THE REPUBLIC OF THE SUDAN
MINISTRY OF AGRICULTURE

ROSEIRES SOIL SURVEY

REPORT No. 8

THE NILE
FROM KAREIMA TO THE THIRD CATARACT

SEMI-DETAILED SOIL SURVEY AND LAND CLASSIFICATION OF SELECTED AREAS

VOLUME I

THE REPORT

HUNTING TECHNICAL SERVICES LTD.
4 ALBEMARLE STREET
LONDON, W.1

SIR M. MACDONALD & PARTNERS
CONSULTING ENGINEERS
LION HOUSE
RED LION STREET
LONDON .. W.C.1

MAY 1965

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Sir M. MacDonald & Partners

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CONSULTANTS:
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G. LACEY, C.I.E., F.C.G.I., B.SC., M.I.C.E., M.CONS.E.
A. M. R. MONTAGU, C.I.E., F.C.G.I., M.I.C.E.

YOUR REF.........................

OUR REF. ....

Lion House
Red Lion Street
London, W.C.1

TELEPHONES: CHANCERY 5747-8-9
TELEGRAMS: SCREETAN, LONDON
CABLEGRAMS: SCREETAN, LONDON

10th July, 1965.

H.E. The Minister of Agriculture,
Ministry of Agriculture,
Khartoum,
SUDAN.

Your Excellency,

ROSEIRES SOIL SURVEY
REPORT No.8 (AREA 4 NORTH)
THE NILE FROM KAREIMA TO THE THIRD CATARACT

We have pleasure in submitting our Report No. 8 for the Roseires Soil Survey Project, the study of which was entrusted to us by the Contract for Soil Survey of Irrigable Lands in the Sudan dated September, 1962.

The Report, which is in two volumes, accompanied by an album of maps, contains the results of the semi-detailed soil survey and land classification for the area between Kareima and the third cataract along both banks of the Nile, the northern section of the area referred to as Area 4 in the Contract.

The interpretation of the land classes as agreed with the World Bank is that Classes 2, 3a and 4a are all suitable for long staple cotton rotation of the Managil type. These lands have self-mulching soils of high clay content which Finck and Ochtman show to be capable of producing high cotton yields; at the same time, the level of exchangeable sodium does not have a depressive effect on the yields of arable crops. Classes 31 and 41 lands may be used for fruit, vegetables or forest areas or for village sites.

The following project areas are recommended for development:- Kerma Basin, (31,580 feddans) Dongola Plain, (7,405 feddans) El Bakri Plain (24,510 feddans) Letti Basin (9,440 feddans) Urbi Plain, (1,675 feddans) Affat Basin, (3,285 feddans) Kulud Plain, (2,025 feddans) Korti Plain, (535 feddans) Gureir Plain, (5,730 feddans) Fitna Plain, (835 feddans). The actual areas for development will depend on the outcome of the study of the Class 5 lands. Outline proposals for irrigating these areas were given in our Roseires Soil Survey Report No. 3, "The Nile from Kareima to the Third Cataract, Soils and Engineering Reconnaissance".

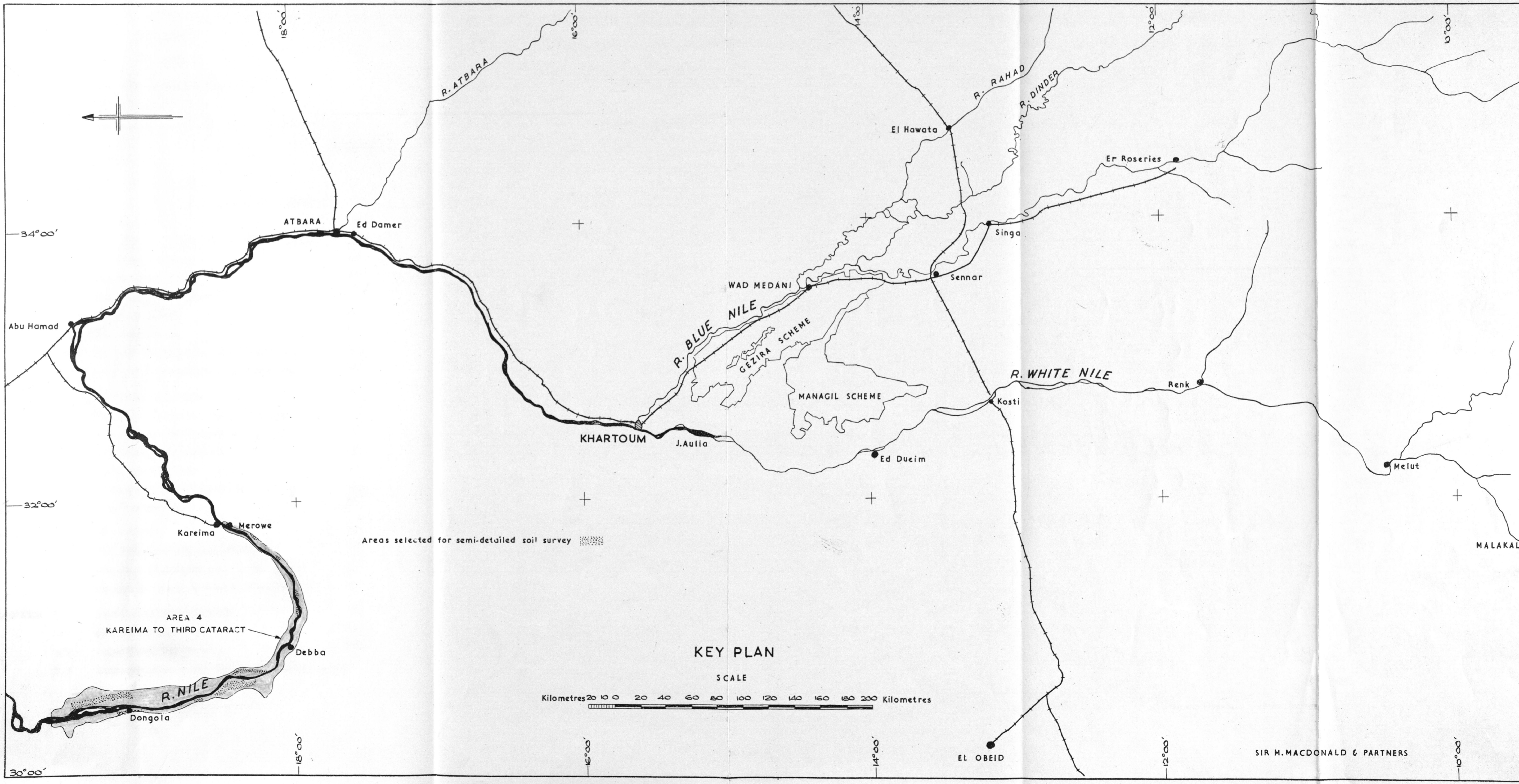
The necessary agricultural and soil studies were undertaken by Messrs. Hunting Technical Services Limited, under the direction of Dr. Robert Smith, Consultant in charge of the Soil Surveys.

We are, Excellency,

Your obedient servants,

I.S.G. Matthews

SIR M. MACDONALD & PARTNERS.


KEY PLAN
SCALE
Kilometres 20 10 0 20 40 60 80 100 120 140 160 180 200 Kilometres
Areas selected for semi-detailed soil survey
AREA 4
KAREIMA TO THIRD CATARACT
R. NILE
R. ATBARA
R. RAHAD
R. DINDER
R. BLUE NILE
R. WHITE NILE
GEZIRA SCHEME
MANAGIL SCHEME
ATBARA
Ed Damer
Abu Hamad
Kareima
Merowe
Debba
Dongola
KHARTOUM
J. Aulia
WAD MEDANI
El Hawata
Er Roseries
Singa
Sennar
Kosti
Renk
Ed Dueim
Melut
MALAKAL
EL OBEID
34°00'
32°00'
30°00'
18°00'
16°00'
14°00'
12°00'
10°00'
SIR M. MACDONALD & PARTNERS

CONTENTS

VOLUME I

		ACKNOWLEDGEMENTS	
		REFERENCES	
		GLOSSARY	
			Page No.
CHAPTER	1.	SUMMARY	1
CHAPTER	2.	THE ENVIRONMENT	9
	2.1	Location of the Lands Selected for Semi-Detailed Survey	9
	2.2	General Description of the Environment	9
	2.3	The Kerma Basin	12
	2.4	The Dongola Plain	24
	2.5	The Urbi and El Bakri Plains	25
	2.6	The Letti Basin	26
	2.7	The Affat Basin	31
	2.8	The Kulud Extension and Korti Plain	33
	2.9	The Gureir Extension and Fitna Plain	34
CHAPTER	3.	SURVEY METHODS	35
	3.1	The Reconnaissance Survey Report	35
	3.2	Aerial Photo Interpretation	35
	3.3	Soil Survey Procedures	37
	3.4	Field Permeability Studies	39
	3.5	Chemical Analyses of Soils	40
	3.6	Map Compilation	43
CHAPTER	4.	PEDOLOGY	45
	4.1	The Soil Classification System	45
	4.2	Physical Characteristics of the Soils	57
	4.3	Chemical Characteristics of the Soils	63
CHAPTER	5.	LAND CLASSIFICATION	68
	5.1	Specifications	68
	5.2	Land Class Standards	68
	5.3	Classification of the Northern Province Lands	72

CONTENTS (cont.)

			Page No.
CHAPTER	6.	ASSESSMENT OF POTENTIAL IRRIGATION DEVELOPMENT IN THE PROJECT AREA	82
	6.1	General Considerations	82
	6.2	The Climatically Adapted Crops of the Project Area	83
	6.3	Arable Basin Lands Suitable for More Intensive Irrigation Development	98
	6.4	Silt Terrace and Basin Lands Needing Further Investigation to Determine Suitability for Development	101

TABLES IN TEXT

		Page No.
Table 2.11	Provisional Climatological Normals 1931-1960 for DONGOLA.	10, 10a
Table 2.12	Provisional Climatological Normals 1931-1960 for KAREIMA.	11, 11a
Table 2.362	Areas Flood Irrigated in Kerma Basin 1952-1962 and other years.	21
Table 2.66	Areas Flood Irrigated in Letti Basin 1952-1962 and other years.	30
Table 2.75	Areas Flood Irrigated in Affat Basin 1952-1962 and other years.	33
Table 3.4	Co-efficient of Conductivity.	40
Table 4.11	Soil Classification Chart.	52
Table 4.121	Specifications for Soil Series and Soil Families.	55
Table 4.122	Frequency Distribution of Soil Series at all Classified Sites in Area 4A.	56
Table 4.23	Hydraulic Conductivity of 3 Sites	62
Table 5.32	Soils Criteria for Determining Land Classes in Area 4A.	74
Table 5.33	Frequency Distribution of Land Classes at all Classified Sites in Area 4A.	75
Table 5.34	Areas of Land Classes in the Project Area.	81
Table 6.20	A List of the Principal Climatically Adapted Crops of the Northern Province of the Sudan.	84
Table 6.21	Sudan Imports of Wheat and Flour, 1960-1963.	88

FIGURES IN TEXT

		Following Page No.
Figure 1	Key Plan.	Frontispiece
Figure 2	Physiographical Sketch Map of Kerma Basin	13
Figure 3	Land-Use Map of Letti Basin	30
Figure 4	Land-Use Map of Affat Basin	30

ALBUM OF PLANS

Soils Maps

Land Classification Maps

VOLUME II

APPENDICES

APPENDIX 1 DESCRIPTIONS OF THE SAMPLE AREAS

Sample Area I

Sample Area II

Table 1.1 Chemical Analyses of 7 Profiles from Area I

Table 1.2 Chemical Analyses of 4 Profiles from Area II

Text Figure 1 Sample Area I

Text Figure 2 Sample Area II

APPENDIX 2 SPECIMEN SOIL DESCRIPTIONS, TOGETHER WITH LABORATORY DATA, OF 15 PROFILES REPRESENTING SOIL SERIES

Soil Series P2

Soil Series F1 (2)

Soil Series F2 (4)

Soil Series F4 (2)

Soil Series F6

Soil Series F10

Soil Series H1 (3)

Soil Series H5

APPENDIX 3 LABORATORY ANALYSES OF REPRESENTATIVE AND ROUTINE SOIL SAMPLES

Table 3.1 Analyses of 26 Representative Pit Sites

Table 3.2 Analyses of 364 Routine Auger Sites

APPENDIX 4 SOIL AND LAND CLASSIFICATION AT ALL SITES

APPENDIX 5 INSPECTION OF ADDITIONAL NORTHERN PROVINCE LANDS BETWEEN THIRD AND DAL CATARACTS.

ACKNOWLEDGEMENTS

The compilation of a report of this kind cannot be complete without reference to many organisations and individuals, both in the Sudan and the United Kingdom, who have assisted us by providing information, advice or facilities. Among the many who have assisted us in this way are the following, to whom our thanks are due.

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THE MACAULAY INSTITUTE OF SOIL RESEARCH, ABERDEEN, SCOTLAND

The Director, for the secondment of Messrs. J.S. Bibby and J.H. Stevens of the Soil Survey of Scotland to share the field work in the Sudan

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ROSEIRES SOIL SURVEY

List of Reports

Report No. 1 Gezira Extension Area, Soil Survey and Land Classification. Vols. I, II and III plus album of maps.

Report No. 2 Blue Nile East Bank, Guneid to Khartoum, Soils and Engineering Reconnaissance. One volume.

Report No. 3 The Nile from Kareima to the Third Cataract, Soils and Engineering Reconnaissance. One volume plus album of maps.

Report No. 4 Rahad and Dinder Area, Semi-Detailed Soil Survey and Land Classification. Vols. I and II plus album of maps.

Report No. 4a Rahad East Bank Extension, Semi-Detailed Soil Survey and Land Classification. Vols. I and II plus album of maps.

Report No. 5 The Nile from Khartoum to Kareima, Soils and Engineering Reconnaissance. One volume plus album of maps.

Report No. 6 The White Nile East Bank, Rabak to Khartoum, Soils and Engineering Reconnaissance. One volume plus album of maps.

Report No. 7 Blue Nile East Bank, Guneid to Khartoum, Semi-Detailed Soil Survey and Land Classification of Selected Areas. Vols. I and II plus album of maps.

Report No. 8 The Nile from Kareima to the Third Cataract, Semi-Detailed Soil Survey and Land Classification of Selected Areas. Vols. I and II plus album of maps.

Report No. 9 Dinder-Blue Nile Gezira, Sennar to Confluence, Semi-Detailed Soil Survey and Land Classification. Vols. I and II plus album of maps.

GLOSSARY

Ardeb	-	A volume measure for agricultural produce equalling 198 litres. 1 ardeb of dura weighs 336 rotls 1 " of dukhn " 360 " 1 " of simsim " 264 "
Bamia	-	Lady's fingers or okra, Hibiscus esculentus Linn.
Dukhn	-	The food grain, Pennisetum typhoideum (Burm.) Stapf. and Hubbard.
Dura	-	The great millet, Sorghum vulgare, Pers.
Feddan	-	An area of land approximately equal to one acre: 1 feddan = 1.038 acres = 0.420 hectares.
Haboob	-	A strong wind usually accompanied thick dust.
Kankar	-	Dark coloured, hard, rounded to semi-rounded calcium carbonate concretions.
Kantar	-	A unit of weight; normally 1 Kantar = 100 rotls = 99.05 lb.
Limoon	-	The lime, Citrus aurantiifolia (Christm) Swingle.
Lubia	-	The bean, Dolichos Lablab Linn.
Marisa	-	Beer made from various grains but chiefly dura; a valuable protective food.
Piastre	-	P.T. for short, a unit of money. 100 P.T. = £1.000 Sudanese.
Rotl	-	A measure of weight approximately one pound: 112 lb. = 113 rotls. 100 rotls = 99.05 lb. = 44.94 kg.
Seluka	-	A digging stick with foot rest; also applied to the land cultivated by the seluka.

CHAPTER 1

SUMMARY

1.1 The semi detailed soil survey and land classification of 10 selected areas of land in the Nile Valley between Kareima and the Third Cataract covers a total area of 87,000 feddans of land distributed as follows:-

Locality	Area (feddans)
Kerma Basin	31,580
Dongola Plain	7,405
Urbi Plain	1,675
El Bakri Plain	24,510
Letti Basin	9,440
Affat Basin	3,285
Kulud Extension	2,025
Korti Plain	535
Gureir Extension	5,730
Fitna Plain	835
Total area	87,020

1.2 These isolated blocks of land are distributed over a 300 kilometre reach of the Nile Valley in the Merowe and Dongola Districts of the Northern Province of the Republic of the Sudan. The lands consist of three basins (Kerma, Letti and Affat) on the right bank of the Nile and seven high level silt terraces, at present mostly unreclaimed desert, on the Nile left bank. Communications within this area are difficult, existing transportation depending mostly on river steamers and road transport on a limited mileage of earth roads. Any plans for further agricultural development in this rather remote area should automatically include provisions for improving communications.

1.3 The project lands lie within the desert region of the Sudan where rainfall is negligeable. The summers are very hot and very dry because the southerly winds do not bring rain to the region. The winters are cool but are characterised by strong drying northerly winds which cause serious sand drift.

1.4 Because of the desert climate there is very little vegetative cover on lands not flooded or irrigated. A typical shrub, found at widely scattered intervals on the dry silt terraces, is "sallam" bush (Acacia Ehrenbergiana).

1.5 Within the basins there is a relatively luxuriant vegetation containing species useful as timber and others which are valuable for grazing. Highly valued for timber are the trees "sunt" (Acacia nilotica) and "talh" (Acacia seyal). The succulent ground vegetation which is of great importance to the local economy for livestock grazing consists of Cyperus rotundus and Heliochloa schoenoides at the lower levels and of Astragalus prolixus, Panicum turgidum and Trigonella laciniata at the higher levels. Other species, mostly shrubs and small trees, which may be used for firewood or for browse include Tamarix spp, Psoralea plicata, Bergia suffruticosa, Desmostachia cynosuroides, Acacia sieberiana, A. ehrenbergiana, Salvadora persica, Prosopis juliflora and Dobera roxburgii. The two latter exotic species are used to stabilize sand dunes, especially near the Seleim Canal. The useless dead sea fruit (Calotropis procera) is also commonly found in the Basins.

1.6 Much of the project lands consist of unreclaimed desert. Only the basins carry appreciable population and provide a livelihood for the inhabitants. The area flood irrigated in each basin varies rather widely from year to year. In an average year the following areas are flooded:- Kerma basin 27,550 feddans, Letti Basin 4,880 feddans and Affat Basin 300 feddans. The flood water is used mainly to provide grazing and tree growth within each basin. In Kerma basin an appreciable area of land is used for arable crops but most of these, especially wheat, are brought to maturity with irrigation provided by sagiyas or diesel pumps operating from wells or drawing water from hollows dug in the canal bed. This does not entirely overcome the hazards of the annually variable flood because the water table is replenished by the flood and the wells may be dry in poor flood years. The southern part of Letti Basin has been converted to pump irrigation and arable crops are grown;

the flooded part of the centre and north is subdivided into plots for grazing, mostly by sheep and goats. Part of the Affat Basin has also been converted to pump irrigation for the growing of arable crops; the flooded basin land, consisting of about 900 feddans of land, is used for grazing only.

1.7 The semi detailed survey was carried out according to the specifications of the Agreement of 27th September 1962. The density of soils examination in the field was at least one site to each 250 feddans. To obtain a fairly uniform geographic scatter of sites the routine observations were made within a grid marked on the air photographs at scale 1:25,000 and the uncontrolled mosaics at scale 1:50,000. The total number of sites examined was 403, consisting of 364 auger sites, 13 sample area pits and 26 representative pits. After examination of the soil and site descriptions and the analytical data from the representative sites, 15 profiles were selected for analysis at series level.

1.8 Soil classification is based on the U.S. Department of Agriculture system of 1960, the Seventh Approximation. The soils of the project area belong mostly to the soil order of Entisols which are soils without natural genetic horizons or with only the beginning of horizons. The Entisolic soils have been subdivided into sub-orders on the basis of drainage status; the Aquents and Udents of the basins show characteristics of impeded drainage whereas the Ustents of the silt terraces are dry almost continuously. The sandy soils of the basins belong to the group of Psammaquents and are subdivided further into the Psammic (very sandy) and Udic (with loamy subsoil) subgroups. The finer textured soils of the basins belong to the group of Hapludents and are subdivided further into the Orthic (loamy) and Vertic (clayey) subgroups. The dry soils at the edges of basins and on the silt terraces (Ustents) belong to the groups of Psammustents (sandy soils) and Orthustents (loamy and clayey soils). The former are subdivided further into Psammic (very sandy) and Udic (with loamy subsoil) subgroups whereas the latter are subdivided into Orthic (loamy), Vertic (clayey) and Psammustentic (with sandy layer) subgroups.

All subgroups are divided into families, largely on the basis of textural groupings, and into series on the basis of alkalinity status.

Four highly saline profiles at the edge of Kerma Basin were classified as Salorthids, a group of the order of Aridosols.

1.9 The specifications for the semi-detailed land classification are based on those of the U. S. Department of Interior's Bureau of Reclamation. Because of the lack of local experimental evidence as to the limiting factors affecting growth of the climatically adapted crops of Northern Province, the U.S.B.R. specifications have been closely followed, especially with regard to soil depth, textural extremes, salinity and alkalinity limits for arable lands. In addition to the limiting soils factors, other limitations of topography and drainage were found in the project area. Drainage limitations were encountered only in the basins. Topographic limitations consisted of moderately sloping or gullied surfaces and/or surface stones, gravel mounds, sandy hummocks or low dunes. More excessive topographic limitations such as large moving dunes or deep and frequent gullies as mentioned in Report No. 3 were on lands eliminated in the reconnaissance survey.

Class 1 land, which is found in Letti and Affat Basins and at the edge of the flood plain, has deep, level, well drained, non-saline, non-alkali soils and is suitable for all the climatically adapted crops of Northern Province. Class 2 land which is found in the basins and in places on the terraces has moderate limitations as to soils and/or topography and/or drainage. Class 3 land, which is found in the basins and in places on the terraces has more severe limitations as to soils and/or topography.

1.10 Because of the relatively dense riverain population of Northern Province, the limited area of arable land and the potentially plentiful supply of irrigation water, the land classification delineates Class 4 and Class 5 lands in addition to the arable classes. The class 4 lands (limited arable or special use lands) are those excessively coarse-textured soils in which the high permeability and low water holding capacity renders the land unsuitable for ordinary arable crops but on which orchards and vegetable crops might be grown with reasonable care. The Class 5 lands, which are non-arable under existing conditions but have potential value sufficient to warrant tentative segregation for special study, are those loamy and clayey soils of the terraces and basins in which the E.S.P. and/or E.C. exceeds the limits for the arable classes.

Unlike the Vertisols of the clay plains south of Khartoum, however, the Class 5 lands of Northern Province are drainable and the salts can therefore be washed out. Whether the high exchangeable sodium content can also be reduced to a safe level is an open question that must be determined by experimental work in a research station and/or a pilot project. Because of the inclusion of most of the saline-alkali loamy and clayey soils under Class 5, it follows that most Class 6 lands are segregated on the basis of excessive sandiness or excessive topographic limitations.

1.11 The following areas of each land class were segregated in the project area:-

Land Class	Area (feddans)
1. Excellent land	3,375
2. Good Land	8,660
3. Moderate Land	8,420
4. Special Use Land	6,390
5. Doubtful Land	43,940
6. Non-Arable Land	16,235
Total Area	87,020

1.12 The areas of arable lands are located mostly in the basins. In Kerma basin the arable lands totalling nearly 10,000 feddans are distributed in reasonably large blocks throughout the five ghisms studied. In Letti Basin there are 7,585 feddans of arable and limited arable lands and in Affat Basin 3,285 feddans. We recommend strongly that all areas of arable lands within basins that have not yet been converted to pump irrigation should be speedily converted to this method of irrigation. The crops to be grown should be the important climatically adapted crops of the Province:- wheat, broad beans (ful musri), haricot beans (fasulia), berseem (Medicago sativa), castor (Ricinus communis), dates and onions. The future prospects for all these crops are considered to be good and, because of its unique soils and climatic conditions, these crops grow better in Northern Province than in any other part of the Sudan.

1.13 The large aggregate area of Class 5 land segregated by the survey points to the urgent need to establish a pilot project where experiments may be carried out to determine the arability or non arability of the Class 5 lands. A suitable site for such a pilot project is available in Ghism 6 of Kerma Basin. An area of Class 5 land near the Bergeig Saliba could easily be protected from flood water, irrigation water is readily available from the Bergeig Government Pump Scheme, and the Bergeig escape channel from Kerma Basin could be used as a drainage outfall for leaching trials. By using these existing facilities it would be possible to establish the pilot project and commence reclamation experiments in a very short period of time.

1.14 The development of the silt terraces and part of the basin lands is dependant on the results of reclamation trials to determine the arability or non-arability of the Class 5 lands. The status of the individual areas is as follows:-

(i) Dongola Plain: The 540 feddans of arable land, already partly developed from shallow wells, is not extensive enough to warrant immediate establishment of a large pump scheme. Should the Class 5 lands be proved arable however, then the pump site 5 kilometres south of Dongola could be developed to command a gross area of about 6,000 feddans of new land.

(ii) Urbi Plain: This small area proved to be mostly Class 6. The 420 feddans of Class 3 land which are partially developed could be left to local enterprise.

(iii) El Bakri Plain: The area of arable land is too small and too scattered to warrant immediate development. Should the Class 5 lands be proved arable, however, then a pump unit at the site mentioned in Report No. 3 could be developed to command a gross area of about 20,000 feddans of new land.

(iv) Kulud Plain: Should the Class 5 lands prove arable then a gross area of about 1500 feddans could be developed as an extension to the existing government pump scheme.

(v) Korti Plain: This small plain of about 500 feddans was found to be excessively sandy and was all Class 6. There are therefore, no developmental possibilities there.

(vi) Gureir Plain: Should the Class 5 lands be proved arable then a gross area of about 5,000 feddans could be developed as an extension to the existing pump scheme.

(vii) Fitna Plain: If shown to be arable this isolated area of about 800 feddans could be commanded by a static pump lift of about 11.5 metres.

(viii) Kerma Basin: If the Class 5 land is shown to be arable then about 14,000 feddans of additional land could be developed in Kerma Basin. This would enable an overall development plan to be executed instead of local development within each ghism.

(ix) Letti Basin: If the Class 5 land is shown to be arable then an additional 1,200 feddans of new land could be developed in Letti Basin. Alternatively part of this land could be developed immediately with the arable land and the results used as a second pilot project.

1.15 In addition to the semi-detailed soil survey of selected areas between the 3rd and 4th cataracts the Consultants also carried out an inspection of the Nile Valley between the 2nd and 3rd Cataracts with a view to deciding whether there are any undeveloped lands worthy of investigation as possible development projects.

The inspection did reveal the presence of a few high level silt terraces in the Delgo-Abri area the development of which is beyond the resources of the local inhabitants but which might be considered further as part of an overall government development plan for Northern Province (Appendix 5). Because these lands are similar to the high level terraces between the 3rd and 4th Cataracts it is recommended that further investigations should await results of the proposed pilot reclamation project in the Kerma Basin.

CHAPTER 2

THE ENVIRONMENT

2.1 Location of the Lands Selected for Semi-Detailed Survey

The lands of Area 4a were first examined by a soils and engineering reconnaissance survey carried out from February to May 1963 in the first season's field work of the Roseires soil survey (Report No. 3, Roseires Soil Survey). As a result of this survey the following lands were recommended for semi-detailed soil survey and land suitability classification:-

Locality	Approx. Area (feddans)
Kerma Basin	29,300
Dongola Plain	8,900
Urbi Plain	3,500
El Bakri Plain	27,900
Letti Basin	12,500
Affat Basin	3,800
Kulud Extension	3,300
Korti Plain	500
Gureir Extension	5,800
Fitna Plain	300
Total area	95,800

2.2 General Description of the Environment

The ten areas selected for semi-detailed soil survey and land classification extend over a 300 kilometre reach of the Nile valley in the Merowe and Dongola Districts of the Northern Province of the Republic of the Sudan. This is the northern part of Area 4 as defined in the Contract of 27th September 1962. Lying between the Third and Fourth cataracts, this environment has been fully described in Roseires Soil Survey Report No. 3.

The project lands lie within the desert region of the Sudan where rainfall is negligeable. The provisional climatological means (1931-1960) of the Sudan Meteorological Service show that the average annual rainfall at Dongola and Kareima is less than 50 mm. (See tables 2.11 and 2.12). The summers are very hot and very dry because the

Table 2.11

SUDAN METEOROLOGICAL SERVICE.

DONGOLA

CLIMATOLOGICAL NORMALS.

(PROVISIONAL)

1931 - 1960

ELEMENT	ATMOSPHERIC PRESSURE (mb.) STATION LEVEL (16YRS)			AIR TEMPERATURE °C DRY BULB (16YRS)			DAILY MAXIMUM (16YRS)			DAILY MINIMUM (16YRS)			VAPOUR PRESSURE (mb.) (16YRS)		
Month	0600	1200	1800	0600	1200	1800	Mean	Highest	Lowest	Mean	Highest	Lowest	0600	1200	1800
January	989.5	986.6		14.5	27.2		28.1	37.0	18.8	9.3	17.5	2.5	7.2	8.6	
February	988.7	986.0		15.0	28.8		29.3	40.4	19.4	10.4	21.8	2.8	6.7	7.5	
March	986.7	984.0		19.6	32.8		33.8	44.7	22.1	13.9	24.7	3.5	7.3	7.6	
April	984.7	981.8		25.5	37.5		38.5	47.2	27.5	18.3	30.5	9.6	8.0	7.8	
May	982.9	980.2		30.8	41.2		42.3	48.1	24.1	23.0	32.0	13.5	9.7	10.1	
June	982.0	979.8		32.1	42.0		43.0	48.3	37.8	24.1	32.7	17.0	11.3	12.0	
July	980.9	979.0		32.1	41.2		42.3	47.4	35.5	25.1	31.9	19.0	14.9	14.3	
August	981.3	979.2		31.4	40.5		41.7	47.2	33.8	26.1	31.6	19.1	18.3	16.7	
September	982.7	979.9		30.1	40.3		41.3	47.1	35.0	24.6	31.3	14.5	13.8	13.4	
October	984.8	981.5		27.1	38.0		39.0	44.6	30.6	21.2	29.3	10.0	12.7	11.9	
November	987.1	984.0		21.2	32.4		33.0	40.2	22.7	15.4	26.7	6.0	10.4	12.0	
December	988.9	985.9		16.0	28.3		29.3	38.2	19.4	11.1	21.5	3.7	9.2	11.1	
Year	985.0	982.3		24.6	35.9		36.9	48.3	18.8	18.6	32.7	2.5	10.8	11.1	

Table 2.11b

SUDAN METEOROLOGICAL SERVICE.

DONGOLA

CLIMATOLOGICAL NORMALS.

(PROVISIONAL)

1931 - 1960

ELEMENT	RELATIVE HUMIDITY % (16YRS)			CLOUD AMOUNT (0 - 8) (16YRS)			RAINFALL (mm.)						EVAPORATION PICHE (mm.)
							TOTAL	NO. OF DAYS			MAX. IN ONE DAY		
Month	0600	1200	1800	0600	1200	1800		0.1	1.0	10.0	TOTAL	DATE	(16YRS)
January	46	24		0.7	0.8		0	0	0	0	0	-	7.9
February	40	19		0.6	0.7		TR	0.1	0.1	0	0	-	9.5
March	33	16		1.0	1.1		0	0	0	0	TR	SEV.	11.8
April	25	12		0.8	0.8		0	0	0	0	TR	SEV.	14.5
May	22	13		0.9	1.1		1	0.1	0.1	0	15.7	11.1945	17.0
June	24	14		0.7	0.6		TR	0	0	0.1	TR	SEV.	17.8
July	32	18		1.3	1.7		9	1.1	1.1	0	32.0	29.1953	15.7
August	40	22		1.9	2.2		13	1.7	1.7	0.2	35.6	22.1946	14.5
September	33	18		1.5	1.3		TR	0.1	0.1	0.4	3.0	9.1951	15.1
October	34	19		0.5	0.6		TR	0.1	0.1	0	3.1	14.1956	13.7
November	41	25		0.6	0.7		0	0.1	0.1	0	2.0	3.1954	10.0
December	50	30		0.7	0.8		0	0	0	0	TR	SEV.	7.8
Year	36	20		0.8	1.0		23	3.3	3.3	0.7	35.6	22.8.1946	12.9

Notes: (1) All times are G.M.T. (Sudan time minus 2 hours).
(2) To obtain approximate evaporation from an open water surface multiply Piche figures by 0.5

Table 2.12

SUDAN METEOROLOGICAL SERVICE
KAREIMA
CLIMATOLOGICAL NORMALS
(PROVISIONAL)
1931 - 1960

Element	Atmospheric Pressure (mb) Station Level (24 Yrs)			AIR TEMPERATURE °C Dry Bulb (30 Yrs)			Daily Maximum (30 Yrs)			Daily Minimum (30 Yrs)			Vapour Pressure (mb) (24 Yrs)		
Month	0600	1200	1800	0600	1200	1800	Mean	Highest	Lowest	Mean	Highest	Lowest	0600	1200	1800
January	986.3	983.4	984.6	15.8	28.2	22.2	29.2	40.5	19.0	12.5	20.2	4.3	6.3	7.2	6.1
February	985.5	982.7	983.6	17.1	29.6	23.7	30.8	42.5	19.3	13.4	23.0	3.5	5.6	5.6	5.0
March	983.8	981.0	981.4	21.5	33.6	27.3	34.7	45.1	22.2	16.9	26.4	7.5	5.6	5.1	4.9
April	981.7	979.3	979.2	26.8	37.8	31.5	38.8	47.0	29.6	21.0	31.0	11.5	6.3	5.6	5.4
May	980.2	977.5	977.5	31.4	41.1	35.2	42.2	48.0	29.0	25.1	32.7	15.5	9.0	7.9	7.9
June	979.7	977.5	977.2	32.6	42.0	36.3	43.2	48.0	36.5	26.3	33.4	13.1	8.9	8.0	7.8
July	979.4	977.4	977.0	31.8	40.5	35.5	41.8	46.8	34.4	26.8	33.2	20.0	14.3	11.4	12.2
August	979.9	977.5	977.4	31.1	39.5	34.6	41.0	46.7	31.7	27.1	33.2	22.0	17.2	13.9	15.5
September	980.6	977.8	978.0	31.1	40.5	34.9	41.6	46.0	35.2	26.7	33.4	19.5	13.3	11.3	11.9
October	982.0	979.1	980.0	28.8	38.5	32.7	39.6	47.0	31.8	24.2	30.2	15.5	10.7	9.9	9.1
November	984.3	981.2	982.5	23.0	33.3	27.3	34.1	41.5	23.7	19.0	27.4	9.3	9.4	9.9	8.5
December	986.1	983.1	984.3	17.9	29.2	23.3	30.0	38.2	19.6	14.2	23.4	6.0	8.3	8.7	7.7
Year	982.5	979.8	980.2	25.7	36.1	30.4	37.3	48.0	19.0	21.1	33.4	3.5	5.6	8.7	8.5

Table 2.12b

SUDAN METEOROLOGICAL SERVICE
KAREIMA
CLIMATOLOGICAL NORMALS
(PROVISIONAL)
1931 - 1960

Element	Relative Humidity % (30 Yrs)			Cloud Amount (0 - 8) (30 Yrs)			RAINFALL (mm)						Evap-ora-tion Piche (mm.)
							Total	No.of Days (25 Yrs.)			Max.in One Day		(25 Yrs)
Month	0600	1200	1800	0600	1200	1800		0.1	1.0	10.0	Total	Date	
January	35	19	24	1.0	1.2	0.6	0	0	0	0	0.3	26.1944	14.8
February	29	14	18	1.0	1.1	0.6	0	0	0	0	1.0	19.1942	17.5
March	22	10	16	1.2	1.1	0.7	0	0	0	0	TR	SEV.	21.4
April	18	19	12	0.9	0.9	0.5	0	0.1	0	0	0.5	30.1944	24.4
May	19	10	14	1.2	1.4	1.1	1	0.5	0.3	0	2.3	12.1949	24.2
June	18	10	13	1.3	1.5	0.9	0	0	0	0	TR	SEV.	24.7
July	31	16	22	2.3	2.6	2.0	11	1.5	1.2	0.3	40.0	14.1950	21.2
August	40	21	30	3.0	2.8	2.4	20	2.8	2.5	0.7	50.8	23.1949	18.7
September	29	15	21	2.5	2.4	1.9	5	0.8	0.7	0.1	60.0	1.1953	22.8
October	27	14	19	0.7	1.0	0.8	1	0.3	0.1	0	10.7	1.1942	21.5
November	33	19	24	0.7	0.9	0.4	0	0	0	0	TR	6.1946	17.8
December	39	21	26	1.1	1.2	0.7	0	0	0	0	TR	SEV.	14.5
Year	28	15	20	1.4	1.5	1.1	38	6.0	4.8	1.1	60.0	1.9.1953	20.3

Notes: (1) All times are G.M.T. (Sudan time minus 2 hours).
(2) To obtain approximate evaporation from an open water surface multiply Piche figures by 0.5

southerly winds do not bring rain to the region. The winters are cooler but are characterized by strong drying northerly winds which cause serious sand drift.

Because of the desert climate there is very little vegetative cover on the lands not flooded or irrigated. The commonest desert shrub is "sallam" bush (Acacia ehrenbergiana). In the basins and along the river frontage there are trees forming clumps and occasional forests:-

"sunt" (Acacia nilotica), "talh" (Acacia seyal), "haraz" (Acacia albida), dom palm (Hyphaene thebaica) and "terfa" (Tamarix articulata).

Communications within the area are difficult. The Sudan railway system extends only to Kareima. The river reach between Kareima and Dongola is served by a twice-weekly steamer service which extends to Kerma when the river levels are high. There is a weekly air service by light plane from Khartoum and Atbara to earth airfields at Merowe and Dongola. Access for motor vehicles is by ungraded earth roads which are continuous along the left bank of the Nile from Merowe to the Third Cataract. Near Debba this road is joined by the desert road from Omdurman which is traversed mostly by trucks and other vehicles with four wheel drive. There is no continuous road along the right bank of the Nile from Kereima to Kerma but the Meheila earth road crosses the desert to link Dongola with the rail head at Kereima. There are no bridges across the Nile between the Third and Fourth Cataracts so that motor vehicles must cross on the car ferries at Argo, Dongola and Kareima - Merowe. Any plans for further agricultural development in this rather remote part of Northern Province should automatically include provisions for improving communications.

2.3 The Kerma Basin

2.31 Location

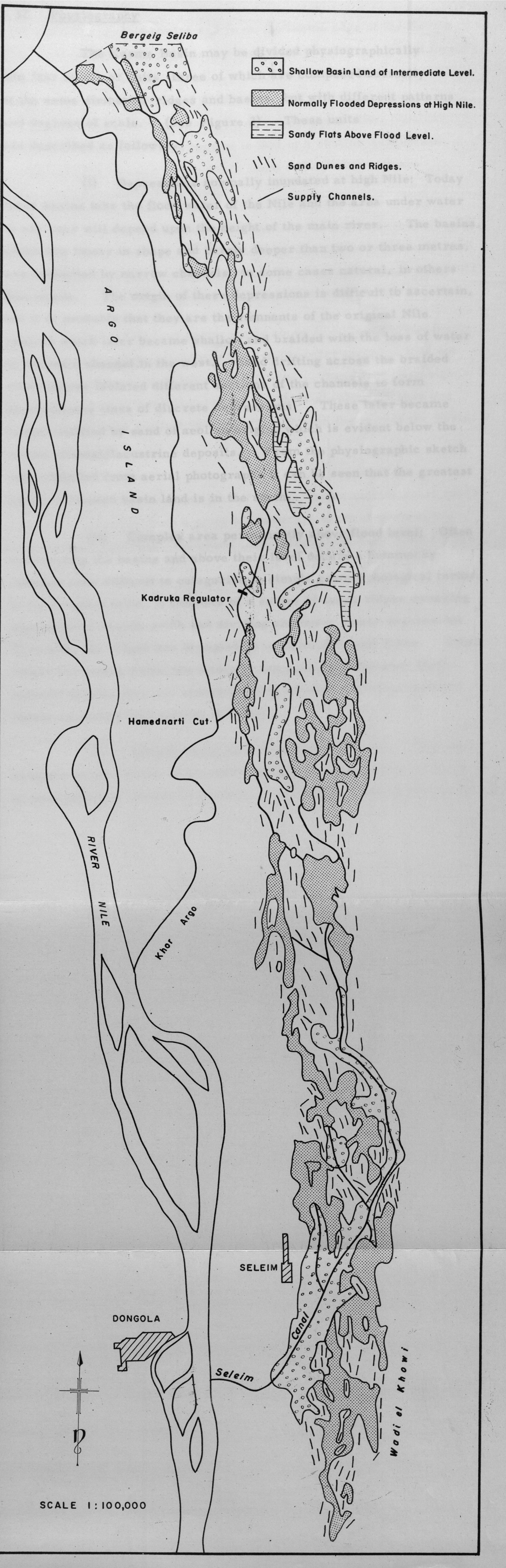
The Kerma Basin is on the right bank of the Nile opposite Dongola, lying roughly between latitude 18^{o} 50' and 19^{o} 50' north and between longitudes 30° 00' and 30° 20' east. The gross area of the original basin is reckoned to be about 90,000 feddans but the part covered by this survey is 34,500 feddans, lying between Seleim Canal headworks and the Bergeig Pump Scheme. (Ghisms 2-6).

Access is by way of the car ferry across the Nile from Dongola, by way of the Meheila desert road from Kereima and by the earth road along the eastern and western edges of the basin to Bergeig and Kerma. Movement within the basin lands is difficult for motor transport because most tracks are suitable only for pedestrians and donkey transport.

The basin itself is formed of an abandoned flood plain of the Nile about 4 to 8 Km. wide. The basin is mostly separated from the river:-

in the south by sand dunes, opposite Dongola by the Agada clay plain, opposite Argo Island by the Argo spill channels and by sand dunes. At its northern end, near Bergeig, the basin lands merge with the flood plain of the river.

On its eastern side the Kerma Basin is flanked by a broad plain of silt and sand up to 15 Km wide. This is the Wadi el Khowi which is itself an old abandoned flood plain of the Nile but at a higher level than Kerma Basin. The Wadi el Khowi is bounded to the north by rugged outcrops of basement complex rocks and to the east by the short steep scarp of the dissected sandstone plateau. Within the Wadi el Khowi plain there are occasional higher gravelly ridges and low outcrops of dark-coloured ferruginous rocks (probably sandstones). The bare surface of the plain is continually windswept and sand shadows form rapidly behind any small obstacles such as a bush or heap of gravel but most of the sand finds its way to the eastern edge of the Kerma basin where it is stabilized by vegetation. The amount of sand transported by the wind is quite small when compared with the lands further south in the vicinity of the Berget el Kuluf. It is considered that drift sand does not constitute a serious hazard to the further development of Kerma Basin.


Bergeig Seliba
Shallow Basin Land of Intermediate Level.
Normally Flooded Depressions at High Nile.
Sandy Flats Above Flood Level.
Sand Dunes and Ridges.
Supply Channels.
ARGO ISLAND
Kadruka Regulator
Hamednarti Cut
RIVER NILE
Khor Argo
SELEIM
DONGOLA
Seleim Canal
Wadi el Khowi
SCALE 1:100,000

2.32 Physiography

The Kerma Basin may be divided physiographically into four forms or units, three of which are composed basically of the same elements, ridges and basins, but with different patterns and degrees of scale. (See Figure 2). These units are described as follows:-

(i) Depressions normally inundated at high Nile: Today these basins take the flood water of the Nile and the area under water in any year will depend upon the height of the main river. The basins, which are linear in shape and rarely deeper than two or three metres, are connected by narrow channels, in some cases natural, in others man-made. The origin of these depressions is difficult to ascertain, but it is probable that they are the remnants of the original Nile channel which later became shallow and braided with the loss of water to the main channel in the west. Sand drifting across the braided river course isolated different sections of the channels to form discontinuous lines of discrete depressions. These later became further infilled by sand of aeolian origin, which is evident below the recent alluvial/lacustrine deposits. From the physiographic sketch map compiled from aerial photographs it can be seen that the greatest extent of flooded basin land is in the south.

(ii) Complex area permanently above flood level: Often surrounding the basins and above their level occurs a hummocky complex area difficult to categorise in simple geomorphological terms. In its simplest form, it consists of a series of sandy ridges sweeping approximately north-south and dividing shallower linear depressions. Very often the ridges are occupied by unstabilised sand dunes. Other ridges are loamy whilst the minority are silty, but whatever their textural nature, they are unconsolidated alluvial or aeolian material rarely exceeding four metres in height.

(iii) Shallow basin land of intermediate level: The third category of land shown in the sketch map is of intermediate level and is intermittently flooded by the Nile. Such land is sometimes peripheral to the normally flooded basins and is on the inside edge of the Kerma Basin in the south and north. The land may possibly represent fossil river terraces. The colonisation of this land for agricultural use has resulted in a local levelling of the area and its present flat nature is probably the result of human activity as much as any other physical factor. The overall cross-section is that of a shallow saucer and the silt and clay fraction of the sandy loam soils of this unit are evidence of occasional inundation.

There are scattered sand dunes in the north-east occurring within land of this category. The leading edge of the dunes to the east of the basin is moving forward rapidly south-west and agricultural sites are becoming drifted over and are subsequently abandoned.

(iv) Flat land permanently above flood level: The fourth and final unit is not genetically related to the other three. It is not well represented and is of little importance. These lands are higher than the previously mentioned basins and their absolute flatness and dark sandy surface suggest an earlier origin than the rest of the Basin.

2.33 Geology

The basement complex of Pre Cambrian metamorphic rocks outcrops northwards from a point 7 kilometres north of Kerma, and again north of Merowe. Between these points, and east of the Kerma Basin, the Basement Complex is overlain by Nubian Sandstones. These sandstones are fossiliferous with much silicated wood which has been determined as Dadaxylon and attributed to the Lower Cretaceous period.

There is no published information as to the nature of the underlying geology of the Kerma Basin. No outcrops of solid rock occur. It would be interesting to know if any records were kept of the tube well borings of the six experimental installations on terrace silt east of Kerma Basin in 1955.

2.34 Sub-recent Geology

The sub-recent geology of the Basin is extremely complex and difficult to unravel. An understanding of this and the series of events which led to the development of the present pattern is a key to the understanding of the distribution of all soil types. The probable main events in the sub-recent geological history of the Basin were as follows:-

(i) the cutting of the main Nile channel in the trough of what is now the Kerma Basin and the formation of silt terraces on its banks (possibly the origin of the silts of Wadi el Khowi) and sand bars and islands within its course, (it is possible that the Kerma trough was always subsidiary to the main channel in the west).

(ii) the shallowing and braiding of the channel with the diversion of the main flow and the laying down of lacustrine clays and silts,

(iii) the occasional inundation of the whole Basin in high flood years and the disturbance and erosion of the formations of the previous two events,

(iv) the isolation of the south of the Basin from the active flood plain of the river by the movement of dune sand from the N. N. E. at Seleim,

(v) the partial infilling of the Basin by wind blown sand,

(vi) the flooding of the depressions within the Basin by the cutting of an artificial canal at Seleim in 1909, resulting in the deposition of silts and clays in these basins and the raising of the water table in the whole area with the concomitant development of arborescent species, and

(vii) the extant and continuing movement of sand from the north-east.

2.35 Vegetation

The natural vegetation is dependent on the annual flooding of the basins which raises the water table in the sub-soil of the Kerma Basin allowing tree growth and provides residual soil moisture in the basins when the flood retreats.

Before the Kerma Basin was flooded at the beginning of the century, vegetation was absent except for scattered Acacia ehrenbergiana bushes each growing above its acquired dune of blown sand. The arrival of flood water brought great quantities of Tamarix nilotica and Tamarix orientalis which proceeded to flourish exceedingly well and became a major weed. On flooded areas it became particularly luxuriant and provided a valuable fuel supply for river boat steamers and steam pumps, but it did not regenerate well and is mostly in the form of straggly, coppiced bushes at present. In the meanwhile Acacia arabica had begun to appear followed by Acacia seyal. These trees were protected at first by regulations so that forests developed. Forested land today is very scattered and unconsolidated, and the land which yields good grazing after the flood, or is best suited to saqiya cultivation, is generally kept clear of trees.

Other species found in the basins are the bushes Psoralea plicata and Bergia suffruticosa which grow in those basins which are non-saline and intermittently flooded, Acacia sieberiana which is found besides the original native, Acacia ehrenbergiana and Prosopis juliflora and Dobera roxburgii which are found on sand dunes. They are used for stabilising active dunes and, at Seleim, Prosopis Juliflora has been introduced to prevent sand drifting into the canal. Desmostachia cynosuroides is a native which performs the same task. Calotropis procera is commonly found in similar situations, but is more frequent on land abandoned after cultivation.

The vegetation of the depressions is of great importance to the local economy for livestock grazing. Heliochloa schoenoides and Cyperus rotundus provide a dense, close cover on the silts and silty clays of the lower and moister parts of the basins. Higher up, but still within the basins, Astragalus prolixus, Panicum turgidum and Trigonella laciniata are usually found after the flood.

2.36 Existing Agricultural Practices

The information which is contained within this section is from published and unpublished material of previous surveys and from observation in the field during the course of the survey in January 1964. It is intended as background information to the main body of the report, soil survey and land classification, and does not claim to be a comprehensive or an up to date review.

2.361 • Brief History of the Scheme

The Kerma Basin was first opened in 1909 when the Seleim canal was dug with the intention of flooding the Kerma plain and producing crops on the model of the basins in Egypt. The Seleim canal drew water from the Nile opposite Dongola and turned north, feeding water into the southern end of the Basin which flushed back into the Nile again forty-five kilometres to the north at Bergeig Saliba, watering twenty to twenty-five thousand feddans of the Basin.

In 1911 it was realised that better drainage was necessary and further work was carried out at Bergeig. The following year the Seleim canal was widened to its present bed width of 20 metres.

At first areas of good soil gave satisfactory crops, but it became clear that deterioration of the original soil was extremely rapid and land, which for the first year had given good crops, barely gave back the seed sown in the fourth year. There was a general belief that the failure was one of husbandry and Egyptian fellahin were brought in to teach the local farmers by precept and practice what was required of them. The soil showed no response and the cultivation of flooded land was soon over-shadowed by tillage of alternative sites within the Basin. This failure of the soil was perhaps inevitable, in that the same husbandry techniques were applied as were practiced in the Egyptian basins, where continuous flood crops were produced on rich silt which had been accumulating for centuries. In the Kerma Basin such silt deposits were absent.

Before deterioration of the flooded land had reduced revenue seriously, crops were grown on sandy islands and around the flooded basins drawing on water which had infiltrated through the soil.

In turn, yields from these sources decreased, but not quite as rapidly as in the case of the flooded land. They were probably not as high in the first place.

The Government's continued participation in the scheme was only made possible by the appearance of the leguminous weed Trigonella laciniata ('Keteih'). This succeeds the flood as a dense pure stand. It is rather similar in appearance and feeding value to Lucerne, although a bit shorter and yields only one cut. Previously unknown to the people, it soon became an essential forage crop for the saquiya bulls and other livestock, and the levying of a tax on its consumption provided the greater part of the scheme's running costs. In addition to this, the growth of trees made possible by the annual rise in the water table, brought about by flooding of the subsoil, added a further source of income to the farmers.

The original impetus with which the scheme was introduced, was slowed with the disappointments of rapid soil deterioration and the diversion of government capital towards the successful Gezira. There was a gradual extension of small canals to distribute water from Seleim and cuts and banks were built to guide the flood through the basins and across the ridges. In 1924 a permanent regulator was built at Kadruka midway between Seleim and Bergeig and later the Hamednarti cut was dug from Khor Argo to form a second supply channel.

Meanwhile, annual flooding had begun to deposit silt in the low lying basins. It was soon found that there was a sufficient depth of silt for flood crops and yields were obtained comparable to the original ones at the inception of the scheme. In other areas, peripheral to the above, it was found that crops could be brought to maturity by 'mataras' ('saquiyas' operating from wells) and perennial irrigation was provided with the combination of flood and saquiya water. This development took place about 1930, and there was a great increase in livestock as the scheme developed.

Bergeig pump scheme was launched in 1942. It consists of 4,500 feddans north of Bergeig saliba, and was outside the project area of the soil survey.

Since these times very few changes have occurred except that the traditional saquiya is being replaced by relatively cheap and reliable diesel oil pumps which often involve the development of co-operatives and the consolidation of holdings.

2.362 The Management of Flood Water

The system of irrigation is simple in theory. The Basin has a feeder canal at Seleim, an escape at Bergeig where there is a cross bank (saliba), and intermediate dykes to train the flood through the Basin. There are cross banks which divide the Basin into 9 'Gisms'. Each 'Gism' is divided into 'Hods' measuring one square mile, which are again sub-divided into 64 plots. On arrival of the flood at suitable level the feeder canal is opened and the depressions allowed to fill to good irrigation level ('Tammam Rai'). This level is generally considered to be that which covers the ground to a depth of from 70 centimetres to 1 metre. After flooding, 'Tammam Rai' is held first in the upper section then released after 15 to 20 days to the lower 'hod', raising its level.

The total area included in the Basin boundaries is approximately 90,000 feddans, but owing to the uneven nature of the bed of the plain, which leaves large sections unflooded, only about 50,000 feddans of this is potentially irrigable. In practice the success of basin irrigation depends on the Nile flood. In years of low floods the areas irrigated are negligible, whereas with a high flood the areas are quite extensive. The extent of this variation in area flooded is given in Table 2.362 below and this clearly indicates the unreliability of this method of irrigation.

Table 2.362 Areas Flood Irrigated in Kerma Basin 1952-1962 and other Years.

Year	Area Flooded
	Feddans
1944-45 (Average year)	27,550
1946 (High flood year)	52,410
1941 (Low flood year)	4,070
1952	19,490
1953	25,400
1954	32,800
1955	23,500
1956	21,000
1957	17,200
1958	27,650
1959	30,000
1960	7,000
1961	37,700
1962	31,700

2.363 Distribution of Cultivated Land

One of the most important factors which must always be remembered is that the soil is extremely variable throughout the Kerma Basin, as a result of the recent complex geological history of the former river flood plain. No soil map, unless on a very detailed scale, could show all the variations which exist. Small pockets and strips of good soil intermingle with sand and clay especially in the complex area of the middle gisms. A few yards may separate soil so good as still to produce flood crops without silt, from soil so barren as to produce not even scrub. The distribution of cultivated land reflects this variation.

By reference to the physiographical sketch map fig. 2, it will be seen that there are four generalised physical land categories of which only the flooded depressions and the shallow basin land of intermediate level are important from the tillage point of view. As suggested in the previous paragraph some cultivation does take place in the complex area, but this represents the pioneer fringe, and movements into, and away from this area are the reflection of critical fluctuations of the fortunes of agriculture in the Kerma Basin.

Of the shallow basin land of intermediate level shown on the sketch map, most is cultivated and parts of the normally flooded depressions as well.

2.364 Crops and Rotations

(i) Flood Crops on the original soil.

In the Basin, as in the rest of Northern province, three seasons are recognised, but these are staggered northwards as the north of the basin has to wait longer for the flood water to be released through the regulator at Kadruka. These seasons are:-

Seifa	-	June to August
Damira	-	August to November
Shitwi	-	November to March

Dura, which is often spoiled by flood water, close to the dykes, is grown during 'Seifi', millet, lubia and maize, during 'Damira', and wheat, berseem and Egyptian beans during 'Shitwi'. From March until June the land lies fallow.

Throughout most of the area where the original soils are cultivated, the crops, especially wheat, are brought to maturity with the irrigation provided by saquiyas or diesel pumps, operating from wells or drawing water from hollows dug in the canal bed. This does not overcome the hazards of the annually variable flood as the water table in the subsoil depends on the flood, and the wells may be dry in poor years. In some of the wells water tasted noticeably salty.

The soils are commonly loam and sandy loam passing on the fringe to loamy sand, where wind blown sand is a problem. In some lower lying areas these have lost their structure with alkalinity and salt crust appears on the surface. Such patches are localised and not generally found on the better drained sites, but where they do occur, crops are markedly retarded, especially wheat.

(ii) Flood Crops on recent silts.

As the flood subsides in the depressions leaving behind a fresh layer of silt, the soil is sown with agricultural lupin (Lupinus termis) which tolerates salinity. Where the soils are only mildly saline, Egyptian beans, or even wheat, may be grown on the silts in the depressions in favourable circumstances. The depth of silt required for the production of flood crops varies with the kind of crops grown, but may be said to average 12 cms. on good soil to one metre on sand.

2.365 General Observations

The size of individual holdings varies from 2 or 3 feddans to about 20. The larger holdings invariably rely on supplementary irrigation from diesel pumps. A saquiya will irrigate 5 feddans in winter and less than 3 when evaporation is greatest.

Tenancies are complicated by sub-letting and sub-tenant labour is arranged on a share cropping basis.

Within the present framework all available land is cultivated and herds of goats graze and browse the existing pasture and bush species to the limit.

2.4 The Dongola Plain

This high level silt terrace on the left bank of the Nile extends from 7 kilometres south of Dongola to 10 kilometres north of the town. At its widest point the terrace is 2 kilometres wide but it tapers off at either end. It is bounded on the west by a very prominent and gullied scarp face of Nubian sandstone and on the east by the cultivated riparian lands or by a rather arbitrary line where erosion becomes dominant and a series of gravel mounds are cut by gullies.

The total area surveyed is approximately 8,000 feddans.

Access is good. The main earth road from Dongola to the south and from Dongola north to the Third Cataract passes through the middle of these lands. The Dongola airfield is also located there.

In the southern part of the terrace area the silts are finer and fairly homogenous and were probably deposited in an old lake bed. This has been partly eroded by the river on the east to expose the underlying gravels, now dissected by lateral gullies. The lands in this part of the project area are without cultivation and without vegetative cover.

The northern part of the terrace area is somewhat different from the southern lands. Near Dongola town the remains of an old river channel can be traced northwestwards cutting into the older lake deposits. It swings northward following the foot of the escarpment and loses its identity to the north of the project lands. The course of this old channel is marked by a series of date palm groves which are irrigated from shallow wells which tap a sandy aquifer in the old channel deposits. Separating these lands from the riparian cultivated lands is a low gravelly and sandy ridge which is not cultivated and is devoid of vegetation.

Although almost devoid of vegetation there are no sand dunes on the plain. Sand drift is not a serious problem here because the plain is protected by the river from the strong northerly winds.

2.5 The Urbi and El Bakri Plains

These high level silt terraces lie on the left bank of the Nile between Dongola and Debba. They are separated from each other and from the Dongola Plain by areas of high rocky ground in places where the present Nile flood plain impinges directly on to the desert plateau of Nubian sandstone.

The area surveyed is approximately 28,500 feddans. Of this, about 3,000 feddans is in the Urbi plain and about 25,000 feddans is in the El Bakri plain.

Access is good. The main earth motor road from Dongola to the south traverses both plains.

The Urbi plain is a small isolated terrace hemmed in between high ground and the river. An old river channel at a slightly lower level occupies the western part of the plain. Here there is a small isolated palmgrove irrigated from wells similar to those described for the Dongola plain. The remainder of the plain is uncultivated and unvegetated except for an extension of the riparian cultivation in the north (about 70 feddans).

The El Bakri plain is 32 kilometres long and up to 6½ kilometres wide. It consists of several silt terraces with two prominent sandy ridges in the northern section. It is bounded by the desert plateau of Nubian sandstone to the north but on the west and south it merges into a slightly undulating sandy plain. The El Bakri plain is bare of vegetation except for a few low sallam bushes (Acacia ehrenbergiana) on small mounds of wind blown sand. Dunes are absent from this area and sand drift is not a serious problem because the lands are protected by the river from the strong northerly winds. There is no cultivation on the plain but cultivated riparian lands lie between the plain and the river.

2.6 The Letti Basin

2.61 Location and General Description of the Project Area

The Letti Basin is on the right bank of the Nile, and lies between latitudes 16° 53' N. and 17° 18' N. and between longitudes 30° 35' E and 30° 40' E. The basin is below flood level and a canal has been dug to divert the Nile flood waters into it.

The total area of the soil survey in this part of the project area is 9,321 feddans.

The basin is reached by a car-ferry from Armentego. Access into the basin is by a route across the sandy plain. There are no motor roads within the basin itself and movement there is difficult.

The Letti Basin, like the Kerma Basin, is formed from an abandoned flood plain of the Nile. It is still linked with the active flood plain of the river in the south, but as the Nile channel has incised its course, flooding is dependent upon a supply canal.

The plain is abruptly terminated by the high edge of the Nubian sandstone outcrops which forms dissected plateau country to the east. The edge of the plateau is cut by numerous sand filled wadis. To the west, by contrast, a low-lying undulating sandy plain separates the basin from the present river course which is five kilometres to the west at the furthest point. This plain, which is in part silty, appears to be of the same origin as that area to the west of the present Nile. The Basin itself is infilled by aeolian and alluvial deposits.

2.62 Physiography

The western half of the Basin consists of a series of discontinuous sandy ridges and silt and clay filled basins which are orientated approximately north-south. During flooding, parts of the ridges form lines of islands or knolls above flood water and after the flood recedes they remain clearly outstanding due to their different soils and vegetation. The lower lying parts which are inundated by the annual flood have a very irregular surface and an incipient trellis drainage pattern resulting from the conformation of ridges and troughs.

The east of the Basin has been subject to the encroachment of sand moving north-east from the Nubian sandstone plateau. Almost half the width of the basin is covered at some points and the sand is continuing to advance. The rate of annual movement may be assessed by comparing aerial photographs of different ages available in the Sudan Survey Department records. The loose dune sand takes the form of long parallel 'seifs' or ridges up to 2 kilometres in length orientated N.N.E. - S.S.W. In the south of the Basin the presence of identical formations on the western edge suggests that at one time the Letti Basin was completely covered from east to west.

2.63 Geology

East of the Letti Basin the Nubian sandstone outcrops on the escarpment. West of the escarpment no other outcrops occur until the Nile is crossed. The Nubian sandstone, especially in the region of Jebel Ghaddar is highly ferruginous.

There is no available information as to the nature of the underlying geology of the Letti Basin. No outcrops of solid rock occur and it must be assumed that the Basin is infilled with unconsolidated deposits to a considerable depth.

2.64 Sub-recent Geology

Like the Kerma Basin the sub-recent geology of the Letti Basin is extremely complex and difficult to unravel. An understanding of the series of events which led to the development of the sub-recent geology is a key to the understanding of soil types. The probable main events were, as follows:-

(i) the cutting of the trough and the formation of the escarpment of the Nubian sandstone plateau by lateral erosion on the outside bend of the river,

(ii) the shallowing and braiding of the channel with the diversion of the main flow to the east and the laying down of lacustrine/alluvial deposits,

(iii) the occasional inundation of the whole Basin in high flood years and the disturbance and erosion of the formations of the previous two events,

(iv) the movement of dune sand from the Nubian sandstone from a N.N.E. direction and the apparent temporary isolation of the Basin from the active flood plain of the river,

(v) the irrigation of the Basin since Turkish times resulting in the deposition of silts and clays and the raising of the water-table in the whole area and the development of woodland, and

(vi) the extant and continuing movement of sand from the N.N.E. which threatens to overwhelm the Basin.

2.65 Vegetation

The vegetation of the Letti Basin is very similar to that of the Kerma Basin, but more luxuriant and varied. The explanation for this is that Letti has a longer history as an irrigated basin and generally has less irregular relief which allows a proportionately larger area of the Basin to be flooded annually. Added to this the regularity of the flood is greater than in Kerma and the difference between good and bad years proportionately less. See table 2.66.

The sands to the east are above flood level, but the roots of date palms are able to reach the alluvial soils below. Generally the dunes are unstable and bare of vegetation.

The alluvial/lacustrine soils in the depressions support a vegetation which is relatively luxuriant for Northern Province. The species found are the same as for the Kerma Basin, but trees, especially Acacia seyal are more important and include Salvadora persica as a commons species. Astragalus prolixus and Cyperus rotundus grow in the annually flooded depressions and provide grazing.

2.66 Present Agricultural Practice

The Basin has been cultivated since Turkish times, but was reopened in 1912. The system of irrigation is basically the same as that of Kerma except that the southern part of the basin is not flooded but devoted to perennial cultivation supported by pump water. Extension of the pump scheme has taken place recently and the area of cultivated land was being extended northwards in January 1964.

The total area of cultivated land appeared to be under wheat or Egyptian beans during January 1964, although the agricultural officials in Dongola claimed that during alternative winters half the land was fallowed. Dura (Sorghum vulgare) is also grown within the rotation and is planted immediately after the flood and followed by wheat or Egyptian beans. Estimated yields in ardebs/feddan were, wheat 4, Dura $3\frac{1}{2}$, Egyptian beans $3\frac{1}{2}$. One ardeb is equivalent to 200 kg. of wheat, 180 kg. of Dura and 200 kg. of Egyptian beans.

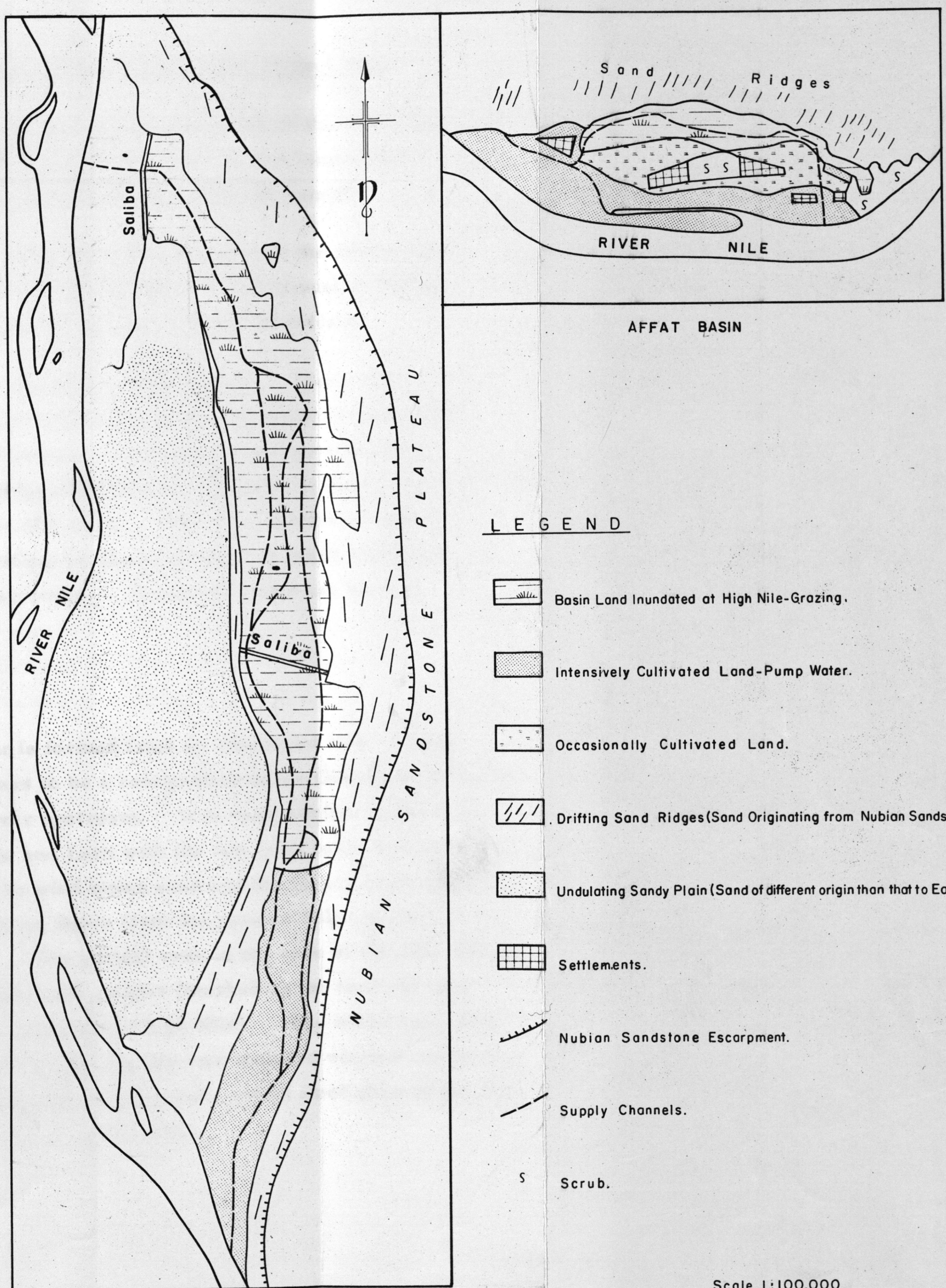
North of this cultivated land the Basin is systematically sub-divided into plots for grazing. The total area is approximately 2,000 feddans. Goats and sheep are favoured rather than cattle. Tillage is absent in this area except for scattered patches on the boundary of the Basin. See fig. 3.

The extent of the annual flood is shown in Table 2.66. The area flooded in an average year (1944-45) is 4,880 feddans. In a high flood year, as in 1946, the area flooded may reach 9,300 feddans. In a low flood year, as in 1941, only 430 feddans may be flooded. The records of the years 1952-1962, however, show that variations in the area flooded were much less in Letti Basin than for the much larger Kerma Basin.

Table 2.66 Areas Flood Irrigated in Letti Basin 1952-62 and Other Years.

Year	Area Flooded Feddans
1944-45 (Average year)	4,880
1946 (High flood year)	9,300
1941 (Low flood year)	430
1952	4,700
1953	4,800
1954	6,490
1955	5,600
1956	4,400
1957	5,380
1958	6,760
1959	6,635
1960	2,700
1961	7,500
1962	5,000

LAND USE MAP


Sand Ridges
RIVER NILE
AFFAT BASIN
Saliba
Saliba
RIVER NILE
NUBIAN SANDSTONE PLATEAU
LEGEND
Basin Land Inundated at High Nile-Grazing.
Intensively Cultivated Land-Pump Water.
Occasionally Cultivated Land.
Drifting Sand Ridges (Sand Originating from Nubian Sandstone).
Undulating Sandy Plain (Sand of different origin than that to East).
Settlements.
Nubian Sandstone Escarpment.
Supply Channels.
Scrub.
S
Scale 1:100,000
LETTI BASIN

2.7 The Affat Basin

2.71 Location and General Description of the Project Area

The Affat Basin is on the right bank of the Nile, and lies between latitudes 16^{o} 27' N and 16^{o} 32' N, and longitudes 31^{o} 20' E and 31^{o} 30' E, opposite the road junction of Ganetti.

The area surveyed within this part of the project area amounts to approximately 3,500 feddans. The amount of flooded basin land proper amounts to little more than 900 feddans.

Access to the Affat basin is poor. There is no right bank motor road to connect the basin with Kereima (upstream) or with Dongola (downstream). The motor road from Merowe to Omdurman and to Dongola follows the left bank but there is no car ferry across the Nile at this point. There is, however a regular felucca ferry from a village on the north bank on which travellers with their livestock may cross. Transport within the basin is by donkey or camel.

2.72 Physiography

The Basin is formed from an abandoned river channel of the Nile and it appears to be a continuation of the Ganetti Basin on the opposite side of the river upstream. It is very similar to the other larger basins at Kerma and Letti with the low lying basin proper to the north partly over-run by wind blown sand and the higher sandy ground to the south separating the Basin from the present Nile channel and its cultivated flood plain. The project area in the case of the Affat Basin was not restricted to the basin proper (marked on the land use map Figure 4 as basin land inundated at high Nile). The whole area lying between the Nile and the desert margin was included which involved the abandoned channel, the sandy ridge and the extant flood plain of the Nile, now perennially irrigated by pump water.

2.73 Geology and Sub-recent Geology

Information on the underlying solid geology is not available, but it would appear that it bears no important relationship to the distribution of soil types within the area which are related, as in the Kerma and Letti Basins to the sub-recent geological events. These are probably closely comparable to those in the larger basins.

2.74 Vegetation

The vegetation of the Affat Basin especially in the depression to the north flooded at high Nile, is similar to the flooded depressions of the Letti Basin and Kerma Basin described above. The sandy ridge is bare of vegetation, whilst the flood plain to the south on the bank of the river, has been cleared for cultivation.

2.75 Present Agricultural Practice

The lands may be sub-divided into a grazing area in the annually inundated basin to the north and a cultivated area fed by pump water in the south close to the Nile. See figure 4.

The annual inundation of the grazing area varies according to the height of the Nile flood. The figures for recent years are given in Table 2.75 and they can be seen to vary between 1,500 and 150 feddans.

Table 2.75 Areas Flood Irrigated in Affat Basin, 1952-62 and Other Years

Year	Area Flooded Feddans
1944-45 (Average Year)	300
1946 (High Flood Year)	800
1941 (Low Flood Year)	nil
1952	200
1953	-
1954	800
1955	350
1956	150
1957	200
1958	1,500
1959	650
1960	-
1961	1,200
1962	150

2.8 The Kulud Extension and Korti Plain

These high level silt terraces lie on the left bank of the Nile near the settlements of Kulud and Korti respectively. They are separated from each other by rough sandy and gravelly lands with frequent sand dunes.

The total area surveyed is approximately 4,000 feddans.

The Kulud extension of about 3,500 feddans lies inland from the Kulud Government pump scheme. It consists of slightly undulating ground upon which lie scattered sand dunes. The inland boundary is determined by the point at which the dunes begin to form continuous ridges. The project lands are uncultivated and mostly unvegetated.

The Korti plain of about 500 feddans consists of slightly undulating land, almost bare of vegetation and uncultivated. It is bounded to the east by sand dunes and gravel ridges.

Access to both plains is good as they are traversed by the Merowe - Omdurman earth road on the Nile left bank.

2.9 The Gureir Extension and Fitna Plain

These high level silt terraces are on the left bank of the Nile between Merowe and Korti. They are separated from each other by undulating gravel ridges, gullied lands and sand dunes.

The total area surveyed is approximately 6,300 feddans.

The Gureir Extension, of about 6,000 feddans, is adjacent to the Gureir Government Pump Scheme. It is separated from the irrigated lands by sand dunes and gullied land. The project lands are uncultivated and almost bare of vegetation. The surface is soft and loose, with many linear sand dunes, from one to five metres high and orientated N.N.E. - S.S.W. Isolated sallam bushes (Acacia ehrenbergiana) are found on the dunes, most of which appear to be actively moving.

The Fitna Plain of about 300 feddans is close to the Merowe airstrip. It is a bare, unvegetated and uncultivated plain.

Access is good, because both plains are traversed by the Merowe - Omdurman road which connects with the Merowe airstrip and Kareima railhead.

CHAPTER 3

SURVEY METHODS

3.1. The Reconnaissance Survey Report

The semi-detailed soil survey & land classification survey in the project area had been preceeded by a reconnaissance soils & engineering survey carried out in Jan-April 1963 and described in Roseires Soil Survey Report No 3, published in September 1963. The reconnaissance survey had delineated, quite accurately, the areas for semi-detailed survey. It had also provided much preliminary information on the general environment as well as field descriptions and laboratory analyses of typical soils. Unlike areas 1, 3b, 3c and 3a, therefore, the soil surveyors had a reconnaissance report to study before commencing the field work.

3.2. Aerial Photo Interpretation

The aerial photography of most of the project area at a scale of 1:25,000 was carried out by the Sudan Survey Department in 1961-62. These photographs were used by Messrs Fairy Air Surveys Ltd. for the production of mosaics at scale 1:50,000 in 1963. The prints covering the area from Kulud to the Third Cataract, were used in the field by the reconnaissance soil surveyor who annotated the prints and then transferred the data to the mosaics at the end of the survey. These annotated prints and mosaics were again used by the semi-detailed soil surveyors together with new prints at 1:25,000 scale covering the Kulud-Merowe area. No mosaics were made for this latter area and map compilation for the Fitna, Korti and Gureir areas has been directly from air photographs.

Report No. 3 contains some useful notes on air photo interpretation. Additional observations by the semi-detailed field parties in relation to land types, drainage, other relief features, vegetation, land-use and population centres are described as follows:-

3.21 Land Type. Three major landforms could be distinguished within the project area:- (a) The active floodplain or basins. These are derived from former river channels, and consist of grey seasonally flooded basins of varying width. The darker patches are those subject to the longest period of inundation, and are often devoid of vegetation.

(b) The higher terraces. These may be distinguished by their relief, and are varied in colour, often being depicted by a mixture of grey and white.

(c) The abraded rock platform and dissected outcrops. The highly eroded state of the Nubian sandstones bordering the Nile is clearly visible on the prints. Gullies and patches of windblown sand appear white against the grey background of the rocks.

3.22 Drainage. The drainage of the basins adjacent to the river is effected by means of canals. On the higher terraces narrow V-shaped and U-shaped gullies could be distinguished leading towards the basins, while the white gullies incised into discontinuous gravel ridges had a characteristc-ally dentritic pattern of drainage. As mentioned above, the localities most prone to flooding within the basins were darkest in colour.

3.23 Other relief features. Micro-relief was not visible on the aerial photographs. Along the desert margin and adjacent to the higher terraces, gravel ridges were discernible, while they could occasionally be distinguished adjoining the floodplain.

Sand sheets are characteristically white and were often colonised by Acacia tortilis, which appeared as irregularly spaced black dots on the prints. Dunes could be distinguished by their relief, while barchans occurred as scattered white crescents.

3.24 Vegetation. The irregular spaced dots representing Acacia ehrenbergia have been alluded to in section 3 above. Date palms appear as a dark star-shaped dot. In general the vegetation was most dense on the sandier soils, but throughout this arid area, the vegetation was rare, or, at most, sparse in its distribution.

3.25. Land Use. Cultivation was either by pump irrigation or by sagiya irrigation or by seasonal flooding. Flood cultivation gives rise to fields irregular both in size and shape. It appears probable that the lighter coloured fields are in fallow, while the darker strips were cultivated at the time the photography was flown. Pumps are visible on the prints which furnish these areas with additional water as the flood recedes. Drainage is provided by inlet and outlet canals. The permanent pump schemes have a more regular field pattern, while date gardens may be recognised throughout the area by their evenly spaced rows of trees. Different varieties of crops could not be identified from the prints without thorough prior ground control. Sagiya cultivation gave rise to a highly distinctive pattern on the prints consisting of a circle adjacent to the river from which issued a narrow inlet channel aligned at right-angles to the edge of the river.

3.26 Population and settlement. Villages gave rise to a characteristically elongated ribbon pattern of settlement, often forming a long and narrow strip of built-up land where villages merged into one another. On the prints, villages appeared as a series of dark rectangles set against a bare light grey background. They were restricted to the higher portions of the basins, being situated on ridges and on the higher terraces.

3.3 Soil Survey Procedures

The semi-detailed survey of the project area was carried out in January 1963 by a team of five soil surveyors. Because the project lands consist of 10 discrete areas, rather widely separated, the survey parties worked in two or more groups from a number of different headquarters.

3.31 Sample Areas

The method adopted for the survey followed the suggestion made in the contract of September 27, 1962 and since used in Areas 1 & 3. Because of the considerable data made available from the reconnaissance survey only two sample areas were studied, one in Kerma Basin and one on the El Bakri Plain (See Appendix 1). From 13 profile pits, 34 samples were dispatched to the laboratory for the following analyses:-

(i) Mechanical Analysis (International Fractions)

(ii) Salinity Test (E.C. on Saturation Extract)

(iii) pH on 1:5 suspension and soil paste

3.32 Routine Semi-detailed Survey

The sampling density was at least one site to each 250 feddans. An even geographic spread of sites was obtained by marking up the prints and mosaics with a grid based on a side of 1.025 km. One routine site was then selected as representative of the area within each square of the grid. Each bore site was investigated to a depth of 2 metres, with every 50th bore being taken to a depth of 3 metres. The sampling tool was an Australian jarret type auger of approximately 5 cm diameter. The description of the site characteristics, the soil profile and the bore samples were made at the time of sampling. Soil samples were taken to fixed depths of 0-45 cm, 45-90 cm and 90-150 cm at each site.

There were 364 bore sites within the project area. A total of 1092 samples were sent for the following analyses:-

(i) Salinity test (E.C. on saturation extract)

(ii) Clay content of the air-dry soil

(iii) Exchangeable sodium

The exchangeable sodium percentage (E.S.P.) was then calculated from (ii) and (iii) as follows:-

$$E.S.P. = \frac{\text{Exchangeable Na as m.e./100gm soil} \times 100}{\text{Clay per cent.}}$$

3.33 Representative Sites

At 26 selected representative sites throughout the project area, pits were accurately described and sampled by major horizons.

A total of 75 samples were sent for the following analyses:-

(i) Mechanical Analysis (International Fractions)

(ii) Salinity Test (E.C. on Saturation Extract)

(iii) Soluble Sodium on Saturation Extract

(iv) Soluble and Exchangeable Sodium

(v) pH on soil paste.

Exchangeable sodium was then determined from (iii) and (iv), by difference. The E.S.P. was calculated from (i), (iii) and (iv) as described under 3.32.

3.34 Series Sites

After examination of the soil and site descriptions and the analytical data from the representative sites, 15 of these profiles were considered to be representative of the major soil series of the project area. Samples from the major horizons at these sites (39 altogether) were then sent for the following analyses:-

(i) Cation Exchange Capacity (C.E.C.)

(ii) Exchangeable Cations, Ca, Mg, Na, K.

(iii) Soluble Cations, Ca, Mg, Na, K.

(iv) Soluble Anions:- sulphates, chlorides, carbonates and bicarbonates.

(v) Total carbonate expressed as $CaCO_3$

(vi) Organic Nitrogen

(vii) Organic Carbon

(viii) Total K, in the rooting zone only

(ix) Total P, in the rooting zone only.

The Exchangeable Sodium Percentage was then calculated as follows:-

$$E.S.P. = \frac{\text{Exchangeable Na (m.e.\%)} \times 100}{\text{C.E.C. (m.e.\%)}}$$

3.4 Field Permeability Studies

Field permeability tests were carried out at 3 pit sites. Two tests were made at one of these sites so a total of 4 tests were made.

The method was adapted from the type 'A' test described in the Earth Manual, United States Bureau of Reclamation., 1951, as used by Hunting Technical Services Ltd, in their Kirkuk (Iraq) and Pangani (Tanganyika) projects.

Apparatus:

Land Rover	Clean gravel
2 x 4 gallon drums	Mirror
2" Jarret auger	50 cc. graduated cylinder
10 m. rubber tubing	250 cc. graduated cylinder
2 screw clamps	Stopwatch
2 m. measuring tape	Thermometer

Procedure:

The tests were carried out in or beside the 2m. pits dug in the Sample Areas of the soil survey whose textural layers had previously been defined and described. Horizons more than 25 cm. had to be used as the method is unreliable where the length of the test section is less than five times the diameter of the bore. The top of the horizon was cut back as a step in the pit and a hole bored in it vertically with the Jarret auger. The bore was examined with a mirror and was only used if no cracks were visible.

If the inflowing water is colder than the soil, dissolved air comes out of solution as it enters the soil and the bubbles produced block the soil pores and reduce the soil permeability. As the water was if anything slightly warmer than the soil, however, it was considered that possible errors from this source could be neglected.

After boring, the depth of the hole was measured in centimetres. A few handfuls of gravel were then put in and a 1 m. length of auger tubing inserted. The hole was then filled with gravel. The top of the gravel is considered to be the top of the test section. Its depth below the top of the hole was measured and substracted from the total hole depth to give h, the height of the test section. The gravel is needed to prevent the hole collapsing when wetted and the auger tubing is needed to facilitate the introduction of the water.

The hole is then filled to the mark with water from the drum through the rubber hose. The screw clamp on the hose is used to maintain the water surface at the level of the top of the gravel. The rate of inflow is measured at 5 minute intervals by catching the flow in a graduated cylinder for a timed period. The rate steadily decreases at first but becomes more uniform after 20 minutes, and the final reading of the rate of flow is taken when the readings have become reasonably constant - generally 30-45 minutes after the commencement of the test.

From the final reading the permeability is deduced from the formula given below:

$$K = \frac{864Q}{Curh}$$

where K = coefficient of permeability in m/day/unit hydraulic gradient

Q = rate of steady inflow in ml/sec.

r = radius of bore in cm.

h = height of water column in cm.

Cu = coefficient obtained from Table 3.4

Table 3.4 - Coefficient of Conductivity

h/r	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
Cu	32.0	32.9	33.7	34.5	35.3	36.1	36.9	37.8

h/r	14.0	14.5	15.0	16.0	17.0	18.0	19.0	20.0
Cu	38.6	39.4	40.2	41.9	43.5	45.2	46.8	48.5

Results of the tests are given in Chapter 4.

3.5 Chemical Analyses of Soils

The following methods were used by Agricultural Services (Sudan) Ltd. in making the determinations:-

(i) Mechanical Analyses: Bouyoucos Hydrometer Method

40 grams soil soaked with 250 ml. water and 11 ml. of 10% sodium hexametaphosphate solution overnight, and dispersed the next morning in an electric stirrer for 10 minutes, transferred to a 1 litre measuring cylinder, shaken and readings taken after 4 minutes, 2 hours and 7 hours. With every reading the temperature is recorded and corrections made for temperature and dispersing agent content. The readings are also corrected for moisture content, when required, by performing separate moisture determinations.

(ii) pH

Potentiometric determinations using a glass electrode on the soil paste or 1:5 suspension, were carried out.

(iii) Electrical Conductivity

Calculated by usinga Solubridge on the saturation extract.

(iv) Total Organic Nitrogen

Estimation of Organic plus ammonia nitrogen, by Kjeldahl digestion, followed by distillation of freed ammonia into a boric acid solution, and titration with 0.05 N. HCl.

(v) Organic Carbon

Wet oxidation of the organic matter by the Walkley-Black rapid method (ref. C.S. Piper, Soil and Plant Analysis, 1942, page 223).

(vi) Total extractable Phosphorus

Extracted using constant boiling hydrochloric acid on a sand bath for a few hours (ref. Soil and Plant Analysis). Estimated by reduction of an aliquot portion, with ascorbic acid in sodium hexametasulphite, to molybdophosphoric blue, and comparison with standards on the spectrophotometer.

(vii) Total extractable Potassium

Extracted during the above process. An aliquot is taken, treated with ammonia to precipitate the sesquioxides, reacidified, and compared with standards flamophotometrically.

(viii) Carbonate as Incorporated Calcium Carbonate

Gasiometrical determination in Collins calcimeter (ref. Collins S.H. 1906, J. Soc. Chem. Ind. 25: 518). The volume of CO_2 generated from a known weight of the soil is reduced to standard conditions, and calculated as if the total volume were derived from calcium carbonate only.

(ix) Carbonate and Bicarbonate in Saturation Extract

A suitable aliquot of saturation extract is pipetted and titrated first against phenolphtalein indicator (it is essential to add always the same amount of indicator to the same volume) followed by titration against methyl-orange.

(x) Chlorides in Saturation Extract

A suitable aliquot is pipetted into a porcelain evaporating dish, and the chloride content determined by Mohrs method (ref. Vogel, Quantitative Analyses) using 5 per cent potassium chromate as indicator, and titrated with 0.02N silver nitrate solution.

(xi) Sulphate in Saturation Extract

1 ml. of suitably diluted saturation extract is added to a medium of glycerol and glucose solution, barium sulphate generated, (ref. Current Science Vol. 31, No. 10, October 1962, page 419).

(xii) Soluble Calcium and Magnesium in Saturation Extract

A suitable aliquot of saturation extract is titrated with 0.01 N sodium versenate solution first against the Eriochrome Black T indicator and a second aliquot against the Purpurate (Murexide) indicator. It is essential in this second titration to work to as much as possible with equal volumes as the end point of titration against Purpurate varies with the dilution. (Ref. Agric. Handbook No. 60, U.S. Dept. of Agriculture).

(xiii) Soluble Sodium and Potassium in Saturation Extract

Appropriately diluted saturation extract is analysed on flame-photometer for Na viz K.

(xiv) Exchangeable Sodium and Potassium

12.5g of soil are soaked in 50 ml. of normal ammonium chloride, left for one hour then leached a few times (about four times) by decantation. Then the soil is transferred into the filter and leached with successive portions of normal ammonium chloride when drained. Leaching is continued until 250 ml. of filtrate are collected. The filtrate (5ml.) is diluted 20 times and sodium read off on flamephotometer against 10 ppm. sodium standard containing the same amount of ammonium chloride. Zero is set with 0.05 N. ammonium chloride. In another portion of suitably diluted filtrate potassium is determined flamephotometrically against standards containing the same amount of ammonium chloride. From these readings the sum of soluble plus exchangeable sodium viz. potassium are calculated. By subtracting the soluble sodium and potassium from saturation extract data the net figures for exchangeable sodium and potassium are obtained.

(xv) Exchangeable Calcium and Magnesium

The method is essentially that described in C.S. Piper, Soil and Plant Analysis, page 170, the difference being only in the amount taken and leached twice with 250 ml. of normal sodium chloride. Ca viz. calcium plus magnesium are determined by versenate titration (ref. Agric. Handbook No. 60, U.S. Dept. of Agriculture, page 94).

(xvi) Cation Exchange Capacity

The clay is converted into a sodium clay using sodium acetate. Soluble salts are washed out with 95% alcohol, and sodium is released by ammonium acetate. It is estimated flamephotometrically. (ref. U.S.D.A. handbook No. 60).

3.6 Map Compilation

3.61 The Base Maps

The Base Maps were compiled from 1:25,000 scale mosaics and reduced and fair drawn by Hunting Technical Services at 1:50,000.

The investigated sites were marked on the base maps as follows:-

- O — 2 metre auger bore.
- ◎ — 3 metre auger bore.
- △ — 2 metre pit.
- ★ — site of permeability test.

3.62 The Soil Maps

A coded soil classification is marked beside each site on the soil maps. The full classification system is explained in detail in Chapter 4.

Because of the intricate soil pattern found in the project area it was not possible to draw boundaries around each soil series. Instead, the mapping units are soil associations which include a number of soil series, usually arranged into recurring landscape patterns. The following soil associations, which are listed in the map legend, are shown on the soil maps:-

Association No.

1. Psammic Psammaquents
(Deep, poorly drained sands).

3. Orthic and Vertic Hapludents with fine texture
to at least 30 cm.
(Poorly drained loams and clays).

4. Orthic and Vertic Hapludents with fine textures
to less than 30 cm.
(Poorly drained loams and clays).

6. Orthic and Vertic Orthustents
(Well drained loams and clays).

7. Psammustentic Orthustents
(Well drained sandy and loamy soils).

8. Oxic Psammustents
(Deep, well drained sands).

10. Salorthids (highly saline soils).

It should be noted that Associations 2 (Udic Psammaquents), 5 (Psammic Hapludents), and 9 (Orthustentic Psammustents) which occur in the Nile Valley were not mapped in the project area.

The soil examination sites were located in the field on aerial photographs and later marked up on the aerial mosaics. The series classification at each site was later determined on field and laboratory characteristics and marked on the mosaic beside the soil examination site. The soil associations were then defined, largely on the basis of grouping together soils of similar texture. Soil boundaries were then drawn between the different soil associations, by photo interpretation where possible, otherwise by interpolation between soil examination sites.

The data on the mosaics was then transferred to the base maps.

3.63 The Land Class Maps

A coded land classification is marked beside each site on the land class maps. The land classification system is explained in full in Chapter 5 of this report.

The land class at each site was first marked up on the aerial mosaics. Boundaries between areas of the various land classes were then drawn on the mosaics, by photo interpretation where possible, otherwise by interpolation between soil examination sites. The data on the mosaics was then transferred to the base maps.

CHAPTER 4

PEDOLOGY

4.1 The Soil Classification System

4.11 Definitions

The classification of soils within the project area is based on the Seventh Approximation, U.S. Department of Agriculture (1960). See table 4.11 and the album of soil maps. The soil orders, sub-orders, groups and subgroups are defined as follows:-

Order: Entisols:

Are soils either without natural genetic horizons or with only the beginnings of horizons. The horizons present are so weakly expressed that they fail to meet the requirements of any of the diagnostic horizons, except the albic (white) horizon and those that are produced through cultivation by man. At one extreme in age, an Entisol might consist of very recent alluvium; at the other extreme in age it may include quartz sands which have been in place for many thousands of years.

The central concept of Entisols includes soils in deep regolith or earth with no horizons except perhaps a plough layer. Colour is not of significance in defining this group. Under arid conditions, the Entisols may show small secondary accumulations of carbonates, sulphates or more soluble salts. Clayey soils that lack distinct horizons are excluded from this group if they develop wide cracks at some season and have gilgai microrelief, slickensides close enough together to intersect within each ped, or parallelepiped, or wedge shaped peds, that have their large axis titled from the horizontal by 10 to 60 degrees.

Order: Aridisols are primarily soils of dry places. They have an ochric epipedon (light coloured surface horizon) and one or more additional diagnostic horizons. These are cambic, argillic, natric, calcic, gypsic and salic horizons and duripans. The Aridisols do not have a spodic or oxic horizon, nor do they have a mollic or umbric epipedon. Included in the Order of Aridisols are most soils that previously were called Desert Soils, Red Desert Soils, Sierozems, Reddish Brown Soils and Solonchaks. Some of the Regosols and Lithosols of dry climates and some Brown Soils and Solonetz are also included.

Sub-Order: Aquents

The Aquents are Entisols that are saturated with water at some season, or are marshy soils that have been artificially drained. They have, in addition, one or more of the following properties at depths of less than 50 cm:-

(i) A histic epipedon (surface horizon high in organic matter).

(ii) Sodium saturation of more than 15 per cent in the surface horizon, with decreasing E.S.P. below 50 cm.

(iii) Colours as follows:-

a. In hues as red or redder than 10YR, chromas of 2 or less if mottled, and less than one if not mottled.

b. In hues between 10YR and 10Y, chromas of 3 or less if with distinct or prominent mottles, and one or less if lacking mottles.

c. Hues bluer than 10Y.

d. Any colour that may be due to uncoated sand grains.

The Aquents are Entisols found in naturally wet places such as permanent or temporary swamps and marshes. In the Northern Province of the Sudan they are found in the lowest areas of the Kerma Basin, where they are characterized by an absence of iron oxide coatings on the sand grains and the concentration of the free oxides to form mottles in the more compact horizons.

Sub-Order: Udents

The Udents include the Entisols that are usually moist in some horizon or layer within the soil but which lack the characteristics associated with the waterlogging of the Aquents. In general, if mottles are present within 50 cm of the surface, the dominant chromas are more than 2 in hues as red or redder than 10YR.

The Udents may have an ochric, anthropic or plaggen epipedon and an albic horizon. Other diagnostic horizons are not permitted, nor are fragipans or duripans.

The textures must be finer than loamy very fine sand somewhere within 50 cm of the surface. The clay content may not exceed 40 per cent, however, if there are slickensides, gilgai, or cracks and structures diagnostic for Vertisols.

The Udents, which include some of the soils that have been called Regosols, Lithosols and Alluvial soils, are found chiefly in humid climates, ranging from the tropics to the tundra. A few are found in arid and semi-arid climates where there is natural irrigation. In the Northern Province of the Sudan the Udents are found in the Kerma, Letti and Affat Basins and on the edge of the Kulud Pump Scheme.

Sub-Order: Ustents

Ustents are Entisols that, unless irrigated, are dry soils. They include many of the soils of arid and semi-arid regions of the world that have been called Lithosols, Regosols and Alluvial Soils. The Ustents have ochric epipedons (light coloured surface horizons). They lack other diagnostic horizons, although they may have discernible secondary carbonates or accumulations of salts. They may even show slight cementation in some horizons, enough to give few to many, hard or very hard, disconnected nodules. Unless the soil is irrigated, moisture is held at tensions of more than 15 atmospheres throughout the soil for more than half the year. If irrigated, the soil soon becomes dry when irrigation ceases.

Sub-Order: Orthids

The Orthids are the Aridisols that have an ochric epipedon and a cambic horizon, a duripan or an illuvial horizon of water soluble material (a calcic, gypsic or salic horizon). The Orthids do not have an argillic, spodic, oxic or natric horizon.

Group: Psammaquents

The Psammaquents are the sandy Aquents. Sandy textures, including the loamy fine sands and coarser textures, must extend to depths of 50 cm. or more. Most commonly the colours are white with faint or distinct mottles. Faint A and B horizons may be recognisable but they should not exceed the degree of development specified for the Entisols.

Group: Hapludents

The Hapludents are the Udents which do not have anthropic or plaggen epipedons nor agric horizons. They are soils with textures as fine as or finer than loamy very fine sand within a depth of 50 cm. The soil colours usually have chromas of 3 to 4 in the upper 50 cm. Soil moisture is held at tensions of less than 15 bars (below wilting point of plants) in some horizon or layer of the soil for most of the year.

Group: Orthustents

Orthustents include dry, loamy and clayey soils with textures finer than loamy fine sand extending to 50 cm.or more. They have an ochric epipedon that may or may not be slightly darker than the underlying horizons or layers. Weak cementation that is not destroyed by soaking in acid is permitted in the lower horizons if only cemented nodules are present. Accumulations of secondary lime, gypsum or salts may be seen as efflorescences or mycelia. Distinct CS and SA horizons may be present but not gypsic or salic horizons (accumulations of gypsum exceeding 5 per cent or soluble salts exceeding 2 per cent). Redistribution of carbonates sufficient to give a CA horizon underlying a horizon that has lost its carbonates is not permitted, for the leached horizon comes within the definition of a cambic horizon (a changed or altered horizon). These soils are found on flood plains, fans and uplands throughout the arid and semi-arid regions of the world. Vegetation if undisturbed, consists of annuals and zerophytic perennials.

Group: Psammustents

The Psammustents are the coarse - textured soils that lack water held at tensions of 15 bars for most of the year. They are dry sandy soils. Textures coarser than loamy very fine sand must extend to depths of 50 cm or more.

Psammustents are found throughout the world, usually in association with partially stabilized dunes but in many places they have been deposited by water on fans or on flood plains. Both modes of origin have operated in the Northern Province of the Sudan where Psammustents cover wide areas of land.

Group: Salorthids

The Salorthids are the Orthids that have a salic horizon at a depth of less than 50 cm. This group is not subdivided further in the Seventh Approximation system.

The Salorthids were previously called Solonchaks. They are frequently associated with zones of high water table. When dry, the surface soil is usually covered by a white salt crust. Vegetation is sparse and salt loving. Salts usually appear as an efflorescence on the walls of pits as the damp soil dries out. Where salts have come to the surface by capillary rise the soil just below the surface is very fluffy and the salt crust is lifted in places to form a hummocky surface with a microrelief of 15 to 30 cm.

Throughout the world, Salorthids are commonly found in playas (intermittent lakes) but they are also found on terraces, fans and deltas. In the Northern Province of the Sudan they are found in places around the edge of Kerma Basin where the sandy soils allow large amounts of evaporation from a shallow water table. No downward leaching occurs at these sites which are above flood level.

Sub-Group: Psammic Psammaquents

The Psammic Psammaquents, like the Orthic Psammaquents, are deep sands with sandy textures extending to 75 cm or more, but differing in colour from the Orthic Psammaquents. In the Psammic Psammaquents the chromas of 2 or less cover less than 80 per cent of the mass to a depth of 75 cm. or there are higher chromas than 2 in most of the matrix in some of the horizons or layers that lie within the upper 50 cm. From a genetic viewpoint, the groundwater is deeper in these soils or persists for shorter effective periods.

Sub-Group: Udic Psammaquents

The Udic Psammaquents include those Psammaquents that have textures finer than loamy fine sand between 50 and 75 cm. and that have colours other than those of the Orthic Psammaquents. Either chromas of more than 2 occupy more than 20 per cent of the mass to a depth of 75 cm. or chromas of more than 2 cover most of the matrix in some of the horizons or layers that lie within the upper 50 cm.

Sub-Group: Orthic Hapludents

The Orthic Hapludents include the Hapludents that, within the upper 50 cm, have an ochric epipedon on C material that has chromas of 3 to 4 or more; have no mottles with chromas of 2 or less; have textures that are as fine or finer than loamy very fine sand; lack as much as 40 per cent expanding clay; have less than 60 per cent allophane in the clay fraction and volcanic ash in the silt and sand; and have no R layers (underlying bedrock). One horizon or another within the soil is usually moist, with moisture held at tensions of less than 15 bars in some horizon or layer most of the year.

The lack of diagnostic horizons in Hapludents is attributed to lack of time for formation. They are therefore found largely in places where there has been geologically recent deposition or erosion. In the Northern Province of the Sudan they are found on Nile silts recently deposited in the basins.

Sub-Group: Vertic Hapludents

This subgroup includes all Hapludents that have more than 40 per cent expanding lattice clay. They have an ochric epipedon, clayey textures, and chromas usually near 3 but too high for the Aquents. Mottles with high chromas may be present or absent in the upper 50 cm. These soils, however, lack the gilgai the intersecting slickensides and the wide deep cracks or structure diagnostic for Vertisols. In the Northern Province a few profiles have been mapped in the Kerma and Letti Basins.

Sub-Group: Orthic Orthustents

This subgroup includes the loamy soils extending to 30 cm. or more, having less than 40 per cent expanding lattice clay and, in lower horizons, lacking cementation into small nodules that will not soften in acid. Secondary accumulations of gypsum and salts that do not constitute gypsic or salic horizons are permitted but not required. Visible secondary lime is also permitted, but leached surface horizons lying on CA horizons are excluded. These soils mostly occupy the lower silt terraces and the higher parts of the basins of the Northern Province.

Sub-Group: Vertic Orthustents

This subgroup includes the Orthustents that have more than 40 per cent expanding lattice clay but that lack the cracks, slickensides, gilgai or structure diagnostic for Vertisols. In the Northern Province of the Sudan a few profiles of these soils were found associated with Orthic Orthustents in the silt terraces and basins.

Sub-Group: Psammustentic Orthustents

This subgroup is an intergrade towards the group of Psammustents. The soils have a layer of sand or loamy sand in the upper 50 cm of the profile. In the Northern Province they are found in the basins where a shallow layer of Nile silt may overlie sand and on the terraces where a shallow layer of desert sand may overlie silt deposits.

Sub-Group: Oxic Psammustents

This subgroup includes soils that have been highly weathered during some previous geological period. The sand fraction is dominantly quartz, 95 per cent or more. The clay fraction is mostly 1:1 lattice clay and free oxides, but the clay content is too low for an oxic horizon. These soils are not known to occur in the United States but are recorded from Australia and Africa. In the Northern Province the Oxic Psammustents are formed both from weathering of the Nubian sandstones of Mezozoic age and from river sands laid down in the Quaternary age by the Nile.

Table 4.11 Soil Classification Chart
(U.S.D.A. 1960 System)

ORDER	SUB-ORDER	GROUP	SUB-GROUP
1. ENTISOLS	1.1 AQUENTS	1.12 PSAMMAQUENTS	1.12-1.2 PSAMMIC PSAMMAQUENTS
			1.12-1.4 UDIC PSAMMAQUENTS
	1.3 USTENTS	1.31 PSAMMUSTENTS	1.31-9 OXIC PSAMMUSTENTS
			1.31-1.32 ORTHUSTENTIC PSAMMUSTENTS
		1.32 ORTHUSTENTS	1.320 ORTHIC ORTHUSTENTS
			1.32-2 VERTIC ORTHUSTENTS
			1.32-1.31 PSAMMUSTENTIC ORTHUSTENTS
	1.4 UDENTS	1.43 HAPLUDENTS	1.430 ORTHIC HAPLUDENTS
			1.432-2 VERTIC HAPLUDENTS
4. ARIDISOLS	4.1 ORTHIDS	4.14 SALORTHIDS	

Sub-Group: Orthustentic Psammustents

This subgroup is an intergrade towards the group of Orthustents. The soils have a layer of loamy or clayey material between 50 and 75 cm. In the Northern Province they are found on the upper river terraces where the old silt layers have been covered by a fairly deep mantle of desert sand.

4.12 Classification of the Northern Province Soils

The soils of the project area belong mostly to the soil order of Entisols but a few profiles belong to the soil order of Aridisols. See tables 4.121 and 4.122.

The Entisolic soils have been subdivided into sub-orders on the basis of drainage status; the Aquents and Udents of the Basins show characteristics of impeded drainage whereas the Ustents of the silt terraces are dry almost continuously.

Within the basins the sandy soils appear to be marginal between Aquents and Psamments; they are not classed as Psamments, however, because they are not always moist in some horizon and because their high chromas appear to be the result of uncoated sand grains rather than coatings on sand grains. They therefore belong to the subgroups of Psammic Psammaquents and Udic Psammaquents.

Within the basins, the finer textured soils cannot be classed as Aquents because of the total absence of gleying and the irregular distribution of alkalinity. They are therefore classed as Udents because they are generally moist in the subsoil owing to their higher water holding capacity and slower permeability as compared with the sandy soils. These Udents belong to the group of Hapludents which are again subdivided into the subgroups of Orthic and Vertic Hapludents.

The dry soils at the edges of basins and on the silt terraces belong to the sub-order of Ustents. They are subdivided into the groups of Psammustents (sandy soils) and Orthustents (loamy and clayey soils) which are again subdivided into the subgroups of Oxic and Orthustentic Psammustents and Orthic, Vertic and Psammustentic Orthustents.

The subgroups are divided into families, largely on the basis of textural groupings, and into series on the basis of alkalinity status. See table 4.121. Non-alkali soils are those in which the exchangeable sodium percentage (E.S.P.) is less than 15. In alkali soils the E.S.P. exceeds 15.

It will be noted that table 4.121 shows a list of 36 soil series which are derived from combinations of the main variable characteristics used in the soil classification system. In fact six of these possible combinations did not occur in the project area. It will be seen from table 4.122 that a total of 30 soil series were recognized in Area 4a at a total of 360 inspection sites. An additional 4 sites were classified as belonging to the order of Salorthids, without more detailed categorization.

Table 4.122 shows that 78 per cent of the sites were included in nine soil series:-

C1, C2, C3, C4, F1, F2, F4, H1 and H2. These are the major soil series of the project area. The remaining 21 named soil series are of much less importance and are each found at from one to nine of the inspected sites.

Table 4.121 Specifications for Soil Series and Soil Families

SUB-GROUPS	FAMILIES	SOIL SERIES
1. PSAMMIC PSAMMAQUENTS	A. Deep sands to 75 cm (Over 90 per cent S).	P1 Non-alkali P2 Alkali
	B. Deep Loamy sands to 75 cm. (80-90 per cent S.)	P3 Non-alkali P4 Alkali
2. UDIC PSAMMAQUENTS	C. Sands overlying medium textured soils (under 40 per cent C)	P5 Non-alkali P6 Alkali
	D. Sands overlying fine textured soils (over 40 per cent C)	P7 Non-alkali P8 Alkali
3. OXIC PSAMMUSTENTS	A. Deep sands to 75 cm (Over 90 per cent S).	C1 Non-alkali C2 Alkali
	B. Deep loamy sands to 75 cm. (80-90 per cent S).	C3 Non-alkali C4 Alkali
4. ORTHUSTENTIC PSAMMUSTENTS	C. Sand over fine soil within 50-75 cm.	C5 Non-alkali C6 Alkali
	D. Loamy sand over fine soil within 50-75 cm.	C7 Non-alkali C8 Alkali
5. ORTHIC ORTHUSTENTS	A. Coarser Loamy soils with 10-25 per cent C.	F1 Non-alkali F2 Alkali
	B. Finer loamy soils with 25-35 per cent C.	F3 Non-alkali F4 Alkali
6. VERTIC ORTHUSTENTS	C. Sandy & silty clays with 35-45 per cent C.	F5 Non-alkali F6 Alkali
	D. Clays with over 40 per cent C.	F7 Non-alkali F8 Alkali
7. PSAMMUSTENTIC ORTHUSTENTS	E. Shallow loamy soils on sand within 30 cm.	F9 Non-alkali F10 Alkali
	F. Sand or loamy sand on fine soil within 50 cm.	F11 Non-alkali F12 Alkali
8. ORTHIC HAPLUDENTS	A. Loamy soils to over 30 cm.	H1 Non-alkali H2 Alkali
	B. Loamy soils to less than 30 cm.	H3 Non-alkali H4 Alkali
9. VERTIC HAPLUDENTS	C. Clayey soils to over 30 cm.	H5 Non-alkali H6 Alkali
	D. Clayey soils to less than 30 cm.	H7 Non-alkali H8 Alkali

Table 4.122 Frequency Distribution of Soil Series at all Classified Sites in Area 4a.

Soil Series	1 FITNA	2 GUREIR	3 KORTI	4 KULUD	5 AFFAT	6 LETTI	7 EL BAKRI	8 URBI	9 WEST DONG-OLA	10 KERMA	Total Sites
P1										7	7
P2										3	3
P3										4	4
P4										4	4
P6						1				1	2
C1		1		1		1	4	2	2	6	17
C2			1	1			5	2	4	8	21
C3						1	10	3		4	18
C4	1	2	1	1			10		1	5	21
C5							1				1
C6										1	1
F1					2	2	7	1	4	7	23
F2	1	15		8			39		7	11	81
F3		1			1	3	1		1	2	9
F4		4					14		14	1	33
F5					1	1	2				4
F6						1	5		2	1	9
F8							2		1	1	4
F9										3	3
F10							1			1	2
F11		1			1						2
F12		2								1	3
H1				3	8	17				18	46
H2						6				15	21
H3					2	1				1	4
H4										3	3
H5						1				6	7
H6										1	1
H7						1				4	5
H8										1	1
Total	2	26	2	14	15	36	101	8	36	120	360

Note:

There are four additional sites in Kerma Basin which are classified as Salorthid.

4.2 Physical Characteristics of the Soils

Area 4a is a large complex area consisting of 10 smaller units often widely separated. For the purposes of this general description it is convenient to group these units into two classes, a) the alluvial terraces on the left bank of the Nile comprising the Dongola Plain, the Urbi Plain, the El Bakri Plain, the Kulud extension, the Korti area, the Gureir extension and the Fitna area; and b) the seasonally inundated basins on the right bank, comprising the Kerma, Letti and Affat basins.

4.21 The Alluvial Terraces

The physical characteristics under consideration are texture, structure, consistency, colour and any characteristic aggregated minerals present in the profile. The soils in these areas are all Entisols and by definition lacking in genetic horizons, but depositional layers are often present and are generally recognised by changes in texture.

4.211 Texture

The texture of the alluvial soils varies considerably according to the location of the site. The soils over most of the area are loamy, varying from loamy sand to clay loam with considerable textural variations down the profile. Where coarse grained material overlies finer grained deposits, the top layer is usually wind-blown deposition in depressions, and has to be dug out before the compacted alluvium can be reached. The soils near the river are usually sandy, as are those outside the alluvial area away from the river, on the outer edges of the area.

The lack of uniformity in the deposits is shown by the sample area, which has one pit of almost pure sand down to two metres, while all the other have loamy textures.

When texturing these soils in the field, surveyors tended to describe the soils as silty. Although the silt content is fairly high, it is exceeded by the fine sand content and the soils would more correctly be called fine sandy loams, fine sandy clay loams, etc.

4.212 Structure

The soils of the area show weak structural development. The structure of many sites is a reflection of the texture; a surface horizon of loamy material may show variable blocky structure, or often a fine platiness associated with the depositional layers. There may be frequent vertical cracks but the areas in between cracks are so compacted that much force is needed to break the blocks, and the term massive may be used. This is particularly true of loamy material at depth, when the vertical cracks are fewer and depositional lines are not evident. This material is very compact and augers and even pick-axes had difficulty penetrating it due to its rock-like nature.

Where sands are dominant the profile is again structureless, apart from depositional layers in the riverine deposits. These layers are often of different colours with diagonal planes. Occasionally they are found cemented into sandstone, possibly by calcium carbonate.

Where aeolian sand deposits are present overlying riverine material the horizon is again structureless.

4.213 Consistency

As the soils of the area are all dry the consistency is limited to loose, soft, and degrees of hardness. The sands are usually loose, verging on hard where there is cementation and soft where the texture is very fine. The compacted loams are very hard or extremely hard with occasional hard peds near the surface. The textures with hardest consistency seem to be clay loams and sandy clay loams with a fairly large silt and fine sand fraction.

4.214 Colour

The colour of these soils seems to be dictated in part by the amount of sand present. Loamy soils are usually grey ranging from 10YR 4/2, 10YR 5/2 to 2.5Y 5/2 with occasional 5Y 4/1 and 5/1. The sands have colours of 10YR 5/3 and 5/4, and in-between colours and intergrades are often produced by the intermediate textural classes. The colours of riverine sand deposits are often impossible to estimate owing to the different colours of the bleached grains, which became translucent upon wetting.

4.215 Mineral Aggregates

The surface of the area is covered by a thin layer of wind-blown sand amongst which many kankar have been deposited. These are very hard, black or grey concretions of $CaCO_3$, which are most abundant on the surface, and decrease with depth. When found at great depth they have usually been sloughed down cracks. Small white $CaCO_3$, concretions, gravel and pebbles are also frequently encountered on the surface.

Mineral deposits below the surface depend on the type of profile present. If there is any depth of aeolian material, inclusions will be virtually absent, and surface deposits will be greatly reduced, although the sand fraction will include a proportion of finely divided calcium carbonate, visible with a lens. The same is true of riverine sand under a loamy top-soil; in this case calcium carbonate will have been leached out. In both cases much mica was evident.

The main inclusions therefore occur in the loamy deposits; hard calcium carbonate concretions, soft calcium carbonate aggregates, mycelia of finely divided calcium carbonate and gypsum crystals being present. Lesser occurrences are shell fragments, gravel and pebbles. The density of the deposits varies considerably, in some cases being sufficient to provide a calcium carbonate horizon in the lower part of the profile. Compacted sandstone horizons were also encountered at depth, possibly cemented by calcium carbonate.

4.22 The Seasonally Inundated Basins

The Kerma, Letti and Affat basins are parts of an old river channel. The rise in the level of the Nile during the flood season causes parts of the basins to be flooded by way of canals, constructed for that purpose. For this, and topographic reasons, the soil types of these areas can be divided into those of the flooded areas, the cultivated areas, and the sand dunes and other higher sandy areas. This applies particularly to the Kerma Basin.

The soils of these three types are so completely different from each other that it has been decided to describe a typical profile from each group. In order to emphasise the distinctiveness of the groups, the profile described will be the most advanced reflecting the soil depositing processes at work there. There are naturally integrades between the soils of the three groups and these will be mentioned.

4.221 The Flooded Depressions

The soils in these areas have a shallow surface horizon, often less than 10 cm. deep. The surface is a honeycomb of cracks, of up to 2 cm. diameter, which continue to the bottom of the horizon, and form distinct blocks of approximately 10 cm. diameter. These blocks were very slightly moist, at the time of the survey extremely hard, and their internal structure is diagnosed structurally to be strong coarse sub-angular blocky. There are some fine gravel and calcium carbonate aggregates intermixed, and the basic colour is 10YR 4/2, with intergrades to 10YR 4/3 and 3/3 occasionally present. Texturing was made difficult owing to the extreme firmness of the blocks, which are usually clay. Roots were frequent throughout this top layer, but pores were rare.

Underneath this layer lies almost pure sand, and the transition is so sharp that the surface blocks can be lifted off from the underlying sand. The second horizon extends to two metres and is loose and structureless, with depositional layers present, often only a few centimetres thick and oriented at an angle to the horizontal. These layers consist of different sand fractions, gravel and different coloured sands, so that determining the horizon colour was not practicable. On returning to the site a few days after the digging, the fossil remains of old root channels are apparent. Some sand falls away from the face of the pit leaving the hollow shells of decayed roots, in the form of sand grains, cemented probably by calcium carbonate, extending down the pit face. At some depth before the two metre mark, the water table was reached, or at least, the capillary fringe. In areas not subjected to the same amount of flooding the surface horizon is not as distinct from the second horizon.

4.222 The Cultivated Areas

In this group is included all land in the basins at present under cultivation, fallow land previously under cultivation, and land used for grazing purposes, the latter being particularly dominant in the Letti basin.

These soils are remarkable for their uniformity and lack of differentiation. The typical profile shows a gradual increase in the sand fraction with depth, and a corresponding decrease in structural definition. Horizons are recognised by change in colour, where one is apparent, or by change in texture, where the change takes place over a sufficiently small increase in depth. For the rest however the profile can be said to consist of approximately two horizons when recognised in a pit site, the first being sub-angular blocky and the second massive or structureless, according to the amount of sand present. The texture shows a gradual transition from sandy clay loam through sandy loam to loamy sand, and the consistency is usually firm. The colour is 10YR 4/2, or intergrades thereof, throughout the profile, occasionally becoming paler with an increase in sand towards the bottom.

One remarkable feature of these soils is the absence of any inclusions in many of the soils, with only traces of calcium carbonate in most of the others, and a few kankars on the surface.

Many areas consist of soils similar to those described in this section which have been over-run by advancing sand dunes. They are included in the group described in the next section.

4.223 <u>The Sand Dunes</u>

This section covers those areas of sand dunes, and adjacent land affected by drifting of the sand. In the first case the sand was loose and soft and only the top 50 cm could be examined by digging. It invariably proved to be about 90 per cent sand. In the second case the underlying soil could be examined by digging if the sand covering was not too deep; the soil characteristics proved to be similar to the soils of the previous section. The overlying sand was dry, loose, structureless and single-grain, with no inclusions.

Often a thin layer of more loamy material, a few centimetres thick, overlay the sand, in areas where any vegetation managed to survive.

4.23 Hydraulic Conductivity

Hydraulic conductivity tests were carried out on three sites, by the method previously described. The first site was in the Letti Basin where tests were carried out on two horizons. The remaining two sites were in the El Bakri Plain and were subjected to one test each.

The following table shows the conductivity in relation to the soil texture.

Table No. 4.23 Hydraulic Conductivity at 3 Sites

Site	Depth in cm.	Soil Particles % Sand	Silt	Clay	Hydraulic Conductivity (m/day/unit gradient)
5400	52 - 92	70	5	25	0.17
"	90 - 130	48	25	27	0.09
5409	45 - 105	48	30	22	0.03
8161	60 - 105	65	20	15	0.04

The low values obtained for the sites on the El Bakri Plain reflect the very compact nature of the lower layers of these terrace soils there.

4.3 Chemical Characteristics of the Soils

Because of the practically rainless desert climate, pedogenetic processes have not been operative in the soils of the project area. There are no pedogenetic horizons in these Entisolic soils and the distribution of water soluble salts, exchangeable cations, etc., is on a randomized basis. In fact, most soil layers appear to have remained unaltered since they were deposited as sediments in the channels, levees, back-waters and lakes of the pre-existing Nile flood plain.

4.31 Water Soluble Salts

The distribution of water soluble salts generally shows no distinct pattern either vertically within the soil profile or horizontally in a specific area. See appendices 2 and 3. The high level silts show very variable salinity, some being non-saline but the majority are saline. The salinity of individual silt layers may be very high in some cases; at pit No. 3500 in the Gureir Extension the 7-28 cm. layer has an E.C. of 44 millimhos per cm. at 25°C. The soils of the newly deposited silts of the basins and of the edges of the flood plain are invariably non-saline. Other parts of the basins, especially Kerma Basin, show variable salinity. In sandy soils at the edge of Kerma Basin where the water table is close to the surface, a strong surface salt crust has developed at four sites described as Salorthids.

The composition of the soluble salts at 15 sites within the project area is indicated by analysis of soluble cations and anions in the extract from a soil paste. (See appendix 2). Soluble carbonates are not present in most soils and when present, occur at a dilution of less than one milliequivalent per litre. Soluble bicarbonates are present in all samples, generally at levels between one and six m.e. per litre but occasionally higher, reaching a maximum of 10.6 m.e. per litre in the 0-20 cm layer at pit no. 5392 in the Letti Basin. Soluble chlorides and sulphates vary enormously in concentration from site to site. In non-saline soils of the basins and silt terraces (Pits 6321, 8147, 4434 and 5400) sulphates may be absent and chlorides at a very low concentration. In saline soils, however, the concentration increases enormously; the highly saline 7-28 cm layer of Pit No. 3500 contains 440 m.e. of sulphate and 164 m.e. of chloride per litre of soil extract.

Soluble sodium is the dominant cation in all soils; only in occasional horizons of non-saline soils is sodium exceeded in concentration by soluble calcium. In the saline soils the salts are dominantly sodium salts, consisting of a mixture of sodium chloride and sodium sulphate. The highly saline, 7-28 cm. layer of Pit No. 3500 contains 544 m.e. per litre of soluble sodium ions.

Soluble calcium is present in all soils, at a concentration of less than 10 m.e. per litre in non-saline soils but at higher concentrations in saline soils, reaching a maximum of 46 m.e. per litre in the 0-15 cm. layer of Pit No. 6358 in the Urbi Plain.

Soluble magnesium is present in all soils, its level varying with that of calcium and usually amounting to one half to one third of the calcium concentration. Soluble potassium ions are often present at a low level of concentration, always less than 3 m.e. per litre.

4.32 Exchange Capacity

Because these desert soils contain very little organic matter, the exchange complex is almost entirely centred in the clay fraction of the soil. There is, therefore, a positive correlation between clay content and exchange capacity in all horizons of the 15 soils examined. (See Appendix 2). The exchange capacity varies from a minimum of 2 m.e. per 100 gm. of soil in the very sandy horizon (94-200 cm) of pit No. 8147 to a maximum of 53 m.e. per 100 gm of soil in the clay loam horizon of site No. 3500. The ratio between clay content and cation exchange capacity indicates that the clays are probably dominantly of montmorillonitic type but with admixture of other clay types.

4.33 Exchangeable Cations

The non-saline soils of the newly deposited silts of the basins and flood plain are calcium soils. In these soils calcium is the dominant exchangeable cation, comprising from 55 to 75 per cent of the exchangeable cations, the remainder consisting mostly of exchangeable magnesium ions and with very little exchangeable sodium. The soils of the old silt terraces, by contrast, are mostly sodium soils; here the E.S.P. mostly exceeds 15 and often reaches 50 or even 75 per cent. Some of these alkali silts contain as much as 35 m.e. of exchangeable sodium per 100 gm. of soil.

Exchangeable potassium remains at a comparatively low but fairly constant level of usually less than 2 m.e. per 100 gm. of soil.

4.34 pH

The pH on soil paste showed the remarkably small range of 7.4 to 8.6 between layers in profiles and between widely scattered sites.

The pH on the 1:5 suspension, as expected, showed a wider range between the values of 7.4 and 9.8.

In the soils of the newly deposited silts of the basins and the flood plain there were only small variations between pH determined on soil paste as against the 1:5 suspension. The soils of the silt terraces showed greater variation in this respect, however, the pH on the 1:5 suspension sometimes exceeding the pH paste by as much as 1.5 units.

4.35 Calcium Carbonate

As described in section 4.215 and Appendix 2, field observations show that calcium carbonate is present in almost all soils in the form of nodules and concretions both on the surface and within the profile and as flecks and smears within the profile. Most of this material is separated from the fine earth fraction (material finer than 2mm diameter) when the soil sample is ground and sieved prior to sending to the laboratory. The purpose of the laboratory analysis is to determine the amount of calcium carbonate incorporated in the fine earth fraction and often not discernible in the field.

Analyses of incorporated calcium carbonate in samples from 15 pit sites show that all layers at all sites contain carbonates. In the newly deposited silts the amount of calcium carbonate is usually less than two per cent. The soils of the old silt terraces often contain considerably more, the maximum amount recorded being 18.1 per cent in the 100-200 cm. loamy layer at pit No.6414 on the El Bakri plain.

4.36 Phosphorus

Total phosphorus, extractable in hot concentrated acid, was determined on all layers of the 15 pits samples at series level. (See Appendix 2). This amount does not necessarily represent what is available to plants but is presented here in the absence of data on "available" phosphorus in the soils of Northern Province. The average figure for total phosphorus is about 50 milligram per 100 gram of soil (500 parts per million). The lowest figures (15 mg/100 gm soil) are recorded in the very sandy layers of Pit No. 8147 on the El Bakri plain. The highest figure of 84 mg/100 gm soil is from a recent silt in the Affat Basin (Pit No. 4434).

Northern Province farmers appear to use only nitrogenous fertilisers. As crop yields appear to be good it can be assumed that the level of available phosphorus is generally adequate for crops. It is possible, however, that on sandy soils and/or with specialised crops, phosphorus may sometimes be limiting.

4.37 Potassium

Total potassium, extractable in hot concentrated acid, was determined on all layers of the 15 pits sampled at series level. (See Appendix 2).

Montmorillonite type clays can fix large amounts of potassium and there is in fact a strong correlation between total potassium and clay content in these soils. The lowest values (72 mg/100 gm of soil) are in the very sandy layers of Pit No. 6416 on the El Bakri Plain. Silty soils generally show very high values of potassium ranging from about 200-1000 milligram per 100 gm of soil. The highest value recorded was 1,600/100gm soil (16,000 parts per million = 0.16%) in the 28-200 cm layer of Pit No. 3500 from the Gureir extension.

The level of potassium in these soils is similar to that in the Gezira soils. Although only a part of the extractable potassium is available to plants, no potassium deficiency has been recorded in Northern Province. The reserve of potassium in the silty soils is very great and even the sandy soils have a good reserve of this essential element.

4.38 Nitrogen

The determination of organic plus ammonia nitrogen by the Kjeldahl method was carried out on all layers from the 15 pits sampled at series level. Nitrate nitrogen was not determined.

The level of nitrogen is very low in these soils, averaging about 0.025 per cent. The maximum level was 0.070 per cent from the 0-44 cm layer of pit No. 3347 from the Kerma Basin. The minimum level of 0.008 per cent was from the very sandy subsoil of Pit No. 6321 from Kerma Basin.

From an agricultural point of view the Northern Province soils are deficient in nitrogen. Crops generally show a good response to nitrogenous fertilisers which are being used on an increasing scale when available.

4.39. Organic Carbon

Total organic carbon by the wet combustion method was carried out on all layers from the 15 pits sampled at series level.

The level of organic carbon is low. In the periodically flooded soils of the basins where the carbon content tends to be somewhat higher there is often a concentration in the surface layer and a gradient to the deep subsoil. In the terrace soils of the unreclaimed desert, however, organic carbon content is at a minimum and the distribution between layers shows no consistent pattern.

CHAPTER 5

LAND CLASSIFICATION

5.1 Specifications

The Sudan Government specifications for the semi-detailed land classification were based on those of the United States Department of the Interior Bureau of Reclamation Manual, vol. V, Irrigated Land Use, 1951.

The objective of the soil survey and land suitability classification was to assess the suitability of the lands for irrigated cultivation in general, and for specific crops in particular, for the purpose of delineating lands to be irrigated within the areas selected by the reconnaissance survey in Area 4a. The results of the survey were to be incorporated into a land suitability classification map for irrigation cultivation classifying in broad lines according to the U.S. Bureau of Reclamation standards, but adjusted where necessary for satisfactory application under Sudan conditions. The land suitability classification maps at scale 1:50,000 would show land classes 1, 2, 3, 4 and 6, thereby showing the boundaries of the irrigable areas. Because of the conditions encountered in the Northern Province it was decided also to show class 5 lands on these maps.

5.2 Land Class Standards

The Bureau of Reclamation capability classes are numbered from 1 to 6. The higher the number, the lower is the capability rating. The first three classes, 1, 2 and 3, are considered arable with progressively increasing limitations on their use and/or with increasing costs of reclamation and management. Class 4 is land suited only to special uses. Class 5 is land needing further investigation, and Class 6 is permanently non-arable.

The observation density used on the project was approximately one 2 m. bore per 250 feddans with every fiftieth to 3 m. This closely approximates to the standards given in the Manual for "semi-detailed reconnaissance". The objective of this type of survey is to separate arable from non-arable land with considerable accuracy, while delineating boundaries between classes and sub-classes in less detail. The Manual states "Generally, Classes 1, 2, 3 and 6 and their sub-classes are mapped. Special sub-classes under Classes 4 and 5 are differentiated when conditions warrant".

The following are the definitions of land classes 1-6, as given in the Manual.

Class 1 - Arable. Lands that are highly suitable for irrigation farming, being capable of producing sustained and relatively high yields of a wide range of climatically adapted crops at reasonable cost. They are smooth lying with gentle slopes. The soils are deep and of medium to fairly fine texture with mellow, open structure allowing easy penetration of roots, air and water and having free drainage yet good available moisture capacity. These soils are free from harmful accumulations of soluble salts or can readily be reclaimed. Both soil and topographical conditions are such that no specific farm drainage requirements are anticipated, minimum erosion will result from irrigation, and land development can be accomplished at relatively low cost. These lands potentially have a relatively high payment capacity.

Class 2 - Arable. Lands of moderate suitability for irrigation farming being measurably lower than Class 1 in productive capacity, adapted to a somewhat narrower range of crops, more expensive to prepare for irrigation or more costly to farm. They are not so desirable nor of such high value as lands of Class 1, because of certain correctable or non-correctable limitations. They may have a lower available moisture capacity, as indicated by coarse texture or limited soil depth; they may be only slowly permeable to water because of clay layers or compaction in the subsoil; or they may also be moderately saline which may limit productivity or involve moderate costs for leaching. Topographic limitations include uneven surface, requiring moderate costs for levelling, short slopes requiring shorter length of runs, or steeper slopes necessitating special care and greater costs to irrigate and prevent erosion. Farm drainage may be required at moderate cost and loose rocks or woody vegetation may have to be removed from the surface. Any one of the limitations may be sufficient to reduce the lands from Class 1 to Class 2, but frequently a combination of two or more of them is operating. The Class 2 lands have intermediate payment capacity.

Class 3 - Arable. Lands are suitable for irrigation development but are approaching marginality for irrigation and are of distinctly restricted suitability because of more extreme deficiences in the soil, drainage or topographic characteristics than described for Class 2 lands. They may have good topography but because of inferior soils they have restricted crop adaptability and require larger amounts of irrigation water or special irrigation practices, and demand greater fertilization, or more extensive soil improvement practices. They may have uneven topography, moderate to high concentration of salines or restricted drainage, susceptible to correction but only at relatively high costs. Generally greater risk may be involved in farming Class 3 lands than the better classes of land, but under proper management they are expected to have adequate payment capacity .

Class 4 - Limited Arable or Special Use Land. Lands are included in this class only after special economic and engineering studies have shown them to be arable. They may have an excessive, specific deficiency or deficiencies susceptible of correction at high cost, but are suitable for irrigation because of existing or contemplated intensive cropping such as for truck or fruits; or, they may have one or more excessive non-correctible deficiencies thereby limiting their utility to meadow, pasture, orchard or other relatively permanent crops, but are capable of supporting a farm family and meeting water charges if operated in units of adequate size or in association with better lands. The deficiency may be inadequate drainage, excessive salt content requiring extensive leaching, unfavourable position allowing periodic flooding or making water distribution and removal very difficult, rough topography, excessive quantities of loose rock on the surface or in the plough zone, or cover such as timber.

Class 5 - Presently Non-Arable. These lands are non-arable under existing conditions but have potential value sufficient to warrant tentative segregation for special study prior to completion of the classification, or they are lands in existing projects whose arability is dependent upon additional scheduled project construction or land improvements. They may have a specific soil deficiency, such as excessive salinity, very uneven topography, inadequate drainage or excessive rock or tree cover. In the first instance, the deficiency or deficiencies of land are of such nature and magnitude that special agronomic, economic or engineering studies are required to provide adequate information, such as extent and location of farm and project drains, or probable payment capacity under the anticipated land use, in order to complete the classification of the lands. The designation of Class 5 is tentative and must be changed to the proper arable class or Class 6 prior to completion of the land classification. In the second instance, the effect of the deficiency or the outlay necessary for improvement is known, but the lands are suspended from an arable class until the scheduled date of completion of project facilities and land development such as project and farm drains. In all instances, Class 5 lands are segregated only when the conditions existing in the area require consideration of such lands for competent appraisal of the project posibilities; such as when an abundant supply of water or shortage of better land exists, or when problems related to land development, rehabilitation and resettlement are involved.

Class 6 - Non-Arable. Lands in this class include those considered non-arable, under the existing project or the project plan because of failure to meet the minimum requirements for the other classes of land, arable lands definitely not susceptible to delivery of irrigation water or to provision of project drainage, and Classes 4 and 5 land when the extent of such lands or the detail of the particular investigation does not warrant their segregation. Generally, Class 6 comprises: steep, rough, broken or badly eroded lands; lands with soils of very coarse or fine texture, or shallow soils over gravel, shale, sandstone or hardpan, and lands that have inadequate drainage and high concentration of soluble salts or sodium. Excluding the position sub-classes the Class 6 lands do not have sufficient payment capacity to warrant consideration for irrigation.

5.3 Classification of the Northern Province Lands

5.31 General Considerations

The lands of Northern Province differ considerably from the virtually undrainable clay lands of the plains south of Khartoum. A different approach has therefore been used in assessing the limiting factors that determine the irrigability of these lands.

Roseires Soil Survey Reports 1 and 4 describe the criteria used in determining land classes in area 1 (the Gezira Extension) and areas 3b and 3c (the Rahad and Dinder lands). The criteria were adopted after full discussions about soils and the agronomy and economics of climatically adapted crops with the Director and Officers of the Department of Agriculture's Research Division at Wad Medani. Full use was made of the extensive production records of long staple cotton production in the Gezira and Managil areas together with research work on cotton and other crops carried out at the Gezira Research Station, Wad Medani. The correlation between cotton yields and clay content (positive), sodium value (negative) and salinity (negative) was used in evaluating limiting soils factors in the land classification system eventually adopted for these virtually undrainable soils, some of which have now been under an extensive cotton rotation for about 50 years. In this way the U.S.B.R. system of land classification was adjusted where necessary for satisfactory application under Sudan conditions.

In the Northern Province both soil and climatic conditions differ considerably from the Gezira and a different emphasis is required in evaluating the limiting physical factors to agricultural production. Because of the cool winters, Mediterranean type arable crops such as wheat, Egyptian beans, lupins and berseem clover give good yields as winter crops. Because of the dry summer climate date palms flourish. Because of the permeable soils there are commercial orchards of citrus fruits and mangoes; vegetable gardens flourish and cash crops such as castor and the large groundnut that do not thrive on clay soils can be grown.

Another factor to be considered is the relatively large population of Northern Province and the relatively small amount of arable land. For this reason the emphasis has for long been on food crops mostly for local consumption and on fodder crops for the working oxen. The growing population requires more irrigated land both for food crops and for industrial cash crops to raise the standard of living. With the possibility of obtaining greatly increased supplies of irrigation water on the completion of Roseires dam the Northern Province faces the possibility of having to develop the less favourable lands of the Province. For this reason the land classification system for Northern Province includes class 5 lands which are non-arable under existing conditions but have potential value sufficient to warrant tentative segregation for special study in pilot projects.

5.32 <u>Limiting Physical Factors in the Land Classification System.</u>

The limiting soils factors used in the land classification system are shown in Table 5.32. The ranges of tolerance for soil depth, textural extremes, salinity and alkalinity are closely aligned to the U.S.B.R. specifications. All the evidence indicates that the soils are drainable and the irrigation water from the Nile is of excellent quality. There is no specific local experimental evidence on which to base standards for the climatically adapted crops so that the U.S.B.R. specifications which have international acceptance have been closely followed.

In addition to the limiting soils factors, other limitations of topography and drainage were also encountered in the project area. Drainage limitations were encountered only in the basins. Topographic limitations consisted of moderately sloping or gullied surfaces and/or surface stones, gravel mounds or sand hummocks or low dunes. More excessive topographic limitations such as large moving dunes or deep and frequent gullies as mentioned in Report No. 3 were on lands eliminated in the reconnaissance survey.

5.33 <u>Distribution and Characteristics of the Land Classes.</u>

The frequency distribution of the land classes at all classified sites (364) is shown in table 5.33. Local characteristics of the land classes are described as follows:-

TABLE 5.32 Soils Criteria for Determining Land Classes in Area 4a.

LIMITING SOILS FACTORS	LAND CLASSES 1	2	3	4
1. SHALLOWNESS				
The depth of soil over sand exceeds	90 cm	60 cm	45 cm	10 cm
2. TEXTURAL EXTREMES				
(a) Silt plus clay exceeds	20%	20%	15%	10%
(b) Clay is less than	35%	45%		
3. SALINITY				
E.C. is less than:-				
0-45 cm	4	8	12	12
45-90 cm	12			
4. ALKALINITY				
E.S.P. is less than:-				
0-45 cm	5	15	15	15
45-90 cm	15			

TABLE 5.33 Frequency Distribution of Land Classes at all Classified Sites in Area 4a.

	LAND CLASSES						TOTAL
	1	2	3	4	5	6	SITES
1. FITNA				1	1		2
2. GUREIR			3	2	20	1	26
3. KORTI				1		1	2
4. KULUD	2		2	1	7	2	14
5. AFFAT	6	5	2	2			15
6. LETTI	6	16	1	5	5	3	36
7. EL BAKRI	1	5	7	19	57	12	101
8. URBI		1	1	2		4	8
9. WEST DONGOLA		3	2	1	24	6	36
10. KERMA	4	11	20	16	48	25	124
TOTAL	19	41	38	50	162	54	364
As per cent of total	5	11	11	14	44	15	100

Class 1 Land is found in Affat, Letti and Kerma Basins and at the edge of Kulud and El Bakri Plains where these impinge on the flood plain. There are 19 sites representing 5 per cent of the total.

Class 1 land is well-drained level land without surface stones, gravel or sand hummocks. The soil consists of at least 90 cm depth of good uniform, free-working soil (sandy loam to clay loam), free of stones, gravel and sand layers. It is a non-saline - non alkali soil. It is suitable for all the climatically adapted crops of the Northern Province.

Class 2 land is found in the Affat, Letti and Kerma basins and in places on the El Bakri, Urbi and West Dongola plains. There are 41 sites representing 11 per cent of the total.

Class 2 land is moderately to well drained; it is fairly level and some surface stones, gravel mounds or low sand hummocks are acceptable. The soil consists of at least 60 cm of good free working soil with only small amounts of gravel or occasional stones. It may be non saline to slightly saline and is always a non-alkali soil to 45 cm.

The following subclasses are shown on the land class maps:-

Class 2a has an E.S.P. between 5 and 15 in the 0-45 cm horizon or the E.S.P. exceeds 15 in the 45-90 cm horizon.

Class 2t has a topographic limitation such as shallow gullies or low sand hummocks.

Class 2d has a drainage limitation, usually at a low point in Letti or Kerma Basins.

Class 2ad has limitations both of alkalinity and drainage as described above.

Class 21 has the same significance as Class 2 on the maps. It refers to the sites which differ from Class 1 only in the matter of soil depth.

Class 3 land is found in Affat, Letti and Kerma Basins and on the Gureir, Kulud, El Bakri, Urbi and West Dongola plains. There are 38 sites representing 11 per cent of the total.

Class 3 land may have the following limitations:- poor to moderate drainage conditions and/or moderately sloping or gullied surfaces and/or surface stones, gravel and sand hummocks. The soil profile consists of at least 45 cm of reasonable soil material from loamy sand to clay texture which may contain moderate amounts of gravel and stones.

The following subclasses are shown on the land class maps:-

Class 3l consists of loamy sand extending to a depth of at least 45 cm. The silt plus clay content lies between 15 and 20 per cent.

Class 3h is a clay soil extending to a depth of at least 45 cm. The clay content exceeds 45 per cent.

Class 3a is a loamy or clayey soil overlying sand at depths between 45 and 60 cm; the E.S.P. lies between 5 and 15 cm in the 0-45 cm layer or exceeds 15 in the 45-90 cm layer.

Class 3al has limitations of coarse texture and alkalinity as described above.

Class 3lt has limitations of coarse texture and a topographic limitation such as shallow gullies, sand hummocks or occasional low dunes.

Class 3ht has limitations of excessively fine texture and a topographic limitation, usually shallow gullies.

Class 3 lst has limitations of coarse texture, high salinity (E.C. exceeds 8) and a topographic limitation usually sand hummocks or occasional low dunes.

Class 4 Land is found in all 10 of the areas studied. There are 50 sites representing 14 per cent of the total.

The class 4 lands of the Northern Province are those excessively coarse textured soils in which the high permeability and low water holding capacity renders the land unsuitable for ordinary arable crops. It is considered, however, that with proper care these lands may be used for orchards and vegetable crops. Because of the high annual returns to be expected after establishment of citrus, mango and date orchards it is considered that such units could bear the cost of sprinkler irrigation which would result in very efficient and economical water applications on these soils.

The following subclasses are shown on the land class maps:-

Class 4l may consist of from 10 to 45 cm depth of loamy or clayey soil overlying sand or deep sands and loamy sands in which the silt plus clay fraction lies between 10 and 15 per cent or sands with less than 10 per cent silt plus clay overlying loamy or clayey layers at depths of less than 50 cm.

Class 4al is a coarse textured soil as described above in which the E.S.P. exceeds 15 in the subsoil.

Class 4lt has limitations of coarse texture and a topographic limitation such as shallow gullies, sand hummocks or occasional low dunes.

Class 4 alt has limitations of coarse texture, alkalinity and topography as described above.

Class 4 asl is a coarse textured soil in which the E.S.P. exceeds 15 and the E.C. exceeds 12 in the subsoil.

Class 4 ald has limitations of texture, alkalinity and drainage through being in a low point of the Kerma Basin.

Class 5 Land is found in nine of the areas studied, the exception being the small Fitna plain. There are 162 sites representing 44 per cent of the total.

The class 5 lands of the Northern Province are those loamy and clayey soils of the basins and terraces in which the E.S.P. and/or the E.C. exceeds the limits for the arable classes. Some of these sites are strongly saline - alkaline. Because of the shortage of good land in Northern Province, however, the Class 5 Lands have been separated from the Class 6 lands for the purpose of further study to determine their arability or non-arability. Unlike the Vertisols of the clay plains south of Khartoum, the class 5 lands of Northern Province are drainable. The salts can therefore be washed out. Whether the high exchangeable sodium content can also be reduced to a safe level is an open question and must be determined by experimental work in a research station and/or a pilot project (see recommendations in Chapter 6).

The following subclasses are shown on the land class maps:-

Class 5a is loamy or clayey soil, at least 45 cm deep, in which the E.S.P. exceeds 15.

Class 5s is loamy or clayey soil, at least 45 cm deep, in which the E.C. exceeds 12.

Class 5as has limitations of alkalinity and salinity as described above.

Class 5al is a loamy sand, at least 45 cm deep, in which the silt plus clay content lies between 15 and 20 per cent and the E.S.P. exceeds 15.

Class 5at has limitations of alkalinity and topography such as shallow gullies, sand hummocks or occasional low dunes.

Class 5ast has limitations of alkalinity, salinity and topography as described above.

Class 5 alt has limitations of alkalinity, coarse texture and topography as described above.

Class 5 asl has limitations of alkalinity, salinity and coarse texture as described above.

Class 5 asd has limitations of alkalinity, salinity and drainage through being in a low point in Kerma Basin.

Class 6 Land is found in 8 of the areas studied, the exceptions being the Fitna plain and Affat Basin. There are 54 sites representing 15 per cent of the total.

Class 6 lands include all sites which fail to qualify for a higher land class. Because of the inclusion of most of the saline-alkali loamy and clayey soils in class 5, it follows that most class 6 lands are segregated on the basis of excessive sandiness or excessive topographic limitations. The following subclasses are shown on the land class maps:-

Class 6l are deep sands in which the silt plus clay content is less than 10 per cent. A surface covering of loamy or clayey soil is permitted provided it is less than 10 cm thick. Subsoil loamy and clayey layers must lie at a depth below 50 cm.

Class 6 lt has the limitation of excessively coarse texture and the topographic limitation described for the arable classes such as shallow gullies, sand hummocks or occasional dunes.

Class 6 al has the limitation of excessively coarse texture and the E.S.P. exceeds 15.

Class 6 asl has the limitations of texture and alkalinity described above and the E.C. exceeds 4.

Class 6 alt has the limitations of alkalinity, texture and topography described above.

Class 6 aslt has the limitations of alkalinity, salinity, texture and topography described above.

Class 6 ast has limitations of alkalinity and salinity and excessive topographic limitations such as frequent gullies, continuous sand hummocks up to 50 cm high and frequent dunes.

5.34 Areas of Land Classes.

The total area mapped under each land class is shown in table 5.34.

Table 5.34 Areas of Land Classes in the Project Area

Locality	LAND CLASSES 1	2	3	4	5	6	TOTAL AREA
Fitna					835	-	835
Gureir					5,255	475	5,730
Korti					535	-	535
Kuludi				415	1,075	535	2,025
Affat	1,195	1,790		300	-		3,285
Letti	2,090	4,895		600	1,200	655	9,440
El Bakri	90	420	1,195	3,105	15,400	4,300	24,510
Urbi			420			1,255	1,675
W. Dongola		300	240		5,490	1,375	7,405
Kerma		1,255	6,565	1,970	14,150	7,640	31,580
Total	3,375	8,660	8,420	6,390	43,940	16,235	87,020

CHAPTER 6

ASSESSMENT OF POTENTIAL IRRIGATION DEVELOPMENT IN THE PROJECT AREA

6.1 General Considerations

In Chapter 5 we drew attention to the special conditions existing in Northern Province which tend to set it apart from the Provinces of the Central Sudan. The narrow ribbon of arable land beside the river in a vast expanse of desert resembles conditions in Upper Egypt rather than the Central Sudan. The inelasticity of supply of arable land in response to an expanding population has caused great population pressures on the land and has resulted in many breadwinners seeking employment in other Sudanese Provinces and abroad in order to support the family at home. Because of these conditions we have diligently investigated all basin lands and unused high terrace silts and we recommend further investigation of the presently non-arable (Class 5) lands through pilot projects as well as more intensive development of the arable lands in the basins.

In Chapter 2 we mentioned that the development of Kerma Basin was one of the first Sudanese irrigation development projects of the twentieth century. Unfortunately the disappointing crop yields with the corresponding low return on invested capital discouraged any further government investment in the development of Northern Province Basin lands. The success of the Gezira pilot project about this time diverted government and private capital to the development of the Blue Nile Province. As the Gezira Scheme prospered, more development capital was invested there, and agricultural research was centred at the Gezira Research Farm at Wad Medani. During these years the returns from Kerma Basin hardly repaid the cost of operation and maintenance of the Seleim Canal system until eventually the project was operated on a caretaker basis only. Government considered it not worth while to use any of its limited budget on reclamation research and development in Kerma Basin when so much better returns could be obtained from the Gezira Scheme. This attitude has unfortunately continued to the present. Government funds for Northern Province development have been available only in war years as a temporary measure to expand food production. Of the five government pump projects developed in this way, four are on the fertile flood plain silts and only one, Bergeig, was developed on inferior land in the northern Ghisms of Kerma Basin. Although no research work has been carried out on land reclamation at Bergeig the Scheme has been successful and we consider that a careful study of the soils, crops and irrigation system at Bergeig would provide much useful information on possible reclamation methods for the saline-alkali and sandy soils of the old silt terraces. We consider that the lands in Ghism 6 of Kerma Basin adjacent to Bergeig could be used for a pilot reclamation project, using irrigation water from the Bergeig canal system. The results from the pilot project would be applicable, not only to the silt terraces of the project area, but also to those terraces north of the Third Cataract extending to Dal Cataract and any available terraces, as at El Kab, between the Fourth and Fifth Cataracts.

Because little systematic agricultural research work has been carried out in the past in Northern Province we have been obliged to make use of farm and estate experience and of the opinions of qualified observers with regard to crop suitability, yields, production costs and profits. Excellent research and extension work is now in progress at Hudeiba Research Station, Berber District and at the Government pump project at Nuri in Merowe District which specializes in horticultural crops. It is expected that future agricultural development projects will benefit greatly from this work.

6.2 The Climatically Adapted Crops of the Project Area

The soil and climatic conditions of the Northern Province differ considerably from those of Blue Nile Province; in fact they more closely resemble those of Egyptian Nubia and Upper Egypt. The winters are distinctly cool so that Mediterranean type arable crops such as wheat, broad beans and lentils give excellent yields. The dry desert climate is also optimum for date palms, one of the Provinces most important crops. The fertile, permeable soils of the flood plain will support all climatically adapted crops whether cereals, pulses, fodders, oil seeds, fruits, vegetables or industrial crops.

Table 6.2 gives a list of the principal climatically adapted crops of the Northern Province of the Sudan. Notes on some individual crops are as follows:-

Table 6.20. A list of the Principal Climatically Adapted Crops of the Northern Province of the Sudan.

Category of crop	1 Main crops	2 Secondary crops	3 Other crops
1. Cereals			
Winter	Wheat	Barley	
Summer	Dura	Dukhn	Maize
			Rice
2. Pulses			
Winter	Broad Beans	Lentils	Lupins
		Chickpeas	Lubia
		Field peas	
Autumn	Haricot beans		
3. Fodder Crops			
Perrennial	Berseem		
Seasonal	Lubia	Sudan grass	Chickling
		Trigonella spp.	Vetch
4. Oil Seeds			
	Groundnuts	Castor	Safflower
		Sesame	
5. Fruits	Dates	Citrus Fruits	Guavas
		Mangoes	Bananas
6. Garden Crops			
	Garlic	Melons	Fenugreek
	Onions	Tomatoes	Senna
		Potatoes	Cumin
			Coriander
			Henna
			Caraway
7. Industrial Crops	Cotton	Tobacco	Sugar beet
			Sugar cane

6.21 Wheat

Wheat is the chief winter cereal crop of Northern Province which is the Sudan's chief production centre of wheat. In the 1960-61 season the area planted to wheat in Northern Province was 28,980 feddans out of a total of 39,060 feddans for the whole country.

The crop is planted in November on land previously watered and ploughed. Wheat responds strongly to nitrogenous fertilizers which are usually applied in the early stages of growth. About 8 irrigations are given during the growing season of the crop which is harvested in March.

In Northern Province wheat yields are higher, and annual fluctuations in yield smaller, than in Khartoum Province and the Gezira Scheme. In the 1960-61 season the Northern Province produced 133, 148 ardebs of wheat from 28,980 feddans at an average yield of 4.59 ardebs per feddan (0.744 metric tons per feddan). In the 1961-62 season a crop-cutting survey resulted in estimates of an average yield of 3.913 ardebs per feddan in Merowe-Dongola Districts as against an estimated 1.198 ardebs per feddan in the Gezira.

Wheat Production Costs and Returns

A study of the monthly retail prices in the Northern Province markets shows that in Merowe-Dongola Districts the average price of wheat to the farmer ranges from about L.S. 7.500 to L.S. 8.700 per ardeb. If we assume that a reasonable expectation of price if L.S. 8,000 per ardeb and that the average yield is about 4 ardebs per feddan, then the gross return per feddan of wheat is about L.S. 32,000.

Costs of production are more difficult to assess and various estimates have been made.

The Agricultural Inspector, Dongola District, gives the following estimates of costs of production on a private pump scheme:-

Item		Cost, L.S.
(i)	Fuel	2.322
(ii)	Labour	0.813
(iii)	Land rent	0.100
(iv)	Maintenance & Depreciation	1.306
(v)	Ploughing	1.500
(vi)	Seed	1.925
(vii)	Fertiliser	2.200
(viii)	Sacks	1.080
	Total:	11.246

Under the usual arrangement between pump scheme owner and tenant half the cost of items (v), (vi), (vii), and (viii) is paid by the tenant and half by the owner. The owner takes half the crop as his share of the enterprise and from this he pays the costs mentioned above, the costs of supplying the water and any other charges related to the project before assessing his profit.. The tenant receives half the crop which is worth about L.S. 16.000 per feddan and after deducting production costs of about L.S. 8.000 per feddan is left with a net return of about L.S. 8.000 per feddan.

On Government pump schemes the tenant pays a water rate, usually L.S. 6.350 per feddan of wheat. If his other costs are similar to those on the private pump schemes and if yields are the same, then the tenant's net return would be somewhat higher at about L.S. 15.000 per feddan.

Khidir and Baptista carried out a study of wheat production costs on an area of 2,584 feddans in Merowe-Dongola Districts during the 1961-62 cropping season. They concluded that the costs of production amounted to a total of L.S. 20.380 per feddan, assessed as follows:-

Item	Cost L.S.
Cultivation operation	4.153
Harvesting and threshing	3.583
Materials and supplies	5.481
Others	7.163
Total:	20.380

If, as seems probable, the cost of the farmer's own labour is included in this estimate of cost, then the balance between returns and costs represents profit on the enterprise.

Wheat Research Programme

The Hudeiba research station is carrying out an active programme of selection and breeding of improved strains of wheat for the Sudan. Between 1958-59 and 1962-63 trials at Borgeig, Gureir and Hudeiba compared the yields of the genetic stocks of wheat recommended for release as new varieties as against the standards commercial (baladi) types at present grown in Northern Province. The trials show that the following varieties are superior to the Baladi types and are recommended for release to the farmers:-

Index No. 164 (Giza 141 X NA116) has given consistently high yields over a wide range of environmental conditions. Its milling and baking qualities are good and it is considered to be the most reliable variety to grow in new areas to ensure against crop failure and possible rust attack.

Index No. 154 (Giza 141 X NA1167) has a good production record similar to No. 164. It is, however, less affected by hot weather during the grain-filling stage.

Index No. 57 (L950 X Hindi D) is a high yielding variety with a large, white, medium - soft grain which is easier to grind in the local mills. It is expected to serve as a dual purpose variety for the biscuit and bread industries.

Index No. 29 (Hindi 62 X Giza 139) is recommended for cultivation on heavy clay soils. Its yield is slightly higher than that of Hindi 62. The Sudanese millers prefer it because of its softer grain.

Index No. 203 (L950 X Giza) has yielded well at Borgeig, Shambat, the Gezira and Khashim el Girba.

It is expected that the use of these new varieties will improve both yield and quality of the commercial crop, resulting in a greater financial return to the growers.

Another important result of the Hudeiba research programme has been the exploitation of the summer season to multiply stocks of wheat more quickly by using two seasons per year instead of only the winter season. The results obtained show that with selected varieties it is possible for the summer crop to equal the yield of the winter crop. Investigations are now in hand to find out if these research results can be used in commercial practice. The economic advantages of summer grown wheat would be very important to Northern Province because it would provide a more valuable summer cereal crop to replace the less valuable dura and dukhn which are grown at present.

Economic Outlook for Wheat

The Republic of the Sudan is a large net importer of wheat and flour. See table 6.21.

Table 6.21 Sudan Imports of Wheat and Flour, 1960-1963

Year	Tons	Value L.S.
1960	76,272	1,858,775
1961	87,255	2,192,527
1962	76,392	2,089,822
1963	94,851	2,862,294

There is a very strong case for increasing wheat production in the Sudan in order to save valuable foreign exchange. Government has, in fact, taken steps to do so through the Ten Year Plan of Economic of Social Development and hopes to replace imports by domestic production completely by the end of the Plan period. Part of the Government plan is eventually to grow 180,000 feddans annually in the Gezira and Managil Schemes and 30,000 feddans at Khashm el Girba. Because wheat gives higher yields in Northern Province, however, we recommend that all suitable lands there should be used for wheat growing in order to supplement the supply of wheat to the country.

6.22 Broad Beans (Vicia faba)

Known as "ful musri" (Egyptian beans) the broad bean is an important winter crop in Northern Province, second only in importance to wheat. Because the crop requires cold weather for healthy growth and good yields it is grown only in Northern Province. The dried bean is long-keeping and easily transported and the surplus production finds its way to the Omdurman market.

The seed is sown broadcast in November on land that has already been irrigated and ploughed. The crop receives rather less irrigation water than wheat. Some beans are harvested green, mainly for domestic use, but the main crop is harvested in April when the beans have thoroughly dried.

The crop is hardy, generally resistant to disease, a builder of soil fertility and generally high yielding. In the 1961-62 season the 15,540 feddans planted in Northern Province produced 13,550 tons of beans giving the excellent return of 0.871 tons per feddan. Farmers and Agricultural Officers state that the average yield is about 4 ardebs per feddan.

Records of monthly retail prices in the Merowe-Dongola districts show that the price received by the farmers at harvest is about L.S. 6.000 per ardeb, although it may go higher later in the season. The gross return to the grower is therefore about L.S. 24.000 per feddan.

Costs of production on a government pump scheme are reported to be L.S. 13.790 per feddan, itemised as follows:-

Operation	Cost L.S.
Ploughing	1.000
Sowing Seed	0.500
Cost of Seed	2.250
Water	4.890
Harvesting	1.500
Transport to threshing floor	1.250
Threshing	2.000
Transport to market	0.400
Total:	13.790

The net return to the tenant on a government pump scheme would then be about L.S. 10.000 per feddan.

On private pump schemes the profit is shared between the owner and the tenant. Some figures received show that the tenant's profit on a 12 inch pump scheme is about L.S. 6.500 per feddan and on a 6 inch pump scheme, about L.S. 5.000 per feddan.

6.23 Haricot Beans (Phaseolus vulgaris)

Known as "fasulia" the haricot bean is widely grown in the Northern Province as a late damira (flood season) or early winter crop. Part is used as a green vegetable but the major part is allowed to ripen and is sold as the dried haricot bean of commerce. A local white variety commonly grown in Northern Province is known as "fasulia baida". The crop is usually given about 4 waterings.

In the 1961-62 season the 8,970 feddans planted in Northern Province produced 4,850 tons of dried beans giving a return of 0.540 tons per feddan. Northern Province farmers claim that they expect a yield of about 4 ardebs per feddan.

Much of the crop is exported so that local prices are controlled to some extent by the international market. The price of haricot beans ex store Port Sudan was L.S. 46.000 per ton on 16th April, 1964. The average price in Northern Province is generally around L.S. 6.000 per ardeb. The gross return to the farmer is therefore about L.S. 24.000 per feddan.

The costs of production per feddan on a private pump scheme at Shendi are given as follows:-

Operation	Cost, L.S.
Ploughing by tractor	1,000
Seed (half sack)	1.500
Weeding	0.600
Levelling by tractor	0.400
Bunding	1.000
Sowing	0.950
Cost of Water	0.200
Harvesting and transport	4.000
Threshing	1.813
Total:	11.463

The net return to the growers is therefore about L.S. 12.500 per feddan of "fasulia". This will then be further subdivided according to the landlord and tenant arrangements in force at the time.

6.24 Berseem (Medicago sativa)

This perennial forage crop, variously known as alfalfa or lucerne, flourishes in Northern Province. There is an estimated 890 feddans of berseem in the Dongola district and smaller areas in Merowe, Berber and Shende districts.

Cut just before flowering the fodder is highly nutritious; the oven-dry hay contains over 28 per cent crude protein. There is a keen demand for either the green forage or the hay, especially in the towns where households may keep horses and milch animals such as cows or goats. A well kept plot of berseem in the vicinity of a town may therefore give a gross return of about L.S. 100.000 per feddan.

In the Shendi area, where berseem has long been grown, new plots are established by seed in November and the crop is ready for the first cut about 7 weeks later. Thereafter the crop is cut about once a month for nine months of the year; the exception is the winter months when growth is slow. The crop is irrigated every 10 days in summer and at wider intervals in other seasons (up to 15 to 20 days in midwinter). Under good conditions of management, in the absence of strong weed competition, the stand of berseem may be maintained over a five year period before ploughing up and resowing. The average yield per cut may be about 5 tons of green fodder and the annual yield amounts to about 40 to 50 tons. Although production costs, especially for water, may be high there is no doubt that well-managed berseem fields are highly profitable in the vicinity of towns.

6.25 Castor (Ricinus Communis)

Castor, which occurs semi-wild throughout the Sudan, is grown for its non-drying poisonous oil which is used in the manufacture of high-grade lubricants, soaps, paints, varnishes, plastics and nylon, in textile dying and for medicinal purposes. There is a rising world demand for castor oil which has stimulated increased production in the main producing countries:- Brazil, India and Thailand.

Sudanese production of castor oil is concentrated mainly on the permeable silts of the Gash delta where, in 1960-61, 8,900 feddans under flood irrigation produced 3,900 tons of castor beans at an average yield of 0.434 tons per feddan. During 1962 Sudanese exports of castor beans amounted to 3,397 tons, valued at L.S. 191,998. Aware of the soundness of the world market for castor beans the Republic of the Sudan is anxious to expand production of this crop. The Advisory Committee on Agricultural Research in the Sudan in 1959 recommended that castor cultivation should be extended in Northern Province, Khartoum Province, the Gash and Tokar deltas. Successful trials have since been carried out on Nile silts in Northern Province and it is hoped that castor will become a useful addition to agriculture there, once its agronomic requirements are fully understood. It would seem, indeed, that in Northern Province castor could well replace groundnuts which can be grown equally well in Equatoria, Kordofan, Darfur and Blue Nile provinces where it can out-yield castor.

The earliest castor trials at the Hudeiba Research station gave a mean yield of 590 Kg. per feddan. The best variety was Pacific No. 6, a dwarf, relatively early-maturing and high yielding variety which produced 732 Kg. per feddan. Other high yielding varieties tested were Cimarron, Chickasha and SMPC. It was considered that these yields were being depressed by moderate soil salinity at the station. New varieties from West Africa which are now being cultivated experimentally at Shendi are said to be even more vigorous and to be able to withstand the adverse affects of salinity better than the Gash varieties. Commercial trials of varieties selected at Hudeiba have since given encouraging results. Irrigated crops on the Aliab, Kitiab and Bauga estates yielded as follows:-

Variety	Yield, Kg/feddan of clean beans
Cimarron	871
Pacific 6	1008

On a private estate at Shendi the yield was said to be 1,430 Kg. per feddan of clean (hulled) beans.

Experimental results at Khashm el Girba indicate that good yields can be obtained with the following cultural treatments:-

(i) Plant at end of July and space plants approximately 60 x 80 cm. apart.

(ii) Use nitrogenous fertilisers ($1 - 1\frac{1}{2}$N).

(iii) Spray once or twice, with D. D. T. against Laphygmas, and Roger against white fly and jassids, when necessary.

(iv) Supply irrigation water as required.

(v) Pick beans three or four times, generally from end of November to early March.

The world demand for castor is reasonably steady and a fair estimate of expected prices is L.S. 50.000 per ton of hulled beans at Port Sudan. The marketing costs including processing, storage, railway freight and shipping charges, agents fees, export duty etc. have been estimated at L.S. 15.000 per ton. The gross return at the farm, therefore, would be about L.S. 35.000 per ton.

Farm costs per feddan cultivated, at Zeidab estate in Northern Province, are reported as follows:-

Operation	Cost L.S.
Ploughing and ridging	2.000
Galwal making and sowing	1.000
Weeding	2.000
Irrigation	3.000
Picking	0.500
Clearing after harvest	0.500
Fertilisers	3.000
Seed	3.250
Other	0.750
	16.000

If the expected yield is 0.8 ton per feddan of hulled beans then the gross return is L.S. 28.000 per feddan, leaving a surplus of L.S. 12.000 to be divided between landlord and tenant. On a government pump scheme the tenant's share of the profit (including return on his own labour) would probably be greater than on a private pump scheme.

6.26 Dates

The date palm, (Phoenix dactylifera) is undoubtedly the most important fruit producing tree in the Sudan. It needs ample sunshine and abundant water at its roots but at the same time requires high temperatures and low humidity. It needs rainless conditions at pollination and again when the fruit is ripening, because rain at pollination interferes with fruit setting and later rains cause fruit rot, splitting and premature drop. These favourable conditions of climate, soil and irrigation are found only in Northern Province to the north of Shendi where the principal date producing areas are found. In the 1961-62 season the total production of dates from the Halfa, Dongola and Merowe districts amounted to 48,702 tons, valued at L.S. 1,433,680.

Dates may be classified as soft or dry dates. Soft dates contain sufficient sugar to prevent fermentation and may therefore be preserved and used in a moist condition. The better known varieties of soft dates are Misherig, from the Abu Hamed area, containing about 20 per cent moisture and Medena which contains up to 40 per cent moisture and spoils easily. Dry dates ripen to dryness on the palm; they keep well and are easily transported large distances in sacks. The principal dry date of commerce is Barkawi or Baracoli which is widely grown in Merowe District. Other varieties of dry date are Gondeila and Bint Tamoda. Inferior dates, usually grown from seedling stock, are known as Jaw or Gow.

In most date groves the palms are irregularly spaced and the number of basal branches is not controlled. In better kept groves the spacing is irregular but the clump is confined to three palms; this practice is defended on the ground that a single palm is not easily replaced if it should be blown over in a high wind and destroyed.

Only in Government experimental plantations does one find single palms planted in rows, 8 x 8 metres apart (giving 65 palms per feddan) and kept free of side shoots.

The cost of establishing a date plantation is about L.S. 175 to L.S. 200 per feddan. Nearly half of this amount is accounted for by the cost of planting material:- suckers of improved varieties provided mostly by government nurseries at a cost of L.S. 1.500 each plant. Upkeep of a young plantation is small. It consists of regular watering throughout the year, establishment of a cover crop and general tending of the young palms. If they have not been established in a nursery before planting in the field, each palm must be protected in the early stages by shading. A cover crop of lubia or berseem will pay part of the upkeep costs of the plantation until the palms begin to bear fruit after 5 to 6 years.

Date palms reach full production at about 7 years from planting and have a useful life of about 80 to 100 years when well managed. They are irrigated every 15 days in summer and every 20 days in winter. The crop is hand pollinated and the main date harvest is in late September to early November, although very early varieties may be harvested from July onwards. Yields are high. Each palm produces about 5 - 7 keilas of dry fruit so that the yield per feddan from 60 palms is as much as 420 keilas (11,760 lbs). It is considered that an average yield on a plantation planted 60 trees per feddan and properly cultivated would be 5,000 lbs. per feddan.

In the Dongola district growers sell their crop to local merchants who distribute dates to other parts of the country. Shortly before harvest the price is about 60 piastres per keila and during the season about 35 piastres per keila. At this lower price the gross return per feddan of date orchard is about L.S. 140.000.

Production costs per feddan are estimated as follows:-

Operation	Cost, L.S.
Harvesting @ 15 pt. per palm	9.750
Irrigation water	20.000
Govt. tax @ 2 pt. per palm	1.300
Transport to market	2.000
Sacks	2.000
Fertiliser	3.000
Weighing	0.500
Handling crop in field	2.000
Total Cost	40.550

The net return is about L.S. 100.000 per feddan. An efficiently run date plantation is therefore the most profitable agricultural enterprise in the Sudan.

Under present conditions dates are a highly remunerative crop so long as production does not exceed local demand. The position with regard to the export market is very uncertain and it appears that this aspect has not been sufficiently studied. Over the past 10 years exports (mostly to the United Arab Republic) have fallen from about 7,000 tons worth L.S. 270,000 to 1,500 tons worth about L.S. 60,000. The fall in exports may, of course, be due to an increased local demand. The recently established date packing factory at Kareima is hoping to establish overseas markets for Sudanese dates, especially the export of dry dates to Central Africa.. The success of such an operation would certainly encourage an extension of date planting in the Northern Province.

6.27 Onions

Onions are one of the most important minor products in Sudanese internal trade and are grown wherever irrigation water is available into the early summer. The most important centres of production are in Northern Province and Khartoum Province. In 1963-64 there were 350 feddans planted to onions in Dongola district, 300 feddans in Berber district and about 700 feddans in Shendi district. In 1960-61 the total Sudanese production was 2,900 tons from 3,790 feddans at an average yield of 0.765 ton per feddan.

It is claimed that consistent yields above one ton per feddan may be obtained by using sulphate of ammonia fertiliser.

Onion seed is sown in a nursery bed in October or November. The seedlings remain about 2 months in the nursery bed before being transplanted into the field in January or February. Nitrogenous fertiliser is generally applied at the time of transplanting. Green onions, usually thinnings, may be pulled about two months after transplanting but the main crop of mature onions is harvested in May.

The price of onions fluctuates from month to month depending on the supply. Retail price statistics show that prices are lowest in the May - July period when the main crop comes on to the market. Thereafter prices tend to rise steadily to reach a maximum about the end of the year. At harvest time the selling price is about L.S. 5.000 per ardeb. A crop yielding 25 ardebs per feddan, therefore, would give a gross return of about L.S. 125 per feddan.

Production costs per feddan on a successful private pump scheme in Shendi District are itemised as follows:-

Operation	Cost, L.S.
Seed ($\frac{1}{2}$ keila)	2.400
Nursery costs	3.000
Ploughing	1.000
Rolling and levelling	2.000
Transplanting	8.000
Weeding (twice)	2.500
Fertiliser	5.000
Harvesting	5.500
Cleaning crop	1.000
Storage	1.000
Total cost	32.900

The net return from a 25 ardeb crop as outlined above, therefore, would amount to about L.S. 90.000 per feddan. This would then be shared between landlord and tenant according to the local agreements.

The future prospects for the onion industry are considered to be bright. Even allowing for fairly wide fluctuations in price the margin of profit is high. At present almost the entire local production is consumed in the Sudan. Proposals have been made to establish a plant at Shendi for producing dessicated onions, for the export market. It is understood that an onion drying factory sponsored by Russia is under construction in Kassala Province. An export market in dried onions would certainly enable onion growing to be expanded in Northern Province.

6.3 Arable Basin Lands Suitable for More Intensive Irrigation Developments

In earlier chapters we have pointed out that there are, within the basins, arable lands which are undeveloped or only partially developed at the present time. We recommend that, where feasible, these lands should be brought into full production in the shortest possible time. Our proposals for each basin are as follows:-

6.31 Kerma Basin

The semi-detailed soil survey and land classification survey covered the lands of Ghisms 2, 3, 4, 5 and 6, aggregating 31,580 feddans. The lands were classified as follows:-

Land Class	Area (feddans)	
2	1,255	
3	6,565	
4	1,970	23,940
5	14,150	
6	7,640	
Total	31,580	

The arable lands, totalling nearly 10,000 feddans are distributed in reasonably large blocks throughout the five Ghisms studied; the highest percentage of arable land is in Ghism 2 and the lowest percentage is in Ghism 5. There are quite large blocks of Class 5 land in all Ghisms, lying beside the arable lands, and it is evident that the type of further development within the Kerma Basin will depend on the arability or non-arability of these lands. If the Class 5 lands should prove to be arable then it would be possible to plan the overall development of the basin by one or two or more pump stations on the Nile and a reticulated canal system for the 5 Ghisms as outlined in Roseires Report No. 3. For the present, however, a more limited development of local arable areas would seem to be indicated.

The Glennie report of 1954 provides some useful suggestions for a limited development of arable lands. Glennie considered that the only area that could be developed economically by pump irrigation from the river is an area of about 2,500 feddans near Seleim village. He suggested that all other areas could be more economically and successfully developed from tube wells. In spite of the lack of success from the tube wells subsequently developed in the Wadi el Khowi we consider that Glennie's original suggestion has considerable merit and should be studied again in connection with limited developments in Kerma Basin.

We recommend that irrigation development in Kerma Basin should be based on the climatically adopted crops discussed in 6.2.

We would again draw attention to the need to study reclamation methods on Class 5 land and to repeat our suggestion that a pilot project for this purpose could be developed in Ghism 6 of Kerma Basin using irrigation water from the Borgeig Government Pump Scheme. An area of Class 5 land near the Bergeig saliba could easily be protected from flood water and the Bergeig escape channel could be used as a drainage outfall for leaching trials. By using these existing facilities it should be possible to establish the pilot project and commence reclamation experiments in a very short time.

6.32 <u>Letti Basin</u>

The basin lands are classified as follows:-

Land Class	Area (feddans)
1	2,090
2	4,895
4	600
5	1,200
6	655
Total	9,440

There are 7,585 feddans of arable and limited arable lands and a further 1,200 feddans of doubtful arability (Class 5 lands).

As mentioned in Chapter 2 (2.6) the southern part of the basin is already served by a pump system and the cultivated area was being extended northwards at the time of the survey in January 1964. (See figure 3).

The amount of arable land is sufficient to encourage study of the development of a government pump irrigation project to serve the whole basin as mentioned in Report No. 3. A pump station at the southern end of the basin could command the land with a static lift of 10.5 metres and a rising main 1.25 kilometres in length. The irrigation layout to supply the whole basin presents certain difficulties on account of its shape, the basin being 24 kilometres long and only one to $2\frac{1}{2}$ kilometres wide. There are also topographic difficulties due to uneven ground and the presence of moving dunes on the eastern side. Preliminary studies in 1963, however, show that a supply canal aligned on the eastern side of the basin could command most of the land although it would need protection from drifting sand. An alternative would be to align the canal on the western side where there is no dune hazard and use secondary low lift pumps to obtain command. More detailed studies would show which of these alternatives is the better.

The further agricultural development of the basin should be based on the crops discussed in Section 6.2 above.

6.33 Affat Basin

The basin lands were classified as follows:-

Land Class	Area (feddans)
1	1,193
2	1,790
4	300
Total	3,285

Part of the area classified has already been converted to pump irrigation (See figure 3). There remains, however, about one thousand feddans of flood irrigated land used mostly for grazing which is suitable for perennial irrigation. It is recommended that this land should be converted to pump irrigation and that the crops mentioned in 6.2 should be grown. A static lift of 10.25 metres would command all the land (See Roseires Report No. 3, p. 47).

6.4 Silt Terrace and Basin Lands Needing Further Investigation to Determine Suitability for Development

In Chapter 5 we pointed out that many of the loamy and clayey soils of the basins and terraces are saline-alkali or alkali soils in which the E.S.P. and/or the E.C. exceeds the limits set for the arable classes. Unlike the clay plains south of Khartoum, however, these soils are permeable enough for the salts to be leached out. In the absence of reclamation experiments in Northern Province we do not know the cost of leaching nor the sequence of crops required to reclaim these saline-alkaline lands. On general principles, however, we are optimistic that these lands can be reclaimed at reasonable cost. We have therefore included them as class 5 lands which are non-arable under existing conditions but have potential value sufficient to warrant tentative segration for special study in pilot projects. We trust that our recommendations regarding pilot projects will be implemented by government so that the arability or non-arability of these lands will be speedily established.

Because class 5 land is dominant on the silt terraces the question of development of the Dongola, Urbi, El Bakri, Kulud, Korti, Gureir and Fitna plains depends on the eventual arability or non-arability of the class 5 lands. Notes on these lands are as follows:-

6.41 The Dongola Plain

This elongated silt terrace was classified as follows: -

Land Class	Area (feddans)
2	300
3	240
5	5,490
6	1,375
Total	7,405

The 540 feddans of arable land, already partly developed from shallow wells, is not extensive enough to warrant immediate establishment of the pump scheme mentioned in Report No. 3. Should the pilot projects show the present class 5 lands to be arable, however, then the pump site five kilometres south of Dongola could be utilised to develop a gross area of about 6,000 feddans of new land.

6.42 The Urbi Plain

This small area of land (1,675 feddans) proved to be mostly class 6. The 420 feddans of class 3 land which are already partially developed by local well irrigation are probably best left in the hands of local entrepreneurs.

6.43 The El Bakri Plain

This large area of land was classified as follows:-

Land Class	Area (feddans)
1	90
2	420
3	1,195
4	3,105
5	15,400
6	4,300
Total	24,510

The area of arable land is too small and too scattered to warrant the immediate installation of the large pump unit mentioned in Report No. 3. Should the pilot projects show the present class 5 lands to be arable, however, then a pump unit at the selected site could be developed to irrigate a gross area of about 20,000 feddans of new land.

6.44 The Kulud Extension

This silt terrace which flanks the Government pump scheme at Kulud was classified as follows:-

Land Class		Area (feddans)
4		415
5		1,075
6		535
	Total	2,025

Should the pilot projects show the present class 5 land to be arable then a gross area of about 1500 feddans could be developed as an extension to the existing Government pump scheme. The Kulud extension can be commanded from the present pump site by a static lift of 13 metres and a rising main about one kilometre long.

6.45 The Korti Plain

This small plain of about 500 feddans was found to be excessively sandy and was all class 6. There is, therefore, no scope for development.

6.46 The Gureir Plain

These lands which are adjacent to the Government pump scheme at Gureir were classified as follows:-

Land Class		Area (feddans)
5		5,255
6		475
	Total	5,730

Should the pilot projects show the present class 5 land to be arable then a gross area of about 5,000 feddans could be developed as an extension to the existing pump scheme. Probably the most satisfactory layout would be to use the existing pump site at which a static lift of 13.75 metres would be required through a rising main 4.0 kilometres in length.

6.47 The Fitna Plain

This isolated plain of about 835 feddans consists of class 4 and class 5 land. If shown to be arable it could be commanded by a static lift of about 11.5 metres without a rising main.