REPUBLIC OF KENYA

LAKE BASIN DEVELOPMENT AUTHORITY

SONDU RIVER MULTIPURPOSE DEVELOPMENT PROJECT

VOLUME V

SUPPORTING STUDY REPORT FOR IRRIGATION PLAN

DECEMBER, 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

NAIROBI OFFICE
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TOKYO JAPAN

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APPENDIX I. LANDSAT IMAGE OF PROJECT AREA

LANDSAT IMAGES OF PROJECT AREA (1)

PLATE 1 SEPTEMBER 22, 1975

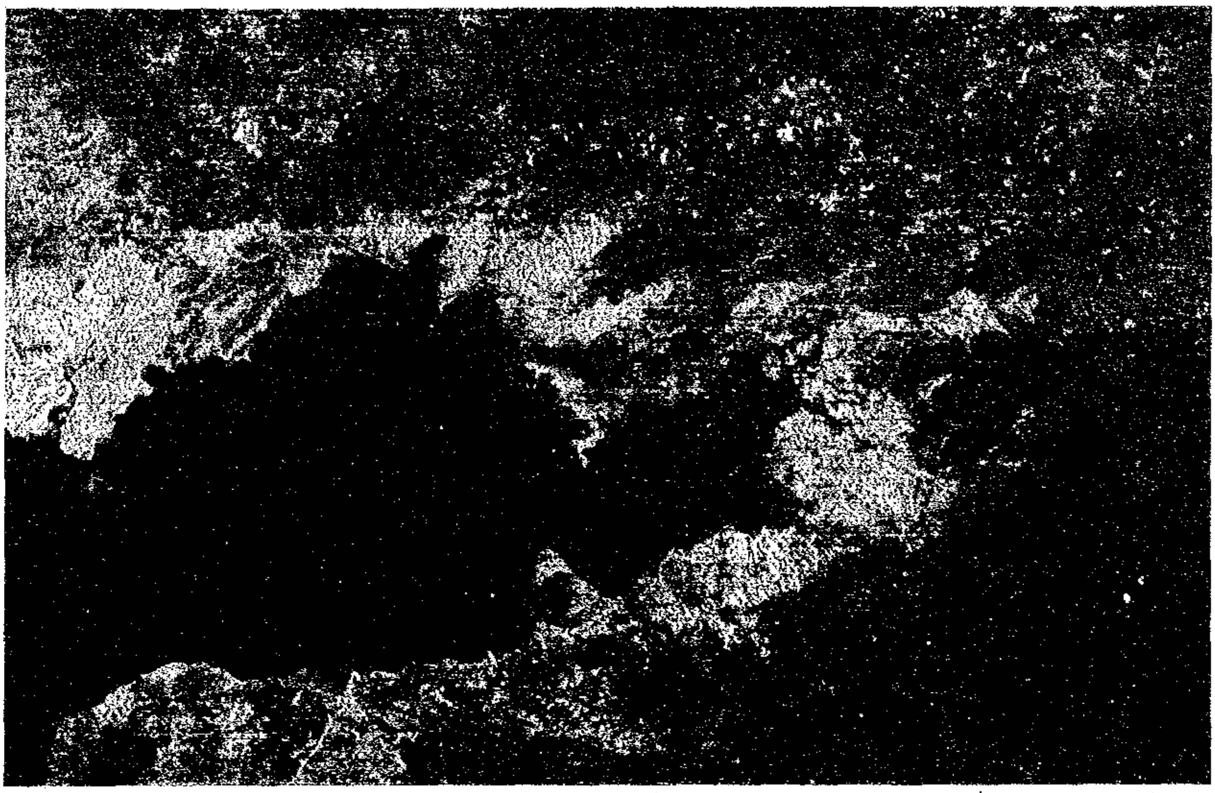

PLATE 2 DECEMBER 21, 1975

LANDSAT IMAGES OF PROJECT AREA (2)

PLATE 3 JANUARY 1, 1979

PLATE 4 FEBRUALY 15, 1979

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Chapter 1. INTRODUCTION

In the inventory survey related to the earth resources aerial photographs have played an important role providing a stereo scopic vision. Although black and white panchromatic photos enable us to obtain much information about the land elements of the survey area such as physiography, drainage condition, vegetation and land use, they have inherent limitations in their coverage of any single photographic scene mainly due to low altitude of air craft.

By coming of space programme, space crafts were envisaged as high altitude platforms of camera or sensor. Since 1972 U.S. orbiting satellites, namely Landsat, have collected the data of earth surface periodically by repetetive coverage of the same area every 16 or 18 days.

The data, gathered by Multispectral Scanner (MSS) a board Landsat, are available for purchase through the U.S. Geological Survey, EROS (Earth Resources Observation System) Data Center. The standard products of Landsat data include computer tapes (CCT) and the photographic images processed from the tapes. For eastern and southern Africa, the photo products are also available from the Regional Remote Sensing Facility which is a division of the Regional Center for Services in Surveying and Mapping, Nairobi.

In the present study, application of Landsat data is tried to obtain the following basic information.

(1) Vegetation and land use

The plural scenes are chosen possibly from two seasons, i.e. rainy season and dry season, and compared them with respect to the seasonal change in vegetation and land use.

(2) <u>External drainage condition</u>

Through comparison of the plural scenes from both seasons, the external drainage conditions in Nyakach and Kano plains are checked. Susceptive lands to flooding are detected and demarcated.

Chapter 2 VISUAL IMAGE INTERPRETATION

2.1 General

Table 2.1 gives the Landsat MSS data catalog for Kisumu region during the period from January 1972 to December 1980. This region is covered by the scene of PATH 182-ROW 060. The catalog shows observation date, image quality, cloud coverage, center coordinate, etc. Out of 39 scenes, 21 scenes are selected for the present study taking cloud coverage and image quality into account. The enlargements of photographic imageries are prepared for this area on a scale of 1:250,000 for the purpose of visual image interpretation.

The fragments of representative images covering the project area and its surrounding are presented in Plates 1 to 4.

Plate 1 ; September 22, 1975
Plate 2 ; December 21, 1975
Plate 3 ; January 1, 1979
Plate 4 ; February 15, 1979

The image is called false colour composite (FCC) because objects appear in colours which differ from those they have under normal light.

In the standard FCC such as these images, healthy green vegetation appears bright red colour instead of green. Deep clear water appears black, whilst turbid water shows blue colour. Urban centers are often blue or blue-gray.

2.2 Vegetation and Land Use

The images show the western part of the Sondu river basin (See Figure 2.1). Except for the lower reaches, the river basin is well-vegetated with forest and scrub. This complex of vegetation is extensive mosaic of evergreen bush and thicket mixed with trees. Due to high precipitation the hillylands are densely covered by forest throughout the year. On the eastern edge of Plate-2, the large scale tea plantation of Kericho is recognized with bright red colour.

On the other hand, the natural phenomena of the Kano plain shows quite different image characteristics from those in the surrounding hills. The Kano plain is the valley fill rising gently from the lake shore surrounded by steep slopes of the hills. In the north it is bounded by the Nandi escarpment and in the south by the Nyabondo escarpment. In the east, lava flow occurs and in the west, phonolite capping of Kisumu township is formed.

The Kano plain proper shows conspicuous red color of swamps and dark blue diffuse spots of wet soils and water bodies. According to the result of soil survey, Pellic Vertisols are identified as major soils in the Kano plain. They originate from lacustrine deposits of Lake Victoria with blackish colour and clayey texture. Due to high water retention and high groundwater table, the soils are poorly drained in general.

In the north east and south of the plain, the belt of higher lands are recognized. They are physiographically classified into piedmont plain which is the coalescing colluvial and alluvial fans formed adjacent to the escarpments. In north of Kisumu town and east of the Kano plain, recurrent pattern of red and dark rectangular mottles are recognizable. They are the sugarcane fields of Kibos, Miwani, Kibigori and Muhoroni. In the south of the Kano plain another piedmont plain is also formed, namely Nyakach plain where the project area is located. Eutric Regosols are the predominant soils consisting of colluvium derived from the Nyabondo plateau. They are unconsolidated soils of loose reddish materials. Due to specular reflectance of quartz sand much contained in topsoils, they show rather whitish tone on the images.

In the central part of the Kano plain, two irrigation schemes are detectable. They are the on-going schemes managed by National Irrigation Board (NIB). One is the Ahero Irrigation Scheme which is located on the right bank of the Nyando with a total service area of about 800 ha. The other is the West Kano Irrigation Scheme which is located on the lake coast covering about 450 ha. Since the West Kano Scheme was established in 1976, it can be seen only on the images from 1979.

2.3 Drainage Condition

The drastic changes can be recognized in Kano plain between the image in Plate-4 and the others. In the beginning of February 1975, rather heavy rain is recorded. Receiving about 180 mm of almost consecutive rainfall during the period from Feb. 3 to Feb. 13 (see Figure 2.2), the small streams locally overflow their banks and the minor depressions were inundated.

Through the soil survey, these inundated lands are physiographically classified into lowlying extensive terrain of lacustrine deposits. Since they are flat, poorly to very poorly drained, they are rather suitable for paddy cultivation provided proper drainage facilities are constructed.

Apart from the Kano plain, the Nyakach plain is less susceptive to inundation due to its higher elevation and well drainage condition. The central part of the cuspate delta formed in the river mouth of Sondu, several small water bodies can be seen in Plate-1 and Plate-4. During dry season, those water bodies would dry up. Through alternation of dry and wet, soluble salts in soil materials would have accumulated in topsoils. This is the process of formation of halomorphic soils, e.g. Solonchaks.

TABLES

Table 2.1 Data Catalog of Landsat MSS Data

Date	SAT	IMAGE QUAL	CLOUD COVERAGE	CENTER CORDINATES		SCENE ID
........................THE FOLLOWING DATA MUST BE ORDERED FROM THE EROS DATA CENTER						
09/10/72	1	8888	20ø	S00D01M17S	E034D54M20S	8104907224500
09/28/72	1	8888	10ø	N00D02M10S	E034D56M42S	8106707224500
12/09/72	1	5588	20ø	S00D10M58S	E034D48M28S	8113907233500
02/01/73	1	5585	00ø	N00D06M17S	E034D52M03S	8119307232500
05/20/73	1	8888	30ø	N00D07M15S	E034D41M29S	8130107233500
03/08/75	2	5588	30ø	S00D06M00S	E034D58M00S	8204507115500
03/26/75	2	5888	10ø	S00D06M00S	E034D56M00S	8206307113500
04/13/75	2	8888	30ø	S00D09M00S	E034D52M00S	8208107114500
06/24/75	2	8558	20ø	S00D04M00S	E034D49M00S	8215307114500
07/12/75	2	8588	90ø	N00D01M00S	E034D51M00S	8217107113500
07/30/75	2	5585	20ø	N00D01M00S	E034D55M00S	8218907111500
08/17/75	2	8888	70ø	N00D02M00S	E035D00M00S	8220707103500
09/04/75	2	8858	60ø	N00D04M00S	E035D00M00S	8222507102500
09/22/75	2	5555	10ø	N00D03M00S	E034D57M00S	8224307102500
10/28/75	2	5555	40ø	N00D01M00S	E034D56M00S	8227907100500
11/15/75	2	5555	80ø	N00D02M00S	E034D55M00S	8229707094500
12/03/75	2	5588	70ø	N00D00M00S	E034D55M00S	8231507093500
12/21/75	2	5888	10ø	N00D06M00S	E034D54M00S	8233307092500
01/26/76	2	8828	10ø	S00D01M00S	E034D47M00S	8236907090500
02/13/76	2	5888	10ø	S00D01M00S	E034D47M00S	8238707084500
01/01/79	3	5588	10ø	S00D00M40S	E034D58M19S	83030207122X0
01/19/79	3	8555	40ø	S00D00M14S	E034D56M38S	83032007123X0
02/15/79	2	5588	10ø	N00D00M00S	E034D55M00S	82148506595X0
02/24/79	3	5888	30ø	N00D00M00S	E034D56M00S	83035607122X0
05/16/79	2	8888	10ø	N00D00M00S	E034D52M00S	82157507030X0
05/25/79	3	8555	30ø	N00D00M00S	E034D51M00S	83044607115X0
06/03/79	2	8888	50ø	N00D01M00S	E034D48M00S	82159307035X0
06/12/79	3	8888	90ø	N00D00M00S	E034D54M00S	83046407113X0
06/21/79	2	8888	30ø	N00D01M00S	E034D48M00S	82161107042X0
06/30/79	3	M888	70ø	N00D00M00S	E034D56M00S	83048207111X0
02/19/80	3	5555	10ø	N00D00M00S	E034D53M00S	83071607072X0
07/30/80	3	5555	70ø	N00D00M00S	E034D53M00S	83087807015X0
08/17/80	3	8885	20ø	N00D00M00S	E034D57M00S	83089607010X0
09/04/80	3	2222	50ø	N00D00M00S	E034D55M00S	83091407003X0
09/22/80	3	5555	50ø	N00D00M00S	E034D54M00S	83093206595X0
10/10/80	3	8888	10ø	N00D28M00S	E034D37M00S	83095006591X0
10/28/80	3	8888	50ø	N00D00M00S	E034D56M00S	83096806582X0
11/15/80	3	5555	60ø	N00D00M00S	E034D52M00S	83098606583X0
12/03/80	3	5588	10ø	N00D34M00S	E034D36M00S	83100406592X0

FIGURES

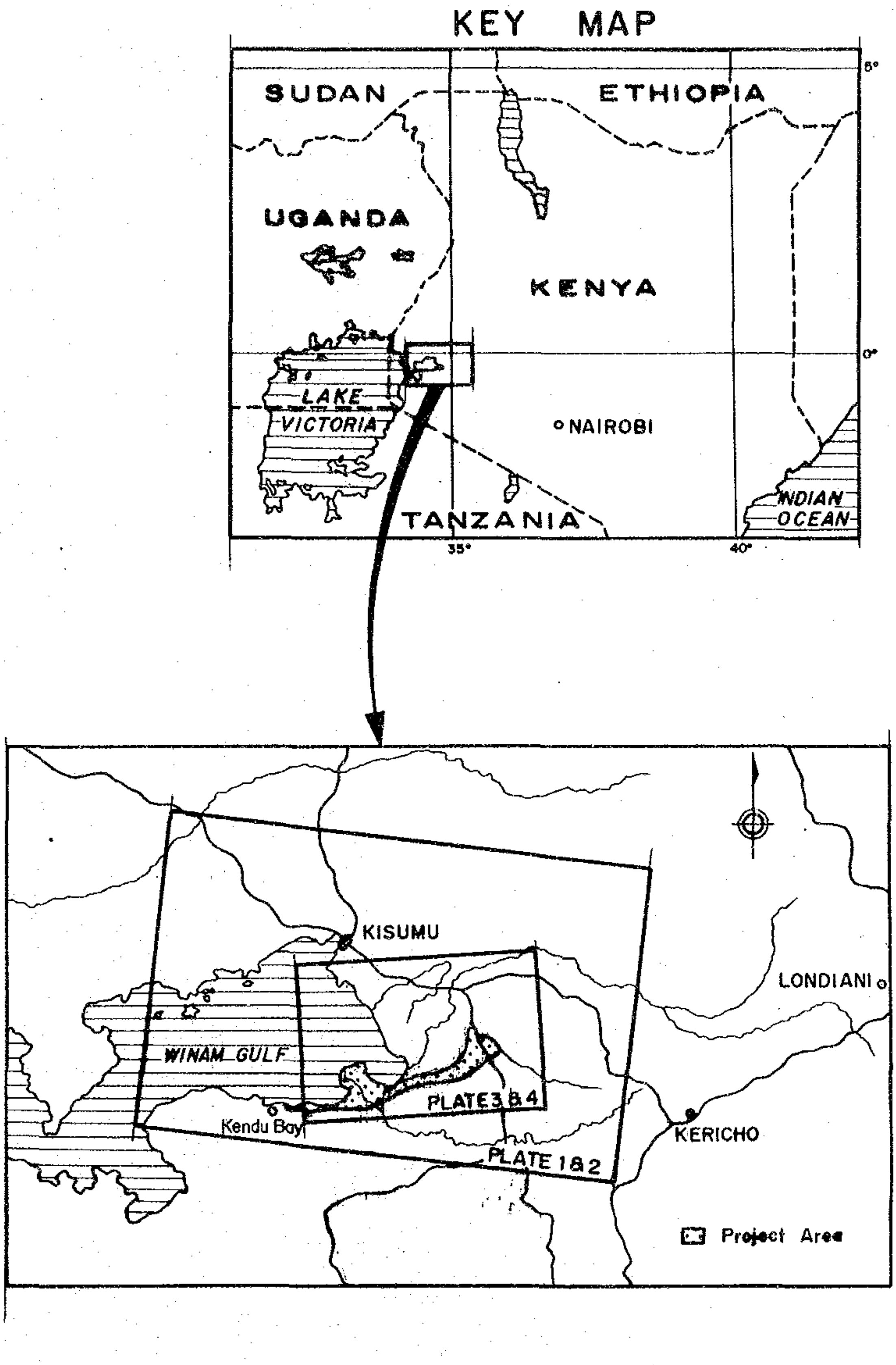

Figure 2.1 Areas Covered by Landsat Imagery Plates

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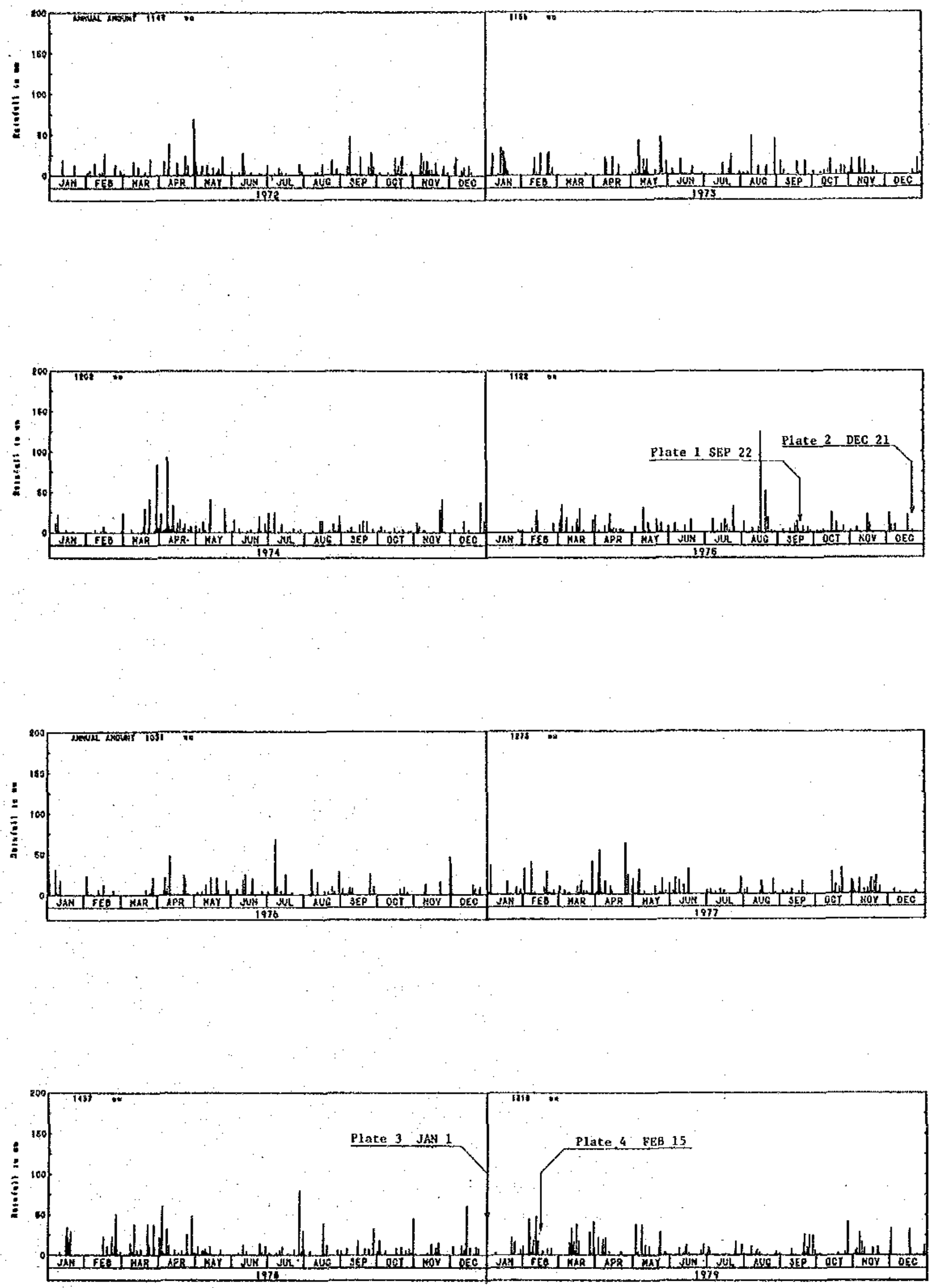

Figure 2.2 Daily Rainfall Record at Ahero

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APPENDIX II. CLIMATE

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1.1 General

The climatological data such as temperature, rainfall, relative humidity, sunshine hours, solar radiation, wind velocity and pan evaporation were collected at Ahero and Nyakwere meteo-stations. Nyakwere station is located in the present project area and has rainfall date only. Ahero station is located at 15 km north from the project area and has all climatological data for estimating irrigation water requirement and for establishing the optimum cropping pattern. The location of both stations and the observation period of the collected data are shown in Figure 1.1.

The climatological feature of the area can be summarized as follows:

(1) Rainfall

Annual rainfall at Ahero vary between 960mm and 1,770mm giving the average at 1,180mm. At Nyakwere, they vary rather widely between 470mm and 1,410mm with the average at 964mm. The rainfall of the area is well distributed throughout the year showing a double peak pattern, in which 30% of total rainfall concentrate in the long rainy season (March to May) and 15% of total rainfall in the short rainy season (October to December) without pronounced dry season. The monthly rainfall, annual daily maximum rainfall and number of rainfall days at Ahero and Nyakwere are presented in Table 1.2 and Table 1.3.

(2) Temperature

The average daily temperature is about 22°C throughout the year with average minima of 14°C and average maxima of 30°C. Tables 1.4 - 1.6 show the monthly temperature and Table 1.7 shows the absolute minimum temperature over past 14 years.

(3) Relative humidity

The area is under rather humid conditions. The mean monthly humidity ranges between 63% in October and 75% in June & July as shown in Table 1.8.

(4) Sunshine hours and solar radiation

The mean daily sunshine hours range between 7.0 hrs. and 8.5 hrs. The shortest month is June and the longest is January. Table 1.9 shows the observation records of sunshine hours at Ahero. In addition, the solar radiation has been observed. Maximum radiation value is 627 cal/cm^2/day in February and minimum value is 533 cal/cm2/day in July as shown in Table 1.10.

(5) Wind velocity

The wind velocity is generally low and constant. The monthly mean value ranges from 4.1 km/hr to 5.6 km/hr. The observation records are given in Table 1.11.

(6) Pan evaporation

Table 1.12 gives the monthly pan evaporation records at Ahero. The annual pan evaporation is about 2220 mm (6.1 mm/day). The monthly mean evaporation reaches its maximum in February and March; 7.3 mm/day and its minimum in July; 5.0 mm/day.

TABLES

Table 1.1 Summary of Climatological Data

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Nyakwere rainfall (mm)													
	59	68	111	150	143	67	64	97	58	61	84	86	1048
Ahero rainfall (mm)													
	71	91	133	187	131	75	74	81	77	79	124	85	1208
Max. temperature (°C)													
	31.0	31.5	31.6	29.6	28.8	28.6	28.6	28.6	30.0	30.9	30.1	30.3	30.0
Min. temperature (°C)													
	13.6	13.9	14.6	15.5	15.3	14.3	13.7	13.7	13.4	13.9	14.2	13.8	14.2
Absolute min. temperature (°C)													
	8.0	7.6	9.0	10.5	8.0	7.0	7.9	8.0	7.5	8.4	9.4	6.7	-
Relative humidity (%)													
	65	65	67	73	74	75	75	73	66	63	66	57	69
Wind velocity (km/hr)													
	5.36	5.57	5.29	4.78	4.09	4.09	3.95	4.35	4.65	4.65	4.61	4.92	4.70
Sunshine hours (hrs)													
	8.5	8.5	7.9	7.3	7.3	7.2	6.8	6.8	7.0	7.4	7.1	8.1	7.5
Solar radiation (cal/cm²/day)													
	606	627	614	586	574	574	533	549	572	593	572	600	582
Pan evaporation (mm/day)													
	6.9	7.3	7.3	6.1	5.5	5.1	5.0	5.4	5.8	6.3	6.0	6.3	6.1

Other than rainfall are data at Ahero

Table 1.2 Monthly Rainfall at Ahero (mm)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	NO. OF RAIN DAYS
1959			125			28	47	61	83	98	135	91		98
1960	42	38	224	156	150	34	80	48	138	50	126	15	1099	162
1961	5	50	99	163	159	29	28	95	110	148	568	324	1777	158
1962	121	20	191	193	227	137	113	48	83	139	167	58	1498	161
1963	108	182	201	210	190	64	38	57	38	44	212	159	1504	153
1964	57	159	105	254	99	69	156	48	53	57	29	93	1181	155
1965	83	23	198	199	76	13	42	38	86	156	50	111	1075	154
1966	48	155	271	198	21	46	94	79	102	145	78	16	1253	126
1967	25	41	90	222	161	67	31	34	91	68	145	116	1090	150
1968	6	203	108	249	107	102	40	71	33	78	102	126	1222	119
1969	135	119	128	175	136	87	58	43	39	37	111	75	1142	90
1970	225	101	146	198	85	96	72	116	38	32	86	56	1251	148
1971	60	7	31	220	171	149	56	71	50	47	134	68	1061	129
1972	34	96	67	203	128	62	52	51	139	102	152	72	1159	159
1973	154	133	4	76	251	49	71	138	70	57	113	28	1144	120
1974	43	19	218	283	127	72	79	84	58	36	109	76	1202	145
1975	10	78	178	98	117	60	102	233	65	61	43	79	1122	132
1976	112	60	43	144	98	82	122	104	79	22	82	84	1031	125
1977	86	124	117	231	121	104	59	68	49	127	157	22	1256	150
1978	126	135	202	234	62	52	151	76	89	125	47	138	1437	171
1979	79	203	225	101	154	65	54	42	134	57	103	105	1320	145
1980	63	31	97	179	103	92	50	46	92	25	68	119	964	141
1981	8	30	222	167	155	51	128	98	115	28	76	8	1086	149
1982	55	175	51	131	199	162	47	167	57	73	178	34	1326	168
1983	32	66	69	217	97	58	70	132	39	153	37	61	1029	146
1984	60	34	54	170	80	121	73	66						
MEAN	71	91	133	187	131	75	74	81	77	79	124	85	1208	

Table 1.3 Monthly Rainfall at Nyakwere (mm)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	NO. OF RAIN DAYS
1955	63	51	93	121	141	12	127	80	131	46	98	163	1124	
1956	93	65	89	173	212	98	44	112	88	64	24	56	1118	
1957	22	100	71	191	162	243	7	214	34	58	58	189	1349	
1958	2	52	167	133	243	54	87	127	17	69	1	56	1007	79
1959	13	46	250	115	117	2	48	22	44	52	41	38	789	91
1960	24	88	150	163	180	15	30	43	60	91	92	14	949	114
1961		37	132	132	213	26	53	176	114	88	518	380		144
1962	117	41	171	107	361	134	101	39	83	77	91	94	1415	136
1963	129	68	159	210	238	24	83	40	7	15	136	202	1311	120
1964	43	85	53	239	59	94	143	71	149	71	2	78	1088	112
1965	10	9	45	192	96	32	53	20	26	86	73	38	679	74
1966	22	115	192	157	56	32	67	121	90	42	36	26	955	102
1967		53	91	221	137	176	116	53	36	54	119	130		113
1968	9	156	107	280	157	38	108	189	28	61	92	62	1289	107
1969	133	119	214	63	239	56	67	41	59	132	83	38	1246	97
1970	59	88	173	185	70	59	75	89	39	29	32	119	1018	110
1971	25		22	123	122	81	61	49	34	69	55	29		57
1972	51	50	58	37	78	49	42	118	81	74	125	74	837	91
1973	88	35	17	172	227	123	5	149	15	28	62	75	997	98
1974	41	11	103	137	138	104	103	126	147	44	25	52	1031	74
1975	25	61	156	101	197	81	51	188	171	88	21	50	1188	80
1976	10	57	12	87	119	29	121	120	65		96	219		39
1977	323	78	120	444	250	107		91	39	177	249	47		
1978	138	103	264	199	99	8			39	32	100	18		118
1979	53	106	89	57	32	86	42		14	9	13	74		64
1980	15	96	48	94	63	32	34	23	7	15	38	6	470	51
1981	57	89	104	53	32	86	42		14	9	13	74	571	64
1982	18	19	37	35	50	29	27	63	27	51	89	79	523	65
1983	11	28	21	113	62	27	3	190	24	69	68	29	644	89
MEAN	59	68	111	150	143	67	64	98	58	61	84	86	982	

Table 1.4 Monthly Maximum Temperature at Ahero (°C)

Year	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	MEAN
1970	29.3	30.3	29.8	28.9	28.5	28.7	28.7	28.8	29.8	31.3	31.1	30.6	29.7
1971	30.9	32.7	34.0	29.0	28.0	27.7	27.8	28.4	29.8	30.9	30.9	29.2	29.9
1972	31.5	29.7	32.1	30.7	28.6	28.1	29.1	30.1	30.8	30.1	28.7	29.9	30.0
1973	30.4	31.7	33.3	32.1	29.1	28.4	28.9	28.9	29.5	31.5	29.8	31.7	30.4
1974	32.1	33.8	31.6	28.4	27.9	28.4	27.2	29.2	29.5	31.6	30.9	30.7	30.1
1975	31.9	32.5	30.2	29.3	29.2	28.3	28.4	27.1	28.2	29.5	31.0	30.4	29.7
1976	31.6	31.3	32.6	29.8	28.6	28.4	28.0	29.0	30.2	32.8	30.8	30.5	30.3
1977	29.3	29.9	31.1	28.6	29.1	28.6	28.9	29.8	31.4	31.7	28.0	30.4	29.7
1978	30.8	30.9	29.4	29.1	29.1	29.1	28.9	29.0	30.1	30.4	30.0	29.3	29.7
1979	30.6	28.6	30.1	29.3	28.9	28.1	29.0	30.0	31.0	32.2	30.5	30.7	29.9
1980	31.5	32.7	32.0	30.4	29.2	28.6	28.9	30.1	30.8	31.6	30.2	30.4	30.5
1981	32.2	32.4	30.1	29.0	28.8	29.5	28.1	29.2	29.1	30.9	30.6	31.3	30.1
1982	32.1	31.3	32.3	28.7	28.6	28.7	28.9	28.8	30.4	29.6	28.3	29.3	29.8
1983	31.1	32.4	32.7	30.2	29.5	29.1	29.2	28.5	29.6	29.1	30.2	29.6	30.1
1984	29.9	31.8	32.9	29.9	29.6	28.7	28.8	29.7					30.2
Mean	31.0	31.5	31.6	29.6	28.8	28.6	28.6	29.1	30.0	30.9	30.1	30.3	30.0

Table 1.5 Monthly Minimum Temperature at Ahero (°C)

Year	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	MEAN
1970	12.6	12.0	12.9	13.3	13.1	12.0	11.4	11.5	11.2	11.4	11.8	11.5	12.1
1971	11.5	11.0	11.9	13.4	12.9	11.3	10.6	10.6	10.5	11.6	11.7	11.9	11.6
1972	10.8	11.2	11.9	13.1	12.9	12.2	12.2	11.1	11.4	12.5	13.0	12.3	12.1
1973	12.1	12.5	11.8	13.2	13.5	12.4	11.5	11.2	11.6	11.5	12.6	10.2	12.0
1974	10.3	10.0	12.2	13.6	13.2	11.7	11.8	11.5	11.0	11.0	11.4	11.8	11.6
1975	14.3	14.8	16.1	15.9	15.7	14.9	14.2	15.1	14.4	14.5	13.5	14.3	14.8
1976	13.2	14.0	15.1	16.2	16.6	14.5	14.5	14.1	13.5	14.4	15.2	14.6	14.7
1977	15.3	15.1	15.4	16.7	16.8	15.8	15.0	14.2	14.6	15.9	16.4	15.4	15.6
1978	14.4	15.6	16.8	16.3	15.8	15.3	15.2	15.6	14.3	15.8	15.2	16.0	15.5
1979	15.8	16.3	15.6	16.5	15.5	16.6	14.7	15.2	14.9	15.1	15.6	14.9	15.6
1980	14.7	14.5	15.2	16.3	16.7	15.5	14.5	14.9	14.9	14.7	15.4	14.7	15.2
1981	14.2	14.9	16.5	17.1	16.2	15.3	15.1	14.4	14.7	14.7	15.1	15.0	15.3
1982	15.4	15.9	15.3	16.8	17.1	15.7	15.1	15.0	15.0	15.5	16.5	15.3	15.7
1983	15.6	16.2	17.4	16.9	16.8	15.6	15.1	15.6	14.9	16.3	15.3	14.8	15.9
1984	14.1	13.9	15.3	16.8	16.1	15.6	14.8	15.6					15.3
Mean	13.6	13.9	14.6	15.5	15.3	14.3	13.7	13.7	13.4	13.9	14.2	13.8	14.2

Table 1.6 Monthly Mean Temperature at Ahero (°C)

Year	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	MEAN
1970	21.0	21.2	21.3	21.4	20.8	20.4	20.1	20.2	20.5	21.4	21.5	21.1	20.9
1971	21.1	21.9	23.0	21.2	20.5	19.5	19.2	19.6	20.2	21.2	21.3	20.6	20.8
1972	21.2	20.5	22.0	21.9	20.8	20.2	20.7	20.6	21.1	21.3	20.8	21.1	21.0
1973	21.3	22.1	22.6	22.7	21.3	20.4	20.2	20.1	20.6	21.5	21.2	21.0	21.3
1974	21.2	21.9	21.9	21.0	20.6	20.0	19.5	20.4	20.2	21.3	21.2	21.3	20.9
1975	23.1	23.7	23.2	22.6	22.5	21.6	21.3	21.1	21.3	22.0	22.3	22.4	22.3
1976	22.4	22.7	23.9	23.0	22.6	21.5	21.3	21.5	21.9	23.6	23.0	22.6	22.5
1977	22.3	22.5	23.3	22.7	23.0	22.2	21.9	22.0	23.1	23.8	22.2	22.9	22.7
1978	22.6	23.3	23.1	22.7	22.5	22.2	22.1	22.4	22.2	23.1	22.6	22.7	22.6
1979	23.2	22.5	22.9	22.9	22.2	22.4	21.9	22.6	23.0	23.7	23.1	22.8	22.8
1980	23.2	23.6	23.6	23.4	22.9	22.1	21.8	22.5	22.9	23.2	22.9	22.6	22.9
1981	23.3	23.7	23.4	23.1	22.5	22.4	21.6	21.8	21.9	22.8	22.9	23.2	22.7
1982	23.8	23.6	23.8	23.2	22.8	22.2	22.0	21.9	22.7	22.6	22.4	22.3	22.8
1983	23.4	24.3	25.0	23.5	23.1	22.4	22.2	22.1	22.3	22.7	22.7	22.2	23.0
1984	22.0	22.9	24.1	23.4	22.9	22.2	21.8	22.7					22.8
Mean	22.3	22.7	23.1	22.6	22.1	21.4	21.2	21.4	21.7	22.4	22.2	22.1	22.1

Table 1.7 Absolute Minimum Temperature at Ahero (°C)

Year	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1970	9.5	7.5	10.1	11.4	11.4	9.0	7.9	8.5	8.8	9.1	9.4	8.9
1971	8.0	8.2	9.0	11.3	8.0	7.0	9.0	8.0	7.5	9.7	9.6	8.5
1972	8.5	9.0	9.5	10.5	11.1	10.2	8.0	9.2	8.7	9.1	11.1	10.3
1973	9.0	7.8	9.0	11.2	11.5	9.3	8.5	6.0	9.3	8.5	9.6	7.3
1974	8.5	7.6	9.0	12.0	11.2	9.0	8.4	8.9	8.5	8.4	9.5	6.7
1975	11.8	11.5	13.8	12.5	14.0	12.5	12.0	13.2	10.5	12.7	11.5	11.5
1976	10.5	12.5	12.5	14.0	14.5	12.5	11.0	11.0	11.5	11.5	13.5	11.5
1977	13.0	11.8	12.0	15.0	14.2	13.3	11.0	11.5	11.5	13.0	13.6	12.8
1978	9.0	9.5	12.6	14.0	12.5	13.1	12.2	12.5	11.0	12.9	12.5	13.3
1979	13.1	13.2	10.2	14.7	13.0	13.4	11.5	9.6	12.1	13.2	12.5	13.0
1980	12.0	12.5	11.0	14.0	15.0	13.8	11.8	12.1	13.0	12.0	13.5	11.5
1981	10.5	12.8	14.3	15.2	14.7	11.4	12.5	12.6	12.0	12.0	13.6	11.4
1982	14.0	13.8	13.0	15.0	12.5	12.2	13.2	12.1	12.4	13.0	14.0	11.5
1983	13.5	12.0	14.8	14.2	14.5	13.5	12.0	13.2	12.0	13.5	13.2	12.0
1984	11.6	11.5	11.5	14.8	13.5	13.5	12.0	13.0				
Mean	8.0	7.6	9.0	10.5	8.0	7.0	7.9	8.0	7.5	8.4	9.4	6.7

Table 1.8 Monthly Relative Humidity at Ahero (%)

Year	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	MEAN
1970	77	74	76	78	78	76	76	77	67	62	69	77	74
1971	83	68	71	76	77	79	79	79	67	60	64	69	73
1972	62	71	62	68	64	76	76	70	64	69	73	69	69
1973	70	69	60	67	75	76	74	65	48	48	53	58	64
1974	62	56	72	75	74	74	81	72	71	63	64	59	69
1975	54	61	70	75	72	74	72	79	74	70	59	70	69
1976	60	70	63	72	77	75	79	72	64	63	59	64	68
1977	69	69	67	76	72	76	72	68	59	58	73	63	69
1978	59	65	77	75	71	74	76	73	67	67	64	70	70
1979	67	75	65	75	74	78	72	70	64	64	68	69	70
1980	59	61	63	71	77	74	73	79	71	60	67	63	68
1981	57	54	70	76	75	72	78	75	71	62	65	60	68
1982	63	65	60	74	78	77	77	78	69	68	74	72	71
1983	64	64	64	73	72	72	74	77	71	73	67	68	70
1984	64	56	59	71	70	69	71	68					66
Mean	65	65	67	73	74	75	75	73	66	63	66	67	69

Table 1.9 Monthly Sunshine Hours at Ahero (hrs)

Year	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	MEAN
1970	7.1	9.6	7.2	7.6	7.9	8.0	7.4	5.7	6.8	7.5	7.5	9.0	7.6
1971	8.5	9.6	8.5	7.1	6.6	7.2	7.6	7.6	7.6	8.1	8.1	7.6	7.8
1972	9.3	6.5	8.7	8.7	7.8	6.4	6.8	6.9	7.4	7.1	7.2	8.9	7.6
1973	8.5	7.9	7.9	7.6	7.1	7.7	7.0	6.9	6.3	7.1	7.2	9.2	7.5
1974	9.7	9.3	6.1	7.1	7.5	7.9	6.0	7.5	6.4	7.5	6.9	8.5	7.5
1975	9.0	9.4	8.4	7.2	7.2	6.4	6.2	4.9	5.6	6.4	7.5	8.9	7.3
1976	9.7	8.6	8.3	7.1	5.9	6.6	5.4	6.6	7.1	7.4	6.8	7.3	7.2
1977	6.8	7.6	8.0	5.4	6.9	6.9	7.2	6.8	7.3	7.7	5.6	7.1	6.9
1978	7.8	7.5	5.8	6.7	7.5	6.0	6.5	6.6	6.8	7.3	7.6	7.3	7.0
1979	7.3	7.2	8.6	7.4	7.8	6.8	7.4	7.3	7.6	8.3	7.3	9.0	7.7
1980	8.6	9.0	8.3	8.1	6.3	7.1	7.6	7.5	8.2	8.1	6.2	8.6	7.8
1981	9.5	8.9	6.0	7.2	8.2	8.4	6.0	7.2	7.1	8.4	7.7	8.3	7.7
1982	8.3	8.5	9.1	6.1	6.3	7.8	7.3	6.6	7.2	6.3	6.3	7.6	7.3
1983	9.0	8.4	8.1	7.7	8.1	7.3	6.6	6.5	7.0	6.4	7.5	6.7	7.4
1984	8.6	9.6	8.9	8.4	8.3	7.6	7.4	7.3					8.3
Mean	8.5	8.5	7.9	7.3	7.3	7.2	6.8	6.8	7.0	7.4	7.1	8.1	7.5

Table 1.10 Monthly Solar Radiation at Ahero (cal/cm2/day)

Year	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	MEAN
1970	507	612	548	567	548	528	508	473	567	574	564	600	550
1971	570	619	605	546	524	521	526	529	578	611	586	553	564
1972	629	532	628	593	531	483	509	525	564	561	557	626	562
1973	613	602	656	583	567	552	529	577	560	623	639	659	597
1974	673	653	563	677	581	552	540	534	554	613	568	681	599
1975	661	729	648	642	657	578	579	594	583	619	638	674	634
1976	734	689	711	644	586	591	604	591	650	640	603	613	638
1977	598	627	620	587	641	589	560	552	631	630	608	669	609
1978	635	684	627	575	647	574	541	583	567	601	604	547	599
1979	533	604	537	578	533	504	507	521	540	583	534	575	554
1980	575	600	572	556	493	497	515	531	562	568	491	553	543
1981	590	587	509	573	582	522	441	532	544	578	542	569	547
1982	600	611	609	500	518	574	527	565	562	523	508	580	556
1983	597	601	592	520	567	508	491	511	545	575	559	504	548
1984	575	662	692	646	642	636	614	624					636
Mean	606	627	614	586	574	547	533	549	572	593	572	600	582

Table 1.11 Monthly Wind Velocity at Ahero (km/hr)

Year	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	MEAN
1970	6.88	6.13	5.51	5.11	5.05	5.17	4.96	5.05	5.72	6.00	5.98	6.87	5.70
1971	6.55	7.79	7.56	6.36	4.69	4.60	4.67	5.28	5.43	6.00	5.79	5.74	5.87
1972	6.05	5.99	4.03	6.11	5.03	4.96	4.37	4.96	5.22	5.04	5.19	5.32	5.19
1973	5.78	5.52	6.05	6.12	5.36	4.35	4.55	4.73	4.97	5.08	4.84	5.46	5.23
1974	6.05	6.36	5.28	5.16	4.26	4.69	4.33	4.75	5.02	5.19	5.00	5.10	5.10
1975	6.05	5.83	5.70	4.49	4.19	4.30	3.63	3.79	4.60	4.21	4.23	5.02	4.67
1976	4.87	5.44	5.81	5.01	3.94	3.89	3.73	4.10	4.33	4.78	5.78	5.02	4.73
1977	3.83	4.23	4.69	4.07	4.17	4.07	3.54	4.22	4.62	4.94	3.94	4.19	4.21
1978	4.75	4.79	4.20	3.61	3.35	3.75	4.05	4.24	4.72	4.30	4.11	4.73	4.22
1979	4.73	5.32	5.46	4.58	4.01	3.81	4.31	4.81	5.05	4.60	4.21	5.03	4.66
1980	5.73	5.66	5.57	5.41	2.89	3.27	3.10	4.05	4.66	4.31	4.17	4.53	4.45
1981	4.95	5.95	5.12	4.04	3.75	2.29	1.79	1.92	1.93	2.29	2.41	2.51	3.25
1982	3.07	2.78	2.67	1.27	1.84	3.81	3.74	4.18	4.35	4.04	4.82	4.76	3.44
1983	5.71	5.59	6.04	5.20	4.33	4.29	4.03	4.56	4.52	4.31	4.10	4.55	4.77
1984	5.33	6.16	5.60	5.17	4.51	4.10	4.39	4.59					4.98
Mean	5.36	5.57	5.29	4.78	4.09	4.09	3.95	4.35	4.65	4.65	4.61	4.92	4.70

Table 1.12 Monthly Pan Evaporation at Ahero (mm/day)

Year	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	MEAN
1970	7.1	8.1	6.9	6.8	6.0	6.2	5.9	5.5	6.6	7.4	7.3	8.1	6.8
1971	8.2	9.6	9.9	7.4	6.0	5.5	5.8	6.4	6.6	7.5	7.3	6.7	7.2
1972	8.0	7.0	8.8	7.7	5.9	5.6	5.6	6.3	7.1	6.7	6.4	7.2	6.9
1973	7.3	7.6	8.8	8.0	6.7	5.2	5.6	5.8	5.7	6.8	6.5	7.5	6.8
1974	7.9	8.4	7.3	6.4	5.7	5.3	4.4	5.8	5.7	6.7	6.3	6.5	6.4
1975	7.6	8.4	7.2	6.1	5.7	5.1	5.2	5.3	5.0	5.7	6.2	6.6	6.2
1976	7.5	6.8	7.4	6.0	4.6	4.8	4.4	4.7	5.5	6.6	6.3	5.9	5.9
1977	5.6	6.3	6.4	5.0	5.1	4.7	4.7	5.3	6.1	6.8	4.6	5.5	5.5
1978	6.2	6.2	5.2	4.9	4.6	4.6	4.6	4.9	5.4	5.3	5.6	5.5	5.3
1979	6.1	5.5	6.7	5.3	4.7	4.7	4.9	5.3	6.1	6.2	5.6	5.8	5.6
1980	6.5	7.3	7.1	6.5	5.1	4.8	5.0	5.4	6.1	6.5	5.5	6.4	6.0
1981	7.2	7.5	5.7	5.3	5.4	5.3	4.3	5.2	5.0	5.8	5.8	6.0	5.7
1982	6.9	7.0	7.1	5.1	4.9	5.1	4.8	5.1	5.5	4.7	5.0	5.2	5.5
1983	6.3	6.5	7.0	5.7	7.3	4.6	4.5	4.5	5.1	5.1	5.2	5.1	5.6
1984	5.8	7.2	7.3	5.9	5.5	5.2	4.9	5.2					5.9
Mean	6.9	7.3	7.3	6.1	5.5	5.1	5.0	5.4	5.8	6.3	6.0	6.3	6.1

FIGURES

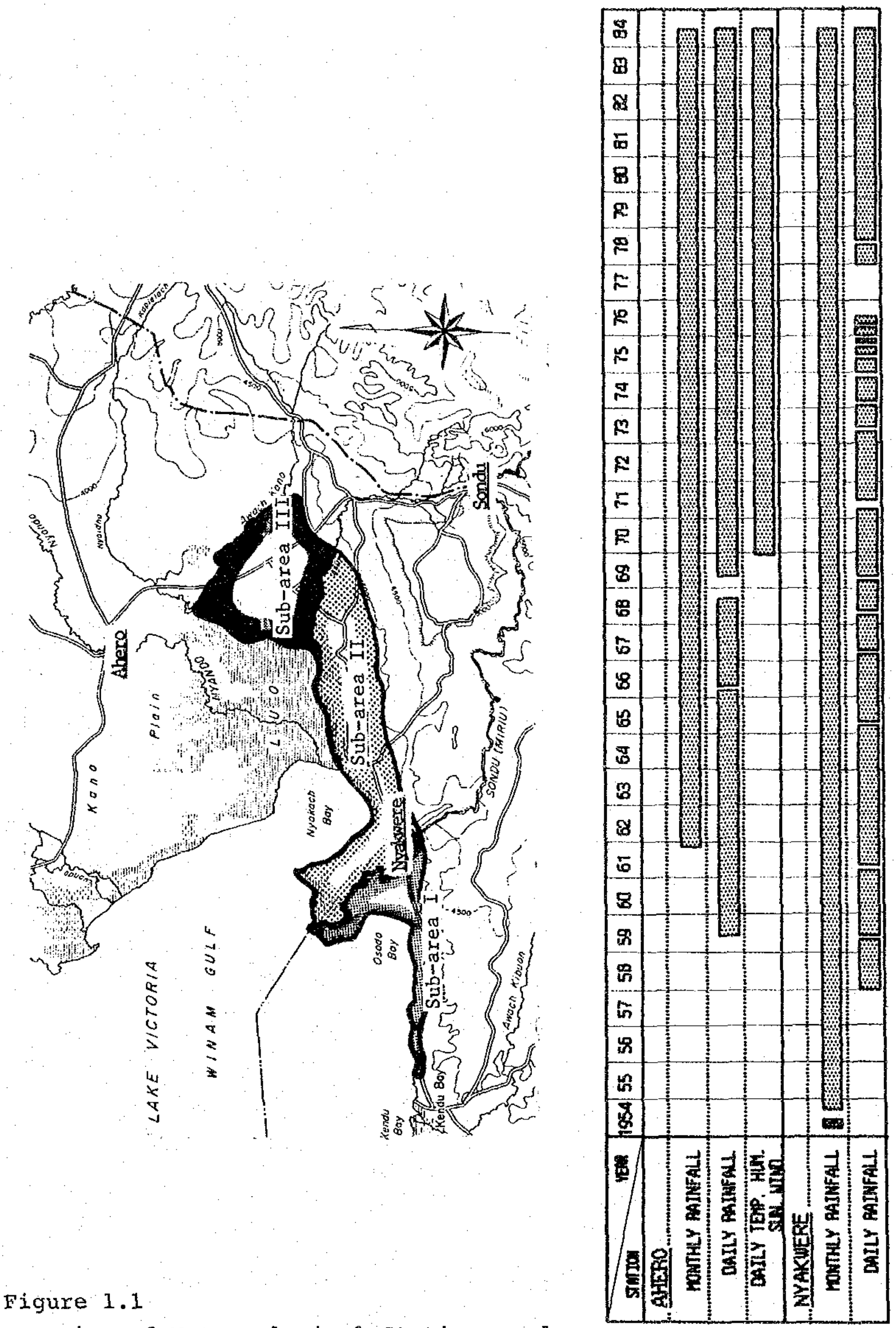

Figure 1.1
Location of Meteorological Stations and Observation Period of Meteorological Data

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APPENDIX III. SOIL AND LAND EVALUATION

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1. "List of Publications" Kenya Soil Survey (KSS), March 1983
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Chapter 1. INTRODUCTION

For appraisal of the land suitability for the future irrigation development, the semi-detailed soil survey was carried out in the Nyakach plain and a part of the Kano plain. The project area is located between latitudes $0^{o}12'S$ and $0^{o}22'S$ and between longitudes $34^{o}40'E$ and $35^{o}03'E$. The area lies on the almost flat terrain which is bordered by Lake Victoria in north, Nyabondo escarpment in south, the Awach Kano river in east and Kendu bay in west (Figure 1.1). Administratively, Kisumu district and South Nyanza district are concerned.

The present study consists of two significant steps, i.e. soil classification and land evaluation. In the first step, the soils of the study area were observed and described through the soil profile survey. At the representative test pit sites, the soils were sampled for the later laboratory test. Based on the survey record and the laboratory test result, the soils are classified into the defined soil units according to the international standard of soil classification and soil units, the semi-detailed soil map is prepared. For the land evaluation, the basic land elements such as physiography, topography, surface geology and drainage condition, are also presented on the soil map.

Following the soil classification, the land suitability for the future irrigation development is evaluated through interpretation of the above soil survey results. According to the Kenya's classification criteria, the irrigation suitability is assessed with respect to the soil mapping units. This information is fully applied to the selection of the irrigation area to be covered by the Project.

Chapter 2. GENERAL DESCRIPTION OF THE AREA

2.1 Agro-climate

For assessing which areas are climatically suitable for various land use alternatives with emphasis on the suitability for particular crops and crop varieties, Kenya Soil Survey (KSS) has prepared the agro-climatic zone map covering all Kenya on a scale of 1:1,000,000. This zoning system has two components, namely water availability (r/Eo = rainfall divided by evaporation) and temperature. As shown in Figure 2.1, the project area falls in the zone III-3 which means semi-humid and fairly warm. As for crop production, almost all crops are adaptable in the zone III-3 as shown in Figure 2.2 and Figure 2.3.

The more detailed meteorological records are available at Ahero Research Station and the Nyakwere meteo-station. The collected data comprise rainfall, relative humidity, air temperature, wind velocity, sunshine hours, solar radiation and evaporation. Their details are presented in Appendix-II "Climate". Table 2.1 summarizes the meteorological features at the project area. The records indicate that the mean annual rainfall ranges from 960 mm to 1,770 mm. The rainfall pattern has two peaks, one is March to May and the other one is October to December. Although there is no pronounced dry season, January and February are relatively dry months.

According to Soil Survey Staff of U.S. Department of Agriculture[17/], the soil moisture regime and the soil temperature regime are determined in Kenya. Water balance diagram is constructed as shown in Figure 2.4. The diagram shows how much moisture surplus is stored during rainy seasons and during which period this surplus, if stored in the soil, can compensate by the excess of evapotranspiration in the dry seasons. It can be concluded from the diagram that the soil moisture regime is "ustic" according to Soil Taxonomy (1975). The ustic (L. USTUS, burnt, implying dryness) moisture regime is intermediate between the aridic (arid) and the udic (humid) regimes.

The concept is one of limited moisture, but moisture is present at a time when conditions are suitable for plant growth. In Kenya, the following relationship is recognized between the soil moisture regime and the moisture availability (r/Eo):

Soil moisture regime	r/Eo ratio (in %)	Moisture availability zones
udic	> 55	I, II, part of III
ustic	31 - 55	part of III, IV, part of V
aridic	< 31	part of V, VI, VII

Temperature of a soil is one of its important properties. Within limits, temperature controls the possibilities for plant growth and for soil formation. Soil temperature often can be estimated from the air temperature. For the soil temperature regime, the following relationship is recognized:

Soil temperature regime	Average annual temperature (in ^{o}c)	Temperature zones
isofrigid	< 8	most of 9
isomesic	8 - 15	7,8, part of 6,
isothermic	15 - 22	3,4,5, part of 6
isohyperthermic	> 22	1,2

The project area belongs to "isothermic" in temperature regime.

2.2 Physiography and Geology

The landscape of the project area and its surrounding is recognized as a part of the Rift Valley system. It shows the typical fault formation resulting from the syntechtonic movement which has taken place during Tertiary period. The landscape is represented by the uplifted horst (escarpment) and the downthrown graben (Nyakach plain) along the Nyabondo fault line traversing with east-west direction. Granodiorite and phonolite are the predominant rocks.

The project area lies mainly on the Nyakach plain which is physiographically classified into piedmont plain. It is the coalescening colluvial and alluvial fans, which are formed immediately adjacent the escarpment, elongating from the Asawo river to Kendu bay. The materials covering the piedmont plain are the unconsolidated reddish particles underlain by the dark lacustrine deposits originating from Lake Victoria.

In the northeastern part of the project area, the widely extending plain appears as the pronounced physiography which occupies the eastern shore of Lake Victoria with a total extent of approximately 70,000 ha. The geological origin is the lacustrine deposits which are characterized by fine texture and blackish colour. The plain is incised by the various rivers and streams which drain into the Lake. The principal river is the Nyando on the eastern plain. The Nyando river flows across the plain with south-west direction and turns southwards at Ahero to terminate in the Miruka (Luo) swamp. Due to unfavourable drainage condition, the plain partly suffers from seasonal flooding.

2.3 Vegetation and Land Use

Several types of natural vegetation are recognized in the area. The hilly lands are generally covered by evergreen or semi-evergreen forests and grasses due to moderately high rainfall and soils of free drainage. The lowland is mostly covered with grassland scarce forests as a result of comparatively lower rainfall and soils of imperfect drainage. Figure 2.5 shows the aerialphoto interpretation map for vegetation and land use.

Forest and scrub woodland are the mosaic of evergreen bush and thicket mixed with trees. Forest partly covers the scarp and convex summits of Nyabondo Escarpment, namely Koguta forest. Scrub woodlands are open stand of trees and bush occuring with low grasses.

The Kano plain and its surrounding highlands are extensively utilized for agricultural implements. Due to favourable drainage and relatively flat topography, the upland crops are planted in the large portion of the project area as shown in Figure 2.5. The main crops are maize and sorghum. Other common crops are peas, beans, groundnuts, cassava and bananas. Cotton is an important cash crop in the area. The plots of upland crop fields are generally parcelled by sisal and a sort of thorn trees. The homestead area, namely Bomma, are located associating with the upland fields.

Locally on the shore of Lake Victoria and back swamp along the small streams, the rainfed paddy is planted. Since the lowlying paddy fields suffer from frequent flooding and draught hazard, the planted area is limited in the project area.

Chapter 3. SURVEY PROCEDURE

3.1 Review of Previous Studies

Prior to the field survey, the following data were collected and reviewed.

1. J. Makin and V. D'Costa, 1966, Soils of the Nyando pilot irrigation scheme. Govt. Report (map scale 1:5,000)

2. V. D'Costa and S.H. Ominde, 1973, Soil and land use survey of the Kano plain, Nyanza Province. Occ. Memoir No. 2, Dept. of Geogr., Univ. of Nairobi (1:50,000)

3. Sir Alexander Gibb & partners, 1981, F/S on the South Kano Irrigation Scheme, Annex 1 Soil (1:10,000)

4. G. R. van Dijk, J. Hayma and J. A. M. van Voorst tot Voorst, 1978, Detailed soil survey of the irrigation scheme Kano west and soil survey of the Ahero Research Station, Agricultural University Wageningen the Netherlands
5. Kenya Soil Survey, 1980, Exploratory soil map and agro-climatic zone map of Kenya (1:1,000,000)

Among them, the second one is the systematic semi-detailed soil survey which aims at giving the soil characteristics of the Kano plain and the suitability of the soil for major crops under irrigation. The soil map covers the whole Kano plain partly including the present study area.

As a nation-wide study the Exploratory soil map of Kenya presents the basic information about not only soils but also geology, topography, vegetation and land use.

3.2 Reconnaissance Survey

In order to grasp pedological features of the project area , the reconnaissance soil survey was carried out in February 1984 in the study area defined as approximately 120,000 ha of Kano and Nyakach plains. The study result is presented in the Inception Report prepared in March 1984.

Through the review of previous studies, the high coincidence has been recognized between physiography and soil formation. In other words, each physiographic unit implies individual geology, topographic condition, soil characteristics, drainage condition and even land use. Therefore, the reconnaissance soil survey was performed by physiographic approach. This means that the highest category is given by physiographic unit in the soil map legend.

For this approach, aerialphoto interpretation was fully applied to clarify the surface configulation of the areas as well as land use features. They also show the external drainage conditions and the distribution of water bodies. In addition to aerialphotos, the visual interpretation of multitemporal images of Landsat are worked out to check the seasonal changes in the land surface.

3.3 Semi-detailed Soil Survey

Referring to the provisional soil map prepared through the reconnaissance survey , the semi-detailed soil survey was carried out in the Nyakach plain covering 14,000 ha during the period from June to August 1985. On the aerialphotos the test pit sites were selected taking account of topographic position and accessibility to the sites.

Through the field survey, about 100 cm deep pits were dug at seventy one (71) sites and observed according to the FAO publication "Guidelines for Soil Profile Description". At the same time, the soil samples were collected for the later laboratory test. Finally eighty two (82) soils were sampled from thirty one (31) profiles. In order to check the location of soil boundaries in the field, auger borings were additionally carried out.

3.4 Laboratory Test

Laboratory test aims at clarification of the physical and chemical properties of soils of the project area. All samples collected in the field were sent to the National Agricultural Laboratories (NAL) in Nairobi through GAUFF. They were analyzed with respect to the following eight (8) test items;

1) Physical Analysis
   - particle size distribution (Soil texture)

2) Chemical Analyses
   - pH value
   - electrical conductivity (EC)
   - total carbon content
   - total nitrogen content
   - available phosphorus
   - cation exchange capacity (CEC) at pH 7
   - exchangeable cations, i.e. Ca, Mg, Na and K

All the analyses are made according to the manual compiled by National Agricultural Laboratories, namely "Physical and Chemical Methods of Soil Analysis". Table 3.1 summarizes the test methods employed.

3.5 Classification and Mapping

Based on the field data and the laboratory test results, the soils were classified into Soil Units according to the legend or "Soil Map of the World" produced by FAO/UNESCO, and the soil mapping units are set up for constructing the systematic legend of the soil map. Pursuant to the survey methodology applied in the reconnaissance survey, the semi-detailed soil survey is also carried out by physiographic approach. Therefore the highest category of the legend is given by physiographic terms, i.e. hill, piedmont plain, lacustrine plain etc. These physiographic units are further divided into the lower categories on the basis of topographic conditions, geological origin, etc. These subdivisions represent mapping units on which one or more Soil Units are identified. They may be similar or contrasting but occur together in a more or less regular pattern, and are so intimately associated that they cannot be separated by boundaries at the semi-detailed level.

In order to show the distribution and the extent of each mapping unit, the soil map is prepared at a scale of 1:50,000.

3.6 Land Evaluation

Land evaluation is the process of interpretation of the basic information gathered through the soil survey, i.e. soil, topography, drainage condition and other aspects of land. In assessing the land suitability for irrigation farming, the land qualities are selected and graded according to the specific criteria set forth by KSS.

Through the land evaluation, the location and extent of suitable land for irrigation farming are demarcated on land suitability classification map scaled at 1:50,000. This information is applied for the selection of the future irrigated land and the crops making comparison of the many crop alternatives.

Chapter 4. SOILS

4.1 Result of Field Survey and Laboratory Analyses

According to the survey procedure mentioned above, the field survey and the laboratory test were carried out. Through the soil profile survey,well-cultivated soils, diggings were also made at Ahero Rice Pilot Scheme and the sugarcane field of Miwani. The soil profile descriptions are summarized in Table 4.2. The laboratory test result is presented in Table 4.3.

4.2 Soil Classification

On the basis of field survey records and laboratory test results, the soils are classified into Soil Units according to the legend of Soil Map of the World (FAO/UNESCO, 1974) and its modification namely "Kenya Concept". Due to complexity of physiography and variation of geological origin, diversities of Soil Units are identified. The major Soil Units in and around the project area are presented below:

1. Eutric Fluvisols
2. Calcaric Fluvisols
3. Eutric Gleysols
4. Eutric Regosols
5. Lithosols
6. Ferralic Arenosols
7. Pellic Vertisols
8. Vertic Cambisols
9. Chromic Cambisols
10. Ironstone Soils

The following paragraphs explain the baseline features of Soil Units identified.

(1) Eutric Fluvisols

Fluvisols are young soils consisting of various thin layers of sediment of differing texture. Eutric Fluvisols are derived from recent fluvial deposits having a base saturation (by NH4OAc) of 50 percent or more at least between 20 to 50 cm from the land surface but which are not calcareous at the same depth. The representative profile of this unit is prepared in Table 4.4.

(2) Calcaric Fluvisols

Calcaric Fluvisols are developed from recent fluvial deposits which have calcarious horizon within 50 cm of the surface. The representative profile of this unit is prepared in Table 4.5.

(3) Eutric Gleysols

Gleysols are poorly drained soils, in low-lying areas and in depressions, which are influenced by high groundwater table and therefore show hydromorphic properties. Eutric Gleysols have a base saturation of 50 percent or more at least between 20 cm and 50 cm from the surface but not calcareous within this depth. The representative profile is prepared in Table 4.6.

(4) Eutric Regosols

Regosols are very young soils, almost without soil development. They consist mainly of unconsolidated soil materials, exclusive of recent alluvial deposits. Regosols retain little water. Eutric Regosols have a base saturation of 50 percent or more at least between 20 and 50 cm from the surface but not calcareous within this depth. The representative profile is prepared in Table 4.7 and Table 4.8.

(5) Lithosols

By definition (FAO/UNESCO) Lithosols are soils limited in depth by continuous hard rock within 10 cm of the surface. This depth limitation was found to be inadequate for Kenyan conditions and is re-set at 25 cm. The representative profile is given in Table 4.9.

(6) Ferralic Arenosols

Arenosols are very light-coloured, coarse-textured sandy soils with a high proportion of almost pure quartz. The subsoil may show characteristics of an argilic, cambic or oxic B horizon. They do not, however, have such horizons because the soil texture is too coarse. Ferralic Arenosols show the ferralic properties with many coarse mottles with hues redder than 7.5 YR or chromas more than 5. The representative profile is presented in Table 4.10.

(7) Pellic Vertisols

Vertisols are heavy clay soils (clay >30%) which shrink and have large deep cracks of more than 1 cm wide at a depth of 50 cm. The soil has a high water retention, but relatively small amount of water is available for plant growth. There are two types of Vertisols, namely Pellic Vertisols and Chromic Vertisols. Pellic Vertisols are dark, almost black, usually occupying shallow depression that are somewhat waterlogged during the rainy season. On the other hand, Chromic Vertisols are brownish and better drained. The representative profile of Pellic vertisols presented in Table 4.11.

(8) Vertic Cambisols

Cambisols have a cambic B horizon or an umbric A horizon (dark topsoils). The cambic B horizon is an altered horizon with a soil structure, or with some clay illuviation, or with a red colour. They are in a transitional stage of development between young soils and the more matured soils. Vertic Cambisols have an ochric A horizon (reddish topsoils) showing vertic properties.

(9) Chromic Cambisols

Chromic Cambisols are Cambisols having an ochric A horizon and a base saturation of 50 percent or more at least between 20 and 50 cm from the surface but not calcareous within this depth.

(10) Ironstone Soils

Ironstone soils is defined so as to embrace all soils with a massive ironstone layer (petro-ferric horizon) starting within 50 cm of the surface. It is a pragmatic grouping to cover a variety of Soil Units that all have in common the presence of massive ironstone at shallow depth, although the soils themselves may be genetically different. The representative profile of Ironstone Soils is prepared in Table 4.12.

4.3 Legend Composition of Soil Map

4.3.1 General

The soil mapping units are grouped according to their physiographic position in the field and the parent material on which they are formed. At the highest category in the legend (entry) the following physiographic units are distinguished:

1. Hills - escarpment and Nyabondo plateau
2. Piedmont plain - Nyakach plain
3. Cuspate delta - deltaic deposits in the river mouth of Sondu
4. Uplands - terrace like elevated lands formed by lava flow
5. Fan base - upper part of Kano Plain
6. Lacustrine plain - Kano Plain proper
7. Swamp - Miruka swamp and other minor swamps

Seven physiographic units are further divided into thirty-four (34) landtypes on the basis of their topographic condition. These landtypes are defined as mapping units in the present study.

4.3.2 Differentiating Criteria

In order to describe and differentiate the soil characteristics in the legend and the mapping unit descriptions, the differenciating criteria are used as follows.

(1) Texture, structure and consistence are described according to the Guidelines for soil profile description (FAO, 1977).

(2) Colour of the soils are described according to the Revised Standard Soil Colour Charts.

(3) Soil reaction is described according to the following classes corresponding to soil pH value.

Class	pH-H_2O rate
Extremely acid	< 4.5
Strongly acid	4.5 - 5.5
Slightly acid	5.6 - 6.5
Neutral	6.6 - 7.3
Moderately alkaline	7.4 - 8.4
Strongly alkaline	8.5 - 9.0
Very strongly alkaline	9.0 <

(4) Soil salinity is described according to the following classes corresponding to Electrical Conductivity (EC) value.

Salinity class	ECe (mmho/cm)	EC 2.5* (mmho/cm)
Non-saline	< 4	< 2
Slightly saline	4 - 8	2 - 4
Moderately saline	8 - 16	4 - 8
Strongly saline	16 <	8 <

* valid for moist material with a texture of clay

(5) Soil sodicity is described according to the following classes corresponding to Exchangeable Sodium Percentage (ESP).

Sodicity class	ESP *
Non-sodic	0 - 5
Slightly sodic	6 - 10
Moderately sodic	11 - 15
Strongly sodic	15 <

* ESP can be given as a value of exchangeable Na divided by total exchangeable cations.

(6) Soil depth is described according to the following classes.

Effective Soil Depth Class	depth (cm)
Very shallow	< 30
Shallow	30 - 60
Fairly deep	60 - 90
Deep	90 <

(7) Topography is described in terms of single slope and complex slope as follows.

- Complex slope	%	degree
(1) Flat or almost flat	< 2	< 1^{o}
(2) Undulating	2 - 8	1 - 4
(3) Rolling	8 - 16	4 - 9
(4) Hilly	16 - 30	9 - 16
(5) Steeply dissected	30 <	16 <
(6) Mountainous	great range in elevation	

- single slope

(1)	Flat or almost flat	< 2	< 1°
(2)	Gently sloping	2 - 6	1 - 3
(3)	Sloping	6 - 13	3 - 7
(4)	Moderately steep	13 - 25	7 - 14
(5)	Steep	25 - 55	14 - 28
(6)	Very steep	55 <	28 <

(8) Soil drainage refers to the rapidity and extent of the removal of water from the soil especially by surface runoff and by flow through the soil. On the basis of the observations, relative soil-drainage classes are described below.18/

1. Very poorly drained - Water is removed from the soil so slowly that the water table remains at or on the surface the greater part of the time. Soils usually occupy level or depressed sites and frequently ponded.

2. Poorly drained - Water is removed so slowly that the soil remains wet for a large part of the time. The water table is commonly at on near the surface during a considerable part of the year.

3. Imperfectly or somewhat poorly drained - Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Imperfectly drained soils commonly have a slowly permeable layer within the profile.

4. Moderately well drained - Water is removed from the soil somewhat slowly, so that the profile is wet for a small but significant part of the time. Moderately well drained soils commonly have a slowly permeable layer within or immediately beneath the solum.

5. Well drained - Water is removed from the soil readily but not rapidly. Well-drained soils are commonly intermediate in texture.

6. Somewhat excessively drained - Water is removed from the soil rapidly. Some of the soils are lithosolic. Many of them have little horizon differentiation and are sandy and very porous.

7. Excessively drained - Water is removed from the soil very rapidly. Shallow soils on slopes may be excessively drained

4.4 Mapping Unit Description

4.4.1 General

Seven physiographic units mentioned above are further divided into thirty-four (34) soil mopping units with the aid of aerial photo. The distribution of each mapping unit is presented on the semi-detailed soil map in Figure 4.1.

The detail information of mapping units can be refered to the legend of soil map. The baseline features of each unit are described below.

4.4.2 Soils of Hills (H)

Hills (H) are represented by the Nyabondo escarpment formed as a result of syntechtonic movement during Tertiary period. The unit stands higher than El.1,260 m. The predominant rocks are intermediate igneous ones, i.e. granodiorite and phonolite.

The soils can be broadly classified into two units, namely Rhodic Ferralsols and Lithosols. Rhodic Ferralsols are the well-weathered soils developed on the Nyabondo plateau (H1). They show the dark red and deep homogeneous profile overlying ironstone or petro-plinthite.

Lithosols are the immatured shallow soils on the steep slopes (H2).

4.4.3 Soils of Piedmont Plain (P)

Piedmont plain (P) is the coalescening colluvial and alluvial fans which are formed on the footslopes of the escarpment. The unit is gently sloping with the gradient of 1/50 to 1/70 and partly incised by deep gullies. The upper part is the narrow strip of colluvial apron lying between El. 1,260 m and 1,400 m, immediately adjacent to the escarpment. The lower part is covered by alluvium transported from the colluvial apron and it extends downward to the lake shore.

Since the parent material of soils is the mixture of alluvium and colluvium derived from the intermediate igneous rocks, the soils are moderately basic. The main soils are Ferralic Arenosols on the higher part (P1, P2) and Chromic Cambisols on the lower part (P3). Ferralic Arenosols are reddish brown and porous loam with gravels and stones. Chromic Cambisols are characterized by the pronounced stratification consisting of the brown porous topsoils of 0.3 to several meters thick and the block of clayey subsoils having vertic property. They occur in association with Eutric Regosols. The soils are extensively used for crop production with maize, sorghum and cotton. Besides the lands are being threatened by severe erosion as a result of heavy grazing prevailing in the area.

4.4.4 Soils of Cuspate Delta (D)

Cuspate delta (D) is the low lying flat terrain formed especifically in the river mouth of the Sondu. On the fringe of the delta, the narrow but pronounced sand ridges (D2) are recognized along Osodo Bay. The soils are loose and well drained. They are classified into Eutric Regosols. Except those ridges the delta area suffers from frequent floods during the rainy season. The origin of soils is the fluvial deposit transported by the Sondu river. They show the gray to brownish black profiles with complex layers of stratified, mixed and varied textured material with a predominance of clay.

Through alternation of inundation and drying, the soluble salts have been accumulated in the upper layers of soils. By the process of alkalization the soil pH increases over 9 and the soils are extremely compacted and poorly drained due to dispersion of clay mineral which is caused by accumulation of sodium in soils. They are classified into Calcaric Fluvisols, sodic phase. In the center of the delta, the seasonally submerged depression (D14) is formed where Eutric Fluvisols occur. The soils are darker and finer than the former type of soils.

4.4.5 Soils of Uplands (U)

Upland (U) occupies the east of Kano plain. They are the remnants of lava flow consisting of basic igneous rock, namely Kericho type phonolite. The unit lies higher than El. 1,200 m. The soils of uplands are the immatured soils showing reddish brown shallow profiles. The main soils are Ironstone Soils.

4.4.6 Soils of Fan Base (F)

Fan base (F) shows the similar external features with the lower part of piedmont plain. The unit lies on the upper fringes of Kano plain between the Awach Kano river and the Asawo river. The origin is the mixture of sediments derived from granodiorite and phonolite of the surrounding hilly lands.

The predominant soils are Chromic Vertisols , Pellic Vertisols and Eutric Regosols. Chromic Vertisols are the widely extending soils which have the reddish porous topsoils overlying the dark clayey subsoils (F11). Pellic Vertisols develop on the lower position of fan base (F12). Vertisols are characterized by the blackish cracking clay and calcareous properties. Eutric Regosols are the loose sandy soils on the higher sites of along the stream banks below the micro-ridges (F4). Eutric Fluvisols occur with high permeability and irregular micro-relief.

4.4.7 Soils of Lacustrine Plain (K)

Lacustrine plain (K) appears as the pronounced physiographic unit in the area. This unit occupies the large portion of the Kano plain. It is an infilled valley rising gently from the lake shore. Their origin is the lacustrine deposits which are characterized by cracking clay of blackish colour. The micro-relief of the plain is gently undulating owing to the minor ridges, water courses, levees, swamps and complicated sequences of hill wash. The plain descends from El. 1,220 m to 1,135 m with ENE-WSW slope. Consequently, the several streams and ephemeral creeks drain in such direction into the Miruka swamp. The main river is the Nyando which rises in Tinderet highlands and flows across the plain in SW direction, until it reaches Ahero, when it turns southwards to terminate in the Miruka swamp. The other rivers and water courses are the Nyaidho, the Awach Kano and the Asawo.

Since these rivers rise in areas of heavy rainfall, frequent flooding occurs in the large portions of the plain. The soils are represented by Pellic Vertisols which are developed on the lacustrine deposits of lowlying terrain (K2). They are very dark gray or black clay with a very shallow surface coverage of dark brown recent origin.

The clay fraction is composed of 60% of montmorillonite with remainder illite and kaolinite in equal proportions. When dry the soils develop deep vertical cracks and become hard to extremely hard in consistency. Since the profile permeability is negligibly slow, the soils are easily inundated after heavy rainfall and overflowing from minor streams. Topsoils tend to be acid to neutral in reaction but subsoils are generally alkaline.

At present, the soils are extensively used for crop cultivation. Along the left bank of the Nyando river, Chromic Vertisols are identified on the slightly higher lands of the massive, alkaline and calcareous mudstone (K1).

4.4.8 Soils of Swamp (S)

Swamp (S) extends near the lake shore. The unit can be further divided into two subunits according to inundated period, i.e. seasonal and permanent swamps. The soils are very poorly drained and covered by partly decomposed peat. The soils are classified into Pellic Vertisols and Eutric Gleysols in the seasonal swamps (S1) and Dystric Histosols in the permanent swamps (S2). Eutric Gleysols are non saline-alkaline clayey soils. This seasonally waterlogged soil appears better suited to rice cultivation. In fact, the seasonal swamp of Wasare is partly used for wetland rice. Dystric Histosols are the organic soils of Papyrus origin.

4.5 Physical and Chemical Properties of Soils

4.5.1 Soil Texture

Soil textural class can be grouped as follows, according to the specific ranges as shown in Figure 4.2. Each class is defined on the basis of the particle size distribution. The texture is the most permanent characteristic of the soil. It influences a number of the other soil properties, e.g. structure, consistency, water holding capacity, permeability, infiltration rate, run-off rate, erodability, workability, root penetration and fertility.

Soils	Texture	Class names
Sandy soils	coarse textured	S and Ls
Loamy soils	moderately coarse textured	SL
	medium textured	L, SiL and Si
	moderately fine textured	CL, SCL and SiCL
Clayey soils	fine textured	C, SC and SiC

As shown in Figure 4.2, the soils of the study area broadly vary from coarse to fine in texture. The soils on the fan base and the lacustrine plain are rather finer. In the piedmont plain, some coarse textured soils are observed.

4.5.2 Soil Reaction (pH)

Soil reaction (pH), which is expressed by the negative logarithm of the hydrogen activity in a soil-water suspension, was measured in the laboratory. The pH values widely range from 4.8 to 10.4 as shown in Figure 4.3. The figure also shows the relation between soil pH and electrical conductivity (EC). The pH values of 8.5 or more usually occur in the soils where presumably alkaline earth carbonates or much sodium ion are present.

Figure 4.4 shows the ph value - EC relation by physiographic unit. In cuspate delta, high pH of 9 or more is observed. In the other physiographic units, the pH values indicate the soils are weakly acid to weakly alkaline.

Figure 4.5 gives the changes in soil pH and EC with depth for five representative soil profiles. In general the pH values of the subsoils are rather constant with depth and have not the pronounced correlation to EC.

4.5.3 Salinity

The EC values of all samples were measured in extraction from a soil-water (1:2.5) suspension. For some samples, saturated paste was prepared and EC of saturation extract (ECe) was measured. Assuming a liner inversed relationship between ECe and EC2.5, the ratio of 2:1 was roughly obtained. This conversion factor of 2 is applied for the appraisal of salinity hazard.

The EC2.5 are used for the definition of salinity classes. A saline phase is applicable for soil classification, if some horizons within 100 cm of the surface have ECe of higher than 4 mmho/cm or 2 mmho/cm.

As shown in Figure 4.4, only in the cuspate delta and the lake shore along the piedmont plain the higher EC values are recorded. This means that these lowlying areas have the potential salinity hazard in the future crop production.

4.5.4 Sodicity

Sodicity of a soil is represented by Exchangeable Sodium Percentage (ESP) adsorped on the soil exchange complex. Soils which have more than 6% saturation with exchangeable sodium in some horizons within 100 cm of the surface are identified as soils with a sodic phase (FAO-UNESCO, 1974).

The soils having ESP of more than 15 are classified into alkali soils. As shown in Figure 4.6, extremely high ESP values are observed in the cuspate delta.

4.5.5 Cation Exchange Capacity and Exchangeable Bases

The cation exchange capacity (CEC) of the soils ranges from 1.3 to 32.5 me/100g. The variation largely depends on clay content of soil as shown in Figure 4.6. In the soils on piedmont plain, CEC is rather low due to low clay content (see Table 4.3). Although organic matter also contributes to the exchange complex, the pronounced relationship between CEC and organic matter content is not recognizable.

The major exchangeable bases are Ca, Mg, Na and K. The base saturation (total exchangeable cations divided by CEC) of soils is generally more than 50%. Slightly to strongly saline soil horizons commonly have a base saturation of 100%. In these horizons total exchangeable cations exceed CEC. This means that soils contain crystalline salts.

As mentioned in Section 4.5.4, another unfavourable condition is the relatively high amount of Na on the exchange complex which is associated with a considerable dispersion of the soil.

Chapter 5. LAND EVALUATION

5.1 Classification System

The land classification system produced by the U.S. Bureau of Reclamation (USBR) has been applied to a number of irrigation projects in many countries. In the USBR system, the land is categorized into six suitability classes. The basic concept of this system is to evaluate the economic return against the investment for the project works.

Since it is difficult to adapt this system in Kenya directly due to lack of the economic data, KSS has modified the specified criteria to allow for the Kenyan conditions. The proposed criteria for irrigation suitability classification is set forth based primarily on the physical and chemical constraints of the areas (F.N Muchena, 1981). For the present study, this modified classification system is employed. In order to clarify the land suitability for the alternative crop production, the appraisal is made for both wetland rice and the common upland crops.

5.2 Land Suitability Classes

There are two kinds of interpretative land classification as follows;

a) Current land suitability: an appraisal of the suitability of land for irrigation without significant land improvement measures as to alter the present limitations and qualities of the land.

b) Potential land suitability: an appraisal of the potential suitability of the land for irrigation with significant land improvement measures as to require improvement level and type of land.

In order to clarify the suitability for the future development, the appraisal of potential land suitability is carried out in the present study. The appraisal is done under the following conditions;

a) Sufficient irrigation water of good quality is supplied to the areas concerned. Irrigability is, therefore, not considered.

b) Proper drainage network is established. This allows to remove the stagnant water in the minor depressions and the excess irrigation water.

c) Except for the extremely populated area, the present inhabitant area can be changed into irrigated land in future.

According to the specific criteria, five suitability classes are designated as follows.

Class S1: Highly suitable

Land of high productivity for most crops under irrigation with minimum costs of development and management associated with the land.

Class S2: Moderately suitable

Land of moderate productivity due to slight to moderate limitations in land characteristics with moderate costs for development and management.

Class S3: Marginally suitable

Lands of restricted productivity due to moderate to severe limitations in land characteristics with relatively high costs for development and management.

Class NS1: Provisionally unsuitable

Lands which are considered unsuitable for irrigation but require further investigation.

Class NS2: Unsuitable

Lands which are unsuited for irrigation due to severe limitations in soils, topography or drainage.

5.3 Specific Criteria

5.3.1 General

In Kenya, suitability for the future land use with irrigation is evaluated with the following land qualities (Muchena, 1981).

a) soil deficiencies (symbol 's')
   - soil texture
   - soil depth
   - alkalinity
   - salinity

b) drainage (symbol 'd')

c) topography (symbol 't')
   - slope
   - microrelief

d) vegetation (symbol 'T')

Table 5.1 and Table 5.2 give the specific criteria for wetland rice and common upland crops. The following paragraphs deal with the further details of the land qualities concerned.

5.3.2 Soil Texture

Soil texture is given by the particle size fraction. The soil permeability and the water holding capacity are directly related to the soil texture. For upland crops, soils of sandy loam to friable clay are highly suitable. For rice, the subsoil texture should be finer since low permeability is rather favourable.

All soils on the Kano plain has favourable soil texture. On the other hand, the soils on the Nyakach plain are a little porous with the coarser particles. In the Nyakach plain the presence of stratified sand may increase the initial investment for the irrigation canals to intercept permeable sandy layer.

Most of soils in the project area are thick enough for the minimum requirements of soil depth of 45 cm for upland crops and 30 cm for rice.

5.3.3 Alkalinity and Salinity

The soil pH is one of the important characteristics for the evaluation of the land suitability. Because of the basic geological origins, the soil pH values are generally high. Limitations due to acidity are not relevant to the project area. The pH value ranges between 4.8 and 10.4. Higher values occur locally only on the cuspate delta.

Sodic material has an adverse effect on the chemical and physical conditions of soil. The high sodium content on the exchange complex causes easy dispersion of the clay complex. As a result, the soils are extremely compacted and hard. Structure stability of this soil material is low. In the construction of canals, some difficulties may be risen where the sodic materials present at shallow depth.

Soil salinity is also an important characteristics for the evaluation of the land suitability. The electrical conductivity (EC) can indicate the soil salinity classes. In the specific criteria, the EC value of the saturation extract (ECe) is used for the definition of salinity classes, as described in Section 4.3.2 Differenciating Criteria. Most of soils in the project area are rather low in soil salinity except for the extreme cases in the depression into which salts are drained.

5.3.4 Drainage

As mentioned in Section 4.3.2, seven drainage classes are defined in broad terms. According to U.S. Soil Survey Manual, the necessity of artificial drainage works is dealt with these drainage classes.

1. Very poorly drained --- The soils are wet enough to prevent the growth of important crops (except rice) without artificial drainage.

2. Poorly drained --- Artificial drainage is generally necessary for crop production, provided that other soil characteristics are favourable.

3. Imperfectly or somewhat poorly drained --- The growth of crops is restricted to a marked degree, unless artificial drainage is provided.

4. Moderately well drained and Well-drained --- The soils of these classes commonly retain optimum amounts of moisture for plant growth after rains or additions of irrigation water.

5. Somewhat excessively drained --- Only a narrow range of crops can be grown on these soils, and the yields are usually low without irrigation.

6. Excessively drained --- Enough precipitation is commonly lost from these soils to make them unsuitable for ordinary crop production.

In the study area, the soils of lowlying land in lacustrine plain fall the drainage classes 2 to 3. On the other hand, the soils of the piedmont plain are of the drainage classes 3 to 5.

5.3.5 Topography

Topographic limitations are derived from micro-relief of the land. Macro-relief is expressed by the length and steepness of slope. Except on the higher land lying adjacent to the hills, the slope is not limiting factor in the project area. Micro-relief deals with irregularities of land within short distances. The minor irregularities shall be improved through the Project. Particularly for rice, the land levelling shall be required.

5.3.6 Vegetation

This factor indicates the degree of land clearing. Vegetation cover ranges from grass to dense forest. This variation directly relates to the clearing cost. As for clearing needed, the project area is not restricted by vegetation.

5.4 Result of Land Evaluation

5.4.1 General

The appraisals of land suitability are made both for wetland rice and common upland crops. Tables 5.3 and 5.4 give the distribution of suitability classes by Sub-area, which is parcelled by rivers according to geographical location. Land suitable classification map is presented in Figure 5.1. The following tables summarize them.

Land Suitability Classes for Wetland Rice

Suitability Class	Project Area		Extensionable Area	
	ha	%	ha	%
S1	3,120	22.3	3,810	28.6
S2	0	0.0	0	0.0
S3	6,710	48.0	2,690	20.0
NS	4,150	29.7	6,840	51.0
Total	13,980	100.0	13,340	100.0

Land Suitability Classes for Upland Crops				
Suitability Class	Project Area ha	%	Extensionable Area ha	%
1	0	0.0	0	0.0
2	7,910	56.6	2,830	21.2
3	3,200	22.9	5,980	44.8
NS	2,870	20.5	4,530	34.0
Total	13,980	100.0	13,340	100.0

Out of 13,980 ha of Project Area, 9,830 ha (70.3%) are suitable for paddy and 11,110 ha (79.5%) are suitable for upland crops.

5.4.2 Land Suitability Classes for Wetland Paddy

Owing to flat topography and finer soil, the lowlying land on the Kano Plain (K2) is categorized into highly suitable land. Although the irregular micro-relief occurs resulting from small gullies, the lower parts of the piedmont plain (P31, P32) and the fan base (F11, F12, F22) are marginally suitable.

Due to unfavourable topographic condition and coarser soil, the higher parts of piedmont plain (P11, P2, P33, P34) are unsuitable for paddy. The chemical status of soils of the delta (D) severely limit the future agricultural development. The shallow soil depth also restricts the paddy cultivation on the uplands (U1, U2).

In view of distribution of each suitability class, the large portion of Sub-area III is highly suitable for paddy cultivation. Besides, Sub-areas I and II are marginally suitable for paddy.

5.4.3 Land Suitability Classes for Upland Crops

No highly suitable land exists in the study area because of topography dessected by many streams. The lower parts of the piedmont plain (P31, P32) and the rather well-drained land of the Kano Plain (K21) are moderately suitable for diversified upland crops. The other suitable lands distribute on the fan base (F11, F12, F22, F3, F4) and the lowlying area of the Kano Plain (K22). They are marginally suitable for upland crops due to imperfect drainage condition.

The soils on the lake shore (P33, P34) and on the delta (D1) are unsuitable due to the potential alkalinity and salinity hazard. The upland (U1, U2) is also unsuitable due to shallow soil depth.

As mentioned above, about 80% of the study area is suitable for upland crops. Sub-area II lying on the piedmont plain may be the most suitable area for the large scale irrigation farming with upland crops.