheless be representative of the higher elevations. An annual average rainfall of 1 300-1 400 mm would be consistent with the vegetation, though D Western (pers. comm.) suggested that a range from 1 000 to about 1 150 mm is more likely, with a major contribution to the vegetation from mist and dew. Until reputable measurements are initiated it is perhaps idle to speculate, but the satellite images do show forest transpiration continuing through the dry season, probably sustained by both cloud extraction and periodic rainfall. Certainly, the limited Chyulu records indicate not only heavier precipitation during the rains, but also only a single dry season from June to September or October.

So far as direct orographic effects are concerned (other more localised effects are discussed in Section 2.4), over 80% of annual rainfall occurs at

TABLE 1 Average monthly and annual rainfall for selected stations and periods (to nearest mm)

Station location	Elevation (feet)	Period	J	F	M	A	M	J	J	A	S	O	N	D	Annual average
Oltiasika Maasai Rural Training Centre	4 700	1977-81**	127	48	218	355	201	12	12	7	2	64	409	170	1 625
Chyulu I South Chyulu Hills	5 160	1975-82**	20	40	105	255	81	45	0	25	84	74	215	165	1 109
Kibwezi Railway Station	2 990	1977-82*	70	31	69	163	6	0	0	3	0	78	214	166	800
Dwa Sisal Plantation	2 900	1974-82 64 years to 1982	56 40	31 30	94 89	129 123	53 29	1 4	1 1	2 2	7 4	36 24	223 176	137 137	770 659
Muthingiini Primary School	3 000	1977-82*	103	35	71	109	22	3	3	7	5	11	236	160	765
Kamboyo Tsavo Park HQ	3 000	1974-82	56	16	88	132	47	6	3	9	8	25	207	165	762
Masongaleni Railway Station	2 800	1975-82* 61 years to 1982	59 33	30 31	74 68	124 118	26 31	3 3	0 1	3 1	2 5	26 25	232 174	168 140	747 630
Masongaleni Estate near Manoni	2 350	1974-82	44	20	77	131	34	2	3	4	12	31	194	189	741
Ngwata Chief's Office	2 890	1974-82*	55	33	84	137	56	2	0	9	9	24	174	149	732
Maikuu Primary School	3 440	1974-82*	33	36	78	113	23	2	0	0	10	29	228	146	698
Mbuinzau Railway Station	3 280	1974-82*	40	26	80	112	41	0	0	1	5	33	219	131	688
Makindu	3 280	1974-82 79 years to 1982	51 41	17 29	59 76	139 116	34 29	2 2	1 1	2 1	4 2	45 29	161 172	111 116	626 614
Kathekani Railway Station	2 500	1974-82*	51	27	43	117	25	0	1	0	5	3	173	138	583
Chyulu Gate Tsavo West Park	2 550	1974-82	33	13	65	104	38	6	3	11	10	16	134	109	542
Kiboko Camp	3 200	1974-82	48	23	50	110	25	2	2	1	5	29	122	111	528
Bushwhackers Camp Masalani	2 250	1969-78	23	21	66	106	25	2	1	4	6	14	143	79	490
Kilaguni Lodge Tsavo West Park	2 700	1974-82*	31	8	40	107	38	4	2	2	11	13	101	103	460
Mzima Springs Tsavo West Park	2 140	1954-80	42	21	46	90	34	4	2	2	5	12	71	70	399
Ekinjape Primary School : Mbirikani	4 000	1978-82**	41	4	65	59	16	0	1	0	0	31	80	69	366

* Record discontinuous

** Record discontinuous and unreliable

times of low-level convergence when rain-bearing winds are arriving from a direction of around 100°. Since the alignment of the Chyulus is 145°-325°, height for height the southeastern end of the range should receive more rainfall; conversely, there would appear to be a slight rainshadow effect to the northwest. This is confirmed in the mapping of ecoclimatic zonation shown on Map 1.

To the west of the Chyulus, despite the dearth of recording stations, the vegetation of the Lolturesh Valley would seem to bear out a rapid decline in rainfall with elevation, due to the rainshadow effect of the Chyulus during the northeasterly monsoon and of Kilimanjaro when southerly or south-westerly winds prevail. Though unreliable, the data shown in Table 1 for Mbirikani (annual mean 366 mm) may be representative of a wider area. However, a monthly maximum in April rather than November (as is demonstrated at Kilaguni and Mzima) does seem to be more characteristic of stations west of the Chyulus. In contrast, east of the Chyulus, stations consistently show the more reliable and wetter rainy season to occur between October and January.

Mean annual rainfall data do however conceal large critical cyclic, annual and seasonal variations. Rainfall throughout the area is variable in amount and erratic in occurrence both in space and time. For the reliable long-term recording stations shown in Table 1 - Dwa, Masongaleni Railway and Makindu - the short-term rainfall record 1974-82 (chosen as being most comparable amongst the stations selected) is set against the longer records and shown to be, respectively, 17, 19% and 2% above the longer-term mean. It seems therefore that the data shown in Table 1, at least for stations between Kibwezi and Kathekani, should be reduced by perhaps 15%, or 100 mm. Even so, over a wide area from Makindu south to Kamboyo (Tsavo Park) and across almost to the Athi, it appears that the mean annual rainfall should lie within the range 500-700 mm (i.e. Ecoclimatic Zone V). The 10-year record for Masalani (Bushwhackers) would certainly indicate some further falling off in the rainfall close to the Athi and this is borne out by the vegetation. On the other hand the east Chyulu area would in general seem to enjoy a somewhat moister regime than has been indicated by the Kenya Soil Survey (van Wijngaarden, 1984); we return to this important point later.

The data in Table 1 confirm the strongly bimodal rainfall pattern, with more reliable rains between October and January compared with the shorter

TABLE 2 Summary of rainfall and evaporation, Makindu

	J	F	M	A	M	J	J	A	S	O	N	D	Total
Mean rainfall, mm (1904-82)	41	29	76	116	29	2	1	1	2	29	172	116	614
Pan evaporation, mm (1958-70)	171	181	198	169	154	150	145	164	193	210	173	152	2 060
E_0 -Penman, mm (1938-62) Woodhead, 1968	175	179	182	160	151	139	139	153	179	191	154	149	1 951
E_0 , mm/day	5.63	6.35	5.86	5.34	4.86	4.63	4.47	4.93	5.96	6.17	5.12	4.82	

March/May rains. With distance from the Chyulu Hills the dry seasons lengthen, with May and/or October included in the long mid-year drought. Both the length of rainy season and variation in the distribution of rain during the wet season have critical implications for cropping. The variability is well illustrated by data from Mzima Springs in the south where annual rainfall has varied between 84 and 933 mm; at Makindu the recorded annual range is from 67 to 1 964 mm, probably the most extreme in Kenya; the range in annual pan evaporation at this latter station is also unusually wide, from 2 456 to 1 584 mm. Table 2 shows that, at Makindu in an average year, potential evaporation considerably exceeds rainfall in every month except November.

On most occasions when it rains, only light showers occur. Table 3, illustrating the frequency of various amounts of daily rainfall at Dwa Plantation, shows that on 64% of raindays less than 10 mm are received. On the other hand, much of the total rain falls as heavy showers, over a third of the rainfall being recorded on only 4 days each year. Rainfall intensities likely to be exceeded at Makindu during various time intervals have been calculated by Lawes (1974). Intensities higher than 25 mm/hour occur 16 times per year for a duration of 15 minutes, 7 times per year for 30 minutes and twice a year for a duration of at least one hour.

TABLE 3 Distribution of rainfall by raindays at Makindu (Fenner, 1982)

Size-category of rainday, mm	% raindays in each category	% total rainfall in each category
0 - 2.5	31.7	3.4
2.5 - 5	15.6	4.9
5 - 10	17.0	10.2
10 - 20	16.2	19.3
20 - 40	12.4	28.0
40 - 80	6.1	25.9
80 - 160	1.0	8.3

2.2 GEOLOGY AND LANDFORM

The Pre-Cambrian Basement System underlies the entire region. Superimposed upon this are the Upper Pleistocene to Recent chain of Chyulu lavas built up by eruptions from some six hundred volcanic vents aligned along north-westerly and northerly-trending fissures and fault zones. The consequent elongated mass rises from foothills and subsidiary cones at 3-4 000 feet to summits from 5 000 to over 7 000 feet above sea level. The age of this volcanic chain is of some significance in evaluating both the degree of soil mineral weathering and the character of the anomalous forest vegetation that clothes the highest summits. Temperley (1960) ascribes an overall age that pre-dates the last African pluvial; this would seem to be a not unreasonable period for evolution of the soils and vegetation. There are however numerous more recent lava flows, especially towards the south end of the range where, for example, the volcano Shaitani has erupted in historical times producing a long lava flow which is as yet only colonised by occasional bushes.

In general, the lavas comprise vesicular olivine basalts which are strongly fractured and brecciated and hence highly permeable; consequently runoff is negligible and surface drainage on the lavas non-existent. The volcanic cones and associated ash fields are composed of unconsolidated pyroclastic materials, ranging from coarse agglomerates and cinders to lapilli and finer ash with volcanic bombs. Again, these cone belts are also highly permeable on account of the great pore space within the deposits. Some secondary calcium carbonate deposition is evident along lines of lateral seepage. To the west, the Chyulu lavas abut against the more massive Pleistocene volcanics of the Kilimanjaro sequence; the valley of the Lolturesh, blocked by the Chyulu Range and now filled with alluvium, divides the two volcanic formations. To the east, north and south, lava fields have spread outwards from the Chyulus filling up former drainage lines within the Basement, as in the Masongaleni Valley.

The Basement gneisses, which outcrop east of the Chyulu volcanics, can be subdivided into those that are poor in ferromagnesian minerals, as between Kibwezi and Kiboko where the resulting soils are sandier and lower in fertility than those to the south of Kibwezi which are derived from gneisses rich in ferromagnesian minerals. Locally, granitoid inselbergs outcrop, as

at Mbuinza, or protrude through the surrounding blanket of lava, as at Nooka.

Further east, the country comprises a gently undulating peneplain with an average slope of less than 2%. Much of this is underlain by gneisses with occasional outcroppings of crystalline limestone. Locally, these gentle slopes are dissected by streamlines often derived from springs along or close to the ends of the lava sheets. These valleys have an average depth of about 100 feet forming fairly steep and strongly dissected slopes and often exposing gneiss at the sides; elsewhere, localised colluvial and alluvial deposits may be laid down. Similarly, close to the Athi, valley oversteepening has allowed erosion of much of the surface soil cover leaving wide stretches of shallow stony soil and rock outcrops.

Since the geology and hydrogeology are to comprise major topics for investigation by the Project, these aspects are not further considered here.

2.3 SOILS

The soils of the area have been subject to recent investigation at reconnaissance level by the Kenya Soil Survey and mapped at a scale of 1:250 000 (Touber, 1983; van Wijngaarden, 1984). Semi-detailed soil surveys have also been undertaken in two localities to the east of the Chyulus: on 31 000 ha around the Kiboko Range Research Station with mapping at 1:50 000 (Michieka and van der Pouw, 1977), and on 68 000 ha to the west of the Athi, between the Masongaleni and Mito Andei rivers and extending as far west as the Nairobi/Mombasa railway with mapping at 1:100 000 (Athi Basin Study, 1981). While these studies have provided valuable information, the broader reconnaissance was necessarily superficial; it also over-relied on API at the expense of field observations, the consequent excessive correlation of soil areas with vegetation patterns lowering the credibility of the resulting maps. The problem of inadequate soil information on the Chyulu Range is taken up in Part 8.

The character of the soils is closely related to the nature of the rock material from which the soils derive. Soils developed from lava tend to be stony clay loams and light clays with low sand content. Because of the limited weathering however, much of the lava surface comprises outcropping

boulders and fissured lava sheets, the weathered clays being concentrated in local pockets often less than a hectare in extent. Highly permeable and well drained, these soils are characterised by dark black or grey topsoil. A transitional calcareous and gravelly dark brown horizon may serve to separate topsoil from parent rock but, more usually, the soil is very shallow and directly overlies the basalt. Where, as on some more level areas, the profile is reasonably deep, the soils may be regarded as either mollic andosol (lithic phase) or even haplic chernozem. Soil reaction (pH) is generally 6.5-7.5, organic content 3-5%, the CEC at 30 to 40 me or more/100g soil and the fertility invariably high. The soils exhibit rapid infiltration and permeability with no evidence of surface capping under cultivation. Results of pF analyses, undertaken by the National Agricultural Laboratory and set out in Table 4, demonstrate the reasonable moisture holding capacity potential of these soils wherever sufficient depths can accumulate. In general, however, the lava flows comprise little else but basalt blocks and boulders.

The more recently developed soils, mostly on or close to the summit ridges of the Chyulus, derive from ash and pumice, are often very shallow though easily penetrable by roots and moisture, and have gravelly sandy loam to clay loam surface textures. At quite shallow depths, unconsolidated calcareous layers of pumice-like materials are encountered. These are calcaric regosols; considering the nature of the climate and vegetation on the Chyulus, they are surprisingly low in organic material (possibly owing to seasonal burning). These coarse materials are highly porous, have a low bulk density and exhibit such very rapid rates of infiltration and permeability that even heavy showers will tend to flow quickly through the subsurface layers and pass beyond the depth of rooting. The low moisture holding capacity implies that the contribution of soil moisture to transpiration may only be of major significance when moisture can be drawn from strata receiving lateral seepage.

In areas east of the Chyulus not covered by lava, most soils have developed over long periods from the Basement, principally gneiss but locally granites, quartz and limestone. The soils of the Basement plain are predominantly well drained, very deep (1.5-2 m), dark red to brown and of a sandy clay loam to clay texture. Sometimes the topsoil is missing and the profile is clay throughout; elsewhere, a surface cover of loose coarse sand is indicative of sheet erosion. The soils have to a greater or lesser

TABLE 4 Soil pF analyses (average of several profiles except where indicated by*), from Michieka and van der Pouw, 1977; Touber, 1983

Soil class	Horizon	Moisture content (vol. %) at pF						Available** % moisture	% silt + clay
		0	2.0	2.3	2.7	3.7	4.2		
Mollic Andosol	A	51.7	37.8	34.3	28.8	21.1	17.6	13.2	43
	B + C	52.5	40.2	37.8	32.1	23.8	21.2	14.0	38
Chromic Luvisol/ Cambisol	A	52.6	33.1	31.2	27.8	23.9	21.3	7.3	84
	B	48.7	36.7	34.5	31.5	26.1	24.2	8.4	87
Ferral-chromic Luvisol	A	41.8	25.3	23.6	20.7	18.4	15.9	5.2	46
	B	41.6	31.5	29.5	26.7	20.2	19.3	9.3	67
Ferric Luvisol	A	36.6	22.2	20.9	18.0	12.4	11.2	8.5	33
	B	42.8	28.1	26.0	22.5	16.9	15.8	9.1	52
Acric-xanthic Ferralsol	A	42.0	21.1	19.4	16.9	12.0	10.5	7.4	32
	B	45.4	32.9	30.3	25.2	16.8	15.6	13.5	57
Acric-orthic Ferralsol*	A			20.9		14.2	11.6	6.7	48
	B			23.0		16.8	15.7	6.2	52
Acric-rhodic Ferralsol	A			24.1		16.6		7.5	
	B			25.6		17.9		7.7	
Calcic Chernozem*	A			35.8		26.7	24.2	9.1	62
	B			42.7		31.8	26.7	10.9	72
Calcic Cambisol* (sodic phase)	A			43.0		30.3	27.3	12.7	72
	B			46.8		26.1	23.7	20.7	84
Gleyic Solonchak* (sodic phase)	A			48.4		31.1	27.9	17.3	72
	B			44.3		34.5	31.3	9.8	60

**Available moisture taken as Moisture content at pF 2.3 minus Moisture content at pF 3.7

extent been enriched by volcanic ash derived from recent eruptions in the Chyulus; the ash tends to be more prevalent 'downwind' (i.e. in soils to the west of the Chyulus) and ceases to be of much significance east of the Nairobi/Mombasa road. Differences in the soils however are in general closely related to mineralogical differences in the underlying rocks. Thus sandier, more acid, less fertile and more highly weathered materials occur on gneiss poor in ferromagnesian minerals giving rise to intergrades between Acrisols and Ferralsols, while less sandy, more fertile chromic Luvisols and xanthic, orthic and rhodic Ferralsols are derived from gneisses rich in ferromagnesian minerals. In complete contrast, the limestones give rise to shallow brown loams with chromic Vertisols in localised depressions.

The Athi Basin Study found that rhodic Ferralsols, the most characteristic soils of the peneplain, covered about 70% of the 68 000 ha surveyed. These Ferralsols have a low CEC despite the relatively high (but kaolinitic) clay content and are generally low in most major nutrients other than potassium and magnesium. Despite their relatively high base saturation, pH values vary from 5 to 7.5, while organic content is rather low, mostly in the range 1-2.5%. The low fertility is however counteracted by good physical properties, a friable consistence when moist, easy workability, porous structure with intense termite activity and moderate permeability, though with some tendency to develop hard structural units on drying and also capping of the soil surface especially after heavy rain. These soils exhibit some sheet erosion with localised gullying (notably at Kalulini where there are gullies 3-4 m deep), a trend that may be expected to increase with increased intensity of cultivation. The not-dissimilar Luvisols share many of these features in common, but are characterised by an argillic subsoil of clay accumulation, are less permeable and enjoy a significantly higher CEC, kaolinite and illite contributing about equally to the clay mineral content.

Infiltration tests, using rainfall simulation and conducted on a range of Luvisols (Touber, 1983), showed that a majority of test sites registered moderate (10-20 mm/hour) to moderately rapid (20-40 mm/hour) infiltration rates; lowest rates coincided with sites having the least vegetation cover. Equivalent measurements on Ferralsols at Kiboko (Michieka and van der Pouw, 1977) indicated rather lower rates of infiltration with median figures in the order of 15 mm/hour on brown Ferralsols and only 10 mm/hour on red Ferralsols. Percolation rates in the subsurface horizons were however found

to be generally higher than those in the topsoils. Since rainfall intensities exceeding 10 mm/hour are not uncommon, it is hardly surprising that surface runoff occurs on ferralsols, especially in situations where the surface vegetation cover is sparse. Table 4 gives an indication of the water holding capacity of some ferralsols and luvisols; in general it is not high. Indeed, the average values for all the Acrisol/ferralsol intergrades is only 7.1% available moisture. This implies that, for a rooting depth of 100 cm, the available moisture is only 70 mm which is barely enough to cover the evaporative demand of a 100% grass cover for about 3 weeks. As the grass cover is generally less than 100%, the 70 mm storage may well be sufficient to sustain evapotranspiration for longer than 3 weeks. Moreover, it is thought that a substantial proportion of water held in the soil at tensions higher than pF 3.7 is available to plants, if only slowly. The figures for total available water holding capacity (pF 2.3-4.2) for rhodic ferralsols vary between 70 and 105 mm/m of soil, depending on clay content. Data quoted in Touber (1983) also show that soils developed on the Basement have significantly lower porosity and higher bulk density compared with those derived from volcanic and pyroclastic rocks.

The soils of the alluvial basins and swamps vary widely in character, from moderately well drained strongly calcareous brown clays (calcic chernozem), to imperfectly drained stratified calcareous alluvium with saline and alkaline subsoils (various types of fluvisol), to poorly drained strongly calcareous saline clays (solonchak), and periodically flooded dark greyish-brown, saline, alkaline and calcareous, seasonally cracking heavy clays (chromic vertisol). The sodic phases of these soils exhibit particularly low percolation rates. In general, the alluvial soils have a higher level of available moisture and a higher water content at pF 3.7 than, for example, soils derived from the Basement. Chromic vertisols predominate in the Lolturesh Valley west of the Chyulus; volcanic ash enrichment may have contributed to the formation of clays with vertic properties. Immediately adjoining the Lolturesh Valley (as at Iltital), mollic andosols are found with strongly calcareous and alkaline subsoils.

2.4 VEGETATION

As a consequence of the wide range of altitude (from 2 000 feet to a little over 7 000 feet) and the influence that this has on climate, the study area

embraces very diverse vegetation - from dry Acacia/Commiphora bushland characteristic of the drier sectors of the East African Ecoclimatic Zone (ECZ) V to extensive mist forest with canopies 50 m high near the summits of the Chyulus (ECZ II). On a broad scale therefore climate is seen to have the dominant influence in determining vegetation distribution. At a more local level, man's influence is paramount, in particular where charcoaling or settlement are leading to widespread bush clearance; elsewhere grazing pressure and seasonal burning are influential. Edaphic influences are also strong, especially as regards the development of particular types of woodland and thicket on lava flows, or grassland where soil drainage is impeded.

The regional zonation has recently been reassessed at a reconnaissance level and mapped at a scale of 1:250 000 (Touber, 1983; van Wijngaarden, 1984). Somewhat surprisingly, the vegetation was principally described in terms of the dominant perennial grass species, the effect of which is to play down the major role of tree and bush species in the vicinity of the Chyulus. Michieka and van der Pouw (1977) have produced a valuable map of the vegetation of Kiboko Range Research Station at 1:50 000. We have supplemented these maps by notes made while travelling around the area but, as in the case of the soils, we cannot claim to have carried out a comprehensive investigation. Should this prove important for the purposes of the Project, more detailed vegetation mapping could be undertaken at photo-scale through API; Map 3 (Kibwezi Forest, 1:20 000) is an example of just such detailed mapping of physiognomic vegetation types on a small area (5 850 ha).

The vegetation encountered seems to show that the Chyulu Hills have a more extensive orographic effect than that indicated on the maps of the previous reconnaissance survey. Thus the extent of the moist ECZ II is wider than that shown and, in the south of the Chyulus, not only invades the area mapped as 'Zone III' but even encroaches on 'Zone IV'. Our interpretation of the boundary between Zones II and III is indicated on Map 1. The boundaries between the other zones have not been mapped since they do not differ very significantly from those shown on the reconnaissance maps, except that a general widening of all the zones may be necessary. At the dry end of the vegetation spectrum however, we find little evidence of Zone VI anywhere in the study area (thus confirming the evidence of the rainfall

data discussed in Section 2.1) and prefer to redesignate the area previously mapped as Zone VI as a dry form of Zone V.

There follows an outline of the major ecological zones and vegetation types in the study area.

Zone V covers all the lower-lying drier parts of the area, including all lands between the Athi River and the Nairobi/Mombasa road (also a limited distance west of that road). It also extends around both the northern and southern footslopes of the Chyulus almost up to the 3 500 foot contour, while in the west incorporating the entire Lolturesh Valley up to an altitude of about 3 750 feet. The characteristic bushland of Zone V tends to be dominated by Acacia species - A. tortilis, A. senegal, A. mellifera, accompanied by shrub species of Combretum, Commiphora, Cordia and Grewia, together with Boscia coriacea, Bauhinia taitensis, Cadaba spp., Cassia abbreviata, Delonix elata, Melia volkensii and Sterculia rhynchocarpa. Adansonia digitata ('baobab') is important locally, while the dominant grass on the Basement is almost invariably Chloris roxburghiana. Locally, in wetter areas of Zone V on well drained ferralsol, there are extensive Commiphora woodlands and woodland thicket (as on Kiboko Range Research Station), with Acacia spp., Balanites aegyptiaca, Combretum aculeatum, Dalbergia melanoxylon, Dichrostachys cinerea, Grewia spp., Lanea triphylla and Maerua kirkii.

West of the Chyulus on the heavier soils, more open bushed grassland tends to occur, with Acacia tortilis, A. nilotica, A. mellifera and (on clays) A. drepanolobium with the grasses Chrysopogon plumulosus, Digitaria macroblephara and Sporobolus fimbriatus, forming excellent wet season grazing. On the heaviest alluvia of the Lolturesh Valley, Pennisetum mezianum and P. stramineum are characteristic with scattered Acacia tortilis and Balanites aegyptiaca. The swamps, as at Soitpus, are dominated by Cyperus papyrus, C. immensus and Typha angustifolia.

Zone IV is recognised by the appearance of Combretum molle but merges on its drier side with ECZ V and on its wetter with ECZ III; consequently it is the least easy zone to define. Definition is made harder by the woodland/bushland thicket on lava flows which includes elements more typical of moister regimes, presumably a consequence of deeper, more extensive rooting into the lava fissures and of very low surface evaporation losses due to

high infiltration. A theory ascribed to Greenway also has it that this more luxuriant bush survived on the lava owing to the disinclination of elephants for hurting their feet on the jagged basalt.

A study was made of the Zone IV bushland and woodland in the Kibwezi Forest (see Map 3 and Table 2 of Appendix 1). Woodland postulated to include phreatophytes has been mapped from the airphotographs; suspected phreatophytic components include Acacia clavigera, A. xanthophloea, Albizia sp., Cussonia holstii, Ficus spp. (including F. malatocarpa, F. rhynchocarpa, F. sycomorus), Haplocoelum foliolosum, Newtonia hildebrandtii, Olea africana and Terminalia brownii. Phreatophytic woodland is estimated to comprise 6% of the Kibwezi Forest, but the Cyperus swamp on the Umani stream will also transpire perennially. Components of the bushland and bushland thicket on lavas in Kibwezi also include Acacia ataxacantha, Combretum apiculatum, Commiphora baluensis, Croton dichogamus, C. scheffleri, Dichrostachys cinerea, Euclea divinorum, Euphorbia candelabrum, E. nyikae, Fagara chalybea, Lanea floccosa, Maerua kirkii, Rhus vulgaris, Trema orientalis and Triumfetta flavescens. Such thickets tend to be infested with tsetse. Grass cover is confined to sparse clumps of Digitaria milanjana, Enteropogon macrostachyus, Heteropogon contortus, Panicum coloratum or Sehima nervosum.

Away from lava flows, Zone IV is mostly represented by Acacia-Combretum bushland merging into Combretum woodland. Where groundwater is shallow there are stands of Hyphaene coriacea; poorly drained (and saline?) sites are marked by bushed grassland of Pennisetum mezianum with Acacia drepanolobium, A. seyal, Balanites aegyptiaca or Salvadora persica. In the east Chyulus, Zone IV extends roughly up to the 3 000 foot contour to the south of the Machakua River but, further north, it extends upslope to about 3 500 feet. West of the Chyulus, however, Zone IV barely exists except as a narrow transitional band in which ECZ V merges into III at around 3 600 feet.

Zone III, with its wooded and bushed grasslands on sloping ashes and cinders, is more distinctive. Typically, the associated fire sub-climax comprises scattered small trees or clumps of bush set in grassland subject to grazing and annual burning. The more common trees and bushes include Combretum molle, Croton scheffleri, Dodonaea viscosa, Dombeya rotundifolia, Euclea divinorum, Lanea elata, Maytenus senegalensis, Ozoroa reticulata,

Pavetta teitana, Rhus vulgaris, Trema orientalis and, confined to altitudes above 4 000 feet, Acacia hockii, Cussonia holstii and Erythrina abyssinica. Characteristic associates include Artemesia afra and Rumex sp., and the grasses Hyparrhenia, Hyperthelia, Themeda, with Setaria on damper sites and Eragrostis superba to the west of the Chyulus.

On the lava flows, thickets and woodland occur which are similar to those described earlier for the Kibwezi Forest (ECZ IV). On the northwestern side of the Chyulus, rocky lava flows in both Zones III and II can be dominated by the pencil cedar, Juniperus procera, with a distinctive associated bushland thicket including Diospyros scabra, Dodonaea viscosa, Euphorbia candelabrum, Garcinia livingstonei, Olea africana, Pistacia aethiopica, Pteridium aquilinum (around the fringes), Rhus vulgaris and Vitex doniana.

The presumed boundary between Zones III and II is shown on Map 1. Because of the complex of factors involved, it was concluded that there are no reliable indicators, the presence or absence of which could establish a clear zonal boundary. Bracken (Pteridium aquilinum) proved of value in this respect but, though growing taller and more luxuriantly in ECZ II proper, bracken patches are found in ECZ III (down to 4 800 feet) in shadier, concave sites and on deeper soils. Perhaps the most reliable indicators of Zone II will prove to be the absence of Acacia hockii and/or the presence of Podocarpus gracilior. In any event, the boundary roughly coincides with the 4 500 foot contour at the southern extremity of the Chyulu Range; elsewhere it exceeds 5 000 feet, increasing in elevation with distance north from the summit Chyulu 2 until, at the north end of the Range, the boundary broadly approximates to some 5 750 feet above sea level with a maximum elevation exceeding 6 000 feet upslope from the Oltiasika Maasai Mission on the west Chyulu.

Zone II vegetation along the higher-lying areas of the Chyulus effectively demonstrates two contrasting forms: grassland or clumped bush grassland on the one hand and closed forest on the other. The distribution of these two forms appears to be related neither to rainfall nor to soils; indeed, the forest boundaries are seen often to lie straight up and down slopes. Moreover, the forest edges are abrupt and show no transition. Since there seems to be no consistent correlation of forest with site, slope, topography or drainage, one is driven to the conclusion that the forest/grassland patterns are maintained by seasonal burning. Burning occurs every year near

the end of the long dry season (between August and October) throughout the predominantly Themeda/Hyparrhenia grasslands. Nevertheless, only locally was evidence noted of these hot fires entering and causing destruction within the high forest. This seems to be due to a fringing barrier of dense and mostly green herbaceous material (? sustained by leaf drip and shade), together with frequent Erythrina abyssinica trees which seem to be both highly resistant to fire themselves and also capable of promoting in their shade a fire-break of these tall herbaceous species (like Erlangea and Solanum campylacanthum) rather than grasses. Indeed, the Erythrina appears instrumental in nursing emergent saplings, as evidenced by the number of trees like Cussonia holstii growing through and ultimately overshadowing it. In this way, a probably tenuous balance seems to have been established between forest advance and retreat, but one that may easily be upset by climatic change, increased incidence of fire or grazing pressure. Since the RAF airphotography of 1967/69, there would appear to have been little change in the relative coverage of forest and grassland.

None of which goes to explain how the forest became established in the first place. Forest, the natural climax vegetation of ECZ II, seems able to thrive on the hillslopes only at the highest altitudes and then probably only with contributions from mist (negative evapotranspiration, leaf drip, etc). Pockets of forest are found below 5 000 feet, but these survive only in response to special microclimatic effects (e.g. shade cast by steep slopes in the interiors of volcanic cones) and the species composition is usually that of drier woodland types, e.g. Catha edulis and Olea africana. The profound influence of microclimatic effects (especially shade and aspect) is well illustrated along the forest road on the west side of the Chyulus between 5 000 and 6 000 feet, where long steep convex slopes are clothed only in grass with scattered bushes of Acacia hockii, Combretum molle and Ozoroa reticulata, typical of ECZ III, whereas the shadier concave re-entrants are often filled with dry forest of Catha, Cussonia holstii, Erythrina, Ficus capense, Olea and Prunus africana, more reminiscent of ECZ II. It seems that the forests managed to secure a foothold first on more favoured locations (shady upland valleys, cone interiors, deep cinder deposits on footslopes receiving lateral drainage) above 6 000 feet in the southerly section of the hills to the south of the principal summit (at 7 134 feet). From this nucleus, in an area favoured by the orographic effects discussed earlier, the forest was able to advance onto less favoured sites, in part through generating its own microclimate (increased ambient

humidity, deeper soil organic matter). Even so, it is significant that the steep east-facing slope immediately below the highest summit of all is still maintained in grassland.

Little significant difference could be found between forest distribution on westerly aspects as against easterly. While eastern slopes may benefit from a rather higher rainfall due to the direct orographic effect (but this has yet to be established), there does seem to be a possibly equivalent advantage on the western side of the Chyulus which are sustained by mist and low cloud during the more severe of the two dry seasons (i.e. between June and October) when winds blow from that general direction. Of course, during the January/March season, clouds blow onto the east side but the net beneficial effect must be much less since the soil moisture deficits at that time of year will be less. There should also be a differential diurnal effect, which may merit investigation, in that the cloud base is at its lowest in the early morning, the clouds steadily rising as temperatures rise during the day; this effect seems likely to favour east-facing slopes, which naturally receive less radiation in the afternoon, as compared with the westerly aspects.

So far as forest composition is concerned, little time was devoted to species determination. Bally (1938) was probably the first to point out that the Chyulu forest includes representatives of the floras of Kilimanjaro, the Taita Hills and of the Machakos highlands. The majority of the species determined were those more typical of the forest fringe, including Allophylus abyssinicus, Carissa edulis, Cassia didymobotrya, Catha edulis, Croton macrostachyus, Dombeya burgessiae, Erythrina abyssinica and Olea africana. Tree vegetation on the high altitude lava flows is often restricted to Cussonia holstii, Erythrina and Olea. The forest proper includes Albizia gummifera, Calodendrum capense, Ficus spp., Ilex mitis, Myrica salicifolia, Olea hochstetteri, Podocarpus gracilior, Prunus africana, Schefflera abyssinica and S. polysciadia.

2.5 WILDLIFE

The principal concentration of wildlife in the area lies within the boundaries of the Tsavo West National Park. Although reckoned to contain some 60 mammal, 400 bird and 1 000 plant species, the Tsavo Parks (West and

East together comprising Kenya's largest national park) cannot in fact boast especially high densities of wildlife; much higher concentrations occur around Amboseli and along the Tana River. Indeed the Tsavo Parks cover 3.6% of Kenya's land surface but include only about 4% of the larger mammals (Ecosystems, 1982a). Tsavo's claim to fame, apart from its scenic diversity, lies with its relatively high though currently declining populations of elephant and rhinoceros. The elephant is a major determinant of the dominant vegetation cover, in large numbers effecting a change from Acacia/Commiphora bushland to grassland, with commensurate changes in the balance of the associated wildlife and perhaps contributing to the current decline in rhino. Vegetational changes from bushland to grassland and back to bushland are probably cyclic in nature, as are fluctuations in the population of elephant. In the mid-19th Century, Krapf and Rebmann made little mention of elephants in the area and the numbers only appear to have built up in the mid-20th Century as a result of the gazetting of the Park and in response to ever-encroaching human settlement.

Certainly wildlife concentrations outside the Park boundaries have been seriously curtailed by expansion in human and livestock populations and resulting habitat destruction over the past two decades. This is especially the case along the eastern side of the Chyulu Hills where classic elephant and rhino country has been transformed by widespread charcoaling and settlement into country where the principal wildlife now comprises Kusu and European rats and a variety of snakes, especially mamba. A small herd of buffalo still exists in Kibwezi Forest. Along the Chyulu Hills themselves above an altitude of about 4 500 feet, kongoni and eland are common in grassy glades, with waterbuck and buffalo in the thickets and true forest.

Both within the Park and on the Kajiado side where the Maasai still largely co-exist with the wildlife, there are scattered zebra, impala, kongoni, waterbuck, oryx and giraffe, the latter apparently in larger numbers than for many years past. Klipspringer and mountain reedbuck frequent the rocky hills and lava flows. Among the carnivores, lion, leopard, cheetah, hyaena and jackal all occur sporadically.

2.6 WATER AVAILABILITY

Since a principal objective of the Project is to determine and quantify the groundwater resources of the study area, this section is treated briefly and, indeed, is only included for the sake of completeness since water resources do represent the greatest single limitation to development.

The Chyulu volcanics comprise a variety of rocks ranging from near-zero porosity (e.g. some hard basalts or trachytes) to rocks with porosities exceeding 50%, as in the ash and cinder deposits. Because of the marked tendency of the lavas to fracture and fissure, surface drainage is totally lacking on both cone belts and lava fields, with infiltrated water emerging at springs near the periphery of the lava. Much of this water is concentrated at the Mzima Springs some distance south of the Chyulus and at an altitude of only 2 140 feet. These springs currently constitute the main water supply to Mombasa as well as providing base flow for the Tsavo and Athi rivers. A second pipeline from Mzima has been recommended.

Other springs from the Chyulu Hills are currently used for irrigation, domestic supply, the railway, ranching, etc. A programme to develop three of these subsidiary springs has been designed by Carl Bro to distribute water by pipeline to settlers east of the Mombasa-Nairobi road between Kiboko and Mtito Andei. The capital cost of this project is estimated at KSh 216 million. West of the road the increasing numbers of settlers are dependent on the transport (by vehicle, donkey, bicycle or manual labour) of domestic water from springs and from a limited number of scattered wells on the Basement where quality is often poor. Appendix 2 shows some of the problems faced by recent settlers along the eastern flanks of the Chyulus, where water may retail at between 3 and 9 shillings for four gallons. The Kiboko Range Research Station in the north east is currently supplied both from the Makindu Springs and from boreholes sunk in the Basement; the former supply is polluted, while the latter are somewhat saline.

Indeed, most springs coming off the lavas are not only highly calcareous but also contain varying quantities of dissolved salts (see Table 5). Apart from Mzima, the best quality water derives from the Umani Springs which re-emerge as the Kibwezi River near the Forest Research Station. These springs provide the base flow which is supplemented by additional runoff during the rains. Large quantities of water drawn from a dam near Kibwezi

are used for sisal decortication on the Dwa Plantation; the polluted water is then recycled via settling tanks and used for the furrow irrigation of bananas and papaya. Further east, at Manoni Farm, cotton, okra and other crops are furrow-irrigated from two offtakes, one from the Kibwezi River and the other from the Manoni Springs. Finally, the Masongaleni Estate pumps from the Kibwezi River for the overhead sprinkler irrigation of vegetables for seed. A number of other small farms employ pump irrigation for vegetable production, principally from the Kambu and Kiboko rivers, both of which have perennial flow downstream of spring lines.

Although a much larger river, the Athi flows are severely seasonal and, in its present unregulated state, dry season flows are already essentially fully committed while, during the rains, substantial water goes to waste. The Athi also transports heavy sediment loads estimated at nearly 10 million tons/year. Plans for regulation upstream could lead to irrigation on 13 000 ha south of the Kibwezi River by the early 1990s, including local domestic supplies.

To the west of the Chyulus, there appears to be a total absence of springs fed by Chyulu groundwater and lack of water is a severe dry season constraint: hence the lack of a settled population and the movement patterns of the Maasai. The Lolturesh River, which is fed by springs in the foothills of Kilimanjaro, generally terminates through evaporation in the Soitpus Swamp. At Oltiasika Maasai Mission, water is obtained from the Lolturesh River by a complex system of seven hydrams pumping water 7 km to a main reservoir from whence water is to be pumped by diesel the remaining 8 km to the Mission; water is currently carried from the main reservoir by tractor for supply to the local people and their stock.

TABLE 5 Conductivity of local water supplies east of the Chyulus

Location	Electrical conductivity /u mhos/cm	Date sampled
Umani Springs	450	25.11.83
Mtito Andei River (west of Mtito Andei)	975	3.12.83
Machakua River (North of Kambu)	1 300	4.12.83
Kiboko River (Hunter's Lodge)	1 825	14.12.83
Kiumbi River (Makindu)	1 900	14.12.83
Mathaioni Borehole	4 250	11.12.83
Kambu River (Headwaters near Miamba Itano)	5 800	4.12.83

High potential for rainfed cropping	33	4	0	37
Lowest potential for rainfed cropping	503	685	185	1 373
Subject to settlements, high risk of rainfed crop failures	0	0	132	132
Recommended for pastoralism	1 181	17	27	1 225
Recommended for conservation	52	78	13	143
Reserved for charcoal and browse	381	723	185	1 289
Total area	2 150	1 487	1 728	5 365

* The full definitions and areas involved are given in Table 2 (in back map folder)

† Area 1 is part of the Mtito Andei area

‡ Area 2 is reserved for charcoal and browse on the Mtito Andei River

PART 3 LAND EVALUATION

3.1 LAND POTENTIAL

Map 2, at a scale of 1:125 000, provides a generalised view of land potential, based on an evaluation of the Kenya Soil Survey's agroclimatic and soil zonation. Such an evaluation, taken together with land tenure and current and projected population data, should provide some indications of land pressure, now and in the future. Table 6 shows the areas of land of broadly contrasting potential, west of the Chyulus, east of the Chyulus as far as the Nairobi/Mombasa road (Area 1), and between the road and the Athi River (Area 2).

TABLE 6 Land potential by location, km²

Map unit	Land development potential*	East Chyulu		Total
		West Chyulu	Area 1† Area 2**	
1	High potential for rainfed cropping	29	4 0	33
2	Lower potential for rainfed cropping	503	665 785	1 953
3	Subject to settlement: high risk of rainfed crop failure	0	0 732	732
4	Recommended for pastoralism	1 181	17 25	1 223
5	Recommended for conservation	62	78 0	140
6	Reserved for charcoal and browse	<u>381</u>	<u>723</u> <u>186</u>	<u>1 290</u>
Total area		2 156	1 487 1 728	5 371

* For full definitions and areas involved see Map 2 (in back map folder)

† Area 1 is west of the Nairobi/Mombasa road

** Area 2 is between the Nairobi/Mombasa road and the Athi River

The case for basing an evaluation of land potential on ecological or agroclimatic zonation is now well accepted in Kenya, though there is still room for discussion over the details. It is on this basis that we have suggested (Section 2.4) some modification to the extent of the zones mapped by Touber and van Wijngaarden. These modifications have been incorporated into our mapping of land potential.

Notwithstanding such refinements, it is generally accepted that ECZ II-IV have agricultural potential but that Zone V is either marginal or too dry for cropping. Braun, in his analysis of the reliability of the rainy seasons in Machakos and Kitui Districts (1977), has pointed out that with a ratio of average annual rainfall to average annual potential evaporation (r/E_0) of 0.37 (a level he defines as representing the uppermost figure for ECZ V) there is a 25% probability that the rainfall in both rainy seasons will be less than two thirds of E_0 (assumed to be the minimum requirement for a good yield from a crop like Katumani maize with a 90-day growing period). At the dry end of the range for ECZ V, with an r/E_0 of 0.22, there is an 80% probability that the rainfall in both seasons will be less than $2/3 E_0$. Cropping probabilities for selected stations in Zone V are set out in Table 7, based on crop failure when rainfall is less than $1/2 E_0$. In considering these data, it should be appreciated that no allowances have been made for inevitable losses due to surface runoff and/or deep percolation - the latter may be especially important in the study area because of the natural concentration of the rainfall at the start of the rainy season; Braun (1975) has estimated for East/Central Kenya that 50% of the 3-monthly rainfall occurs in the first 22 days. It is of some interest that, in Table 7, the station in Zone V quoted as enjoying least risk of total crop failure is that of Kamboyo, the headquarters of Tsavo West National Park!

TABLE 7 Annual probabilities of seasonal cropping*, % (after Braun, 1977)

Location	Two good crops	One good crop	No good crops	Total crop failure (both seasons)
Kamboyo, Tsavo Park	8	42	28	22
Kibwezi	8	43	26	23
Makindu	7	42	27	24
Masongaleni	6	39	28	27
Darajani	5	34	31	30
Kiboko	5	34	30	31
Kenani - (ECZ VI, southeast of Mtito Andei)	1	17	26	56

- *Assuming: (i) a crop with a growing period of 90 days
(ii) a good crop when rainfall exceeds $2/3$ of E_0
(iii) crop failure when rainfall is less than $1/2$ of E_0

In devising a classification for land potential in the study area, there would be everything to be said for regarding Zone V as unsuitable for cropping. This is hardly a tenable position however when significant tracts of Zone V east of the Chyulus have been under rainfed cropping for at least the past decade; there is every indication moreover that cropping will intensify in the next. Instead, those areas with deeper soils west of the Athi and mapped by van Wijngaarden as ECZ VI have been categorised as Land Potential 3, i.e. used for settlement but nevertheless having a high risk of crop failure unless irrigation is provided. In this latter respect, it is of significance that 13 000 ha, or 18% of this area, is eventually planned to be irrigated from the Athi (c.f. Map 2 with Text Map 2). Elsewhere in the drier parts of Zone V east of the Chyulus, shallow and/or rocky soils combined with the prevailing aridity renders the land unsuitable for development. In the wetter parts of Zone V the risk of crop failure is less, though still ever-present and, there, the deeper soils have been ascribed to Category 2 with potential for rainfed cropping. On the west side of the Chyulus, much of Zone V coincides with heavy, seasonally poorly

drained and often alkaline clays with poor infiltration and moisture availability characteristics; this has been designated Category 4 to be reserved for seasonal grazing, except on the lavas where the development prospects are even more limited. Occurrences of poorly drained clay and alluvia elsewhere in the study area have also been placed in Category 4.

Within Zones III and IV, the deeper Basement soils are designated as Category 2 for rainfed cropping while the limited area of deeper volcanic soils with their superior fertility and moisture holding capacity are regarded as having high potential for rainfed cropping (Category 1). Much of the remaining land area within these zones comprises shallow rocky lava flows, often on moderate or even steep slopes. Though designated Category 6, "unsuitable for agriculture", it was recognised in Section 2.3 that the lava sheets do include pockets of deeper soil which can be opened up for cropping; indeed, some of these are already successfully cropped not only with maize and beans but also with perennial crops, papaya and bananas. The moister and cooler the climate, the shallower the depth of soil needed to produce a crop. For purposes of population projections later in this report, it will be assumed that 10% of the Category 6 land to the east of the Chyulus will eventually be cropped to a standard equivalent to that of the Category 1 soils. The position west of the Chyulus will continue to be complicated by shortages of domestic water as discussed in Part 4. Nevertheless, even in the west within Zone III it is anticipated that cultivation could eventually extend to occupy some 5% of the land surface.

The potential of Zone II is perhaps most problematic and yet most crucial to the Project. No Government Department consulted made any claims on the Chyulu Hills themselves, while the Permanent Secretary of the Ministry of Lands and Settlement was adamant that the Chyulus should be preserved for forest conservation and as a water catchment area. A change of use (where the soils are sufficiently deep) to seasonal food crops, say potatoes, or to production forestry, need not necessarily affect the role of the Chyulus as a water catchment area - change to farm cropping might indeed reduce evapotranspiration losses overall since these would become seasonal rather than perennial as with the present forest and grassland. Nevertheless, having regard to the generally stony nature of the soils, the prevalent steep slopes, the attractiveness of the scenery, the easy accessibility of much of the Chyulus to Tsavo West National Park and the urgent need to preserve the fast-dwindling areas of native forest and wildlife, there seems on balance

little doubt that the entire area of the high Chyulu Hills should be conserved as it is; we so recommend. Precise boundaries to the proposed conservation area are considered in Part 6 but, for the purposes of Map 2, the area of the Chyulus proposed for conservation north of Tsavo West National Park is taken to coincide with the boundaries of Zone II.

3.2 LAND ALLOCATION

Consideration of land potential cannot be divorced from the actual divisions of land tenure, or from known Government plans for land allocation in the future. As is evident from Text Map 2, the situation differs radically between districts. Whereas the whole of Taita District within the study area is gazetted as Tsavo West National Park, Kajiado District is former Trust Land now largely adjudicated as group or individual ranches. Land tenure in Machakos District on the other hand is more complex because the progressive impact of population pressures emanating from the Machakos highlands is now being rapidly imposed on an earlier division of land between Government (former 'Crown Land') and alienated estates. The present position is as set out in Text Map 2 though there must be considerable doubt as to how long this will be maintained.

In the northwest, there is the Kiboko National Range Research Station and, sandwiched between it and Kajiado District, the Makululo Ranch, a Kamba group ranch which is only now getting under way. In the northeast, north of the Kibwezi River, the land has mostly been settled for at least two decades and is essentially divided between Government Land and Masaku Trust Land administered by the County Council. The 4 770 ha demarcated as belonging to the University of Nairobi was intended for integrated range research, experimentation into methods of dryland farming, and selection of appropriate crops and systems of cultivation, with a proportion of the area set aside for ecological studies on the part of Kenyatta University College. The precise status of this University farm is currently in doubt and it may well be absorbed into the general pattern elsewhere of intensified dryland farming by smallholders without official title.

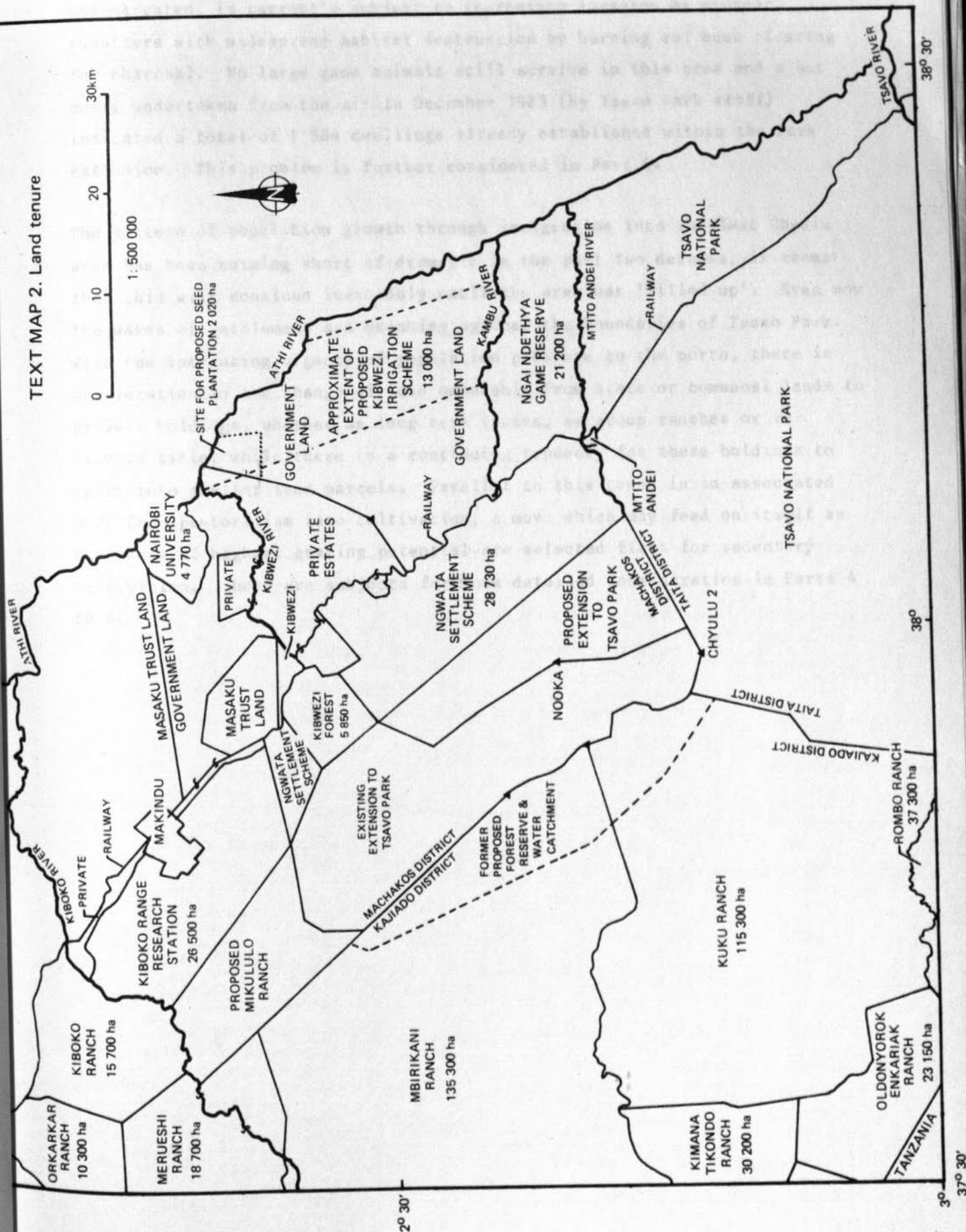
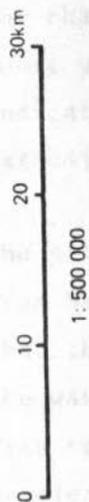
Along and to the south of the Kibwezi River, between Kibwezi town and the Athi, there are a succession of private holdings, mostly very small but with a few larger estates, the principal titles being the Dwa Sisal Plantation

(established in 1915), Manoni Farm and the Masongaleni Estate, all currently run by Sulmac Co. Ltd., a subsidiary of Brooke Bond. In the event of the Athi Basin Irrigation Project (Kibwezi Scheme) being implemented, it is apparent that part of the Masongaleni Estate and the neighbouring proposed seed plantation of some 2 000 ha would be taken over for development by the National Irrigation Board. Text Map 2 illustrates the possible conflicts of land use along the right bank of the Athi. Also near Kibwezi is the Kibwezi Forest Reserve of 5 850 ha, gazetted in 1936 as protection forest administered by the Forest Department.

By far the greater part of the East Chyulu area, i.e. all the land remaining south as far as the Taita District boundary (i.e. the Tsavo National Park), is Government Land subject to a greater or lesser extent to various forms of unofficial and semi-official settlement. The gross tenurial status shown in Text Map 2 may be compared with the map of current land use (Map 1), from which it may be concluded that it is now too late for Government to stem the tide of spontaneous settlement. Indeed the Ngwata Settlement Scheme areas (totalling 28 750 ha) have already been taken over by unplanned settlement and, belatedly, adjudication is now proceeding in the Kibwezi area, issuing title to land 'after the event'. Elsewhere, some "cluster village projects have been established with county council support, but without formal encouragement from the Ministry of Lands and Settlement. The Ministry now acknowledge that it is just not possible to displace the tens of thousands of unofficial settlers, both for political reasons and because displacement would merely transfer the problem elsewhere. Instead, existing farms will probably be legalised as they are; this will have the effect of legitimising the current maldistribution of land, with a few individuals holding much larger hectarages (up to 200 ha each) than the bulk of the population with a median range of holdings between 3 and 7 ha. Legalisation will probably also apply in the Ngai Ndethya National Reserve, located between the Kambu and Mtito Andei rivers and proclaimed in 1976 for the purpose of forming a buffer between the Tsavo West Park and encroaching cultivation, but now both extensively settled and cultivated.

Some explanation needs to be made of the status of possible extensions to Tsavo Park demarcated on Text Map 2. Because of extensive settlement and cultivation, the proposed extension east of Nooka is clearly untenable and should now be incorporated into the Ngwata settlement area. The existing extension west of Nooka and the Kibwezi Forest, gazetted in 1979 but as yet

TEXT MAP 2. Land tenure



30° 30' 38° 30' 37° 30' 38° 30'

undemarcated, is currently subject to increasing invasion by pioneer squatters with widespread habitat destruction by burning and bush clearing for charcoal. No large game animals still survive in this area and a hut count undertaken from the air in December 1983 (by Tsavo Park staff) indicated a total of 1 584 dwellings already established within the Park extension. This problem is further considered in Part 6.

The pattern of population growth through immigration into the East Chyulu area has been nothing short of dramatic in the past two decades; it seems that this will continue inexorably until the area has 'filled up'. Even now the waves of settlement are breaking against the boundaries of Tsavo Park. With the increasing urgency of population pressure to the north, there is acceleration in the change of land ownership from state or communal lands to private holdings, whether as long term leases, as group ranches or in private title, while there is a continuing tendency for these holdings to split into smaller land parcels. Parallel to this trend is an associated move from pastoralism into cultivation, a move which may feed on itself as the areas of highest grazing potential are selected first for sedentary cultivation. These are subjects for more detailed consideration in Parts 4 to 6.

By the 1930s it was estimated that Kajiado District contained 100 000 cattle, as numbers increased, so livestock became more valuable in drought, resulting in disastrous populations over the next 50 years from 1940 to 1990, reaching 1 750 000 cattle. Adding sheep and goats, the total livestock population probably reached 1.5 million animals in 1980 (much as 1950 and 1970), to be reduced to half that number within the space of a year or two when drought hit. Grazing pressures of this magnitude have tended to impoverish the grass cover and reduce also the population of wild ungulates. Undoubtedly the drive for increased livestock numbers has been spurred by increasing human population. By 1980 the Kajiado District totalled about 150 000. This equates with a fourfold increase over the recorded population of 1948. This exceptional increase (11% per annum) is sometimes attributed to

4.1 HISTORICAL PERSPECTIVE

Pastoral Maasai have been associated with the Chyulu area for several centuries. However, even before they were confined to their present district boundaries early this century, it is unlikely that the Maasai made much use of either the hill tops or the eastern flanks of the Chyulus for lack of water or the presence of tsetse flies. Nonetheless, confinement must have significantly changed the grazing patterns which formerly prevailed, since more people were restricted to a smaller area and the possibility was lost for far-ranging movement to the north and east. New seasonal patterns of movement were required, determined by the location of permanent and temporary water, the availability of grazing and the distribution of tsetse and other hazards. The first consideration always was the well-being and productivity of the livestock, on which the people were almost wholly dependent for subsistence, and the main management tools (other than animal care, accumulation and breeding) were movement and fire. In the process each Maasai section (former tribe of the Maa-speaking people) established its normal range, its internal organisation and its inter-section dependencies for times of need. The area of interest to the present study all falls within the normal range of the Ilkisongo Maasai, though Ilkaputiei section abuts the study area north of the Kiboko River.

By the 1930s it was estimated that Kajiado District contained 300 000 cattle. As numbers increased, so livestock became more vulnerable to drought, resulting in fluctuating populations over the next 50 years from lows of 250 000 to highs of 750 000 cattle. Adding sheep and goats, the total livestock population probably reached 1.5 million animals in peak years (such as 1960 and 1974), to be reduced to half that number within the space of a year or two when drought hit. Grazing pressures of this magnitude have tended to impoverish the grass cover and reduce also the population of wild ungulates. Undoubtedly the drive for increased livestock numbers has been spurred by increasing human population. By 1980 the Kajiado Maasai totalled about 150 000. This equates to only 7 head/km² but nonetheless represents a fourfold increase over the recorded population of 1948. This exceptional increase (13% per annum) is sometimes attributed to

immigration but perhaps it also reflects an under-estimate of population in 1948.

The period 1930-80 saw several government interventions in Kajiado, starting with roads, primary schools, rudimentary health services and veterinary and livestock marketing services, leading to water development and a variety of grazing control schemes. From 1954 to 1960 the whole of Ilkisongo section was encompassed within the Il Kisongo Grazing Scheme, which was supervised by a government livestock officer stationed at Loitokitok, working through grazing committees of Maasai elders. There were then around 120 000 cattle within the scheme area, which equated with a stocking rate of one beast to 11 acres, though carrying capacity was assessed at one beast to 20 acres (Kenya Board of Agriculture, 1962). Permanent water was provided by three off-takes from the Loitokitok-Sultan Hamud pipeline (which had been installed in 1955 to serve the Mombasa-Nairobi railway) and by a 6-mile furrow from the Lolturesh River to bypass the Soitpus Swamp at the foot of the Chyulu Hills. An additional 22 dams and tanks were installed in wet season grazing areas. The scheme ceased to operate in 1960 because of drought and heavy stock losses, and the general disinterest in government-controlled grazing schemes which prevailed around the time of Independence.

At the same time that grazing schemes were being introduced, wildlife management was also receiving attention. Tsavo West National Park (Part 6) had been established in 1948 but, subsequently, the West Chyulu Game Conservation Area and Amboseli Game Reserve were demarcated and the rest of the District was subdivided into eight hunting blocks (though two were reserved for photography only). The hunting blocks operated from 1958 to 1974, when they were further subdivided into 24 wildlife management units, to allow greater local participation and benefit. At the same time (1973) Amboseli was given the status of national park. The Ilkisongo Maasai were debarred from the new park and later (1976) were compensated by the provision of alternative water supplies (tanks) outside the park boundary.

In succession to the earlier grazing schemes, group ranches were introduced to Ilkisongo in 1980. The Land Adjudication and Land (Group Representatives) Acts had been promulgated in 1968, to allow traditional land rights to be adjudicated in favour of customary users who, in return for freehold title, were expected to adopt a legal corporate constitution

which allowed for the designation of elected group representatives who could act on behalf of the group. The idea, in pastoral areas, was that group ranches so constituted would encourage corporate responsibility for the land and provide a framework for development, including the application of loan funds to water development, without imposing all of the sophisticated requirements of company or cooperative law. Livestock, for example, could remain the property of individuals and did not automatically become the property of the group, as would happen with a cooperative. The first group ranches were established in Ilkaputiei section under the first phase of the national livestock development project, supported by the World Bank; those in Ilkisongo had to await a later phase of the project.

Other developments which have occurred in recent years, small in scale but noteworthy, include an increase in cropping in Kajiado, rising to about 20 000 ha in the 10-15 years post-Independence, and the establishment in 1968 of Kiboko Range Research Station on 26 500 ha of land in the north of the study area. The station actually lies in Machakos District but, since it is concerned principally with range management and improvement, it is considered here as an adjunct to Kajiado District. Within Kajiado itself, a pastoral training institute and 2 000 ha demonstration ranch were established in the mid 1970s at Oltiasika, directly below the Chyulu Hills. Oltiasika operates as a substation of the parent institute at Isenya (north of Kajiado town) and is funded by the National Christian Council of Kenya (NCCCK).

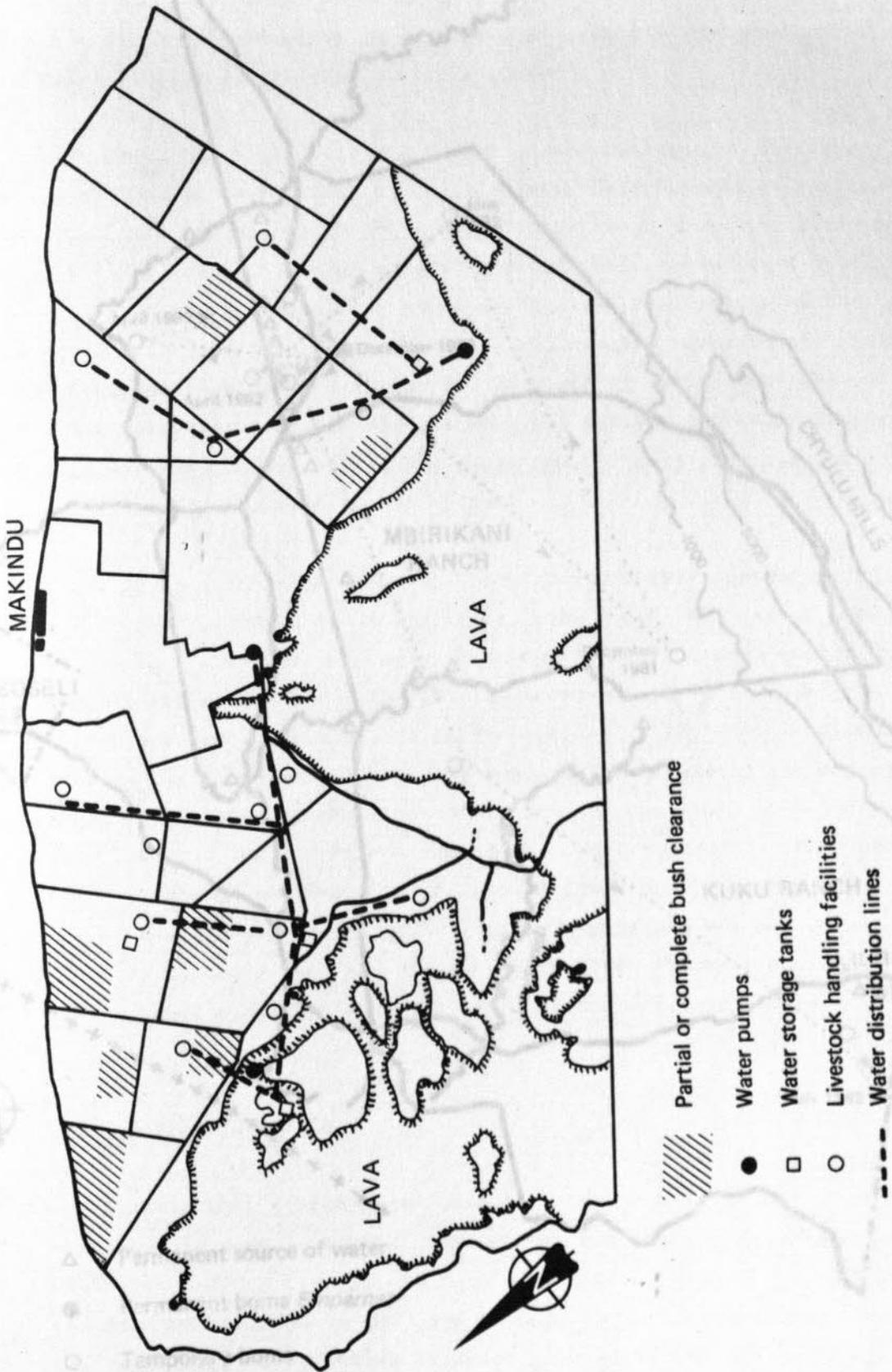
4.2 PRESENT LAND USE

Since 1980 the whole of that part of Kajiado District which lies within the study area has been divided between two group ranches, Mbirikani in the north and Kuku in the south. The boundaries extend to the district boundary along the top of the Chyulus and include the former West Chyulu Game Conservation Area. Oltiasika lies within Mbirikani Group Ranch. The boundaries and their relation to Kiboko Range Research Station are shown in Text Map 2. Text Maps 3 and 4 show, respectively, the basic infrastructure at Kiboko and the distribution of watering points on the group ranches. The latter map (from Peacock *et al.*, 1982) also shows the movements of a single household over 18 months in 1981/2, to illustrate the amplitude of movements that can occur and the fact that, as circumstances demand, people and

livestock still move freely outside the confines of individual group ranches.

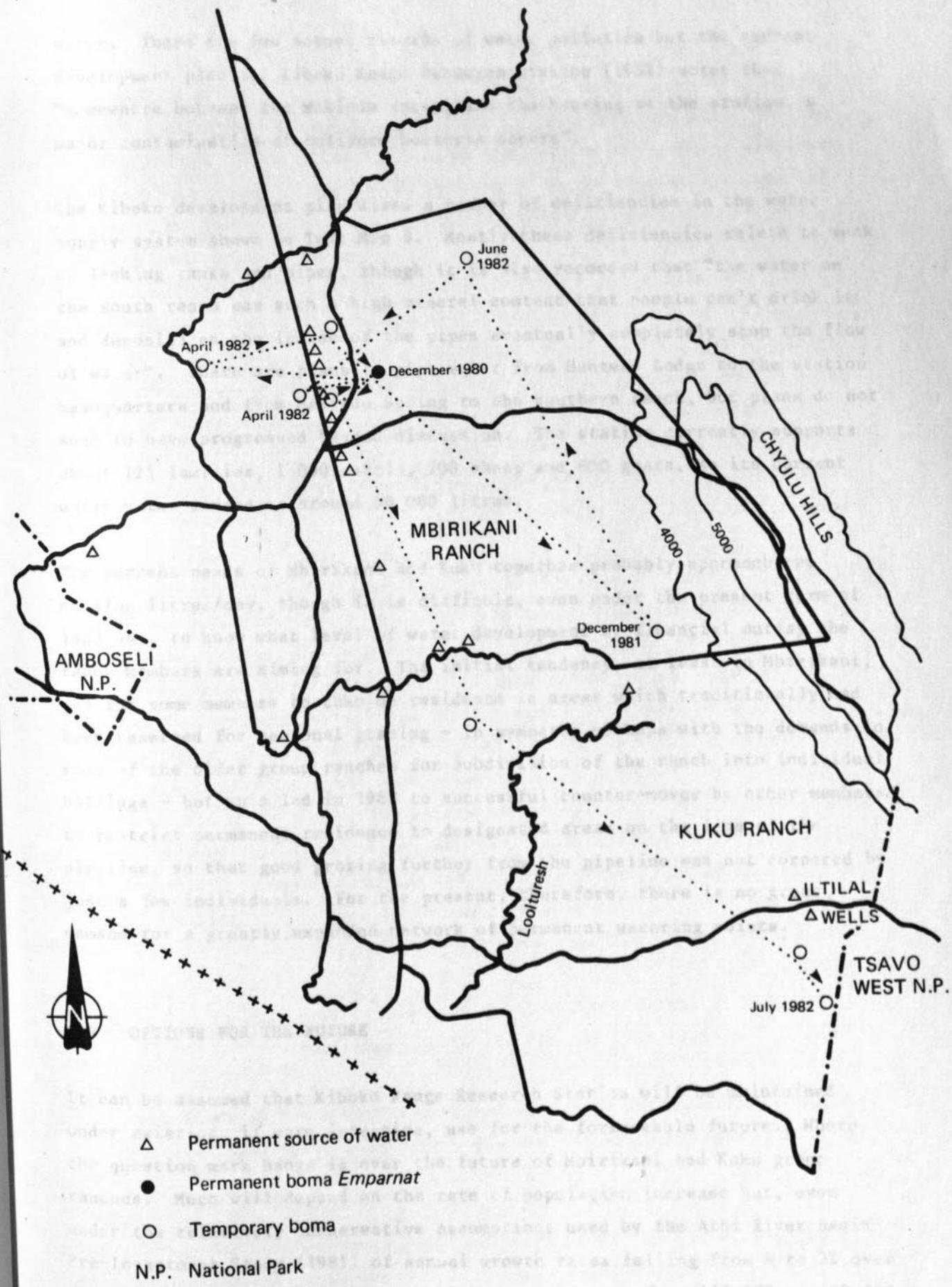
The movement of people and livestock outside their allotted group ranch is seen by some as evidence that group ranches are not working. The purpose of group ranches, however, is not so much to stop movement as to encourage proprietorship for the 'home range' and provide a framework for organising development inputs and offtake. So long as movement between group ranches is by treaty and not by poaching, it is no bad thing and can be compared with the practice of agistment in the western world. Where group ranches have tended to fail, or be failed, is in lack of advice and encouragement to the representatives and membership in coming to terms with their new responsibilities and opportunities; the tendency has been to regard group ranches as an end in themselves and not simply as an enabling mechanism. Another fault which has crept in since Ilkaputiei was planned and adjudicated is that the land adjudication process has proceeded in advance of preplanning and discussion with the people to help ensure that units of appropriate size, configuration and grouping were presented for adjudication.

In the case of Mbirikani and Kuku, both ranches are probably big enough (about 135 000 and 115 000 ha respectively) to be viable, but they are still relatively new and are still in a stage of transition between the old order and the new. Now, as before, the Chyulu Hills are used for wet season grazing, while most of the residential areas now lie on the line of the Loitokitok-Sultan Hamud pipeline. Both here and along natural water courses minor irrigation is increasing, so that some 40% of the members of Mbirikani ranch now own or have access to a cultivated plot, whether within or outside the study area (Peacock *et al.*, 1982). Neither ranch has yet taken a development loan. Their population averages about 4 persons/km² and their livestock total about 60 000 cattle and probably nearer 40 000 smallstock. The cattle number close to 25/km². Averages, however, give little idea of distribution. An aerial survey in June 1982 showed well over half the area to be empty, with local concentrations of over 300 (and up to 460) cattle/km². At night, of course, concentrations increase a thousand-fold because of the practice of corralling livestock in close proximity in thorn-fence enclosures. Where these enclosures are maintained for a long period of time, there is some danger of polluting groundwater or nearby surface water, as also is the case where animals habitually concentrate around



TEXT MAP 3. Block boundaries and water distribution system – Kiboko National Range Research Station. (adapted from Kiboko Range Research Expansion Project: 'A plan for action, 1980–1985', 1981)

TEXT MAP 4. Water distribution and stock movement patterns on Mdirikani and Kuku ranches (Fritz Paschke et al, 1982)



- Δ Permanent source of water
- Permanent boma *Emparnat*
- Temporary boma
- N.P. National Park

TEXT MAP 4. Water distribution and stock movement patterns on Mbirikani and Kuku ranches (after Peacock et al, 1982)

water. There are few actual records of water pollution but the current development plan for Kiboko Range Research Station (1981) notes that "somewhere between the Makindu spring and the housing at the station, a major contamination of coliform bacteria occurs".

The Kiboko development plan lists a number of deficiencies in the water supply system shown in Text Map 3. Mostly these deficiencies relate to weak or leaking tanks and pipes, though it is also recorded that "the water on the south ranch has such a high mineral content that people can't drink it and deposits on the inside of the pipes eventually completely stop the flow of water". There are plans to pipe water from Hunters Lodge to the station headquarters and from Makindu Spring to the southern ranch, but plans do not seem to have progressed beyond discussion. The station currently supports about 125 families, 1 000 cattle, 700 sheep and 600 goats, so its current daily water demand is around 50 000 litres.

The current needs of Mbirikani and Kuku together probably approach two million litres/day, though it is difficult, even under the present form of land use, to know what level of water development or financial outlay the ranch members are aiming for. The initial tendency, at least in Mbirikani, was for some members to take up residence in areas which traditionally had been reserved for seasonal grazing - in sympathy perhaps with the demands in some of the older group ranches for subdivision of the ranch into individual holdings - but this led in 1982 to successful counter-moves by other members to restrict permanent residence to designated areas on the line of the pipeline, so that good grazing further from the pipeline was not cornered by just a few individuals. For the present, therefore, there is no great demand for a greatly expanded network of permanent watering points.

4.3 OPTIONS FOR THE FUTURE

It can be assumed that Kiboko Range Research Station will be maintained under existing, if more intensive, use for the foreseeable future. Where the question mark hangs is over the future of Mbirikani and Kuku group ranches. Much will depend on the rate of population increase but, even under the relatively conservative assumptions used by the Athi River Basin Pre-Investment Study (1981) of annual growth rates falling from 4 to 3% over the next 25 years, the Kajiado population would rise from 150 000 to 400 000

by the year 2010. Since some would argue that already the population exceeds the human support capacity of the District, it can safely be assumed that Mbirikani and Kuku will be under pressure to intensify the use of available resources. At the same time, opportunities for radical change are limited. Undoubtedly the area under cultivation will increase further but, with known technology, dryland cropping is impossible in the drier areas of Mbirikani and Kuku, and prospects for obtaining water sufficient for a substantial increase in irrigated cropping are equally remote; much of the land in the Lolturesh Valley is in any case alkaline clay and consequently unsuitable for irrigation. Climatically it would be possible to cultivate parts of the Chyulu Hills themselves, but there could be no resident population on the hills unless they were provided with or paid for an expensive pumped and piped water supply from the Soitpus Swamps or further afield, or unless the population were limited to that which could be supported by rainfall catchment and storage.

As for those areas which remain under rangeland use, the only possibility for significant intensification lies with inputs that increase the livestock carrying capacity of the range. Change in the status of the group ranches or in the ownership of group lands - from group to cooperative or from group to individual - offers no prospect in itself for increasing the human support capacity of the land. Indeed, a change from group to individual ownership, though expensive in infrastructure and over-demanding on water resources, is more likely to decrease than increase productivity and human welfare since, at any one time, only few people would have access to the best grazing (when it probably would not be "best" anyway, having already been grazed off at a season when it was below par!). A significant degree of intensification could only come from:

- fertilisation and/or overseeding with a competitive pasture legume in order to increase the productivity of the rangeland
- removing unproductive woody species, where they occur in abundance, in order to reduce competition and allow more productive species to take their place
- planting up sites of higher potential (e.g. depressions with fertile soils in receipt of surface water run-on) with crops and/or high yielding fodder or browse plants for drought or dry season use

- providing at least some of the animals with supplementary feed when range grazing is inadequate and when further grazing would damage the rangeland
- selection within existing stock, including greater use of prolific smallstock, to produce animals that are higher yielding even given current systems of feeding and management.

Although most of these improvements are technically possible (the only one in doubt being "a competitive pasture legume" for overseeding), most are also uneconomic under present circumstances. Time and research and changing price ratios may however change this situation.

It is problematic to predict how soon and with what effect range and livestock improvements will be introduced. As a rule of thumb, however, it would not be unreasonable to expect a package of appropriate improvements to allow livestock numbers to increase by 50% and human population to double by 2010, while remaining within the carrying capacity of the land. The implications of this and other assumptions on land use and water requirements are considered further in Part 7.

District, ... provided by ... Even so, ... resources ... 1942 and 1979 ... century ... in ... with a ... from the ... by the ... following ... (based on ... 1942 and ... from 1948):

1942	...
1945	...
1948	...
1951	...
1954	...
1957	...
1960	...
1963	...
1966	...
1969	...
1972	...
1975	...
1978	...
1981	...
1984	...
1987	...
1990	...

5.1 HISTORICAL PERSPECTIVE

The earliest historical evidence for settlement in the Chyulus is a complex of possibly Early Iron Age burial mounds, hut sites, and trackways formed on the steep slopes of loose volcanic ash by the regular passage of cattle. Pottery found, mostly water pots, reflects the lack of surface water. The Akamba are believed to have arrived in the Machakos highlands from the south via the Chyulu Hills area some time in the 15th or 16th century. The population initially centred on the Mbooni Hills which provided permanent surface water and defence from the Maasai. With population increase, the people were forced to disperse, despite the Maasai threat, though they tended to keep to the moister hilltops while the low country of Ukambani remained sparsely populated. In particular, the bush areas of Kikumbulyu proved relatively unattractive owing to thicket and the related presence of tsetse fly, lack of surface water and the erratic distribution of rainfall which was the cause of periodic droughts of great severity. Nevertheless, population pressure and the desire of the Akamba for individual land ownership did gradually force people into the southern parts of the District, a movement which was encouraged from 1915 onwards by employment provided by the Dwa Sisal Plantation and subsequently by other estates. Even so, famine in the 1920's coinciding with "deterioration in water resources" (Owako, 1971) led to the total depopulation of Kikumbulyu between 1932 and 1936 (this period included 1934, probably the driest year of the century to-date). Despite these vicissitudes, the rate of population growth in Machakos District tended to accelerate, with a ten-fold increase from the turn of the century to the present day, as shown by the following estimates (based on numbers of taxpayers prior to 1948 and on census data from 1948):

1902	102 000
1918	125 200
1932	283 910
1948	356 245
1962	548 862
1969	707 214
1979	1 022 522

The rapid growth of recent years (annual population growth rates just exceeding 4%) led to the dispersal of population to the more marginal areas, including Kikumbulyu. This is illustrated by data for the wider Ecosystems study area (Ecosystems, 1982a) which show that, whereas in 1948 11% of the land area supported people at a density exceeding 30/km², by 1979 some 26% of the land supported that level of population density; in the same period, areas supporting fewer than 5/km² had fallen from 80% to 43% (c.f. Table 8).

TABLE 8 Percentage of population at different categories of population density, within 20 km of Tsavo Parks, 1948-79 (after Ecosystems, 1982a)

Year	High >50/km ²	Medium 30-50/km ²	Low 5-30/km ²	Very low <5/km ²
1948	0	3	6	91
1962	1	4	22	73
1979	5	9	36	50

The Athi - Chyulu Settlement Area, bounded by the Athi River, Tsavo Park and the Chyulu Hills, was created in 1956 under the Crown Lands Ordinance with the aim of relieving Machakos District of surplus population and livestock. Although development was slow at first, owing to the natural constraints of the area, a succession of wetter than average years following 1961, coinciding with Independence and completion of the surfacing of the Nairobi/Mombasa road, seems to have given impetus to settlement in what was to become the Ngwata Settlement Scheme. The pressures from immigration have continued to the present day.

5.2 PRESENT LAND USE

The study area east of the Chyulus falls within the Kibwezi (formerly Makindu) Division of Machakos District. This has a total area of some 3 479 km² with a population at the 1979 census of about 95 600, excluding the urban townships of Mtito Andei and Kibwezi itself. The overall rural

population density is 27/km², the lowest by far in Machakos District, but with 3.9 people per cropped hectare. Basic data by sub-location relating to populations, livestock and cropped areas are summarised in Table 9; these were derived from the 1979 Census (Central Bureau of Statistics, 1981) and from sample surveys undertaken in February 1981 by Ecosystems Ltd on behalf of the Machakos Integrated Development Programme, using a combination of visual observations and vertical photography from low-flying light aircraft (Ecosystems, 1982b). The northwest of the area, comprising the Kisingo and Manyatta sub-locations, are principally occupied by the Kiboko Range Research Station and by the Mikululo Kamba group ranch, already discussed, respectively, in Sections 4.2 and 3.2. This Section is principally concerned with the more extensive areas of cropping between the east Chyulu Hills and the Athi River shown on Map 1 (hectarages of the major land use categories are given in Appendix 1).

Although the active cropland over the Division as a whole is still only 7% of the entire land area, scope for cultivation expansion is limited by the extensive rocky lava flows. The range of farm size is not recorded but a majority of holdings seem to be between 3 and 10 ha; in the moister zones, farms often lack set boundaries. Holdings below 1.5 ha, unless irrigated, are not currently regarded as viable. Because some holdings are very much larger than the median, extending up to 200 ha, the average farm size is estimated at about 12 ha.

The prevailing pattern of land use is one of groups of cropped fields surrounded by patches of bushland; these latter are preserved for grazing and browse, especially at times when the cultivated land is under crop. Estimated livestock numbers are set out in Table 9 by sub-location. Traditional practice allows farm stock to roam widely so long as they do not trespass on neighbours' crops. Because of the fundamental importance of livestock as a capital reserve in the event of crop failure, when stock can either be slaughtered or sold to buy in grain, it is most unlikely that cultivation will ever become continuous. Moreover, the present pattern of holdings is already established over much of the area based on rights of usufruct and there is therefore only limited scope for cultivation expansion in the present settled areas. In the Zone III bush grassland, extensive burning is practised in August to promote additional grazing. Near the lava flows with associated bushland thickets, stock are rarely seen, however, because of the prevalence of tsetse fly.

TABLE 9 Summary of rural population and land use by sub-location in Kibwezi (Makindu) Division (Kenya Population Census, 1979; Ecosystems, 1982b)

Administrative Unit and location	Population		Livestock		Land categories, ha					Crops, ha						
	Total	Density/km ²	Number of dwellings	Cattle	Shoats*	Total area	Cropped	Irrigated	Fallow		Forest†	Maize**	Beans**	Pigeon pea**	Cotton	Sisal
									Recent	Old						
Sub-locations																
Kisingo	9 311	16	5 029	11 445	12 533	58 321	3 377	234	148	397	0	1 387	2 557	0	41	0
Ngulu	5 165	20	2 735	4 351	2 021	25 526	2 318	0	332	339	0	2 245	1 001	0	0	0
Manyatta	3 951	25	1 098	1 728	1 333	15 580	492	55	24	0	0	422	290	66	0	0
Kai	5 541	13	3 303	4 015	2 727	43 102	1 127	0	373	1 161	12 213	1 105	80	424	21	0
Syumile	2 502	56	876	147	113	4 507	231	0	17	80	0	219	155	0	0	17
Ndetani	1 330	40	697	206	198	3 304	362	0	231	137	0	342	328	33	0	7
Kathyaka	2 161	24	1 057	273	455	8 900	588	0	104	92	0	564	89	0	0	0
Mbuinzau	925	56	551	304	295	1 663	329	0	51	0	0	329	0	0	0	0
Kalungu	1 006	91	310	39	0	1 100	43	0	64	36	0	43	0	0	0	709
Ngandani	4 522	78	1 049	203	353	5 790	1 377	64	70	122	0	535	121	0	0	0
Mukuyuni	2 198	46	916	459	290	4 809	823	0	80	130	499	216	15	0	0	606
TOTAL:†† Kikumbulyu Location	38 612	22	17 617	23 098	20 192	172 602	11 139	353	1 501	2 513	12 712	7 424	4 696	523	62	1 339
Sub-locations																
Thange	13 606	36	4 118	1 907	886	38 107	3 428	14	203	57	2 667	1 622	391	549	79	1 523
Muchingini	12 681	41	5 336	3 574	1 165	30 809	2 927	0	301	237	6 891	2 830	80	1 663	26	0
Mukange	7 705	19	4 404	1 472	1 178	40 956	2 495	0	163	514	0	2 214	861	517	0	0
Kambu	7 610	54	1 438	1 078	1 263	14 141	1 340	0	183	302	0	1 340	101	65	0	0
Mangelete	15 375	30	7 305	5 786	2 082	51 248	3 261	0	162	437	4 591	3 064	294	2 079	0	0
TOTAL:†† Ngwata Location	56 977	33	22 674	13 885	6 574	175 261	13 485	14	1 019	1 565	14 397	11 115	1 714	4 920	105	1 523
GRAND TOTAL:†† Kibwezi Division	95 589	27	40 303	36 966	26 744	347 863	24 630	367	2 520	4 058	27 364	18 547	6 406	5 460	167	2 862

* 'Shoats' represent the total number of sheep and goats

† 'Forest' is as defined by Ecosystems and may include areas of woodland and bushland

** Maize, beans and pigeon pea are often intercropped; hence total area in these crops may exceed figure for total cropped area

†† (i) Totals based on mean density data/km² and not on column totals

(ii) Totals exclude Tsavo Park and also the townships of Mito Andei and Kibwezi.

Maize is the principal crop throughout the area and the preferred food. About half the maize is intercropped, either with beans or pigeon pea - the other major crops of east Chyulu. An estimated 98% of pigeon peas and about two thirds of the beans are intercropped with maize. Maize/legume intercrops are attempted in both wet seasons, though the November rains are regarded as being more reliable than the April rains. Pigeon pea is generally planted in October/November with a view to harvest the following August. Maize/ cotton intercrops are also seen, the cotton being planted in November for harvest during June and July, ginning taking place at Makueni. Fields growing pigeon pea and cotton are therefore only cultivated once a year, prior to the 'short' rains. Intercrops may be planted in alternate rows with the maize, or two rows of intercrop alternate with a single row of maize. Both Katumani maize and a local (90-day) variety are grown, the latter outyielding Katumani in a trial east of the Chyulus.

No particular crop rotations are practised, maize and beans generally following maize and beans. Drought-resistant crops more appropriate to Zone V are not well favoured and there are only very minor hectarages of such crops as sorghum, cowpeas, cassava, millet or green gram. This is essentially because maize remains the preferred food and, moreover, gives higher yields when the rains are adequate, despite serious failures at other times. Indeed, away from the Chyulus, failure in the April rains is the rule rather than the exception, the customary 6 weeks of rain being inadequate to produce any but the most meagre crop. The reliability of cropping can however be improved somewhat by growing a quick-maturing maize combined with low plant populations (Dowker, 1963). Nevertheless, although the net product from maize over the years, expressed in terms of yield or value, may be greater overall than that from more drought-resistant crops, the disruption caused by widespread food crop failure in the drier years can be considerable. Land 'carrying capacity' is therefore rather an abstract concept unless it can take account of recurrent crop failure.

By contrast, in Zone III and especially above about 4 250 feet, given some depth of soil, climatic conditions are sufficiently favourable to allow regular double cropping of maize and beans, the cultivation of perennial bananas and papaya, and even the local production of potatoes and cabbage.

So far as crop investment overall is concerned, the general neglect of crop inputs is not irrationally related to the risk factor involved in produc-

tion. Furthermore, the 'substandard' levels of crop care on smallholdings are in part related to the high labour demand if the crops are cultivated manually as is still usual practice. Ploughing with oxen is frequently seen, however, and even tractor cultivation (often on hire) is occasionally undertaken, particularly for cotton. While oxen may also be used for weeding, hand hoeing is still normal practice. A remarkably wide range of yields results - from nothing at all to yields that would look respectable under the best growing conditions. Table 10 attempts to set out, for the general run of crops, the range of yields that might be anticipated under all but the most extreme conditions.

Supplementary irrigation of several crops occurs locally from the Athi but more particularly from its tributaries, the Kiboko, Kibwezi and Kambu, wherever the base flow is sustained from springs. In recent years several farms in the area have taken to small-scale hose-basin and furrow irrigation of vegetables, principally Asiatic and with a high demand for labour. Such vegetables are in increasing demand on the London market; marketing is organised by a local group, the Makindu Growers and Packers Ltd. Principal crops for air freighting overseas include kerala (the bitter gourd) grown on climbing frames, okra, aubergines, dudhi, melons, hot chilli, guar, and capsicum; onions, tomato, peas, cowpeas, cabbage and spinach are also produced for local consumption. Investment on these farms, including pumps and piping, fertiliser, chemicals and labour, can be considerable and the degree of entrepreneurship is impressive.

In addition to these smallholdings, a chain of larger estates, Dwa, Manoni, Chai and Masongaleni, use the waters of the Kibwezi for a range of cropping. At Dwa, the largest and longest established upstream plantation, some 3 200 ha of sisal are grown rainfed, with water pumped from a dam on the Kibwezi principally for use in the decortication process but also to help establish the sisal nurseries. Chai also produces sisal, while Manoni (73 ha) has moved out of sugarcane and into cotton and okra, with subsidiary production of hot chilli, courgettes and sunflower. Masongaleni, 84 crop-hectares and last in the line, specialises in the production of vegetable and flower seed, mostly for export, using overhead sprinkler irrigation. A principal concern of these enterprises is that, the more water that is piped from the Umani Springs for the Kikumbulyu Water Supply Scheme, the less will be left to sustain irrigation downstream.

TABLE 10 Estimated yield ranges of the more common crops grown on smallholdings in Kibwezi Division under rainfed and irrigated conditions, t/ha

Crop	Rainfed	Irrigated
Maize: ECZ III	0.7 - 1.6	-
IV	0.5 - 1.2	-
V	0.2 - 0.9	2.5 - 4.0
	(average 0.5)	
Beans: ECZ III/IV	0.3 - 1.0	-
V	0.2 - 0.7	1.1 - 2.0
	(average 0.4)	
Pigeon pea: ECZ IV	0.4 - 0.8	-
V	0.3 - 0.6	-
	(average 0.4)	
Cowpea	0.3 - 0.8	-
	(average 0.4)	
Sorghum	0.3 - 0.9	-
	(average 0.5)	
Cassava	3 - 10	-
	(average 5)	
Cotton	0.2 - 0.8	1.5 - 3.5
	(average 0.4)	

Despite the obvious profitability of several of these more exotic enterprises, it should be emphasised that the mainstream farm activity in the eastern Chyulus must inevitably remain the production of subsistence food crops under arduous rainfed conditions.

5.3 OPTIONS FOR THE FUTURE

Intense population pressure is building up throughout the area as a consequence of burgeoning population growth in the Machakos highlands and elsewhere (see Table 11). Given limited resources and the relative aridity of the climate, with a continuing influx of population it would seem that the east Chyulus have few options for development other than to face a continuing expansion and intensification of charcoaling and agricultural settlement, there being few other sources of employment.

As was spelt out in Section 4.3, it can be assumed that Kiboko Range Research Station, and probably also the new Mikululo Ranch, will be maintained under existing use for the foreseeable future. It is also to be hoped that the unusual Kibwezi Forest can continue to be protected; the soils there are mostly unsuitable for agriculture and the whole provides valuable amenity, not only for the people of Kibwezi but also for visitors from farther afield. As against this, no case can be made for a further extension to Tsavo Park east of Nooka (Text Map 2); there would be little purpose in it, such is the size of the indigenous population and the extent of farming. There is rather more doubt regarding the status of the existing Park extension to the west of Nooka, also because of the degree to which it is already subject to settlement and charcoal extraction. This is considered further in Part 6. Again, the extent of farming within the Ngai Ndethya National Reserve to the north of the Mtito Andei River is evidence that this area too is a 'Reserve' in name only and that it might as well revert to the status of Government Land available for further settlement.

TABLE 11 District population projections to the year 2010 (after Ecosystems, 1982a)

District	Population 1979 census	Density/km ² 1979	Projected population, 2010	Density/km ² 2010
Machakos	1 022 500	75	2 758 000	201
Kitui	471 000	19	1 250 000	50
Kajiado	149 000	7	402 000	19
Totals	1 642 500	27	4 410 000	73

Intensification of smallholder mixed farming was the subject of a proposal by the Athi Basin Pre-Investment Study (1981) under the title "A Whole Farm Improvement Programme for the Makindu Division". This envisaged technical assistance to smallholders and supporting agricultural institutions, with emphasis on soil water conservation, animal draught, equipment for manure spreading, storage of cereals and pulses, improved plant material, training for extension agents, etc. In our opinion, first attention should be given to moisture conservation in the production of key food crops, using non-capital inputs, sowing at the proper time, using the recommended spacing (whether as intercrop or pure stand) and controlling weeds effectively. In this latter regard, it was observed that smallholdings appear to suffer from shortage of labour at critical times; hence, considerable improvement could be generated through the more widespread adoption of ox cultivation. Such improvements ought to be supported by the Machakos Integrated Development Programme which was set up to encourage the development of semi-arid regions but which has, as yet, made little impact in Kibwezi, other than funding establishment of the Forest Research Station.

Another means for improvement is through adoption of a greater diversity of cropping, including crops better suited to the environment. Rainfed cropping could include cassava for industrial starch, and sesame for edible oil with cake as a by-product for stock feed. Given supplementary

irrigation, dwarf castor, groundnuts, sunflower, cotton and grapes could also be considered. Of some interest for the future are the trials in Kibwezi Forest concerned with comparing the utility of various Euphorbia species and other succulents for gasohol production. A question mark hangs over the future of sisal production, given continuing low prices and competition from synthetics. This must give greater urgency to the establishment of alternative crop processing and employment-generating concerns. Given a major increase in cotton hectareage, a local gin could be built though the present area of cotton (about 170 ha) hardly justifies this. Another approach would be to build on existing success, vegetable production under irrigation, with construction near Kibwezi of a vegetable packing station; expansion of vegetable seed production for both domestic use and export; and investment appraisal for a fruit and vegetable canning plant.

Only irrigation can sustain a high population density in arid areas. Although there is scope for the development of smallholder irrigation by pumping at suitable sites, any expansion of irrigation is constrained by high capital costs, by lack of local credit facilities, and by seasonal shortages of water, more particularly on the tributaries to the Athi. Despite the capital cost involved and the somewhat shakey economics of development, some hopes must attach to implementation of proposals for regulation of the Athi River by means of a 625 MCM (gross storage) rock/earthfill dam to be sited far upstream near Munyu, where there is a suitable reservoir site and the sediment load is manageable. Given an early decision to move forward to the final feasibility study, dam construction could start in the late 1980s with a view to implementation after 1990. The principal interest in the study area is the potential irrigation of 13 000 ha along the right bank of the Athi within the area sketched on Text Map 2. Other objectives of this scheme (total capital cost KSh 2.3 billion at 1980 prices) can be summarised as:-

- i. release of dry season flows as far as the major offtake at Baricho,
- ii. provision of rural water supplies to villages en route including, possibly, villages in the study area,
- iii. supply into Kitui District via the Tiva,
- iv. generation of 30-40 MW hydropower, and
- v. possible supplementary domestic supply for Nairobi.

Currently, irrigation is envisaged as developing in the Kibwezi area in the early 1990s at a rate of 1 500 ha per year. The overall projected IRR is 12.6% for a capital investment on irrigation and irrigation-related facilities of some \$5 700/ha. A later stage might conceivably envisage extension of irrigation, firstly to 20 000 ha through the adoption of more efficient methods of irrigation and, eventually, to 27 000 ha "or more" based on a second-stage storage structure in the middle reaches of the Athi. The aim would be to develop intensive production systems based on 1.4 ha smallholdings, of which 1.2 ha would be irrigated, growing food crops up to the subsistence needs of the smallholder and devoting the remaining area to cash crops (Athi Basin Study, 1981). On such a basis, a net irrigated area of 13 000 ha could provide opportunities for the development of some 9 250 smallholdings capable of supporting up to 55 000 people, perhaps with a strong minority drawn from local farmers. Even at the probable ultimate of 27 000 ha, this scheme could only support a maximum of 115 000 people, a fraction of the expected "surplus" in the year 2010.

Of particular interest to the Chyulu Hills Project are the possible long-term effects of bush clearing and increased cultivation on groundwater recharge. So far as potential effects on surface runoff are concerned, the impact of cultivation on the stable volcanic soils is expected to be minimal. On the Basement materials, however, there will certainly be some increased losses due to runoff, though the slopes, surface soil textures and infiltration rates are such (Section 2.3) that these losses will only be modest; moreover, the location of the Basement outcrops some distance away from the Chyulu Range diminishes the relative importance of these materials as a groundwater catchment. So far as transpiration losses are concerned, it can be argued that replacement of a perennially transpiring deeper-rooting bush or woodland cover by short duration shallow-rooting annual crops, like maize and beans, should lead to an overall reduction in transpiration and substantially greater groundwater recharge. Certainly this was the result obtained, on not dissimilar cultivated soils with overlays of volcanic ash, in the long-term East African Agricultural and Forestry Research Organisation experimental catchment at Mbeya (Tanzania).

PART 6 CONSERVATION IN TSAVO WEST AND THE CHYULU HILLS

6.1 HISTORICAL PERSPECTIVE

Ecosystems (1982a) recently undertook a regional land use study of the Tsavo National Parks, which gives a comprehensive view of the situation in and around the Tsavo West Park. Four tribal groups have long used the land that now constitutes 'Tsavo' - the Kamba, Maasai, Orma and Watta; their spheres of influence have fluctuated down the centuries but their respective ranges were crucially affected by the rinderpest epidemics of the 1890s. Because the area now known as Tsavo Park was only lightly settled at the time, the Kenya Land Commission of 1933 designated the greater part of the area as Crown Land, while recognising pastoral rights of occupation on the part of the Akamba and also the Orma.

The Royal National Parks of Kenya Ordinance was passed in 1945 and the Tsavo Park was proclaimed in 1948, in very great measure because few people were regarded as residing within it and also because it was considered 'useless' for anything else. The Chyulu Hills themselves have been largely uninhabited throughout their apparently short history. In the years since 1948 and the explosion of populations in the better favoured areas of Kenya, the status of Tsavo Park has gradually altered and it is now viewed as an important conservation area in its uniquely expansive landscapes apparently little touched by the hand of man, despite the successive waves of poaching to which the Tsavos have been subject over the past three decades.

6.2 PRESENT LAND USE

As Ecosystems has pointed out, there were few good reasons of either conservation or scenery for the original designation of Tsavo as a National Park, while the generally arid climate and low overall land capability of the area is such that only relatively low concentrations of wildlife can be supported on the unimproved range within the park boundaries. There are exceptions to this generalisation however and several of the more outstanding areas of scenic and wildlife potential lie within the study area, including the immediate surroundings to the Mzima and Kilaguni springs, and the banks of the Tsavo and Athi rivers. These are the areas to

which tourists are attracted; especially since Tsavo tourism is mostly represented by commuters between Amboseli or Nairobi and the Coast, who have little time (or inclination?) for exploring the vastness of the Park. There are relatively few visitors to the scenically splendid Chyulu Hills however, despite their relative proximity both to Kilaguni and the Nairobi/Mombasa road. This is in part due to inadequate publicity but essentially because of the sad state of the two main access routes (from the southwest and the southeast). Slopes are too great and surfaces too uneven for the average private car, while the principal tourist circuit at the top - the 'Chyulu 2' circuit - is impassable to all but 4-wheel drive vehicles and those only with difficulty.

It is the northern extensions to Tsavo Park which are of principal interest to this study. Of the proposed additional extension east of Nooka (Text Map 2), the opinion has already been expressed (Section 5.3) that the extent of settlement and numbers of people present render this proposal impractical. Within the existing extension west of Nooka however, considerable areas of bushland still exist, though wildlife has largely been driven out while the numbers of settlers have steadily increased over recent years, such that entire areas of country have apparently undergone a remarkable transformation since the 1978 airphotography. Bush has been cleared, motorable tracks developed, villages have sprung up and deeper soil pockets cultivated. The following villages have been established within the delineated Park extension: Yangambo, Mlangoni, Nooka, Kimminga, Mukungula, Kimitundu and Kenzili (see Map 1 for the village locations and Appendix 2 for data on most of these villages); they include between them a total of three schools, as well as several shops and churches. The economic activities of these settlements are divided fairly evenly between charcoaling and farming.

To gain a better idea of the numbers involved, the Tsavo Park authorities undertook a hut count in mid-December 1983. In the southern section of the extension south of Nooka they found a total of 306 dwellings; between Nooka and the main Kibwezi/Chyulu track 826 huts; and north of the Chyulu track 452 huts (W Woodley, pers. comm.). Assuming a high proportion of 'single' huts of pioneers close to the hills and hence a low average of 3 persons per dwelling, the total of 1 584 huts could be sheltering some 4 750 people. This is a potentially large number of people if resettlement outside the Park were to be considered; meanwhile, neither the Park authorities nor the

District administration are doing anything to prevent these numbers from increasing.

Only the extreme southern end of the Chyulu Range actually lies within the Park boundaries; indeed, the greater part of the 'Chyulu 2' circuit is in fact beyond the Park. Moreover, the 'West Chyulu Game Conservation Area', still marked on some maps, exists neither as a legal entity nor as a practical conservation area. Instead, the Chyulus remain open for settlement, logging or any other human activity, permanent settlement only being inhibited by lack of domestic water. Nevertheless, tractors have ascended beyond the 5 000 foot contour up the Kibwezi/Chyulu road, to plough a few fields and carry water to the itinerant Akamba cultivators who currently number about twenty in the immediate vicinity of the track. These cultivators are not entirely dependent on transported water supplies since they report the use of local underground springs which keep flowing except at the height of the dry season. Crops grown in these localised pockets include maize, beans, potatoes, cassava and bananas, with cropping assured twice a year.

Overall, however, there is still very little cultivation on the Chyulus above about 4 500 feet (see Map 1) and this is confined to the eastern side. By far the most important current use for the Chyulus is as a Maasai grazing area, more particularly for the wet season when water supplies are less of a problem. The grasslands are burnt off at the height of the dry season, in August or September, to provide a flush of rich grazing when the rains begin in October. Other economic activities on the upper Chyulus include the collection of 'miraa' (a stimulant obtained from chewing the young leaves of the tree Catha edulis which grows widely in drier forest especially towards the southern end of the hills) and of honey from wild bees in the forest. All these activities could be having a cumulative effect on the vegetation as a consequence of the higher incidence of burning and heightened grazing pressure owing to the denial elsewhere on an ever-increasing scale of Maasai traditional range.

6.3 OPTIONS FOR THE FUTURE

Although we would consider the future of the Tsavo National Parks to be reasonably secure, in their "Tsavo Regional Land Use Study", Ecosystems (1982a) identified the major land use pressures building up around the Parks and presented to the Wildlife Planning Unit an outline of a possible multiple land use option for their future management. In this, Ecosystems concluded that, although the agricultural potential of the Parks is "extremely limited" (perhaps amounting to 10% of the Park area under marginal rainfed agriculture) and there are virtually no prospects for large-scale irrigation, the entire area of the Parks could nevertheless be used for livestock production with the capacity to support one third of a million animals overall. Their report sets out some of the details of such an option on the basis that, given appropriate management control, stock production can be compatible with wildlife conservation. However, there do not appear at this time to be pressures to embark on such a course. Instead, there seems to be consensus within Government on the desirability of maintaining the status quo; in view of the inevitable international displeasure were the Tsavo Parks to be changed in any profound way, we would expect Tsavo to be maintained for the foreseeable future.

There remains the question of what should be done about the various northern extensions, existing and proposed. We have suggested that Government should bow to the inevitable and extend the Ngwata Settlement Scheme westwards at least as far as the existing Tsavo extension boundary running through Nooka (Text Map 2). Data presented above would strongly indicate that the existing Park extension area is also doomed, at least on its present alignments. There are now too many squatters to move, there has been too extensive habitat destruction by charcoaling and there is too little wildlife to conserve. To these arguments can be added the total lack of access from the main Park area and an estimate that just cutting the boundary of this park extension would take two years at a cost of about one million shillings.

Instead, the realistic approach would be for the Park authorities and the Machakos and Kajiado District administrations to agree to reduce the overall area of the park extension and move it westward: to incorporate the entire range of the Chyulus down to the 4 500 foot contour (1 375 m) on the east (Machakos) side of the Hills, but only as far down as the 5 000 foot contour

(1 525 m) on the west (Kajiado) side where difficulties can be anticipated over negotiating seasonal grazing rights for the Maasai. Of course, the demarcated boundaries would not in practice follow the contour precisely and, at the drier northern end of the Chyulus, little would be lost if the Park were deemed to have ended along the line of the Chyulu summit road before it starts to descend in the direction of Makutano. This new extension would incorporate virtually the whole of Zone II (marked as Category 5 on Map 2) and the uppermost parts of Zone III mostly comprising steep grassland. In these ways, the reality of encroaching settlement is accepted but an effort would also be made to preserve the forests and grasslands of the Chyulu summits where lack of water and variable soils provide natural constraints on further human advance. Furthermore, the unique landscape would be preserved together with what is likely to prove a high proportion of the region's endemic plant and animal species. Nor may this be the end of the benefits, since the Chyulus provide an admirable site for diversifying the Park's tourist facilities with spin-off in terms of associated employment opportunities that might result from the development, for example, of self-catering bandas, photographic hides, riding, walking and even caving in the bat/guano caves of the northern Chyulus. It is on the basis of National Park status for the Chyulu summits that the prospects for the future are outlined in Part 7.

PART 7 FUTURE TRENDS AND WATER REQUIREMENTS

7.1 KAJIADO DISTRICT

As indicated in Part 4, there are several options facing future development in Kajiado and the outcome is far from clear. Most problematic are the extent to which individual land ownership and cultivation will spread. In some group ranches the demand for individual land allocation has recently received Presidential support and directives have been issued to proceed with the planning of subdivision. It would be reasonable to assume, therefore, that individualisation will extend also to Mbirikani and Kuku. However, on the basis of the moves taken in Mbirikani in 1982 to counter individualisation and the cost and lack of apparent benefit of subdivision in so dry an area, the counter assumption is preferred here. Similarly, although political pressure could lead to the piping of water to the top of the Chyulu Hills, this too is rejected here. Some cultivation is expected to occur on the hills but not widespread settlement.

In brief, it is assumed for the purpose of this analysis that over the next 25 years:

- the human population will double, increasing on Mbirikani and Kuku from 4 to 10/km² (from 10 000 to 25 000)
- the main residential area will remain along the line of the Loitokitok - Sultan Hamud pipeline but with a second settlement area developing in pockets along the foot of the southern Chyulus, drawing water from boreholes on the line of the Soitpus Swamp and Lolturesh River and supporting perhaps 20% of the population.
- livestock production will remain the predominant form of land use, with total livestock numbers increasing by 50% (with concurrent rangeland improvement) to, say, 75 000 cattle and 75 000 smallstock
- cropping will intensify in residential areas and extend to occupy perhaps 10% of the total land surface, principally by extension into the Chyulu Hills, into which an itinerant work force will move seasonally for this purpose.

The extent of cultivation in the Chyulus will depend on what action, if any, is taken by Government to reserve Zone II and the higher parts of Zone III as an extension to the Tsavo West National Park, as proposed in Part 6. If effective action is taken, 75% of this area could be conserved for forest and wildlife, with localised cultivation in Zone III (5%) and seasonal grazing elsewhere (20%). If, on the other hand, Government fails to gazette the upper Chyulus as National Park, these higher rainfall areas could well be divided between continuing forest conservation (15%), seasonal grazing on grassland (70%) and cultivation of the more favoured sites (15%).

Assuming that, daily, the human population consumes 10 litres/head, cattle 25 l/head and smallstock 5 l/head, the total daily water requirement within the study area and in Kajiado District is projected for the Year 2010 at about 2.5 million litres, according to the assumptions set out above. Since the group ranches extend as far as the Loitokitok/Sultan Hamud pipeline, no more than a third of this total (say one million litres daily at most) would be sought in the vicinity of the Chyulus.

7.2 MACHAKOS DISTRICT

If projections in Kajiado are problematic, those for the Machakos side of the Chyulus are hazardous in the extreme. Nevertheless, as outlined in Parts 5 and 6, the population pressures are such that the future of the area must entail intensification of existing patterns of settlement, insofar as the soils, rainfall, farm boundaries and the needs of livestock permit, and extension of farming via bush clearance onto all suitable and available land, until the area has 'filled up' after which a pattern of net emigration will start to develop. Implementation of the Athi Basin river regulation in the 1990s can be expected to draw off some of the pressures of population, as discussed in Section 5.3, but only as a temporary measure. The Athi project, combined with the Kikumbulyu Water Supply Scheme currently under implementation, should however ensure adequate supplies of domestic water east of the Nairobi/Mombasa road.

It is to the west of this road that domestic water supplies are critical. In view of the relative elevations and the distances involved, there can be no question of water being pumped back round the Hills from Mzima Springs. Instead, the local population will have to depend on existing springs plus

any groundwater located by the Chyulu Hills Water Resources Project.

Estimates of the total rural population that may be involved in 25 years time are dependent on a large number of assumptions including:

- development of all land with potential to support settlement by the Year 2010, with the following exceptions:
 - i. Mikululo Ranch and Kiboko Range Research Station to continue in use as range for livestock supported as at present by local water supplies
 - ii. Kibwezi Forest to remain inviolate as protected woodland
 - iii. No settlement above 4 500 feet in the east Chyulus on the basis that this area is designated National Park (alternatively, any settlement that does occur is regarded as illegal and need not therefore be supplied with domestic water)
- development for farming of 10% of the land on lava flows which, though designated unsuitable for settlement, does nevertheless include pockets of land which are well suited to cultivation: average 3 ha farms in Zone III; 7 ha farms in Zone IV
- 'filling in' of Category 1 land (as defined on Map 2) to give an overall average farm size of 3 ha
- 'filling in' of Category 2 land in Zone III to give average farms of 5 ha
- 'filling in' of Category 2 land in Zone IV and the moistest areas of Zone V to give average farms of 7 ha
- 4.7 persons per rural household (based on 1979 census data).

On the basis of these assumptions, it is projected that the total number of farm holdings west of the Nairobi/Mombasa road could reach 8 430 by the Year 2010 with a total rural population of about 43 600, given an additional 10% population (shopkeepers and artisans) supporting the farmers.

If one were to assume, moreover, that the associated farm livestock were watered from 'surplus' surface sources (stock ponds and the like, which are far more numerous than in Kajiado), the total daily water requirement in Machakos District west of the Nairobi/Mombasa road would be some 450 000 litres, to which should be added the daily requirement of 50 000 litres already computed for Kiboko Range Research Station (Section 4.2). If, on the other hand, one were to assume that water would also be piped in for livestock, there would be a considerably increased requirement. Currently, the area of the east Chyulus west of the Nairobi/Mombasa road is estimated to be stocked with about 10 000 cattle and only 5 000 smallstock. By 2010, it can be assumed that the cattle population will have doubled, while the numbers of smallstock will have increased by about twenty times (to give a plausible average of two to three cattle and about 12 smallstock per holding). On this basis, the additional requirement for watering livestock would amount to a further one million litres per day, to give a total daily water requirement (humans plus stock) of 1.5 million litres.

In conclusion it should be stressed that these calculations (for Kajiado as well as Machakos) tend to give a somewhat unreal estimate of 'requirement' in that they assume population increases that can only take place if water, locally available or transported into the area, is sufficient to support that increase. At the present time water is the ultimate constraint on occupancy and land use and, if increased water supplies are unavailable or are withheld, this in itself will limit the increase in human and livestock populations. It is problematic how much a community might pay for transported water, but the present rates paid for domestic water (KSh 3-9 per debe) are clearly within the capacity of local production systems where these include income from charcoaling.

PART 8 FURTHER INVESTIGATIONS

This section of the report is not intended to be comprehensive; the broad lines of investigation on the part of the Chyulu Hills Water Resources Project have indeed already been decided and the programme is about to get under way. The purpose of Part 8 is merely to highlight some thoughts on data requirements and data measurements that occurred to the authors during their travels.

8.1 METEOROLOGICAL RECORDING

The Project will be using one of the LRDC automatic weather-recording stations and it is hoped that this can be sited in the military enclosure in the central range of the Chyulus at around 6 500 feet. Failing this, a possible site would be at a somewhat lower elevation in the south Chyulus more accessible to Tsavo Park, e.g. in the vicinity of the ruined former Park entrance gate at an elevation of about 4 900 feet, though this area is near the boundary between zones II and III and would not therefore be representative of the Chyulu summits in Zone II. A more representative site is presented by the area of level land along the main Chyulu summit road in Grid Square Reference 7504 Chyulu Sheet 182/2, at an elevation of some 6 000 feet immediately west of the highest summit of the Chyulus. Wherever this station is sited, it will need considerable fencing and barbed wire if it is to be secured for the duration of the Project. Elsewhere along the Chyulu summits, there is we believe a case for spreading a number of totalisers and recording raingauges concreted in at suitable sites, in the hope that a representative number will survive for the duration of the Project. These gauges will tend, for reasons of access and convenience, to be sited near the summit road but it would be valuable to have some measurements on eastern and western aspects at both the northern and southern ends of the Hills.

Use should be made of the relative security of the Oltiasika Maasai Mission which is considered representative of Zone III on the western side of the Hills (elevation just over 4 000 feet). Here it should prove possible to train an observer to take, not only daily readings of rainfall, but also temperature and evaporation. This would also make a good site for a

recording anemometer. Otherwise the western Chyulus will prove a difficult area in which to sustain a network. Negotiation with the Chief at Iltlal Wells might secure a raingauge at about 3 000 feet in the Lolturesh Valley representative of Zone V. Because of the importance of obtaining some data from the west of the Hills, it is suggested that a visit be made to the Ekinjape Primary School near Mbirikani (Makutano - Zone V at 4 000 feet) to instruct and encourage the observer, assuming that he is still there. A few raingauges along the Chyulu/Makutano road would be worthwhile. Consideration should also be given to supplementing the raingauge at Kilaguni Lodge (Zone V, 2 700 feet) with an evaporation pan.

East of the Hills, the recording situation is altogether more promising, with an adequate distribution along the Nairobi/Mombasa road covering the wetter areas of Zone V and part of the inter-zone area between zones IV and V. Recording is sparse however in the southeast corner of the study area along the Athi River. Some effort should be made to install a raingauge and evaporation pan and to train an observer at the Tsavo Safari Camp (formerly Cottars Camp) on the Athi - Grid Reference 2908 Kiasa Sheet 183/2. Records from this site would help to resolve the problem as to whether and to what extent Zone VI occurs in the study area. Despite the stations along the Nairobi/Mombasa road, there are few (if any) between that road and the Chyulu Hills, yet this area is well served with schools which could provide literate observers and secure sites for gauges. Table 12 sets out a representative selection of the schools in this area.

Within the forest there must be significant loss of rainfall through canopy interception and its subsequent evaporation direct from the foliage. This will result in considerable variability in water use relative to E_0 . The forest microclimate is moreover totally different from that outside. It will be necessary therefore, as a contribution to evaluating the water balance, to attempt some estimate of both rain and mist interception by forest foliage. If the automatic weather station is not established at the former Park entrance in the south Chyulus, this would nevertheless make a good site for evaluating moisture interception in the forest (given easy access via the Chyulu 2 Forest Circuit) as well as for recording standard climatic variables as affected by aspect, elevation and vegetation cover.

TABLE 12 Schools east of the Chyulu Hills for possible met. recording sites

Schools	Elevation (m)	Ecoclimatic Zone
Kiminga	1 200	III
Sinai	1 100	
Nooka	1 100	
Milanje	1 100	
Kenzili	1 100	
Mtitori	1 070	
Pondani	1 020	
Utu	1 020	
Kikunduku	1 000	
Kambooyo	950	
Iiani	940	
Makokani	930	
Metava	1 010	III/IV
Bukoni	940	
Kaunguni	1 020	IV
Utithi	950	
Nthangoni	900	
Muthingiini	900	
Yumbooni	870	
Mangelete	780	V

8.2 SOIL/WATER RELATIONS

Investigation of the soil profile moisture characteristics, infiltration, permeability, depth and water holding capacity, is clearly going to feature prominently in any attempt to determine the regional water balance. The project will however face several problems in this regard. In particular, the rocky/stony nature of many of the Chyulu soils will militate against soil sampling, against soil moisture measurements by neutron moisture probe and against studies to determine effective rooting depth. Both in the forest and under grass, the deeper roots undoubtedly draw water from depths too stony for sampling, while the thickets on the lava flows root deeply into extensive fissuring which cannot be traced downwards. Nor can variations in moisture storage be easily estimated in these stony materials. Finally, the great variability of the soils in terms of texture and stone content will make it difficult to type particular sites as representative of wider areas, a problem compounded by lack of detailed soil mapping (the reconnaissance soil maps at 1:250 000 scale, though of value for regional land appraisal, are inevitably almost completely useless for purposes of large-scale, detailed evaluation).

Certainly investigations will need to include a programme of soil sampling for the purpose of contributing an understanding of profile moisture holding capacity and of levels of vegetation transpiration in relation to varying degrees of soil moisture deficit. At the very least, estimates will need to be made of 'losses' due to deep percolation (i.e. beyond the likely depth of rooting) but intelligent guesstimates are likely to be all that are available when it comes to such parameters as depth of rooting and total storage within the rooting zone, let alone the devising of plant transpiration coefficients for forest, bush and grassland.

It is as well, because of the stony profiles, that no great reliance is to be placed on the use of soil moisture probes. The hammering that would be required at many sites to drive in the access tubes would not only be time consuming but might also effectively destroy the soil structure. Instead, if probes are to be used, it would be best first to dig a hole, carefully setting aside the different textural horizons in order of occurrence, placing the access tubes at the required depths in the hole and then back-filling the material in the same sequence as it was dug out. The subsequent measurements on such heterogeneous materials would be unlikely to achieve

either representative or even reasonably accurate results. In the forest, it will in any case be difficult to obtain estimates of profile water use, partly because of the likely depth of rooting and partly because of the canopy interception and consequent 'negative' transpiration alluded to in the preceding Section.

Determination of the regional water balance will necessitate estimation of the relative proportions and overall areas of the diverse superficial volcanic deposits, boulders, lava flows, ash and pumice of the higher Chyulus, together with the various soils derived from them. This will involve a semi-detailed soil survey, with a view to locating, classifying and mapping all the more significant soil types, and including a programme of soil sampling to assess not only the basic soil properties but also the principal soil moisture characteristics. Such a survey might also contribute to elucidating those factors that determine the distribution of grassland, thicket and forest. The soil survey would be undertaken at photoscale, i.e. 1:20 000, but the extent of coverage should only be decided on the basis of hydrogeological advice when the Project has a better idea of the calculations (on groundwater recharge) that it will require to make. However, assuming that surveying would cover the whole of Zone II plus the upper parts of Zone III (the Chyulu Range down to about 4 500 feet), the area involved should not exceed 20 000 ha.

On the basis that API can provide a significant proportion of soil boundary alignments without need of field checking, the rate of soil survey should approach 120 km²/25-day month (i.e. 'medium' intensity) with a density of observations no more than one per 50 ha, and necessarily considerably less than this in the forest. Allowing five days for pre-field preparations and five days for post-survey operations and soil laboratory liaison in Nairobi, three weeks for API subsequently in the UK and four weeks for soil evaluation, map and report preparation, it is estimated that the total time requirement for one soil surveyor would be nine weeks in Kenya and seven weeks in the UK. The survey would need to be undertaken during the dry season, either between January and March or between June and October. A provisional budget is set out in Table 13, based on provision of tentage, camp equipment, transport, survey assistance (two labourers for six weeks) and one driver (for eight weeks) from existing Project resources; any soil equipment could be supplied on loan by LRDC.

TABLE 13 Provisional budget for undertaking semi-detailed soil survey on the Chyulu Hills (1984)

	£
Surveyor's time (16 weeks) - charged at actual cost	5 300
One airfare plus excess baggage	1 200
Subsistence : Nairobi (10 days at £35/day)	350
: Elsewhere (50 days at £15/day)	750
Fuel (landrover)	300
Soil sample analyses	1 500
Map production and area measurement	1 000
Report	1 000
Contingencies	600
	<u>12 000</u>

8.3 ECOLOGICAL MONITORING AND RESOURCE EVALUATION

It would be valuable if the Project were to encourage the establishment of a permanent routine for the monitoring of continuing land use and vegetation changes on and around the Chyulu Hills. In view of the long-term nature of such investigations, it is recommended that the work be undertaken by a Department of Government, preferably by the Kenya Rangeland Ecological Monitoring Unit (KREMU). This organisation should be in a position to provide both technical support (including light aircraft) and necessary expertise, especially since some recent KREMU operations have centred on the neighbouring Taita Hills and their surrounds.

The attention of the Project is drawn to the series of District Resource Evaluations being undertaken by the Tana and Athi Rivers Development Authority (TAARDA). The evaluation of Kajiado District (including the Chyulu Hills), by TAARDA specialists in soils, livestock, hydrology, economics and engineering, is due out in April 1984. Continuing interest in development, both on the Chyulus and along the Athi River, can be expected on the part of TAARDA and also from the Kenya Soil Survey, whose final report on the soils and vegetation of the Tsavo area (including the south east of the Chyulus) is expected later in 1984.

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APPENDIXES

APPENDIX 1 MEASURED AREAS ON MAPS 1 & 3

TABLE 1 Areas of land use categories shown on Map 1 within major divisions of land tenure (Text Map 2) in the east Chyulus - 1983, ha

Map symbol	Land use category	Kiboko Station & Mikululo Ranch*		Kibwezi Forest†	Tsavo Park Extensions		Ngwata Settlement Schemes	Total
		Makindu township	Ranoh†		Existing	Proposed		
1	<u>Cultivation categories</u>							
	Scattered pockets of cultivation (<10%) on shallow soils in ECZ III	42	0	2	2 534	3 625	109	6 312
2	Farm holdings with bushland: cultivation <2%	284	208	0	46	3 033	4 105	7 676
3	Cultivation 25-75% of the land area	2	160	0	193	2 369	10 992	13 716
4	Cultivation over >75% of the land area	0	374	2	183	681	3 352	4 592
	<u>Vegetation categories</u>							
F	Forest (ECZ II)	0	0	0	1 808	0	0	1 808
B	Bushland, woodland or thickets	15 515	913	5 366†	30 085	14 696	10 289	76 864
BG	Bush or shrub grassland	1 160	90	350	8 144	0	63	9 807
G	Grassland	0	0	417	1 894	27	28	1 990
	Total areas on Map 1**	17 003	1 745	5 761†	44 887	24 431	28 938	122 765

* Only relatively small parts of the Kiboko National Range Research Station and of Mikululo Ranch are shown on Map 1.

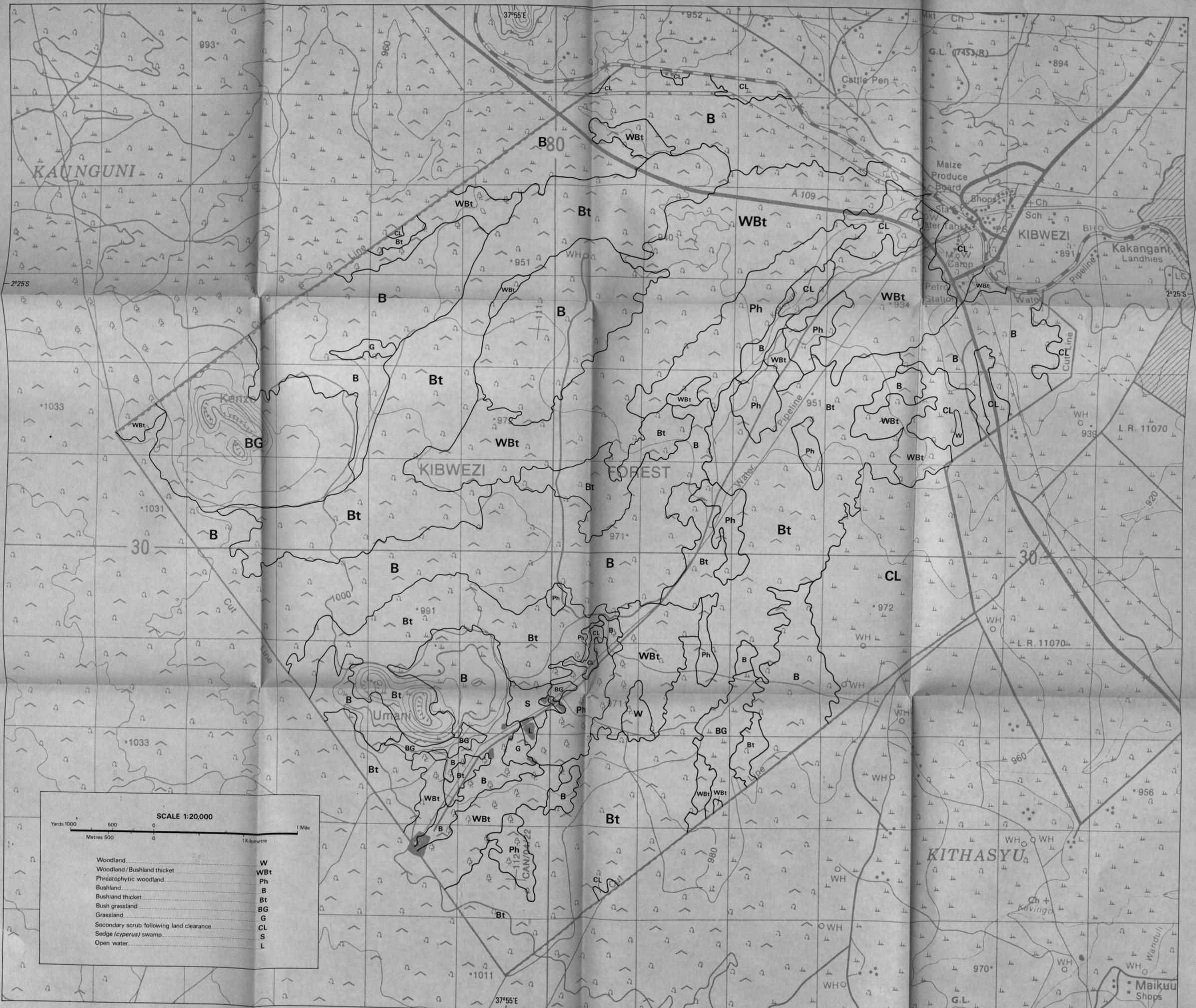
† A more detailed account of the vegetation categories within the Kibwezi Forest is given in Appendix 1 (Table 2) and on Map 3.

**Area totals slightly at variance with those shown on Text Map 2 owing to different methods of area measurement.

TABLE 2 Areas of vegetation categories within the Kibwezi Forest (Map 3)

Map symbol	Vegetation	Area, ha
Ph	Phreatophytic woodland	339
WBt	Woodland/bushland thicket	1 036
Bt	Bushland thicket	1 788
B	Bushland	1 845
BG	Bush/shrub grassland	369
G	Grassland	15
S	<u>Cyperus</u> (sedge) swamp	17
CL	Cleared land with secondary scrub	532
	Cultivation	4
L	Open water	7
	Total area*	5 952

*Total area slightly at variance with totals stated elsewhere in this report owing to different methods of area measurement.



SCALE 1:20,000

Yards 1000 500 0 1 Mile
Metres 500 0 1 Kilometre

Woodland	W
Woodland / Bushland thicket	WBt
Phreatophytic woodland	Ph
Bushland	B
Bushland thicket	Bt
Bush grassland	BG
Grassland	G
Secondary scrub following land clearance	CL
Sedge (cyperus) swamp	S
Open water	L

This map accompanies Project Report 135, Land use and development in the Chyulu Area of Kenya, published by the Land Resources Development Centre, Overseas Development Administration, Tolworth Tower, Surbiton, Surrey, England, KT6 7DY.

Prepared by the Land Resources Development Centre, 1984. Base map derived from 1:50,000 Series Y 731 Edition 3 SK. Specialist information by M J Makin.