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Forest operations in the Nile Province, Northern Sudan: Irrigated Shelter Belt Project

Report of an LRDC Mission, 2 October - 4 November 1978

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ABSTRACT AND KEYWORDS

ABSTRACT

This report contains a brief description of forestry operations in the Nile Province of the Sudan, and in particular the current joint project of the Central Forest Administration, Sudan Council of Churches, and the Nile Province Forest Service to plant shelterbelts designed to protect some of the agricultural settlements along the Nile between Shendi and Berber.

The physical features of the area are described, and an assessment of the shelterbelts planted since 1972 is given. The planting programme to December 1981 is noted, and recommendations for support to this programme offered.

KEYWORDS

Climate, ecology, water resources, irrigation systems, wind erosion of sand, shelterbelts, forest reservation, forest administration, agricultural crops and cropping, Eucalyptus species, Prosopis chilensis, Acacia tortilis, the Nile, Nile Province, Republic of Sudan.

PART 1 INTRODUCTION

1.1 ORIGIN OF STUDY

In December 1977, Mr Peter Wood, Senior Research Officer with the Unit of Tropical Silviculture, Commonwealth Forestry Institute, Oxford, visited the Nile Province, Sudan for 2 days at the request of the Middle East Development Division, to investigate possible UK involvement in the joint Central Forest Administration (CFA) and Sudan Council of Churches (SCC) project designed to control sand encroachment in the Province. (Wood, 1977b) This visit was an extension to Mr Wood's Tokar Delta Study. (Wood, 1977a) Mr Wood recommended a TA Consultancy to formulate a detailed Plan of Operations, and an enquiry into the feasibility of a trickle irrigation pilot project for shelterbelts.

On 2 October 1978, M J Berry, of the Land Resources Development Centre, Ministry of Overseas Development (ODM) visited the Sudan for 5 weeks to carry out the terms of reference listed below.

1.2 TERMS OF REFERENCE

The original terms of reference proposed by Mr Wood in December 1977 consisted of:

1. A review of the whole of forestry operations in Nile Province

2. The preparation of a costed Plan of Operations for the use of the Forest Department, SCC and Aid donors, based on the Sudan DECARP report (1976)* and the budget proposals of the SCC.

3. An examination of the need for a pilot project using trickle irrigation and, if appropriate, the drawing up of specifications for equipment and costings for a 3 year pilot study of this technique applied to plantations of trees, in the Shendi area

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* See References, Part 6.

In February 1978 the CFA Sudan submitted forms A1 to the ODM with the following terms of reference:

1. To formulate a detailed project on the establishment of shelterbelts in the Nile Province

2. To train local staff on project formulation during the visit.

The final terms of reference received at LRDC were to visit and prepare a project proposal for forestry development in Nile Province. The visit was to last one month, and called for:

1. The preparation of a detailed costed project proposal for forestry development in Nile Province, in accordance with the requirements of the Sudan Forest Administration in the context of the recommendations made by Mr P J Wood in his 'Report on forestry in Shendi, Sudan, December 1977'

2. The instruction of counterpart staff in the formulation of such project proposals, within the limits of the time available.

1.3 OBJECTIVES

The general objectives for the visit were agreed as an appraisal visit to all ongoing forest operations in the Nile Province with a local counterpart from the Shelterbelt Section of the CFA. Particular reference should be given to an examination of the joint afforestation project which is designed to (a) establish shelterbelts for agriculture schemes and (b) creat reservations of existing forests.

From this visit, a costed Plan of Operations and control forms should be produced for emulation elsewhere by the CFA.

On arrival it was found that a costed Plan of Operations for all land available for shelterbelts in the forseeable future had already been produced by the Sudan Council of Churches. The objectives were thus changed to provide a costed appraisal of suitable future British assistance with the ongoing shelterbelt project.

1.4 ACKNOWLEDGEMENTS

The writer wishes to express his gratitude for all assistance provided by Mr Ian Gordon of the British Embassy, the staff of Sir M MacDonald and Partners, and Huntings Technical Services Ltd; in particular, to Mr Tom Franks and Mr Rodney Self of the former, and Mr Christopher Howse of the latter, who so kindly provided the Landrover without which field visits could not have been undertaken. Thanks are also due to Syed A A Bayoumi, the Director of CFA, and Syed K A Badi, Deputy Director, for their valuable advice, and to Syed K O Kalifa, Manager of the SCC project, for his inexhaustable patience. Also to Syed Ali Saleem, Conservator, Shelterbelt Section, and staff; Syed I Zein, his deputy, who accompanied me on the field visit; Syed Gamri Ata, Assistant Commissioner for Forestry Affairs, Nile Province, for his advice and assistance; Syed Omran Balila, Forest Officer in charge of the shelterbelt project, Nile Province, for his generous hospitality and assistance. Last but by no means least, my thanks to Syed M Karama, staff counterpart, for his sustained interest and patient assistance throughout the visit.

MEASURES

1 feddan = 1.038 acres = 0.42 hectares
1 hectare = 2.47 acres = 2.38 feddan
1 Sudanese pound (LS) = US$2.8 = £ sterling 99.8

PART 2 SUMMARY OF PROPOSALS

For a fuller description, with more detailed terms of reference and costs, see Section 4.5.

It is proposed that:

1. An arid zone silvilculturalist with a sound practical knowledge of Eucalyptus species should visit Khartoum and the project area for a period of 2–3 weeks to advise on a better choice of shelter-belt species and provenances for this desert and semi-desert environment. It is suspected that the current choice of Eucalyptus microtheca, whilst performing satisfactorily as a shelterbelt species on the cracked clays of the Gezira area, is not the optimum choice for this more arid and sandy area of the Sudan. The timing of this visit is not critical, but should be before the nursery season is nearing its end in April, to enable any seed to be obtained, pre-treated, and to be sown in the nursery for seed trials.

2. A consultant Irrigation Engineer with a specialist knowledge of trickle irrigation should visit the project area for 1–2 weeks to design and cost a trial windmill and trickle irrigation system close to the Shendi nursery (for maximum supervision), since such a system is believed would be economically viable. If viable, it would be necessary for the consultant to see this equipment installed and functioning by March, when normal supplies of water are frequently curtailed due to the reduced waterlevel in the Nile and its canal systems. (It is hoped that the present trickle irrigation equipment, mislaid in Port Sudan since early 1978,(can after enquiries), be recovered in time). If the costing of the system indicates trickle irrigation will be economically worth while, the necessary equipment, as advised by the consultant, should be supplied under British Aid. (see para 4, below).

It is suggested that:

3. Current air photography of the Rivers Nile and Atbara should be flown to allow accurate mapping of forest areas astride these two rivers within Nile Province for future planning of operations for shelterbelts and forest reserves. It will, it is understood, be of particular benefit to the current project being undertaken by Sir M MacDonald Partners and Consortium. An area of 1200 mi^2 (120 x 10 mi) would cover most shelterbelts within the project scheme.

4. Financial assistance amounting to some £38000 would benefit the project by supplying the air photography, any necessary windmill and trickle irrigation equipment, spare parts for project vehicles, barbed wire for use in the new Keli nursery, consultants and technic literature.

It is advised that:

5. The responsibility for the day-to-day management in the project is at present shared between the ACFA Nile Province (part-time), the Shelterbelt Section of the Central Forest Administration (CFA) (advisory role), and the Forest Officer seconded from CFA full-time to the joint project as local manager (see Section 3.2.2). Given existing transport and communication facilities, this require rationalisation. It would appear preferable for a second full-time Sudanese Forest Officer to be seconded to El Damer station, responsible directly to the SCC Project Manager in Khartoum. Transport facilities, and, in particular, petrol supplies, both now and in the forseable future, do not allow the present seconded officer at Shendi to plan and manage all shelterbelts adequately.

6. Consideration should be given to sending one qualified Sudanese forest officer overseas on an inspection tour of a number of similar irrigation schemes, preferably involving tree species such as Eucalyptus and Prosopis. It is believed Egypt might be a suitable country for such a visit. The attendant publicity might assist in obtaining further funds (a greater problem than technical shortcomings perhaps).

7. The following items requested by the Project Manager are considered not suitable for UK assistance at this stage.

i Mobile extension unit The unit will be involved in supplying rural programmes in Arabic, which would be difficult to monitor for the effective use of any aid supplied, even though this sort of publicity would encourage local communities to cooperate in the shelterbelt projects.

ii One long-wheel base Landrover The present Landrover station-wagon stationed in Khartoum appeared to be used as a utility vehicle in town, and not so frequently for desert travel. It is not considered necessary to replace this vehicle after only 3 years service, mostly in town.

PART 3. BACKGROUND DATA

3.1 GEOGRAPHICAL ENVIRONMENT

3.1.1 Location

The Nile Province, where the joint Sudan Government/Sudan Council of Churches (SCC) 5 year afforestation project is being undertaken, lies between 16° - 20° N and 32° - 36° E (see Text Map 1). Most of the area is desert or semi-desert, and receives insufficient rainfall alone to support agriculture. The inhabitants depend therefore on irrigated agriculture along the narrow strip of land bordering the banks of the Rivers Nile and Atbara. The project area is restricted at present to the following agricultural schemes of those listed in Table 1. Gandato, Saiyal, Keli, Zeidab, El Hassa, and the projected scheme at Kabushiya.

3.1.2 Climate

For full details, see Appendix 1. The summer season with high temperatures and low humidity runs from April to October. May is generally the warmest month with mean daily maximum temperatures around 42°C, and a relative humidity of 22-24%. The coldest month is January, with a mean daily minimum temperature of 29°C. December has the highest humidity with over 45%. Rainfall has not exceeded 100mm (4") a year since 1973, and is normally restricted to the months of June, July, August and September, when the prevailing wind is from the south-west. For the rest of the year, only traces of rain have been recorded in the past 4 years. Winds are invariably from the north or north-east from October to May. Wind velocity rarely exceeds 14 kph (8 mph), except in the frequent dust storms that build up over the desert.

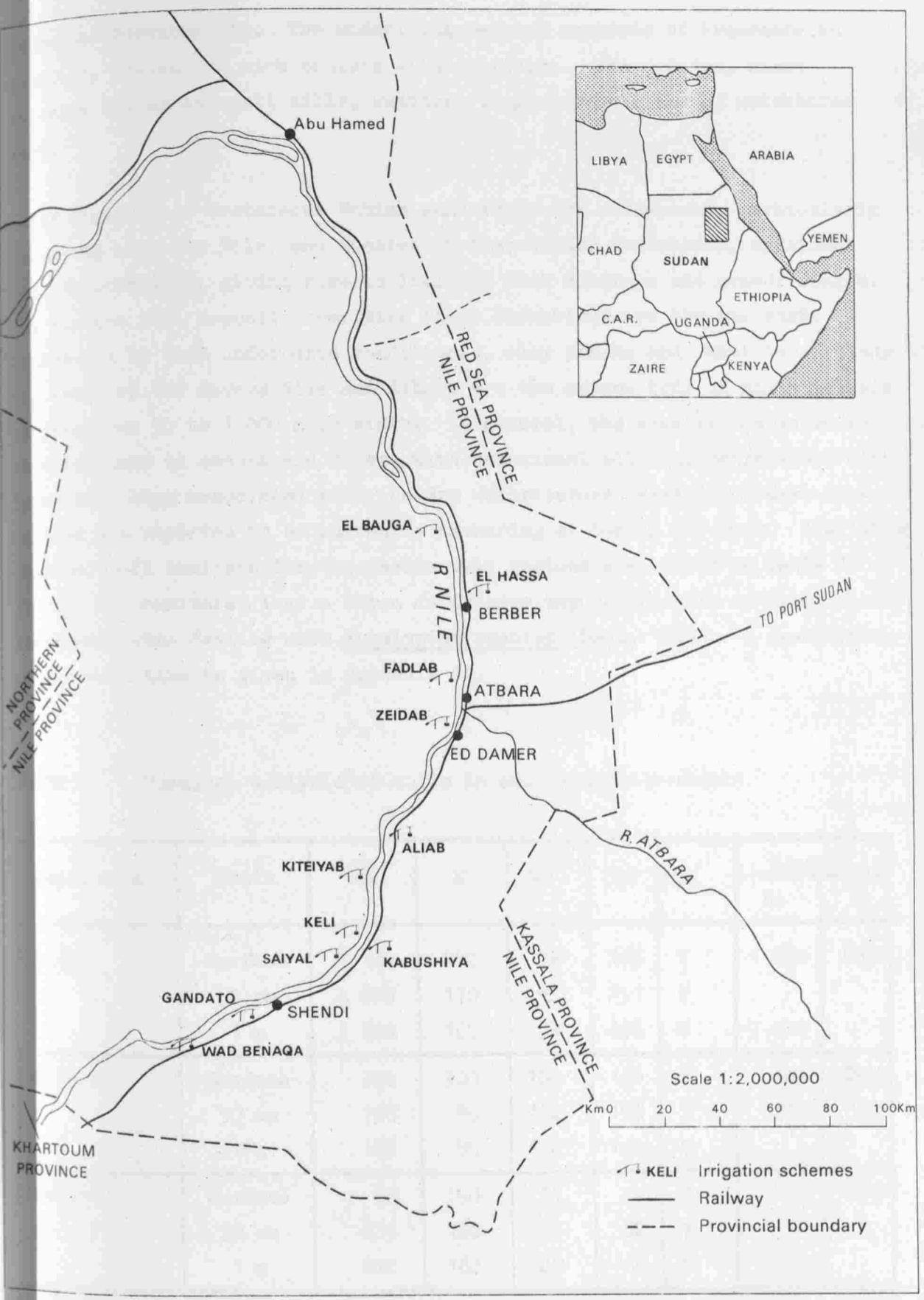
3.1.3 Geology and soils

For a detailed account see the Roseires Soil Survey Report No. 5 produced in 1964 (MacDonald Sir M 1964) by Sir M MacDonald and Partners with Huntings

TABLE 1 Agricultural irrigated schemes, Nile Province

Scheme	Date of Establishment	Farm area, feddan			Land km	Number of tenants	Water pumps		Crops grown (See Section 3.1.5 for detail)
		Government	Freehold	Total			Old	Proposed	
(a) Assisted schemes									
Gandato	1917	2 499	1 001	3 500	20	1 147	5	6	) 26% sorghum, 31% tick beans, 25% maize, 17% Triticum vulgare. Onions, chick peas, dolichos alfalfa, vegetables as winter crops.
El Hassa	1973	Cooperative		550	15	1 000	–	–	)
Zeidab	1904	9 000	21 000	30 000	45	1 451	5	9	) 33% of cotton, 33% winter crops as above 33% fallow
Keli*	1971	9 000	–	9 000	35	1 653	–	6	) 40% winter crops as above 40% summer and Damira crops, 20% fruit
Saiyal*	1973	9 000	–	9 000	30	1 600	–	6	)
Kabushiya	1977	Under construction		7 000	–	1 500	–	–	
Total				59 050		8 351			
(b) Unassisted schemes									
Kiteiyab	1917	4 877	897	5 774	18	1 338	2	3	) As for Gandato scheme
El Bauga		1 226	1 627	3 853	12	1 560	3	2	)
Aliab		5 195	19	5 214	20	483	2	2	)
Fadlab		770	2 600	3 370	17	165	1	2	)
Total				18 211		3 546			

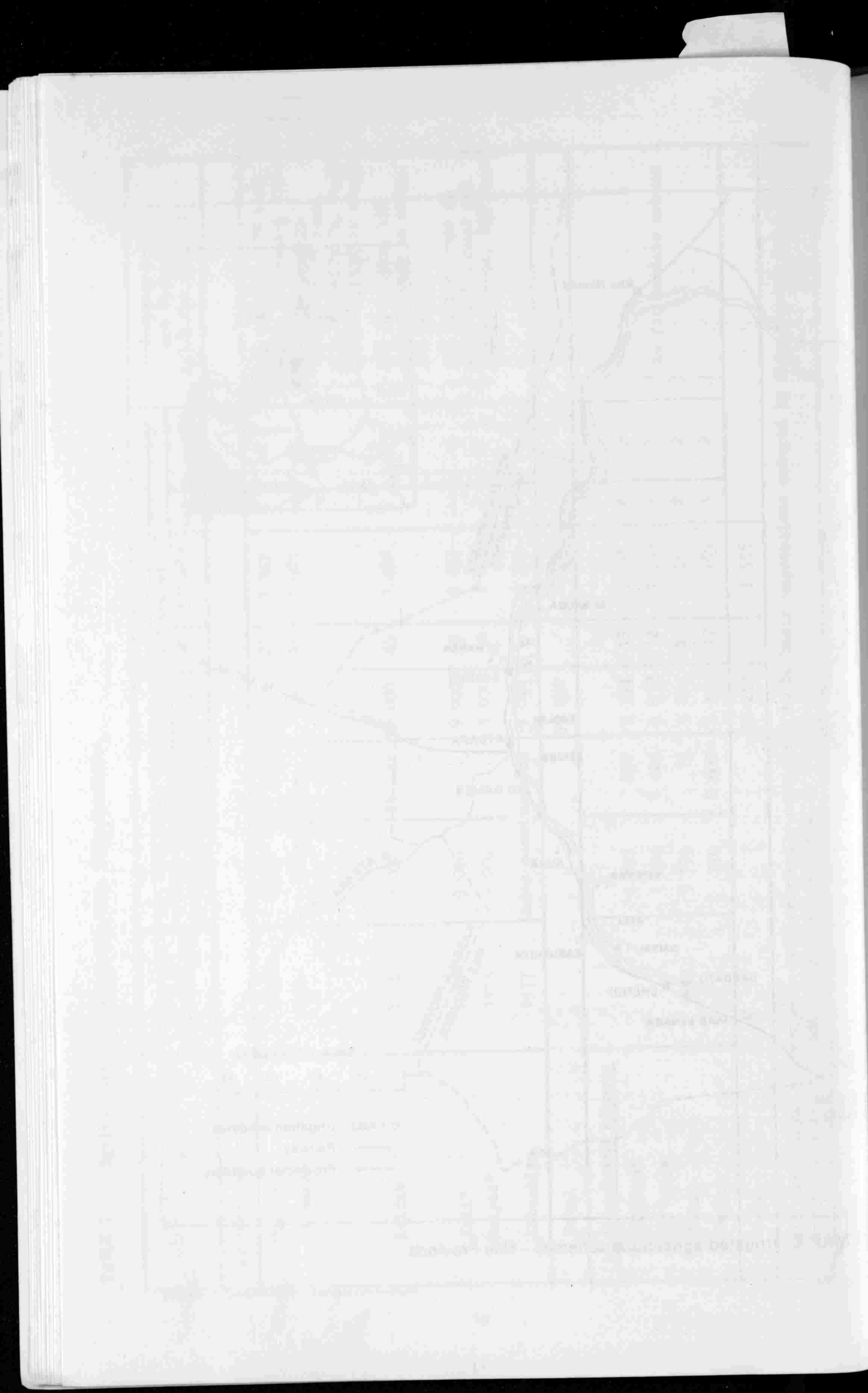
* Keli and Saiyal schemes were both originally considered to be basin depressions watered by Nile floods, but they are now being irrigated by flood channels



TEXT MAP 1 Irrigated agricultural schemes - Nile Province

FP 65/SUD/MB/4

Prepared by Land Resources Development Centre 1978.



Technical Services Ltd. The underlying bedrock consists of Pre-cambrian granites, gneiss and mica schists with quartzite. The granite, where outcrops appear as small hills, weathers to give quantities of waterborne sand.

Later deposits of Cretaceous Nubian sandstones are widespread, particularly occurring near the Nile, and consist of flat-bedded sandstones, mudstones and conglomerates, giving rise to lowlying rock outcrops and gravel ridges. The surface soil deposits overlying these formations are the qoz sands (deposited by wind under arid conditions), clay plains and laterites. Along the banks of the Rivers Nile and Atbara are the narrow beds of silty alluvia varying from 50 to 1 000 m in width. In general, the area is dominated by shifting sand in sheets and dunes, with occasional alluvial depressions with loams and clays associated with the dry watercourses (wadis). Desert conditions are reported to be currently advancing at 5-6 km per year. Available chemical soil analysis for the shelterbelt regions are stated in Table 2. It must be considered that a boron deficiency may be present, of particular importance when dealing with Eucalyptus species (Goda, 1977). A description of the soil taxa is given in Appendix 10.

TABLE 2 Chemical analysis*of soils in selected shelterbelts

Sample area	Depth	Na	K	Cu	Zn	pH/	Control	
							Na	K
Zeidab	Surface	1 180	280	72	105	7	1 190	285
	50 cm	4 600	170	93	151	7		
	1 m	7 600	185	92	146	6	7 400	
El Hassa	Surface	350	300	100	130	6	323	290
	50 cm	190	80	122	195	7	200	90
	1 m	185	85	110	140	7		
Gandato	Surface	60	190	27	49	7	60	175
	50 cm	835	160	35	62	7		
	1 m	220	160	40	68	7	195	

* Analysed by Ministry of Industry and Mining geological laboratory
/ Obtained by indicator papers

3.1.4 Population

The total population of the existing irrigated agricultural schemes, both assisted and others, with some 12 000 tenants (see Table 1) is estimated to approach 60 000 people, (assuming an average family size of five). This figure added to those of Shendi (24 160*), Atbara (66 110*), Ed Damer (17 080*) and Berber (11 300*) makes an estimated total of 180 000 settled residents in the project area. An uncounted population of nomadic graziers (said to make up a further 10% of the population) migrates through the area. Only Atbara has any industrial capacity, with its railway depot and cement factory. The majority of the remainder of the resident population, excluding shopkeepers and boatman, depends upon agriculture (including livestock production) for a living. The Nile Province as such has had no traceable population census since it became divided from Northern Province in 1974, and this present population has been estimated from available data. It has also been assumed that there is a 3½% annual population increase for the whole of the Sudan, though with the attraction of the agricultural development schemes, the natural increase in the project area will be supplemented by some inward migration.

3.1.5 Pattern of agricultural production

The cultivable area of Nile Province is restricted to a narrow strip either side of the Rivers Nile and Atbara; the strips nowhere exceed a maximum width of 4 km (on the Nile) and 1 km (on the Atbara). Rainfall plays a negligible role; inundation or irrigation, which introduces the fertile water-borne silt, is necessary for crop production throughout the Province except near Shendi.

Three main cultivable soil types are recognised locally:

1. The 'gezira' or seluka cultivation occurs on the Blue Nile silt of recent origin. The annual flood deposits a moist fertile silt, which is suitable for sorghum cultivation as the main crop; irrigation is not needed with the temporary high watertable.

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* Population estimate taken from an unpublished 1973 census of these towns.

2. The Saqiya soil type occurs near the river banks where they are not flooded at high river; it is a fertile silt of less recent origin providing a free-working alluvial loam. Today much of this soil type, all privately owned, is irrigated by private pumps rather than by the original water wheels which gave the name to the soil type as well as to the method of cultivation. During the flood period (August-November) sorghum, maize and Dolichos lab lab ('Lubia') is grown. From November to March (in the winter season), wheat and barley are the major crops, with some Vicia faba (tick or egyptian beans or 'ful masri'), Phaseolus vulgaris (haricot beans or 'fasulia') and Dolichos lablab. In the summer period, May to August, sorghum and Medicago sativa (lucerne) is grown, and fruit from the orchards is harvested

3. Basin cultivation occurs in the natural depressions or wadis, which once relied upon extra high Nile floods but are now mostly irrigated by mechanical pumps. The soil, deposited originally by slow running or stationary water, has much finer particles than types 1 and 2 (above); the surface cracks readily when dry and puddles badly. Under annual flooding, crops of sorghum, Dolichos lablab and maize are produced from August to November. From November to March the winter crops of Vicia, Phaseolus, wheat, onions, and Cicer arietinum (chuck peas or 'hummus') are grown. Cotton (American Upland variety) is produced with mechanical irrigation in the summer season (May-August) and is harvested in September. The rainfall from July to September in the Shendi area is often heavy enough to permit crops of un-irrigated maize and sorghum to be produced in the catchment areas formed by these natural depressions, even though yields may be low.

Perhaps the most serious handicap to efficient agriculture is the subdivision of a farmers' land among his heirs on his death, reducing individual holdings to areas too small to support a family or justify efficient husbandry or development.

3.1.6 Natural vegetation

The sparse semi-desert vegetation in the project area is of the Acacia tortilis - Maerua crassifolia scrub association. The following tree species identified are characteristic: Acacia tortilis sub species raddiana, Acacia ehrenbergiana, Acacia seyal, Cassia sena, Balanites aegyptiaca, and Ziziphus spinachristi (the last two species are frequently heavily grazed). Shrub species commonly noticed were Calotropis procera, Capparis decidua and the zerophytic Leptodenia pyrotechnica. Grasses occur infrequently, but are gregarious when present; species collected were Aristida mutabilis, Cymbopogon nervatus and Panicum spp. (probably P. turgidum).

It is obvious that the local requirements for poles and fuel cannot be met by the quantities of natural vegetation available in this area (see Section 3.2.4). Trees are overcut for produce, and even roots are dug up for fuel; the nomadic graziers, who cross the area to water camels, donkeys, goats and sheep, encourage the overgrazing of existing vegetation (see Plates 1 and 2).

3.2 ADMINISTRATION ASPECTS

3.2.1 Forest policy

Government policy, in so far as it affects the irrigated agricultural schemes along the Nile, is quite specific. Five per cent of all new government development projects shall be retained for afforestation to provide windbreaks, wind deflection blocks, and forest production areas to provide local requirements for fuel and poles, at least in part.

However, arable land is in short supply throughout the Nile Province, and the local farmers do not invariably agree with the use of irrigable, or even potentially irrigable, land for tree crops despite this policy ruling. This has created the problem noted for the Zeidab shelterbelt proposed planting area for 1978 (see Appendix 5, Planting proposals and control form).

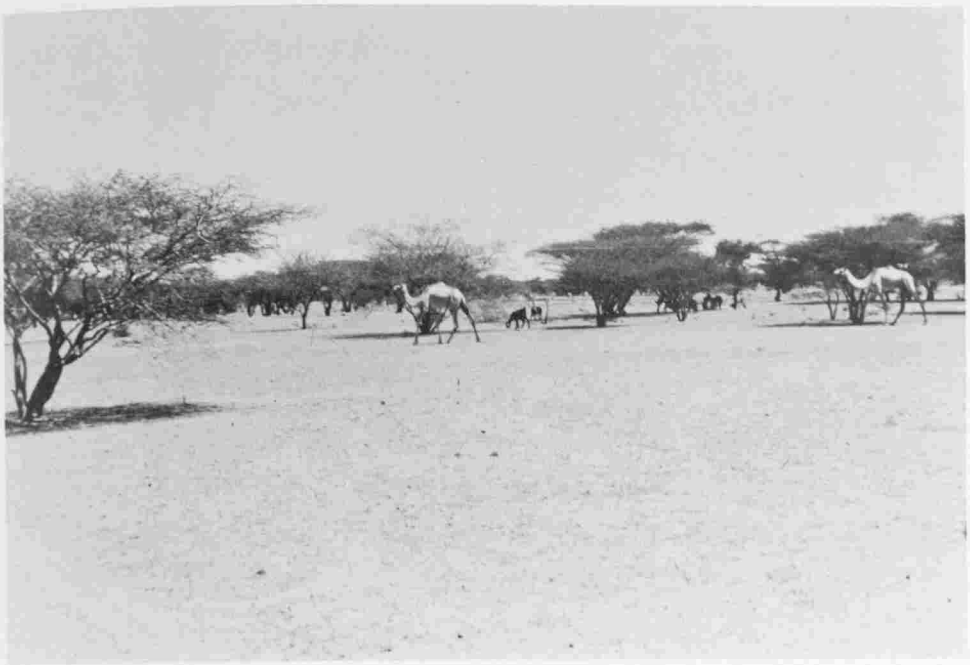

PLATE 1 Nomadic flocks and herds passing through *Acacia tortilis* forest to reach watering grounds close to the Nile

PLATE 2 *Ziziphus spina-christi* closely grazed by nomadic livestock

Prepared by Land Resources Development Centre 1978.

3.2.2 Administration of shelterbelt project

(See Appendix 2) On 28 June 1977 an agreement was signed between the Sudan Government and the Sudan Council of Churches (SCC) to implement a joint aforestation project in the Nile Province. A steering committee was created, to meet in Khartoum, made up of the following members:

Ministry of Agriculture, Food and Natural Resources (2 members from the Central Forest Administration, CFA)
Sudan Council of Churches (2 members)
Ministry of Irrigation and Hydroelectric Power (1 member)
Agricultural Production Corporation (1 member)
Forest Research Division of the Agricultural Research Corporation (1 member)
Ministry of Finance and National Economy (1 member)

Under the agreement, a Manager was appointed, Syed K O Khalifa (the previous Director of Forests, now retired), with Syed Ali Saleem, Conservator, as Co-manager (ex-officio as Head of the Shelterbelt Section of CFA), assisted by his deputy, Syed Zein El Abdin.

The relative responsibilities of each administration sector of management are as follows:

1. SCC contribution

i The provision of the major part of finance, both capital and operating costs, obtained from Aid donors overseas. The annual minimum contribution to be LS 50 000 per annum, subject to satisfactory progress of the project

ii The supply of equipment, in particular seed, tools, vehicles, irrigation and meteorological equipment

iii The responsibility for providing a full statement of accounts

iv The provision of some staff, including the project manager, an accountant, a secretary and such advisers and consultants as from time to time may be deemed necessary

v The provision of drivers and casual labour.

2. Sudan Government contribution

i The provision and recruitment of local personnel and counterparts for both supervisory and silvicultural matters, and technical support from CFA staff

ii The provision of land at a cost of LS 50 per feddan

iii The cost of pumped water supplied, at approximately LS 12 per feddan per flooding

iv The provision of a cash grant of LS 5 000 a year

v The appointment and salaries of two Forest Officers, three Forest Rangers, six Forest Guards, and eight skilled forestry workers for the establishment of plantations and nursery production

vi To continue with the maintenance and extension of established plantations on the completion of this project.

3. Provisional Forest Service contribution (through the Assistant Commissione for Forestry Affairs, Nile Province, stationed at Atbara.

Although not represented on the Steering Committee the Provincial Forest Service is empowered to act for the Forest Administration in the best interest of staffing, equipment, payment and rate of progress, viz:

i The local appointment, transfer, authorisation of payment and disciplinary action for all staff paid under project funds

ii The preparation of monthly and annual reports on the progress of the project

iii Provide for the use of existing and future forest nurseries in the area, and office space.

Although this division of responsibility cannot be strictly adhered to under practical field conditions, there is a considerable level of coordination. However, it has resulted in a number of problems discussed in Section 4.4.1 below.

3.2.3 Staffing of Project

Tables 3 and 4 list the supervisory staff, silvicultural labour, both skilled and casual, and drivers engaged in the project, with the controlling authority responsible for making payment.

TABLE 3 Supervising staff seconded from, and paid by, the Central Forest Administration (CFA)

Rank*	Name	Station	Area responsibility
ACFA	Syed Gamri Ata	Ed Damer	Part time over all areas. (1978)
F O	Syed Omran Balila+	Shendi	In charge, all shelterbelts. (1978)
F O	++	Ed Damer	Proposed charge, north region
F R**	Syed Bashir	Berber	El Hassa Shelterbelt
F R	Syed Babikar	Zeidab	Zeidab, and Damer nursery
F R	Syed Bagin	Shendi	Gandato, Wad Banaqa, Keli, Saiyal. (Kabushiya)
F G	(6) ++	-	One to each shelterbelt project.

* ACFA = Assistant Commissioner for Forest Affairs (Nile Province), F O = Forest Officer, F R = Forest Ranger, F G = Forest Guard

\+ In post as from July 1978 only

** Since the El Hassa programme is a minor responsibility it is possible that the Senior Overseer will take over control, and F R Berber will be sent to the west bank to look after the new Keli nursery and plantations

++ Not yet appointed, as at November 1978

TABLE 4 Field staff and drivers paid full time by the Sudan Council of Churches (SCC)

Station	Rank or occupation, and numbers						
	Forest Overseer	Permanent skilled labour	Casual labour	Drivers			
				Land Rover	Lorry	Tractor	Bulldozer
Nurseries							
Shendi	1	5	4	1	-	1	
Berber	1	(3)*	7	1	-	-	
Ed Damer	-	3	3	1	-	1	
Keli	-	-	-	-	-	-	
Shelterbelts							
Banaga	1	(2)*					
Gandato	1	(2)*					
Saiyal	1	2			1	1	
Kabushiya	1	(3)*			-	-	
Keli	1	(2)*			-	-	(1)*
Zeidab	1	5			-	-	
El Hassa	1	2			1	1	
Total	9	29	14	3	2	1	
* 17 are in post now; the other (12) are envisaged for season 1979							

3.3 RELATED PROJECTS AND REPORTS

As well as the joint CFA/SCC project a number of other agencies are either engaged in, or are planning, shelterbelt schemes in this project area.

3.3.1 Central Forestry Administration (CFA), Shelterbelt Section

This section is responsible for the planning and planting of shelterbelts in all provinces, and is headed by Conservator Ali Saleem.

One of the main objectives of the current 6-year Forest Development Plan (July 1977 - June 1983) is stated to be the planting of 30 000 feddan of shelterbelt around agricultural schemes and towns, some to be in Nile Province, as follows:

Shelterbelts in rain-fed agricultural schemes	15 000
Shelterbelts in irrigated agricultural schemes	10 000
Protection of towns (Khartoum Green Belt, etc)	5 000
	30 000 feddan

Projected expenditure allocated is LS 1 506 399 over this 6-year term. For the next 6-year plan (July 1983 - June 1988), CFA proposes to plant a further 286 750 feddan for a cost as yet unestimated. 155 000 feddan of shelterbelts are destined for rainfed agricultural schemes, and 131 750 feddan for irrigated schemes. In practice, the allocation of development funds to the Shelterbelt Section for 1978/79 has been reduced to LS 9000, of which LS 5000 has been allocated as a cash contribution to the joint CFA - SCC project, and LS 4000 to other provinces. Staff, paid from annual recurrent maintenance costs (unaffected by these cuts), have been supplied to this and similar shelterbelt projects.

3.3.2 Forest Research Institute, Soba

A cost-sharing project between the International Development Research Centre (IDRC) of Canada and the Government of Sudan has been signed. The objectives are to finance FRI Soba investigations, over a 5-year period, into the optimum design of shelterbelts to protect crops and water-courses from wind-blown sand, and increase crop productivity by micro-climatic improvements. The IDRC has granted Canadian $ 165 000 for this research, and the Sudan Government has allocated LS 55 615.

3.3.3 United Nations FAO Programme

Due to the financial constraints on the CFA project (3.3.1), the UNDP is proposing to finance nine projects to cost US $26 million (LS 13 million)

over a 3-year term under their Sudan Desert Encroachment Control and Rehabilitation Programme (DECARP). (Sudan Government 1976).

The Nile and Northern Provinces Project (Proposal No. 7) to be centred at Atbara, was due to start in 1978 but still awaits funding. Project No. 7 is expected to cost US $2 084 290, of which the UN contribution will be US $869 640 and the Sudanese contribution US $1 214 650.

The long-term objectives is the development of a viable and continuing programme for the eventual arrest and rehabilitation of desert encroachment in the Nile (and Northern) Province.

The immediate objectives are the:

1. Development and execution of a provincial extension programme for farmers

2. Demonstration of correct land use on farmer's own land

3. Provision of services and technical assistance in the control and rehabilitation of areas affected by desert encroachment

4. Assistance to national projects of a similar nature

5. Formulation of Aid projects in assistance, such as the World Food Programme.

An additional sub-project, no 6, concerning the establishment of shelterbelts in both Nile and Northern Provinces, is also planned. The total proposed cost over 3 years will be US $1 424 352 (LS 712 176), of which US $616 117 will be donated by overseas aid, and a further US $808 235 from Government contribution. The objectives are to establish new shelterbelts to protect existing and proposed farm schemes, and to extend the shelterbelts started by the CFA Shelterbelt Section. Tree seedlings for 100 km of shelterbelt over 2860 feddan will be provided, and facilities for ground preparation and planting supplied. It is intended that farmers will maintain the establishe shelterbelts themselves under CFA Technical Supervision. Funding is still awaited.

3.3.4 Reports

The major description of this project area is contained in the joint report produced by the consortium of Sir M MacDonald and Partners with Hunting Technical Services Ltd in September 1964, referred to as the Roseires Soil Survey (MacDonald 1964). Area 4 in this report covers the Nile banks from Khartoum to Kareima and includes this present project area. It is described in Report No. 5 and its relevant Soils and Engineering plan book. In the current up-dating and extension project by the same consortium, their original land capability classification will be revised and re-mapped, still using the original field-work described under the Seventh Approximation Soil classification system.

PART 4 THE PROJECT

4.1 THE PROJECT AREA (See Table 1 and Text Map 1)

The joint CFA - SCC Shelterbelt Project is restricted to six out of the 11 pump-irrigated agricultural schemes along the Nile from Shendi to Berber (the Gandato Scheme is in fact 15 km south of Shendi). The total farming area influenced is some 57 000 feddan (58 700 ac; 23 950 ha) containing around 7 300 tenant farmers. The projected Kabushiya Scheme is not included in the above totals.

In addition, a timber production block of 25 feddan in the gazetted Central Forest Reserve at Wad Banaqa 75 km south of Shendi was planted in February 1978 with Eucalyptus microtheca. An area of 20 feddan had been planted previously by the CFA in 1974 (13 feddan) and 1975 (7 feddan) as a production area. A further 5 feddan is available for planting but requires considerable levelling before it can be irrigated by the standard flood channel system.

4.2 OBJECTIVES OF PROJECT

The project, jointly implemented by the Sudan Government and the Sudan Council of Churches, has for its objective the establishment of shelterbelts to protect several areas of highly productive irrigated agricultural schemes along the Nile (see Text Map 1.) Outside the schemes semi-desert exists. The farms are irrigated by open water flood channels, but windborne sand encroaches the farm land and frequently blocks these. Some villages established in the semi-desert region (to avoid wasting fertile ground) are also in danger of being buried under sand (See Plates 4 and 5).

The objectives are therefore to provide the following benefits:

1. The protection of agricultural land and open irrigation canals from desert encroachment
2. Protection of growing crops from excessive wind exposure
3. Provision of fuel wood and building poles for the farmers
4. Provision of edible fruit (Prosopis pod flour etc), and fodder for animals (see Plate 3)

5. Provision of by-products for industrial use (fibre etc)
6. Shelter from sun and wind for man and his animals
7. The amelioration and improvement of agricultural and general living conditions

It is the intention that the project run from January 1977 to December 1981, when the established shelterbelts will be handed over to the CFA for subsequent maintenance, extension, harvesting and replacement. The Sudan Council of Churches is assisted financially by the Swedish Free Mission, the Protestant Central Agency (EZE) of West Germany, and Christian Aid UK.

4.3 PLANTING TARGETS AND ESTIMATED FUNDING BY SCC

As indicated in Section 3.3.2 above, the greater part of the budget will be the liability of the SCC. Table 5 indicates the estimated targets and required funds as at 25 August 1978 for the remaining 3 years this project has to run (see Appendix 5 for details of each shelterbelt).

TABLE 5 Planting targets and estimated funds required, LS

	Jan 79-Dec 79	Jan 80-Dec 80	Jan 81-Dec 81	Total
Target, feddans	417	424	418	1 259
Plants needed	325 000	329 000	325 000	980 000
Expenditure (in LS) on: Personnel	49 153	54 068	59 475	
Transport and machinery	9 305	10 236	11 260	
Field operations	50 369	57 924	66 613	
Seeds and implements	3 200	4 000	4 400	
Capital costs (Pumps, piping etc)	3 000	13 662	25 000	
Extension work	18 285	11 525	1 375	
Administration 10%	14 631	16 519	18 212	
Contingencies	13 000	13 775	14 000	
TOTAL	160 943	181 709	200 335	543 000

PLATE 3 Goats browsing on pods of *Prosopis chilensis* in Zeidab shelterbelt (planted 1972 and now 5 metres average height)

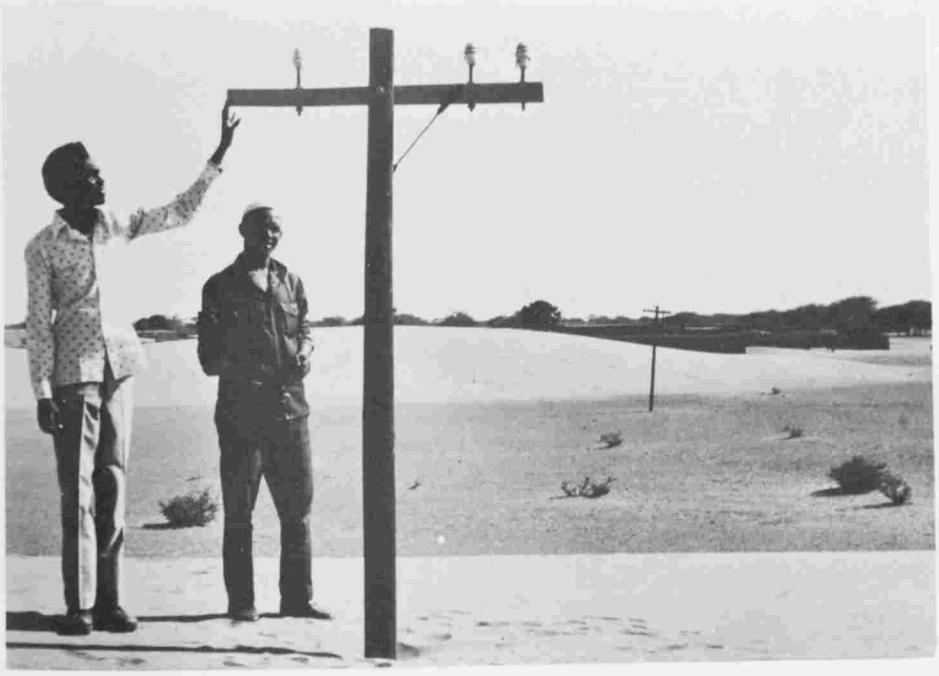

PLATE 4 Sand movement outside Saiyal shelterbelt. The cross-bars of both telegraph posts were the same height above groundlevel last month

Prepared by Land Resources Development Centre 1978.

PLATE 5 Farmhouse in desert outside Gandato agricultural scheme; walls partly blanketed by recently blown sand

PLATE 6 Ed Damer nursery. Potted seedlings of *Eucalyptus* species and *Proscpis chilensis* in background. Delays in obtaining planting sites has meant these plants are much larger than optimum size for planting. Seedlings are now being root and shoot-pruned

Prepared by Land Resources Development Centre 1978.

4.4 DISCUSSION OF PROJECT OPERATIONS, 1978-1981

Estimated cost of operations is given in Appendix 3, and the proposed operations and control form in Appendix 5. This section is intended as an explanation of these figures and the methods in use, in order to highlight problems and discuss possible solutions.

4.4.1 Administration

The division of responsibilities, as described in Section 3.2.2 above, does not invariably operate in practice, although the level of coordination appears acceptable in most cases. However, it seems probable that past shortages of land, and, seasonally, of water, are in part due to administrative shortcomings. Since land and water are both in short supply in most irrigated agricultural schemes, priority must go to the cultivated areas at the expense of shelterbelts however narrow. Many of the shelterbelts are therefore planted on the higher terraces, and thus require more water than usual in order to flood all areas, leading to some inevitable waste of water. This wastage combined with silting of canals, shortage of fuel for the pumps, and the shortage of water at peak periods may all require the irrigation authorities to restrict the water flow to plantations between March and May. From observation, many plantations have in the past (Keli and Saiyal) and are now (Wad Banaqa) seriously affected by drought, and growth has been uneven (see Plate 9).

It has nowhere been found prescribed exactly how much water shall be allocated for shelterbelts (indeed the seasonal fluctuations in the level of the Nile may make any such allocation impossible to define accurately); thus water supply appears to be a matter of cooperation between Forestry and Irrigation authorities.

Since full-time management until July this year has been undertaken from Atbara in the north, it is possible that insufficient pressure could be exerted on local irrigation authorities to supply an adequate share of the

water available. As from July, a second senior Forest Officer who is based at Shendi, could remedy any such deficiency. Syed Omran Balila has, however, insufficient petrol to travel over the whole project adequately, but with the proposed second Forest Officer due to be based in Ed Damer in the 1979 budget, this state of affairs should improve.

However, it is considered that the Project Managers controlling each agricultural development scheme should be encouraged to take a much greater interest in the well-being of shelterbelts, as has proved so successful in the Gezira irrigated plantations.

4.4.2 Nursery operations

At the time of the visit, all nurseries still contained plants (see Table 6) which were due to have been planted that season (July - September 1978). Although artificial irrigation extends the planting season, the seedlings were (in October) above optimum size for planting (Eucalyptus 30-58 cm, measured to leading shoot, and Prosopis 40 cm, Ahmad 1977;Wunder 1966) and were having to be root and shoot pruned heavily.(see Plates 6 & 7) Root pruning proves beneficial; eight times in a season being optimum. However, shoot pruning always produces adverse effects since plants go into a check period, and establishment in the plantation is delayed. The reason for this year's delay is the problem of preparing planting sites in time (see Section 4.4.3 below)

TABLE 6 Nurseries. Total capacity, present stocking and future needs

Nursery	Future total capacity '000	Present stocks '000			Plantations supplied	Future requirements '000			
		Euc	Pros	Total		1978	1979	1980	1981
Shendi	175	20	140	160	Gandato, Banqa, Kabushiya	180	110	160*	150*
Keli (proposed)	175	-	-	-	Keli, Saiyal		170	160	160
Berber	50	15†	32	47	El Hassa	125	40	17	17
Damer	95	59	31	90	Zeidab				
Total	495		203	297		305	320	337	337

* On the assumption that a further 100 feddan of land is available for planting at Saiyal

† Including mostly 'other species', Neem etc.

PLATE 7 Shendi nursery. Potted seedlings of *Prosopis chilensis* after shoot pruning

PLATE 8 *Eucalyptus Microtheca* plantations (planted 1974) in Aliab shelterbelt. Note regular growth, assisted by adequate irrigation

Prepared by Land Resources Development Centre 1978.

PLATE 9 *Eucalyptus microtheca* plantations (planted 1974) in Wad Banaqa production block. Note signs of drought stress, and the decreasing height growth of trees farthest away from water source (to right of picture)

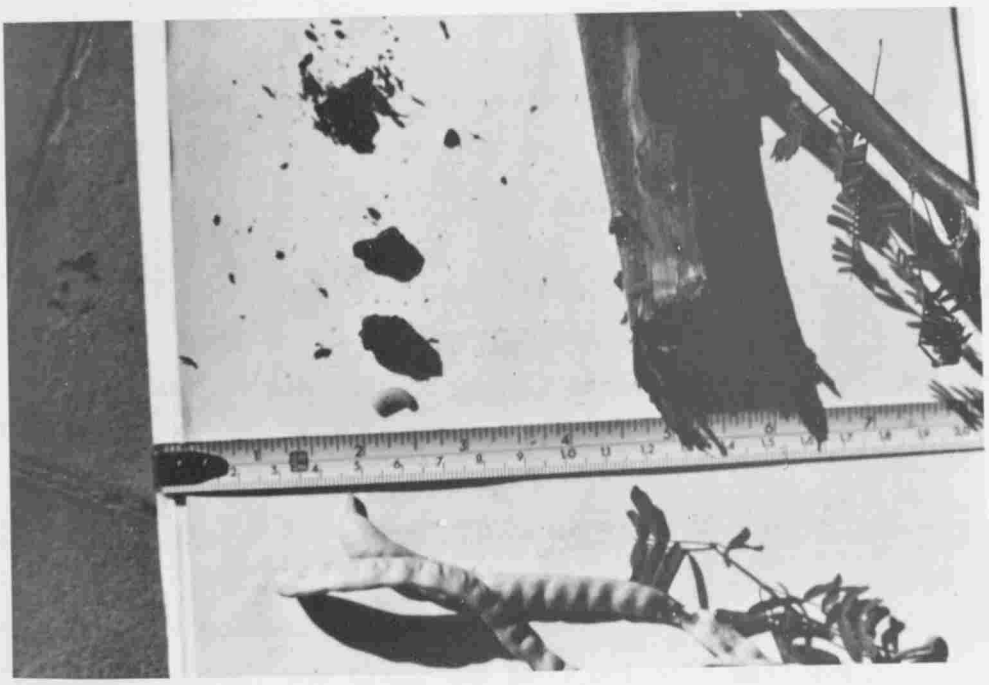

PLATE 10 *Prosopis chilensis* attacked by shoot borer. Collected in El Hassa block. The specimen is being identified in London

Prepared by Land Resources Development Centre 1978.

These are all old, well established forest nurseries, and skilled labour is available. Irrigation presents no major problems since the nurseries are sited near adequate water sources. Shendi nursery has a new 2" pump, Ed Damar is supplied direct from the Nile, Berber has a well and a 2" pump with a new 6 HP diesel engine, and Keli new nursery will have a new 4" pump with an 8 HP engine.

Because the planting out was so long delayed, it would have been advisable to reduce the irrigation. This procedure reduces the plant growth rate and hardens the plants, thereby reducing shock when planted out. Provided the new nursery at Keli can be prepared for this season's planting, no major problems can be foreseen at this stage.

4.4.3 Ground preparation

Most shelterbelts are on higher ground outside the irrigated farmland (see Figure 1). Once the sites have been selected and accurately mapped, the next operation is the design and costing of a separate pumped irrigation system,* followed by scrub clearance and mechanical levelling to enable the future plantations to be flooded section by section. These two stages are major operations carried out by the Ministry of Irrigation (Projects Division) on behalf of the CFA, although the Agricultural Production Corporation are responsible for paying for the operations.

The levelling is followed by ploughing and ridging at 3 m intervals, to give trees the customary 2 x 3 m spacing: this is carried out by project-owned tractors.

This year ground preparation delays have become a major constraint. Planting of stocks at present held in the nursery should have started by the end of July and by now growth should have been well advanced. However the situation over the target for plants in 1978 is as follows

Zeidab belt (103 feddan) Some 50-60 feddan have been cleared, of which 30 feddan have been ploughed and ridged. Heavy rains in August delayed further site preparation, but meanwhile work has ceased due to a dispute with the local Farmers Association, who claim the proposed belt will deflect rainfall runoff from surrounding high ground and so flood the village. Despite the

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* Unlike the Gezira scheme which is gravity fed, the Nile Province scheme is irrigated by pump systems. See Appendix 6.

high soil salinity in the area, an alternative reason may be that the farmers would prefer to use this area for agricultural cropping, now that it can be irrigated. (This dispute will probably have been resolved, by the time this report is printed by the Commissioner for Nile Province). Problems such as these appear to occur often in new schemes, but once settled tree planting can take place. (Both Zeidab and El Hassa schemes are 'cooperative managed', with their own Irrigation Engineer and irrigation unit run by the Agricultural Production Corporation).

El Hassa belt (50 feddan) 32 feddan is now considered ready for planting, and a further 16 feddan of failed shelterbelt will also be replanted. 3 feddan was planted this year before irrigation pumps ran out of fuel, and planting had to stop.

Wad Banaqa Production area (25 feddan) The planting area is on broken ground, and still requires levelling before ploughing, ridging and planting can begin. This area is the unplanted remnant of the main forest reserve. (see Appendix 4) for which the irrigation system was designed in 1974. No project machinery is at present available to undertake this major levelling operation, whilst irrigation authorities have areas of higher priority elsewhere.

Gandato belt (50 feddan) The irrigation system has been designed and costed. A cost estimate of £8 825 (see Appendix 6) for levelling and major canal construction was submitted on 24 July 1978 by the Ministry of Irrigation (after debate) to cover an area of 75 feddan (50 feddan for 1978 and 25 for 1979). The estimate is still being discussed by the CFA.

Saiyal belt (100 feddan) and Keli belt (60 feddan) Both these areas await the design of their irrigation systems (as does Kabushiya belt of 457 feddan, of which 100 feddan is due for planting in 1979).

Delays cannot be blamed on local irrigation teams, even though site maps of all areas were received by the Ministry of Irrigation Projects Division at Medani on September 18 1978. The Ministry of Irrigation's first contention, that the belts should be planted outside the embankments of the agricultural schemes, was disputed by the CFA Shelterbelt Section. However, acceptable plans have now been designed, but await ammonia paper before they can be printed and despatched. Some projected costs are quoted in Appendix 6 for Kabushiya scheme.

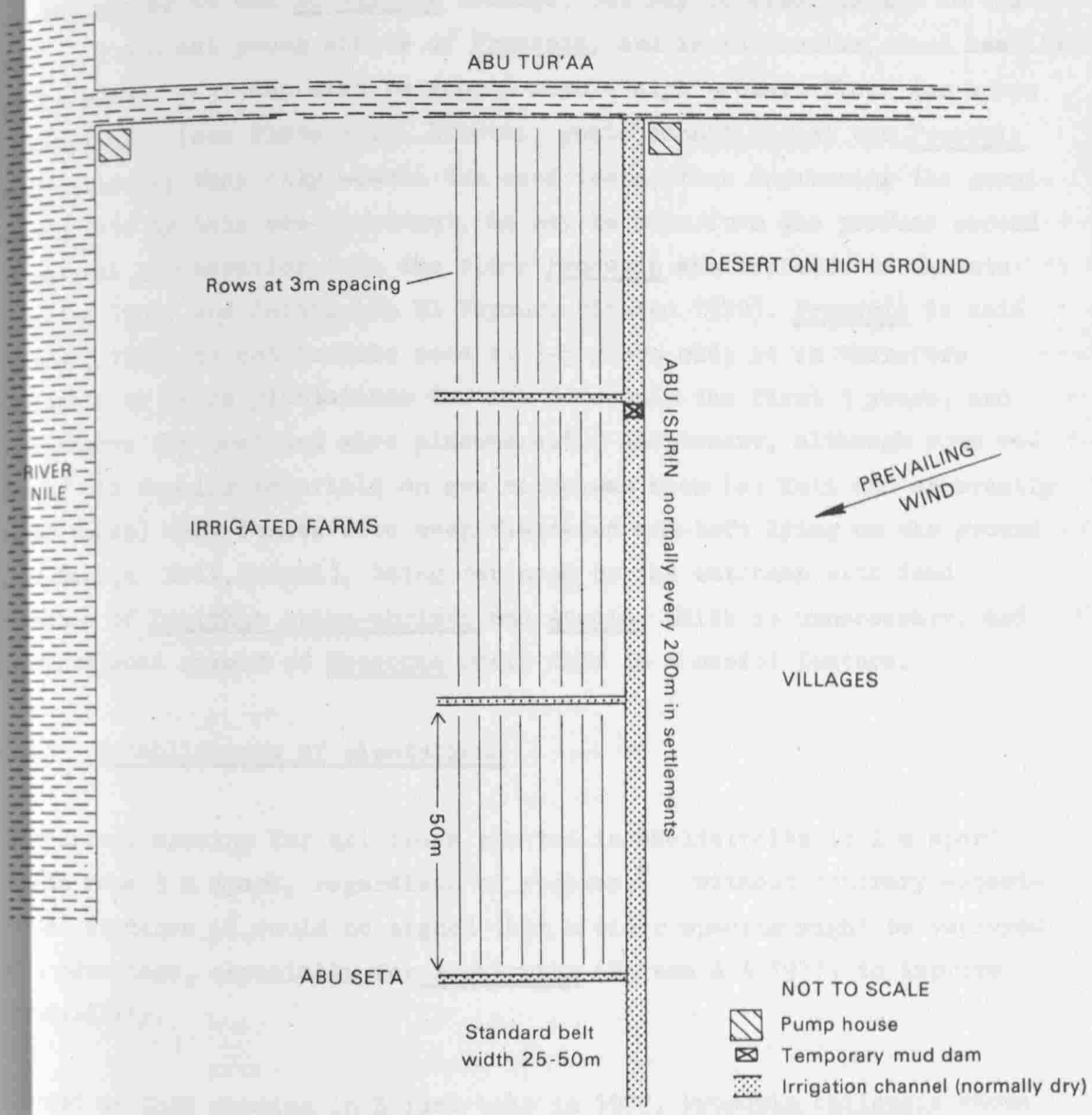

FIGURE 1 Diagrammatic plan of typical Shelterbelt irrigation system

Prepared by Land Resources Development Centre 1978.

4.4.4 Fencing

All plantations on establishment are fenced with 5 - strand barbed wire (of various gauges as available) hung at 4 metre centres on 4" hand-squared fenceposts of 'Sunt' (Acacia nilotica) cut in Gezira Province. Both posts and wire are sent down from Khartoum by rail. It was observed that goats did not appear to eat Eucalyptus foliage, but may do minor damage to the bark. Goats eat young shoots of Prosopis, and in particular, feed heavily on the pods can also be ground into a high protein flour for human consumption (see Plate 3). However, goats cannot digest the Prosopis seed entirely; they only weaken the seed testa, thus increasing the germination rate by this pre-treatment, as may be seen from the profuse spread of natural regeneration from the older Prosopis shelterbelts at Gandato (planted 1957) and Zeidab (Um El Tayour, planted 1972). Prosopis is said (Wunder, 1966) to set fertile seed at 3-5 years old; it is therefore advisable to fence plantations for not more than the first 5 years, and then remove the post and wire elsewhere.* At present, although some re-use of old fencing materials on new sites was seen (at Keli and apparantly at El Hassa) many fences were seen flattened and left lying on the ground (Wad Banaqa, Keli, Saiyal), being replaced by the watchman with dead branches of Ziziphus spina-christi and Acacia, which is unnecessary, and prevents goat spread of Prosopis where this is a useful feature.

4.4.5 Establishment of plantations

The current spacing for all trees planted in shelterbelts is 2 m apart within rows 3 m apart, regardless of species.† Without contrary experimental evidence it could be argued that a wider spacing might be employed with advantage, especially for Eucalyptus (Saleem A A 1977) to improve permeability.

Planted at this spacing in Zeidab belt in 1972, Prosopis chilensis shows no obvious sign of growth rate reduction from overcrowding. However, the 1974 plantations of Eucalyptus microtheca in Banaqa Forest Reserve showed some reduced growth in the centre of the block of 13 feddan. This is more likely to have been due to drought stress rather than root competition, but the latter cannot be dismissed in the absence of proof.

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* Unless the Prosopis is due to be run on a coppice rotation, when fencing will be required to prevent goat damage to young coppice shoots.

† 1666 trees per hectare or 700 trees per feddan

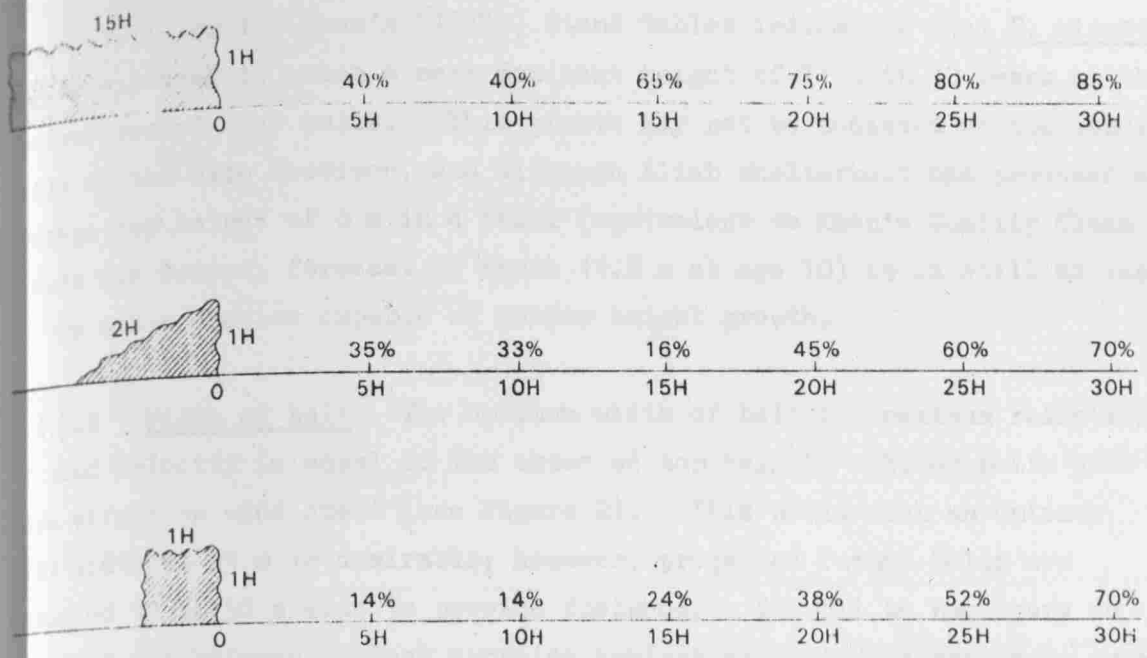
Wind can still percolate through those belts planted at 2 x 3 m; however, optimum permeability should preferably allow 30-40% of the wind to pass through the belt, rather than over (FAO 1974). The closer spacing also provides protection at an earlier age, and the extra cost is negligible (planting at 4 x 3 m would only cost LS 2.50 per feddan less).

Should later experimental evidence, (which it is desirable to obtain) indicate a wider spacing to be optimum for growth, the fault can be rectified by thinning. Meanwhile the standard 2 x 3 m spacing should be retained.

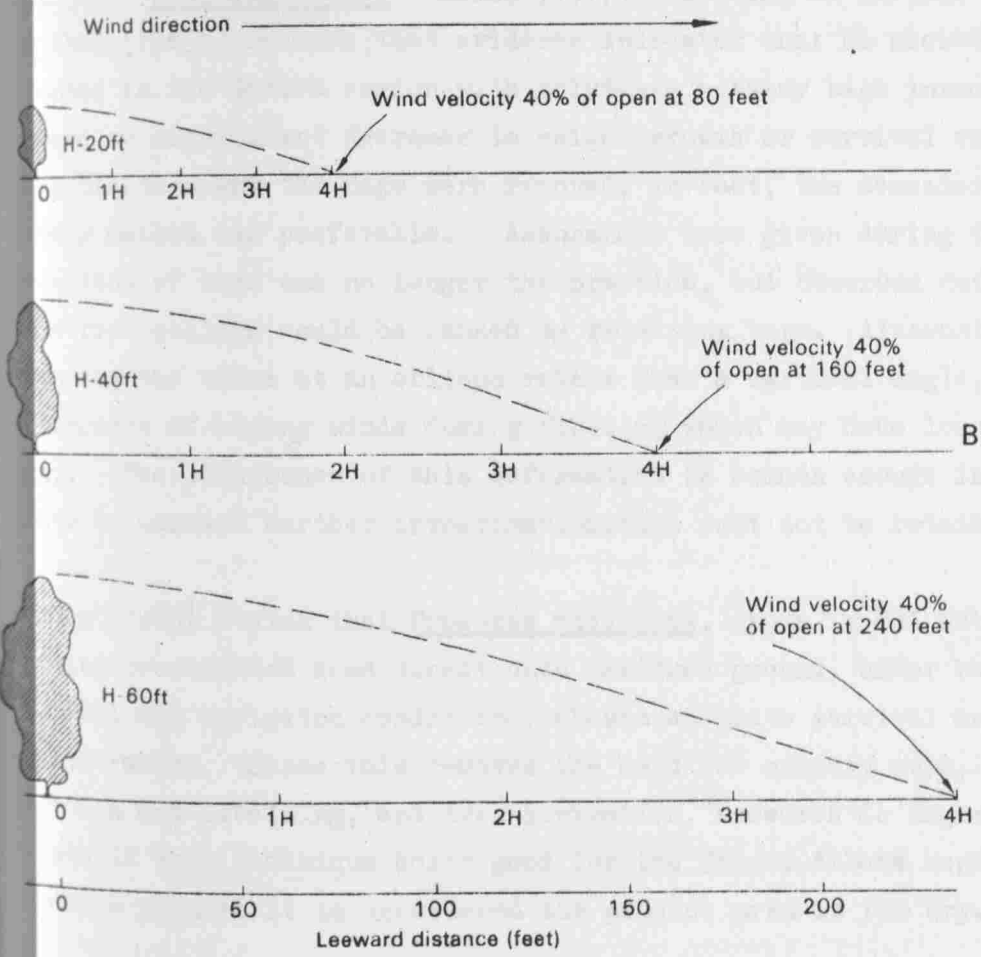
4.4.5.1 Choice of species and provenances Research is urgently required on the use of other species. Table 7 below lists the seed materials available in Ed Damar nursery for such trials. Eucalyptus microtheca in particular, known in Australia as Flood Box, grows well on the flooded clay soils of the Gezira, but the final production capacity on the coarse dry sands and gravels of Nile Province is unlikely to be so high: two provenances of E.camaldulensis, now under trial in Goz el Halag Forest Reserve, 'Petworth and 'Catherine', should be evaluated for growth rates as soon as possible. Observations of past trials plots (Bosshard, 1966) should be considered, and the work extended.

It can be seen from Appendix 4 that pure blocks of Prosopis chilensis have been planted in past years, and enquiries indicated this practice is to be continued. It seems desirable however that Prosopis or Tamarix might be restricted to an initial screen for 2-3 rows to windward of the belt to trap the heavier wind-borne sand particles.

Inside this screen the species selected should be capable of greater height growth than Prosopis, since the object of these belts is to protect farm crops not only from sand deposition but also from the dessicating effect of drying winds. It is nowadays accepted that the effective shelter provided by the shelterbelts is in proportion to their height, rather than width or density (see Figure 2). The maximum height that can be expected for Prosopis chilensis is only some 8 metres (6-year old belts at Zeidab are now 6 metres high). Thus if an acceptable aim is to reduce wind speed by, say, 30% of the velocity in the open desert a normal shelterbelt 8 metres high can only protect an area 30 times this height i.e. 240 metres (see Figure 2), which is not cover enough to protect the full width of most agricultural settlement schemes.



A: Zones of reduced wind velocity as percentage of open wind (at 0.2H above surface) to leeward of different widths and cross-sectional shaped artificial barriers in wind tunnel. Scale of models exaggerated (after Caborn, 1957).



B: Leeward distance of wind protection is proportional to height of barrier (after Read, 1964).

FIGURE 2 Reduction of wind speeds by differing shelterbelt designs (after C P Bhimaya, 1976)

Prepared by Land Resources Development Centre 1979.

Ahmed (1977) quotes Khan's (1977a) Stand Tables indicating that E. microtheca may be expected to reach a mean dominant height of 17 m in 10 years on the Gezira cracked clay soils. This growth may not be achieved on the sandy soils of the Nile Province, and although Aliab shelterbelt has produced an average top height of 6 m in 4 years (equivalent to Khan's Quality Class 11 growth for Gezira, forecast to reach 11.8 m at age 10) it is still advisable to try other species capable of better height growth.

4.4.5.2 Width of belt The optimum width of belt for maximum reduction of wind velocity is equal to the expected top height. Wider belts have less effect on wind speed (see Figure 2). This would mean an optimum belt width of 25 m is desirable; however, projected future belts are designed to be 50 m wide to provide fuelwood. It will be necessary to consider the balance of fuel supplies against projected increases in agricultural crops (and decreased water use). It may prove better to plant fuelwood production blocks at intervals along a shelterbelt of 25 m width.

4.4.5.3 Planting method Ahmed (1977) reporting on earlier experiments by Khan (1965b) records that evidence indicated that E. microtheca, when planted in the Gezira region with polythene nursery bags intact, subsequently showed no significant decrease in height growth or survival rates compared with plants where the bags were removed; in fact, the considered that the former method was preferable. Assurances were given during this visit that retention of bags was no longer the practice, but observed deformation of some root collars could be caused by retaining bags. Alternative causes are planting the trees at an oblique rather than a vertical angle, or by the occurrence of strong winds during flooding which may have loosened the root grip. The occurrence of this deformation is common enough in Keli and Saiyal belts to warrant further investigation, bags must not be retained generally.

Wunder (1966) states that Prosopis chilensis, grown in FRI Soba by broadcasting pre-treated seed direct onto unridged ground, under both natural rainfall and irrigated conditions, showed adequate survival and subsequent growth rates. Since this removes the need for nursery work, ground preparation and levelling, and even irrigation, research is urgently needed to see if this technique holds good for the Shendi-Atbara region. Prior to research results it is considered the project area is too dry.

In order to ensure better establishment, shelterbelts should be established as early as possible, during the season when rain may be expected, and when nursery plants are small. This may seem an obvious observation, but only Zeidab and Aliab belts were recorded as planted between June and August, most others being planted in January and February each year (see Appendix 4).

4.4.5.4 Species trials FRI Soba has received Prosopis spicigera seed ex-Jodphpur (India). Seed stocks held in Ed Damer nursery are listed in Table 7. Trials of these should be made in the Atbara area, also P. spicigera.

TABLE 7 Seed stocks, Ed Damer nursery, as at 11 September 1978

Species	Source	Stocks held
Atriplex nummularia	Darling River, Australia	100 g
" "	not recorded	50 kg
A. hemmibaccata	" "	3 kg
A. latunus	" "	5 kg
A viscaria	" "	20 kg
A. leucoclada	" "	20 kg
A. rhagodiodes	" "	20 kg
A. lentiformis	" "	5 kg
A. undulata	" "	20 kg
A. bunburyana	" "	20 kg
Conocarpus lancifolia	" "	10 kg
Simmondsia chinensis	" "	0.9 kg
Casuarina equisetifolia	France	10 kg
Ephedra nevadensis	USA	220 kg
Cruis loires	not recorded	5 kg
Acacia peuce	N.Birdsville, Queensland	500 g
A. melanoxylon	New South Wales	14 000 seed
Eucalyptus salubris	"	100 g
E. salmonophloia	S. Coolgardie, W. Australia	100 g
E. microtheca	N. Coonamble, N.S.W	100 g
E. angulosa	Wellington, N.S.W.	100 g
E. astringens	Narrogi, Australia	100 g

4.4.6 Irrigation of plantations

4.4.6.1 Quantity of water required It has been stated (Bayoumi, 1976) that a feddan of plantation should have 400 m^3 of water released onto it at each monthly inundation (equal to 45 mm of rain), at a present unit cost of LS 44 per feddan per flooding. This contrasts with 450 m^3 per fortnight for vegetable crops. No tests have been carried out to determine whether this exact amount is applied to plantations, and although the Minister has given agreement in writing to supply sufficient water for plantations, it may not have proved possible to provide this quantity at peak demand periods, since agriculture must have priority on available water.

Drought stress and deaths, particularly in the large Eucalyptus plots in Wad Banaqa and Keli, were observed as was uneven water distribution. The best tree growth is invariably nearest to the canals (see Plates 8 and 9), even though they are normally dry for most of the year. Weakest growth is in the centre of blocks, as might be expected, since areas farthest away from the water source remain inundated for the shortest period. Tests made on the visit to Saiyal Belt showed damp soil at 2" beneath the surface alongside the secondary dry canal (Abu Ishrin) and damp soil 6" below the surface alongside the tertiary canal (Abu Seta), but no water was found 18" alongside the smallest feeder canal in the centre of the belt. It would appear that insufficient water is being applied.

4.4.6.2 Frequency of supply The amount of water released at each flooding is not as critical as the frequency of inundation, since frequency shows a significant linear correlation with annual height growth.

Project management has laid down that standard procedure requiring Eucalyptus and Prosopis should be irrigated twice a month for the first 3 months; and thence monthly for Eucalyptus until age 10 (or when the plantation is felled), and for Prosopis for the first 3-4 years only, depending on crop development. Trials may prove Prosopis does not require as much as this. No frequency experiments have been recorded from the Nile Province, but the Hamdanalla irrigation experiments (Khan, 1965) in Gezira Province (started in 1963) tested variations in Eucalyptus microtheca growth rates for various irrigation schedules.

The irrigation frequency was varied from nine waterings per year 3 600 m^3, equal to 400 mm of rain per year) to 17 waterings per year 6 800 m^3, or 765 mm of rain) in an area where the average rainfall was 450 mm. The results indicated that for optimum growth, increment watering should be not less than 12 times a year (4 800 m^3, or 540 mm of rain) and overwatering is more deleterious than underwatering. Thus combined irrigation and natural rainfall amounted to about 990 mm of rain a year.

There is an added advantage in the Gezira Scheme in that the control of water is administered by the Project Managers of the Social Development Department of the Sudan Gezira Board (SGB). Since forest staff serve under this same department of the SGB, the correct amount of water can more readily be obtained. The Project Managers of the Nile Province settlement schemes are not so involved with their shelterbelt project. (See Part 4, Section 4.4.1, last paragraph).

In the Shendi-Atbara region (where annual rainfall has not exceeded 60 mm over the last 4 years - see Appendix 1) this would be equivalent to 20 waterings a year, virtually twice a month except during the rains. It is doubtful whether there is that much water to be spared from agricultural crop requirements, and research on trickle irrigation is obviously indicated, in particular with buried pipelines.

4.4.6.3 Trickle irrigation The major disadvantages of trickle irrigation are the high initial cost and problems of maintenance by unskilled labour. However, these problems can be largely overcome by choice of equipment, and the following advantages can be expected:

1. Considerably less water is needed, since it all reaches the roots of the plants, and water of a higher salinity may be used (Willens, 1974)

2. A better root system develops. The expected deep rooting reaches down to ground water at an earlier stage, and the equipment can be moved on

3. The need for major earth moving, canal construction and servicing is removed. The local farmers, who appear to resent the use of land with farm potential for shelterbelts, will have less cause to complain, since they cannot use trickle irrigation systems for present crop patterns.

4. If private wells are constructed to feed a low pressure gravity system using a 9–12 m head, flow can be better controlled, less water is used, the true cost of water is decreased, and farmers will not resent any loss of water from their crops

5. Fertiliser or boron can be added simply to the flow of water

Capital cost of field equipment should be under £740/ha, excluding costs of pump or windmill, water tank and mains pipe to the trial area (since a local well could probably be used). With the expected early development of a deep tree rooting system, it is possible that the irrigation, even of Eucalyptus, could stop at mid-rotation (5 years). If a buried pipe system were to be used, the equipment could then be moved, after renovation, to a second area before needing replacement. This would give £74/ha per year costs, as compared with conventional ground levelling and canal construction costing some £370/ha, plus annual operation and maintenance costs.

By the use of erect drip heads, the encrusting of salts at the tip, which can plug the hole completely, can largely be avoided. It is this problem which requires the critical maintenance, and an underground emitter may be required to decrease this risk of this occurring.

On expert advice, an experimental system should be planned and, if considered viable, installed over a trial area, and the benefits of the system measured.

4.4.7 Maintenance of established plantations

The estimated cost of beating up failed areas is based on an average figure, 10% of the previous year's crop requiring replacement. Whilst this is a very generalised assumption, since so much depends on adequate irrigation, it will suffice for purposes of budget estimation. Weed growth, mostly grasses, appears to be scarce on all belts despite flood irrigation, and the work can normally be handled by the watchman alone.

Fence maintenance is considered inadequate, and the retention of collapsed fences wasteful of materials (see Section 4.4.3). They should be removed and rebuilt elsewhere once the need to keeping animals outside new or coppiced young plantations has finished.

4.4.8 Analysis of research requirements (see Table 8)

TABLE 8 Analysis of research requirements (Section 4.4.8)

Problem	Proposed area	Research needed, and agency (funds permitting)
A. Silviculture 1. No formal experimentation with the many species of seed available at Ed Damer has been carried out to test for a better species than Prosopis chilensis and Eucalyptus spp	Over a range of soil types, but close to F O Shendi and F R Research (see B.1 below)	The layout of field trials for the available seed supplies, and development of nursery techniques, should be carried out by F R I Soba, or an expatriate arid-zone silviculturalist. The trials should be installed by Project staff
2. No experiments on belt widths have been made in Nile Province to determine the permeability and sand deposition of various widths	Existing belts of various widths (4 areas)	In selected areas, measurement (with permanent markers) of sand deposition should be regularly recorded. The areas should be selected on the advice of F R I Soba (or the arid-zone silviculturalist). A series of wind anemometer readings should be made (both to windward and leeward) in these areas on a regular basis to test permeability (see also A.3 below). The belt watchman could probably be trained to make the readings and record them
3. No comparison of the growth rates, vitality (resistence to drought stress) and efficiency as a windbreak have been made at the various spacing densities used in plantations in Nile Province	Existing belts of various spacing density	In carefully selected areas, comparison of growth rates and vitality (leaf cover or branching %) should be made, bearing in mind soil conditions and water availability. Permeability to wind should also be regularly measured by wind anemometer as in A.2 above
4. Nursery costs are high, but no tests have been made in Nile Province on the possibility of direct sowing techniques (other than for Acacia species in Banaqa). This technique has been proved for Prosopis chilensis in Khartoum District however (see F R I Soba Pamphlet 16)	Nursery extension areas initially followed by field tests in Government owned land near Shendi and Ed Damer(e g Keli nursery)	Field trials of direct sowing of Prosopis (initially) in irrigated and unirrigated areas should be designed by F R I Soba, and installed by Project staff. The advice of an expatriate arid-zone silviculturalist with a knowledge of Eucalyptus species should also be sought

Problem	Proposed area	Research needed, and agency
5. Belts have been planted close to canals and farms with the object of controlling sand carried from a great distance. However, villages of many established freehold farms were installed outside cultivated areas in the desert, fully exposed to wind. Sand has built up around these houses and from there blows into the cultivated areas. No research has been attempted in Nile Province to stabilise these dunes (but see work at El Bashira Gezira)	Gandato and Keli belts	The experimental design of methods to stabilise dunes with crop residues (stalks of sorghum and cotton, bamboo) used as 1 m high fences (see FAO Conservation Guide Bostanoglu 1976). Advice should be sought from F R I Soba, and an arid zone silvicultural specialist on the use of Tamarix spp, and other species, beside woven fences of Ipomea
6. Farmers in the agricultural schemes are said to resent the use of shelterbelts because of the water they divert from their own use, and the believed reduction in their crop yields despite the usual intervention of a major canal between agricultural and tree crops which prevents trees rooting across into farmland. No attempts have been made in Nile Province to measure the effect of trees and crops grown together to determine the truth or otherwise of this belief	Any land owned by cooperative farmers	Small experimental blocks of trees as part of the project extension programme, should be planted in farm areas by the farmers for their eventual use. A system of 'taungya' could be applied by the Forest Ranger (Research), Ed Damar
B. Soils 1. A desk study is needed to produce a detailed soils map of existing and proposed belts on which to base species trials for new plantations, and the beating up of failed areas in existing plantations (See A.1 above)	All present and future planting areas	Where existing soil sampling is deficient, a representative series of soil samples at surface and suitable depths (as decided by the relevant Government soil survey section*) should be collected by project staff, and analysed (in particular a mechanical analysis) by the Ministry of Industry and Mining's Geological Laboratories

* All use should be made of any soil surveys made in this area by the projected ODM consultancy project

TABLE 8 cont.

Problem	Proposed area	Research needed, and agency
2. Eucalyptus are noted for a susceptibility to boron deficiency. No tests have been carried out in the Nile Province on this possibility	All present and future plantations (due for soil survey)	Analysis of soil samples, and field trials should be made in nurseries and existing plantations by the addition of boron to plants, with suitable control areas
C. Irrigation 1. Experimental records and analysis of any variations in the amount of water applied to existing plantations (both in quantity and frequency) are not available for Nile Province. It is therefore not possible to make decisions for the more economic use of scarce water supplies.	Selected Shelterbelts near F O Shendi and F R (Research) Ed Damer	A series of careful water input/tree height and root growth studies, with controls , in existing irrigated shelterbelts should be undertaken by project staff to investigate optimum water needs of the various tree species. Advice is needed on the design of these studies, possibly from an Irrigation Engineering Consultant
2. In all areas water is at a premium, but no evidence exists on the use of t trickle-irrigation. The competition for water with local farmers is a cause of resentment leading to delays in acquiring and planting land for shelterbelts, and in their further protection. (e.g Zeidab)	Nursery extension areas, followed by selected field areas close to maximum supervision and guarding	In areas of proposed shelterbelts not yet prepared for flood-irrigation the design of a trickle-irrigation system, using hand-dug wells and windmills where and if necessary, should be planned, costed (and if viable, installed) on the advice of a specialist consultant N B A complete trickle-irrigation set of equipment belonging to the project is believed to be a present mislaid in Port Sudan

4.5 PROPOSED ASSISTANCE

The current CFA - SCC project is designed to complete the establishment of shelterbelts for the major irrigated agricultural settlement from Shendi to Berber by financial year 1982. With the agreed financial assistance for this project from the Aid donors* supporting the Sudan Council of Churches these appears to be no need for any major British financial input in the establishment of shelterbelts. Further, with the impending joint UNDP - CFA project at present awaiting the necessary funding, the subsequent maintenance of these belts after 1981 should also be financially assured. Most technical skills, administrative ability and research facilities are already available in the Sudan, where both the calibre and potential of the forestry staff are high. More over, the day-to-day constraints on progress, such as the national shortage of funds, petrol, spare parts for vehicles and minor items of equipment are country-wide problems which the long-term secondment of a British Technical Officer could do little to resolve. It is therefore considered that the full-time assistance of technical staff from UK is not required.

The present aid donors do not finance research, since this is a long-term item with an uncertain end point, and some assistance could be offered in this respect. The major aspects requiring investigation may be listed as:

1. The tree species giving the optimum advantage as a shelterbelt

2. The optimum planting distance and shelterbelt length and width for the most efficient protection

3. The degree of wind reduction and sand deposition on protected agricultural crops, especially the distance protection extends

4. The affect of shelterbelts, if any, on crop yields and maturing times, of all agricultural crops grown in the area

5. The affect of shelterbelts on soil evaporation and evapo-transpiration, including soil moisture studies and water needs.

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* Swedish Free Mission, representing the Swedish Free Church and Social Aid Foundation. Swedish Medical Mission. Protestant Central Agency(EZE) West Germany. Christian Aid UK

4.5.1 Consultancies

Two problems require an early opinion from expert consultants, namely that of an arid-zone Silviculturalist, and an Irrigation Engineer with practical knowledge of trickle irrigation, especially underground systems.

1. Silviculturalist As explained in Section 4.4.3, the basic philosophy behind the present choice of species for shelterbelts, and the establishment techniques, requires further thought. A specialist consultant on the use of Eucalyptus spp., etc could supply this during a visit of some 2-3 weeks.

2. Irrigation Engineer As explained in Section 4.4.5, the use of flood irrigation for the shelterbelts is both wasteful of water, (probably the major limiting factor), expensive and a source of contention between farmers and foresters. The design, costings and installation of an experimental windmill and trickle irrigation system over an area close to adequate supervision could best be carried out by a consultant. An impending project, partially intended to cover this area, over the next 9 months by Sir M Macdonald and Partner's consortium could well supply the necessary expertise if a separate sub-contract could be drawn up. An initial visit of 1-2 weeks should suffice to design the system, and a further 3-4 weeks to oversee the installation and test it.

4.5.2 Financial assistance

Funds are required for the following equipment and services.

1. Spare parts for existing Landrover fleet (See Appendix 8)

Quantity	Description	Cost per unit £	Total cost £
10	Oil filters	2.00	20.00
8	Fan belts	1.20	9.60
2	Alternator	28.60	57.20
2	Water pump kits	13.50	27.00

Quantity	Description	Cost per unit £	Total cost £
16	Sparking plugs	0.63	10.08
4	Sets of points	0.22	0.87
4	Clutch overhaul kits	1.64	6.56
2	Brake master cylinder overhaul kit	3.73	7.46
4	Brake slave kits	5.00	20.00
8	Rear shock absorbers	15.50	124.00
8	Front shock absorbers	15.50	124.00
4	Hot patch clamps)	16.00	64.00
8	Tins hot patches)		
4	Solenoids	3.79	15.16
4	Condensers	8.40	33.60
3	Distributors	21.97	65.91
3	Axle bearings	24.00	72.00
4	Set wheel bearings, front 217270	20.00	80.00
4	Set wheel bearings, rear 217270	20.00	80.00
4	Rear half shafts	24.30	97.70
4	Steel towrope	12.00	48.00
8	Inner tubes for tyres	3.00	24.00
8	New tyres. Michelin 750 x 16 8 ply	15.00	120.00
8	Radiator hoses (4 top -4 bottom)	12.00	96.00
2	Starter motors	31.25	62.50
4	Clutch slave cylinder kit	1.63	6.52
4	Clutch release bearing and sleeve	9.70	38.80
4	Fuel pump kit	2.07	8.28
4	Solenoid switch	3.75	15.00
6	Springs (clutch and handbrake return)	5.00	30.00
6	Circlips (radiator hose size)		
8	U bolts/plates (front and rear road springs)	1.40	11.20
8	Spring shackle bolts	0.62	4.96
			1 380.00

2. The provision of a suitable windmill and trickle irrigation system to cover some 0.5 ha of trial plantation. It is understood that a complete set of Drip-irrigation equipment

manufactured by J A Gordon and Son Ltd of Stonehouse Gloucester, has been purchased by the Project but has been mislaid since early 1978 in Port Sudan docks. The price was £2 981 CIF Khartoum. If this equipment comes to light it could be installed by the proposed consultant Engineer (see 1 above). If it is not recovered by the time the consultant visits the project, a suitable set of equipment should be installed on the consultant's advice. In view of the probable deposit of salts, caused by evaporation at the nozzle or emitter if carried above ground, an underground system should be considered. The "Flapper Emitter", produced by the Irrigation and Industrial Development Corporation of 260 Madison Avenue, New York is of the type of equipment considered suitable. The cost would be in the region of £3 000, but there is a wide choice of systems and costs.

3. Air photography at 1:20 000 scale over a strip from Wad Banaqa north to El Hassa, some 120 miles, for a 10 mile wide strip, an area of 1 200 mi^2, would cost in the region of £20/mi^2 or £24 000

4. The supply of relevant FAO and ODM publications, some £40, as listed below, three copies each should be supplied:

FAO (1976) Conservation in arid and semi-arid zones. FAO Conservation Guide No.3 Rome.

FAO (1974) Heathland and Sand dune afforestation FAO/DANIDA Inter-Regional Training Centre on Heathland and Sand dune afforestation. Rome.

WMO (1964) Windbreaks and shelterbelts. Technical Note No. 59, World Meteorological organisation No. 147. Geneva.

Caborn J M (1957) Forestry Comm. Bulletin No. 29. Shelterbelt and Microclimate. Edinburgh Stationary office.

FAO (1970) Guideline for the preparation of feasibility studies for irrigation and drainage projects. FAO/IBRD Rome.

FAO (1967) Outline for projects to be presented for financing.

Kaul R N (1970) Afforestation in arid zones. Dr W Junk N V Publishers, the Hague.

Beskok T E (1971) Forestry problems of the Yemen Arab Republic and possibilities for afforestation. AGS: SF/YEM 9. FAO Rome.

FAO (1970) Training and demonstration in afforestation and forest management, Jordan. FAO/SF 89. Jor 6. Rome.

5. The provision of 10 000 m (55 rolls x 200 m) of light guage barbed wire @ £12.84 = £706.00.

4.5.3 Budget (costs based on December 1978 prices)

1. Offshore costs (£ sterling)

	Unit	Rate £	Estimated totals £
a. Staff (including travel and allowances)	man/months		
Arid zone Silviculturalist	1	2 000	2 500*
Irrigation Engineer	1.5	2 575	4 000
b. Local transport			
Use of consultant's vehicle	1	300	300
c. Air photography plus 2 prints over area 120 mi x 10 mi	1 200 mi^2	20	24 000
d. Equipment			
Landrover spares (see list at 4.5.2)			1 380
Portable windmill	1		1 000
Trickle irrigation set for 0.5 ha			3 000
Casella cup-type anemometers	6	125	750
Soil thermometers	12	15	180
Miscellaneous, soil augers etc			150
Barbed wire, plus transport	55	12.72	700
Technical literature			40
			38 000

* Return fare UK to Khartoum = £493 sterling

2. Sudanese support costs (LS)

	Unit	Rate £	Estimated totals £
a. Staff			
Counterpart Forest Graduate	2	150	300
Labour to instal irrigation system			
Forest Overseer	1	45	45
Permanent labour	3	25	75
Casual labour	6	20	120
b. Transport			
Landrover driver (2 months)	1	48	96
Petrol and oil, gallons	80	0.55	45
Maintenance			20
			LS 701
			= £700

4.6 JUSTIFICATION FOR PROJECT ASSISTANCE

4.6.1 Advantages of shelterbelts

A full justification for the use of windbreaks has been presented by the present Director of Forests (Bayoumi, 1976, 1977). It is considered sufficient here to summarise some widely quoted advantages, since these are universally accepted as outweighing the disadvantages, viz: shading of crops, shelter-tree competition for land (up to 8% of the area) and available irrigation water, soil overheating during hottest weather, and loss of soil fertility in the fields by sand deposition due to drop in wind speed (but see Section 4.6.1.3 last paragraph).

4.6.1.1 Reduction of actual evapotranspiration*

The amount of evaporation depends on soil factors, crop root system, humidity, wind speed, soil and air temperature and radiant energy. Given nearly uniform temperature, soil and humidity for any one crop the speed of wind is the most important factor (see Figure 2).

1. For a horizontal distance of 10–15 times the height of a properly designed shelterbelt, the air temperature can be reduced by 1–3° C, evaporation by 8–40% and wind speed by 15–25%. Soil temperatures are increased by 0.2–1° C and air humidity by 2–4%

2. In Nebraska, USA, it has been found that alfalfa and legumes require one less irrigation a year when sheltered

3. In the Gezira, Sudan, irrigation requirements for cotton were considered to be reduced as follows:

Reduction of wind speed	Reduction of irrigation requirements
50%	24%
40%	19%
20%	11%

The increased yield from existing cotton plantations from this saving of water was calculated as equivalent to the production from a further 80 000 feddan of cotton plantations

4.6.1.2 Increased crop production Decreasing wind speeds decrease dessication and tearing of leaves; stomata can therefore remain open longer, with increased CO_2 assimilation and hence growth.

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* Evapotranspiration (ET) is the evaporation from soil and water surfaces plus the transpiration from plant cover.
Potential ET is water consumption by a uniform, dense actively-growing crop with ample water supply.

1. Studies in the Soviet Central Asian Research Institute Uzbekistan showed that protected cotton fields had earlier germination (3-4 days) and a better germination percent. The height of cotton plants was greater by 10-15%. The number of flowers per cotton plant was 2-3 times greater, cotton bolls per cluster was 10-12% higher. Crop yield was 10-30% higher. The UAR Delta region cotton yields under shelter were 35.6% higher than in the open. In Texas, cotton yields were up 17% within 5 x shelterbelt height, and 8% between 5 and 10 times the height

2. Cereal yields in the UAR, grown in protected areas, showed increases of 38% for wheat, Nile maize 13%. Summer maize 74% and rice 10%. In Nebraska, maize yields amounted to 19% crop increases within distances 2-10 times the height of the shelterbelt

3. Fruit crops under shelter.showed increased yields and fruit quality. Bud formation and blossoming were increased, pollination by insects was improved, bruising and scarring of fruit reduced, and much less fruit fell to the ground. Citrus yields in sheltered Californian orchards showed a 29% yield increase compared to open fields.

4. Livestock production is greatly increased. Not only are the yields of pasture and forage higher (alfalfa yields in North Dakota increased by 60-70%, grass and clover in Denmark by 22%) but they have a more nutritive value, and cultivation and fertiliser treatments are more effective. In Russia, the protection of sheep flocks from strong winds and heat by shelterbelts increased lambing rates by 30%, wool production by 20%, and a 30% increase in weight gain per head at slaughter. Livestock in Nile Province obtain much food from Prosopis pods produced in shelterbelts (see Plate 3)

4.6.1.3 Improvements in social conditions Wind erosion by soil movement is most common in areas with a pronounced annual dry season. Given favourable conditions, winds of Beaufort Scale 4 (10 mph) can lead to the erosion of sand particles. Apart from the obvious effect of loss of cropland under migrating sand, it is difficult to quantify the discomfort

and health hazards of living and farming in desert conditions. It can be fairly said that once in possession of their farm, either as owner or tenant, the Sudanese farmer will not leave his farm except in very extreme conditions of persistent crop failure due to erosion (see Plates 4 and 5).

However, it can be assumed that the more exposed to erosion, the less the productivity of farmland. The lower the productivity, the smaller the population that can be supported by these degraded farms. This invariably leads to the migration of the elder sons to towns, where unemployment is common and a wasteful use of the national labour force. Where living conditions can be improved by the use of shelterbelts to abate the dust, heat, low crop productivity and fuel shortage, the human carrying capacity of the farmland can be greatly increased.

Wunder (1966) has calculated that 1.40 m of sand has been deposited within the Khartoum plantations in 25 years, filtered out from air-borne sand during sandstorms*. It is also recorded that this depth of deposit failed to kill the Prosopis plantations due to the species ability of secondary root formation. The sand deposits had a mean depth overall of 0.8 m. This is equivalent to 8 400 m^3 (some 160 tonnes) of sand per hectare over 25 years.

4.6.2 Type of assistance needed

The planting of shelterbelts, as in most development, can be considered to require three major inputs. Staff, finance, and technical knowledge. Staff, including supervisory staff and labour, appear to be adequate for the programme envisaged, and does not appear to be in short supply. Sufficient finance, whilst limited, is available through the Sudan Council of Churches funds from Swedish and other church organisations. However the Church agencies cannot finance research to discover optimum techniques. Indeed, this shou ld not normally be a call upon charitable organisations. For this reason, proposed British assistance (see Section 4.5 and Part 2) is restricted to research problems and minor equipment.

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* Which would otherwise be deposited on farmland, thus reducing its fertility

Some consideration was given to the possible provision of a timber treatment plant to increase the working life of house timbers after they have been cut. It was considered, however, that due to the scattered nature of the local sources, any centralised treatment plant would be underutilised. It was further considered that sufficient facilities for treatment are already available in the southern provinces to treat any timber sent down to Nile Province by railway etc.

4.6.3 Terms of Reference for consultants

Irrigation Engineer

1. Design and cost out two trickle irrigation systems, to utilise both hand dug wells with windmill power and existing water supplies, in an area of one acre located close to adequate supervision (eg Seiyal belt).

2. Submit a report to ODM on the economic viability of the recommended system, with details of the commercial equipment advised.

3. If trials are agreed upon, supervise the installation of the recommended equipment, as supplied by ODM, using project labour. Introduce soil moistrue measurement trials with controls.

4. Advise on the design of a series of water input/height and root development studies, with controls, in existing irrigated Shelterbelts to investigate optimum water needs of the various tree species.

5. Design wind speed measurement and sand deposition trials in the lee of existing Shelterbelts.

Arid-zone Silviculturalist

1. Discus with CFA-SCC Joint Project Management the exact aims of the Shelterbelts (protection and/or fuel and fodder supplies) and decide what species, spacing and belt dimensions will supply the optimum advantages.

2. Design representative growth trials plots in existing Shelterbelts.

3. Design the layout of field trials of introduced species for which seed is available, and advise on further species trials of any suggested introductions.

4. In July supervise direct-sowing trials of Prosopis seed or other advised species, close to Shendi and Atbara HQ's for maximum supervision by management.

5. Advise on installation of dune stabilisation pallisade trials using local vegetation (Ipomea trichoma, Capparis decidua and Calotropis-procera).

PART 5 FORESTRY IN NILE PROVINCE

5.1 FUNCTIONS OF NILE PROVINCIAL FOREST SERVICE*

Since 1971, when the Local Peoples Government Act gave Provinces the authority, this service has been directly controlled by the Assistant Commissioner of Forestry Affairs (ACFA), Nile Province (currently Syed Gamri Ata). The ACFA represents the Forest Department as a member of the Executive Council of the Province. As such he is responsible for the supervision of provincial forest administration and technical activities.

Administration involves the organisation and liaison of Departmental activities with other provincial Government departments and corporations, particularly in the supply of forest produce to Railways and Telecommunications etc. Since 1974 the ACFA was authorised to produce an annual budget, and monthly and annual reports on forest activities. The control of the budget consists not only of the careful supervision of approved expenditure, but also the collection of revenue, from both royalty and the sale of forest produce produced departmentally. Technical control of the forests under provincial charge includes supervising nursery work, the survey, protection and utilisation of provincial forest reserves, and their afforestation.

Development is still the responsibility of the Central Forest Administration, thus planning, training, staff secondment and the National Development Plan execution are undertaken by the CFA Planning Unit.

One major duty is the need to explain to the community the beneficial role of forests, as well as to ensure the production of the necessary forest produce, and protect the communities rights and privileges. The ACFA is authorised to detect and detain offenders against the Forest Law, and prosecute the necessary court cases. Authorisation to set up a Board of Discipline for staff and to appoint forest labourers is also accorded.

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* See Appendix 2

5.2 FOREST RESERVATION

There are 58 named forest reserves in Nile Province, covering 85 310 feddan (see Table 9 and Appendix 7). Only a few detailed plans were available, but some 27 reserves lie between Wad Banaqa and Berber along the Nile: the remainder (31) border the Atbara River. With two exceptions, the vegetation of these reserves consists of natural Acacia tortilis forest, with some Dom palm (Hyphaene thedbaica).

Of these existing Acacia tortilis areas, the areas given in Table 9 below are reserved or under reservation as forest production areas. See also Appendix 7.

TABLE 9 Progress in forest reservation, Nile Province

Reserve	Feddan	No. of reserve
1. Central Forest Reserves		
Gazetted	8 257	(8)
Under action to gazette	71 741	(46)
Proposed	-	(0)
Sub-total	79 998	(54)
2. Provincial Forest Reserves		
Gazetted	-	(0)
Under action to gazette	1 632	(2)
Proposed	3 680	(2)
Sub-total	5 312	(4)
Total	85 310	(58)

Only two of the gazetted forest reserves, Wad Banaqa and Goz el Halag, have received any silvicultural treatment (felling and reforestation). Wad Banaqa (492 feddan) has had 45 feddan felled and replanted with Eucalyptus microtheca as described in Appendix 4. In Goz el Halag (not visited during the mission) 104 feddan have been felled and replanted. All planted blocks are irrigated by pumps from the Atbara River, but only the central block receives water from a constant source; the supply for the rest dries out seasonally.

TABLE 10 Planted areas, Goz el Halag Central Forest Reserve

Planting year	Area, feddan	Species	Area and development
1972	7	Conocarpus lancifolia	East block *
1972	20	E. microtheca	"
1972	20	E. tereticornis	"
1972	7	Conocarpus lancifolia	West block *
1972	23	E. microtheca	"
1974-6	27	E. camaldulensis **	Central block +
	104		

* Drought stress appears to have restricted growth

\+ The 1974 plantation averages 12 m height, with a d.b.h. of 13 cm. Water is more readily available

** Two provenances of E. camaldulensis were used here, 'Petworth' and 'Catherine', both ex-Nigeria, these were the most promising out of 90 species and provenances tried. No research measurement plots have yet been installed

The soils over Goz el Halag are loosely formed, probably alluvial, soils with loamy to fine textures. In lower-lying areas, topsoil can be swelling clays which crack during the dry season. Saline or alkaline horizons appear to be absent (Macdonald Sir M and Partners, 1964). The soils thus approximate more to the Gezira cracking clays than the majority of sites in the project area, which may help to explain the better growth rate of Eucalyptus in this reserve.

The previous vegetation on these plantations was mostly Dom palm.

5.3 PRODUCTION AND REQUIREMENTS FOR FOREST PRODUCE

5.3.1 Production of forest produce

The Provincial Forest Service is responsible for felling and processing building poles, fuel and charcoal for sale to the local community. Much of the produce is cut in Forest Reserves carrying Acacia tortilis forest as

part of the process of thinning or clearing for plantations. Permits are also issued to private individuals to collect forest produce. Full records of produce gathered under permit are no longer kept, but estimates deduced from the files, indicating the approximate trend of production, are given in Table 11 below.

TABLE 11 Forest produce gathered, 1974*-1978

Year	Department sales					Permit sales (firewood only) m^3/	Total production				
	Firewood m^3	Charcoal sacks	Poles//				Firewood m^3	Charcoal sacks	Poles		
			1	2	3				1	2	3
1974-5	42**	51**	-	-	-	19 172	19 214	51	-	-	-
1975-6	24	-	-	21	-	13 793	13 817	-	-	21	-
1976-7	436	342	18	-	-	23 288	23 724	342	18	-	-
1977-8	38	99	15	100	50	26 509	26 547	99	15	100	50
						Annual averages	20 825	123	33	121	50

* When Nile Province was separated from Northern Province (1974)
/ Deduced from royalty figures in Nile Province Annual Reports, 1974-8
** Cut from Central Forest Reserve Goz el Halag
// 1 = Eucalyptus, 2 = Dom palm, and 3 others, numbers of poles are quoted

5.3.2 Yields of natural Acacia tortilis forest

True yields are difficult to estimate since few records are available for the Nile Province specifically, and are not common from other areas. Foggie (1967) has estimated the mean annual increment for Acacia tortilis as 0.2 m^3 per feddan per year on the clay of the Gezira region, irrigated by natural rainfall (average of 370 mm per year, ranging from 200-480 mm) and without seasonal floods. Sahni (1968) has estimated the annual yield to be 0.25 m^3 per feddan. Both estimates refer to natural forest felled on a 20 year rotation. The more sandy soil of the Nile Province can be considered markedly less fertile than the clays of Gezira region, even though the majority of the Nile Forest Reserves border on fair to good agricultural alluvial soils. Further the average annual rainfall in the Nile Province (100 mm) is approximately one third of that in Gezira.

At this stage in current knowledge the minimum figure, as used by Foggie (FAO 1967), will be employed and in theory the Forest Reserves in Nile Province could produce a yield of 17 000 m^3 a year (85 310 feddan x 0.2 m^3), mostly as fuel.

5.3.3 Yields of irrigated Eucalyptus plantations

Present yield records in the Nile Province are insufficient to allow any true estimates to be made. The oldest plantation crop of Eucalyptus (the Aliab deflect ion belt, 2.5 feddan of Eucalyptus tereticornis planted in 1941) is the only plantation to be felled in Nile Province to date. The reported yield (1970) was 200 m^3 of fuelwood (but no poles) over the 20 year period. This gives an approximate final stocking of 80 m^3 per feddan of fuelwood, and an average annual increment of 2.75 m^3/feddan. The stumps were uprooted for fuel so no measurement of coppice yield can be obtained.

Some indication of maximum possible production can be obtained from the figures for Gezira plantations; again, it must be remembered that soil and water conditions are considerably better than can be expected in the Nile Province.

Foggie (1967), in estimating the returns from a theoretical Felling Series, gave the following figures for a plantation of Eucalyptus microtheca based on the conventional felling cycle of 8 years to first coppicing, followed by two x 6 year coppice cycles.

Example 1. High productivity with abundant water available until April and May taking cm estimated annual 7 200 m^3 of water per feddan

Felling cycle	Mean annual increment m^3/feddan/year	Total yields m^3/feddan
8 years (initial)	4.24	33.92
6 years (first coppice)	5.63	33.78
6 years (second coppice)	5.63	33.78
		101.48 Total yield

Example 2. Average productivity with average water supplies available until April and May, taking an estimated annual 4 800 m^3 of water per feddan

Felling cycle	Mean annual increment m^3/feddan/year	Total yields m^3/feddan
8 years (initial)	2.92	23.36
6 years (first coppice)	4.23	25.38
6 years (second coppice)	4.23	25.38
		74.12 m^3/feddan

Ahmad (1977), quoting Khan's yield and stand tables for irrigated plantations of E. microtheca in Gezira Region from both seedling and coppice origin, gives the following figures:

TABLE 12 Yield and stand table for Eucalyptus microtheca in Gezira Region

Origin	Mean annual increment, m^3/feddan			Total yield at year indicated m^3/feddan		
	QC I	QC I/II	QC III	QC I	QC II/III	QC III
Seedling origin (year 8)	9.75	5.63	2.70	77.98	45.00	21.56
Coppice origin (year 6)	6.24	3.37	1.32*	37.41	20.19	7.90*
* Given in tables as Quality Class (QC) II						

A conservative annual yield of 3 m^3/feddan from the Nile Province plantation has been taken, allowing for an average water supply of some 4 800 m^3 per feddan per year, in the calculations for produce requirements (section 5.3.4, last paragraph).

5.3.4 Requirements for forest produce

No specific figures are available for the Nile Province, and certain assumptions must be made to obtain any estimate of the local needs for produce. Even the population figures for Nile Province (estimated in Section 3.1.4 above) are too approximate to be valid to use in estimating volume requirements. Estimates have therefore been made (see Table 13 below) for the requirements of only those assisted agricultural settlement schemes

to be protected by the shelterbelt project. The population of these schemes (some 42 000 people) only represent some 20% of the approximate total population of 200 000 for the whole Nile Province.

The most recent and best documented estimates of forest produce requirements of the present (1981) rural populations is given by Foggie (1967), who calculated the needs for farmers and labourers in the Wad Medani rural areas using an average of the past estimates of Kipling, Jackson and Sahni, combined with a household budget survey conducted in 1963. The report estimated that by 1981 the rural areas would consume annually about 0.327 m^3 per caput of fuelwood (stacked in the round, using overbark measurement) and 0.486 m^3 stacked equivalent as charcoal. Thus an approximate figure of 0.8 m^3 stacked (OB) per caput per year will be used for fuel. Building pole needs, assuming each pole must be replaced every 2 years, were estimated as 0.046 m^3 per caput per year and will slowly decrease as more sawn wood becomes available. This is equivalent to one light rafter (rassa) measuring some 6 m x 7 cm diameter being needed per person every 2 years (or 2-3 rafters per household annually).

It is hard to conceive that a family of five can cook on a supply of 4 m^3 of fuelwood (about 5-6 camel loads) for a year, but in addition, it was observed, leaves and twigs are swept from the floor in Eucalyptus plantations for use as kindling, as are certain crop residues. However, cotton stalks, it is believed, must be burnt in situ to prevent the spread of disease, and sorghum residues are needed for cattle feed.

The River Nile probably supplies a steady source of fuel and poles to farmers, including even some sawn timber from crates which have fallen into the river by accident, but it is impossible to estimate any quantities. House poles, when not destroyed by termites, are also used for fuel at the end of their working life.

TABLE 13 Annual forest produce requirements in project area

Assisted agricultural scheme	No. of farmers	Total population (family averages 5)	Annual fuel requirements, m^3 (including charcoal)		Annual poles requirements in m^3	
			Per caput	Total	Per caput	Total
Zeidab	1 451	7 255	0.8	5 804	0.046	333.7
Keli	1 653	8 265	"	6 612	"	380.2
Saiyal	1 600	8 000	"	6 400	"	368.0
El Hassa	1 000	5 000	"	4 000	"	230.0
Kabushiya	1 500	7 500	"	6 000	"	345.0
Gandato	1 147	5 735	"	4 588	"	263.8
Totals	8 351	41 755		33 404		1 920.7

A comparison of the above table with Section 5.3.2 indicates that existing forest reserves of Acacia, worked to their estimated limit (17,000 m^3/year) can supply less than half the estimated fuel needs of the six government agricultural schemes alone, without considering the rest of the population of Nile Province. The balance of the fuel and pole requirements for these assisted schemes would require some 7 000 feddan of irrigated Eucalyptus plantations (see Section 5.3.3). To supply the estimated population of Nile Province annualy with fuel and poles would require over 55 000 feddan of Eucalyptus, plus the calculated total annual yield from the present Acacia forest reserves. However, given only Quality Class II yields from coppice growth, the figure for required plantations could be double this area, so accurate forecasts are not possible at this stage of plantation development.

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APPENDIXES

APPENDIX 1 CLIMATIC DATA

TABLE 1 Temperature data averaged for years 1973-1977 (^{o}C) Shendi Station

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Mean daily (a) maximum	39.96	39.13	39.82	39.7	35.02	32.05	30.03	32.87	36.17	40.15	42	41.5
Mean daily (b) minimum	25.5	25	25.82	23.7	19.97	15.7	12.8	15.37	17.5	20.92	26	27.2
Daily mean $\frac{a+b}{2}$	32.93	32.06	32.82	31.7	27.5	23.9	21.43	24.12	26.85	30.27	34.15	34.36

TABLE 2 Humidity readings averaged for years 1973-1977 Shendi Station

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
M R H at 6 GMT	43.25	50	41.5	35.66	38.25	43.75	41.66	34.5	28.5	25.5	24	26
*Open-pan evaporation in mm	8.91	10.75	15.63	11.22	6.73	5.63	4.97	5.54	6.72	8.88	8.24	8.4
*These figures are obtained by multiplying PICHE figures by the relevant factor. See Table 5												

TABLE 3 Total rainfall (mm) and wind direction averaged for years 1973-1977 Shendi Station

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Total rainfall in mm	11	10	8	1	2	*	-	-	-	-	-	2	34
Prevailing wind direction	SW	SW	SW	NE	NE	NE	NE	NE	NE	NE	NE	SW	
Mean scalar wind speeds in mph (av. 1961-70)& (kph)	7 (11)	7 (11)	6 (10)	6 (10)	6 (10)	6 (10)	7 (11)	7 (11)	8 (13)	8 (13)	7 (11)	8 (13)	

* Figures of rainfall are incomplete. The rainfall at Shendi is considered to be heavier than that at Atbara.

TABLE 4 Temperature data, averaged for years 1973-1977 (C^{o}) Atbara Station

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Mean daily maximum (a)	40	39.67	40.75	39.6	34.67	31.2	28.92	32.22	35.4	39.17	42.17	42.17
Mean daily minimum (b)	26.81	27.07	27.5	24.9	18.9	15.95	13.45	15.62	18.27	21.95	26.07	27.97
Daily mean $\frac{a+b}{2}$	33.45	33.37	34.12	32.25	26.8	23.57	21.2	23.92	26.82	30.55	34	35.1

TABLE 5 Humidity readings, averaged for years 1973-1977 Atbara Station

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
M R H at 6 GMT	44	47.75	40.5	34.25	44.25	48.75	44.25	39.25	29.75	26.75	22	28.25
*Open-pan evaporation in mm	6.76	6.68	6.43	5.76	5.04	4.55	4.63	5.61	6.33	7.28	6.91	6.72
PICHE factor	0.36	0.37	0.33	0.32	0.34	0.36	0.36	0.36	0.34	0.33	0.32	0.31
*These figures are obtained by multiplying PICHE figures by the relevant factor.												

TABLE 6 Total rainfall (mm) and wind direction, averaged for years 1973-77 Atbara Station

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Total rainfall in mm	18	30	3	4	-	-	-	-	-	TRACE	6	TRACE	61
Prevailing wind direction	SW	SW	SW	NE	N	N	N	N	N	N	N	SW	-
Mean scalar wind speeds in mph (av. 1961-70) (and Kph)	6 (10)	7 (11)	4 (6)	5 (8)	6 (10)	6 (10)	8 (13)	8 (13)	8 (13)	7 (11)	6 (10)	6 (10)	
Source: Department of meteorology Khartoum. October 1978													

APPENDIX 2 FOREST ADMINISTRATION AND EDUCATION

Forest Administration

1. Prior to the passing of the Provincial Administration Act of 1960 the responsibility for all forest affairs was in the hands of a centralised Sudan Forest Service, with a distinguished history.

2. From 1960 provincial forest operations were funded from provincial revenues, but the provincial staff were still responsible to the Central Forest Administration (CFA) for the management of Reserves, the production of central demands for forest produce (sawn timber, telegraph posts, railway sleepers etc), and in the spending of their provincial budget (via monthly returns and annual reports).

3. In 1971 The Local Peoples Government Act was passed, which allowed a fuller control of government business at the provincial level. Through newly formed Peoples Executive Councils, some 90% of all public services were placed under the control of these Provincial Centres (with the exception of Foreign Affairs and the Armed Forces). From 1973 these centres controlled their own budget absolutely, with no reference to Central Government.

4. During 1971 the Central Forest Administration handed over to the Northern Provincial Forest Service (amongst others) the major control of their own affairs. Thus both forest royalty and revenue from the sale of produce collected and sold by the Provincial Forest Staff became part of the provincial budget. The CFA only retained the responsibility of advising (through the Ministry of Agriculture, formed in 1971 see diagram) on the execution of the Forest Policy, central planning, and major development schemes, and their evaluation. (The six year National Development Plan 1977-82 is now in its second year). Training, Research, Education; the secondment of staff to the provincial service, construction of working plans and major inventories was also controlled by the Central Administration. In 1972 under this Act, the Southern Provinces, containing the majority of the valuable forests, were placed under a separate Forest Administration with complete autonomy. In this case the CFA only retained responsibility for the execution of Forest Policy, construction of Working Plans, Research, education

and major inventories (see Diagram 2).

5. In 1973 the Forest Ranger School, until then a CFA responsibility, was given to the Ministry of Education as part of the Institute of Technological Colleges. In 1974 the training of graduate foresters was incorporated as a department of the University of Khartoum's School of Agriculture. In 1975, Forest Research passed from the control of the CFA and was given to the Agricultural Research Corporation, directly responsible to the Ministry of Agriculture.

6. The major advantage claimed for the formation of separate Provincial Forest Services was that provincial inhabitants were ensured a more direct say in the conduct of forestry affairs, and more administrative unity was obtained in the provinces.

7. Whilst this advantage is accepted there seems no reason to suppose that past Assistant Conservators of Forest stationed in the provinces were any more likely to ignore the people's needs in his province than his modern counterpart, the Assistant Commissioner for Forest Affairs.

8. Furthermore a number of problems have made themselves apparent under the new system.

   (a) Government timber consumers, such as the Posts and Telegraphs and the Railways, now have to deal with the individual provinces who produce their needs, instead of placing a single order direct with the CFA in Khartoum. This leads to delays and duplication of effort. Some improvement could be expected if forests could be treated as a 'strategic crop', as are sugar, cotton and tea which can only be grown in certain climatic zones. These strategic crops have a separate supply-and-demand administration. If forests are designated as a strategic crop the supply of forest produce could then be handled by the CFA on a national basis.

   (b) Although the CFA supply development funds they may only 'advise' Provincial Services through the Ministry of Agriculture, and not directly. The CFA have little control over local priorities, local funds, staffing and transport conditions necessary to support development operations. Other

government departments in the same difficulty can form a Development Team which can visit the province and install the irrigation scheme, power station, hospital, school, or telephone network. Once correctly installed the scheme can be handed over, with adequate central funding, to be run by provincial staff. The CFA would wish to use this system given the necessary ministerial authority.

(c) The Local Peoples Government Act functions very well in the more developed provinces which are economically viable. It does not function so well when applied to an undeveloped province. Only the over all planning authority in the CFA can judge between all national requirements. Again the inclusion of forests as a strategic crop would assist the CFA to allocate central funds.

(d) Some forestry problems, such as the treatment of watersheds and erosion hazards, cross provincial boundaries. It is not always easy for the CFA to convince the Provincial Services of the need to finance part of an overall regional programme. In cases such as these major forestry problems the scarce resources of development finance, staff and equipment could best be coordinated and controlled by the CFA to avoid wasteful duplication, and ensure a higher standard of technical supervision.

Forest Education

Today most entrants to the professional cadre have received their forestry degrees at overseas Universities, or, from next April, the University of Khartoum. In 1974 the Department of Forestry was inculcated into the School of Agriculture at Khartoum University: the first 20 forestry graduates will be finishing this course in April 1979. The Forest Research Institute at Soba is responsible for Education at Forest Ranger level. Until 1973 this was managed by the CFA, but in 1973 the FRI's course, lasting 2 years (14 courses have been through to date) was combined with the Institute of Technological Colleges, of the Ministry of Education.

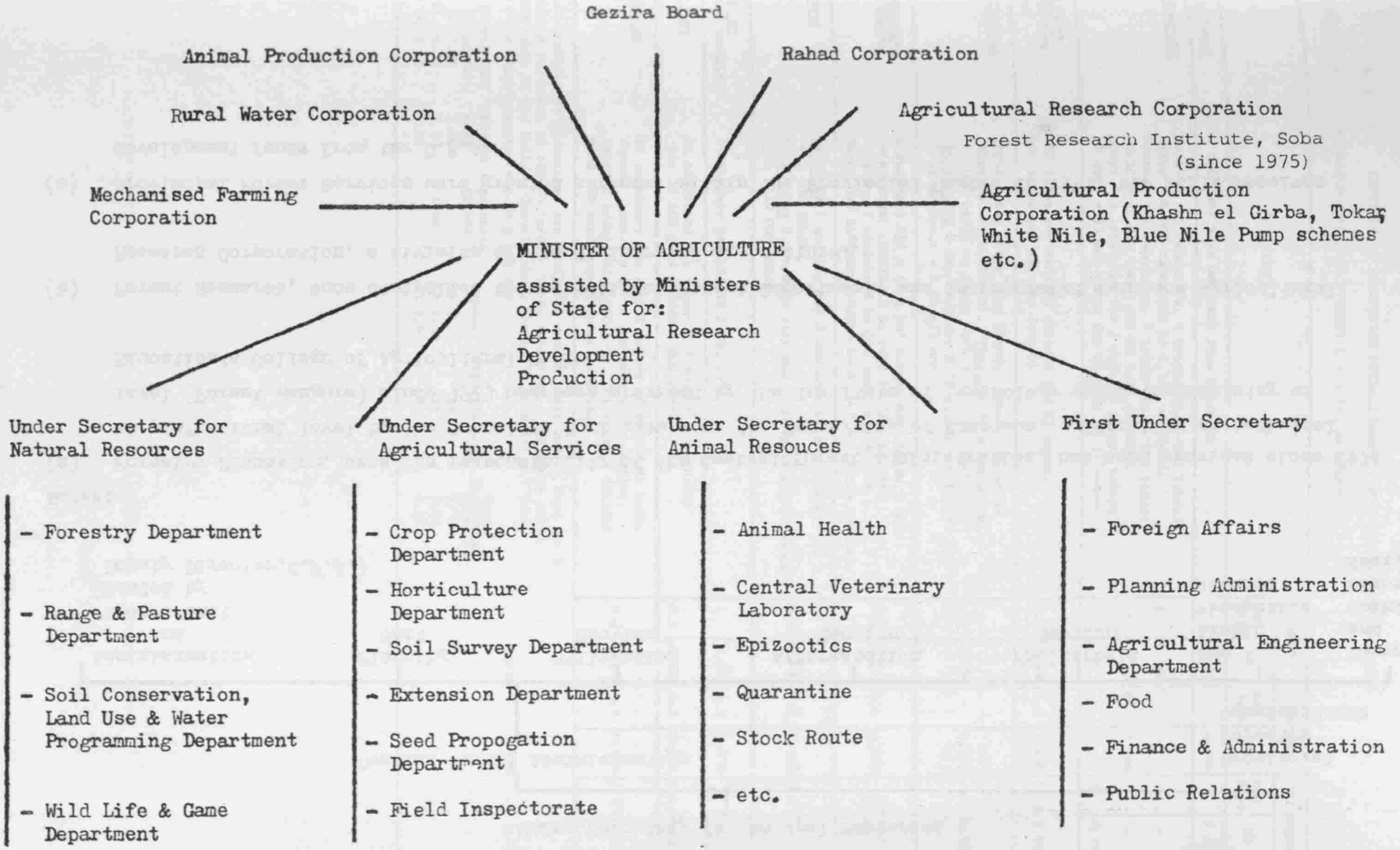
The Senior CFA professional staff are mostly forestry graduates of overseas universities, as are the majority of the young professional staff recruited since 1974. However no foresters were trained overseas between 1966 and 1974, and senior technical staff were promoted to professional rank during this period. Many of these officers are now in positions of authority in charge of Provinces.

Difficulty has been experienced in the posting of the young graduate foresters into the administrative ranks of the Provincial Forest Services which are often commanded by promoted technical officers, especially since the CFA is today reduced to an advisory body. This is a problem by no means confined to the Sudan.

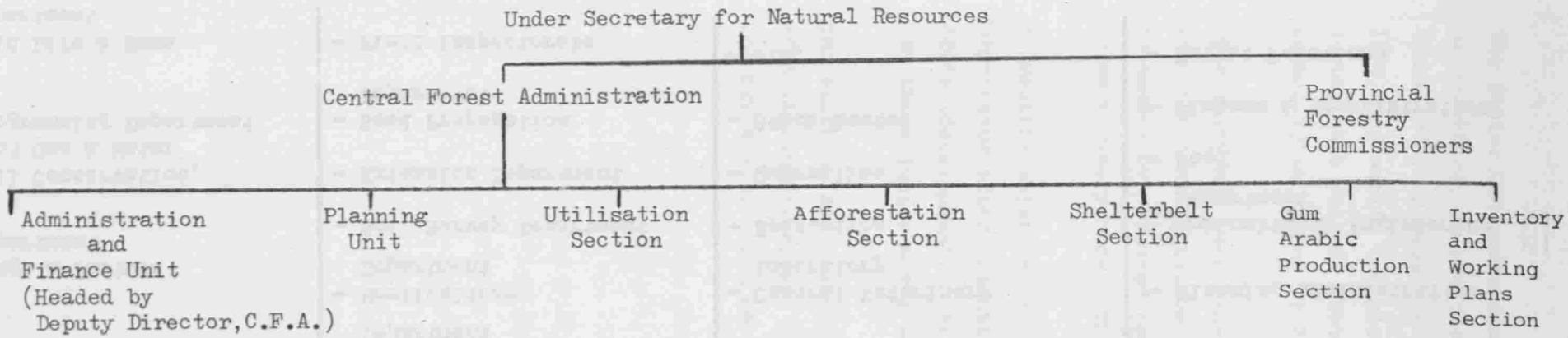
A possible solution, to allow these young graduates the necessary field experience after graduation, would be to post them to the Provinces as ACF's (Development). Since development projects are normally funded by CFA these junior ACF's would be paid by, and answerable to, the CFA direct.

The existing Assistant Commissioners for Forestry Affairs would remain as ACFA (Administration), a task experience has taught them to carry out admirably. The pay scales could be overlapped to avoid contention.

Organisation of the Ministry of Agriculture, Food & Natural Resources



Organisation of Forestry Department



Notes:

(a) Forestry Education, once the responsibility of the Central Forest Administration, has been provided since 1974 at professional level by the School of Agriculture at the University of Khartoum. Education at technical level (Forest Rangers) since 1973 has been provided by the Institute of Technology under the Ministry of Education's College of Agricultural Studies.

(b) Forest Research, once controlled by the National Forest Department, was incorporated into the Agricultural Research Corporation, a division of the Ministry of Agriculture.

(c) Provincial Forest Services were granted autonomy within the Provincial Centre in 1971, but still receives development funds from the C.F.A.

APPENDIX 3 COSTING* OF PLANTATION ESTABLISHMENT (EXCLUDING IRRIGATION WORKS)

AMOUNT COSTS PER 1 000 SEEDLINGS (SUDANESE POUNDS) L S 5 333 ON AVERAGE

	Activity	SHENDI		DAMER		EL HASSA	
		Man days	LS	Man days	LS	Man days	LS
Polythene tubes	(250 x 65 mm) plus delivery from Khartoum	-	2.300	-	2.300	-	2.300
Soil collection	** Tractor + 5 labourers, 4 trips/day, 4 000 tubes/ trip = 16 000 tubes for LS 6.74* at Shendi	5	0.420	-	-	-	-
	Tractor + 6 labourers, 6 trips/day, 4 800 tubes/ trip = 28 000 tubes for LS 7.36 at Damer	-	-	6	0.260	-	-
	Lorry + 4 labourers for 2 days, 9 trips, taking 2 days = 35 000 tubes for LS 9.22 at El Hassa	-	-	-	-	8	0.250
Filling tubes with soil when collected	750 tubes per man/day (Shendi and El Hassa) 600 tubes per man day (Damer)	1.25	1.000	1.3	1.250	1.25	1.000
Seed collection	(From local trees near Shendi Damer + El Hassa supplied by Khartoum). Prosopis 50 p per pound (7 000 seed) on piece work = 0.07 p/1 000 seed. Eucalyptus 2 man/days for 0.75 pounds (60 000 = 1 lb approx.) = 0.03 p/1 000	-	0.050	-	0.050	-	0.050
Bed preparation (as for Shendi)	A standard 25' x 4' x 10" sunken bed holds 2 000 seedlings. Taking 1 man/day to dig out, and lasting 5 seasons = 10 000 seedlings for 75 p Damer had different sized beds, but costs are similar.	0.1	0.075	0.1	0.075	Cement beds	
Sowing seed	Prosopis 1 man/day per 2 000 pots with 2-3 seeds/pot = 5 000 seeds Eucalyptus 2 man/days will sow 2 000 pots with 5 seeds/ pot = 10 000 seeds	0.25	0.150	0.3	0.200	0.2	0.130
Pricking out germinated seedlings	2 man/days per bed of 2 000 pots	1	0.750	1.2	0.870	1	0.750
Weeding beds	As necessary for first 2-3 months. 1 man/day per 10 000 pots (Damer 6 000 pots)	0.1	0.075	0.2	0.125	0.1	0.075
Root and stem pruning	If necessary for last 2 months of period in beds. Shendi 1 man/day for 5 000 pots with overtime, Damer 2 m/day for 3 000 pots. El Hassa 1 man/day does 750 seedlings without overtime.	0.2	0.150	0.6	0.500	1.25	0.660
			4.970		5.630		5.465

* Long-term costings of operations are available though plans are in hand for a detailed monthly statement of expenditure to be submitted. The above costs are estimates taken in the field. Casual labour charge is 50 p for a 7 hour day + 25 p for 3 hours overtime = 0.75 p per day.

	Diesel fuel (42 p/gal)	Drivers Wage	Assistant Driver	Labour	Depreciation	Total Transport cost
Shendi	(2) 0.84	2.00	-	(5) 3.75	15	6.74
Damer	(0.5)0.21	1.50	1.00	(6) 4.50	15	7.36
El Hassa (Lorry)	(6) 2.52	2.52	-	(8) 4.00	20	9.22

2. ESTABLISHMENT COSTS EXCLUDING FENCING* (LS 30.50 per feddan

		LS/FEDDAN
a.	Ploughing	2.500
b.	Levelling	0.500
c.	Opening of canals	1.500
(d.	Fencing*)	(66.000)
e.	Planting	3.000
f.	Weeding	1.000
g.	Watering** (labour), (twice a month)	12.000
h.	Guarding	10.000
		LS 30.50

Establishment costs of LS 30.50 must exclude fencing, since the costs per feddan cannot be calculated with accuracy. No supervision or land (LS 50 feddan) charges, or initial major irrigation work costs are quoted.

Fencing costs are calculated per kilometre as below

	LS
1. Materials	
Barbed wire 25 rolls(a) at LS 19 a roll (5 strands)	475
Fence posts 250 at LS 1.100 each (every 4 m)	278
10 kg of nails at LS 0.6 per kg	6
Tools	2
(a) Barbed wire guages vary. Generally 1 kg = 15 m and 1 roll = 29 kg	761.000
2. Labour	
One carpenter for 3 days at LS 1.500 per day	4.500
4 casual labour for 3 days at LS 0.75 per day each	9.000
Fixing posts $\frac{250}{30}$ x 0.75	6.250
	19.750
3. Transport	
Wire and posts from Khartoum to Nile Province by rail	20.000
(no charge made for Trailer Rail to planting site).	LS 800.750

To calculate fencing costs per feddan approximately

It must be assumed that most shelterbelts are 50 m wide (not common in practice, but quoted in Budget estimates).

Therefore 1 km of belt X 50 m = 50 000 m^2. At 4 200 m^2 per feddan this is equivalent to 12 feddan. $\frac{800}{12}$ = LS 66 per feddan.

**Watering costs

It is assumed that the labour for watering takes 1 man/day per feddan each time to open sluices; this is LS 0.50 a day. If, on average, plantations are watered twice a month, the labour charge is LS 0.5 X 2 X 12 per feddan per year = LS 12. The annual water charge has been quoted in files as LS 44 per feddan for approximately 5 000 m^3 of water per feddan per year.

3. MAINTENANCE COSTS PER FEDDAN, YEAR 2 AND SUBSEQUENT YEARS (LS 17.30)

	LS/feddan
a. Weeding	1.00
b. Watering* (labour once a month)	6.00
c. Beating up 10%**	0.30
d. Guarding	10.00
	17.30

*Watering

Once a month labour would cost 0.50 X 12 = LS 6. It is assumed that if the water charges per feddan per year for watering twice a month are LS 44 during establishment, then watering once a month will mean half this charge = LS 22.00

**Beating up

It has been assumed that 10% of all belts must be beaten up in year 2. If the labour charge to plant 1 feddan is LS 3 during establishment, then costs of labour to beat up will be 10% of LS 3.

APPENDIX 4 DESCRIPTION OF SHELTERBELTS

APPENDIX 4 Description of shelterbelts - Nile Province (as at 12 October 1978)

Location	Name (agency)	Block no.	Size of belt			Date plant	Species (soil type)*	Stocked %	Av. ht. metres	Irrigation system	Remarks (purpose, area protected, crops grown, damage to trees etc.
			Area fed	Length km	Width rows						
Wad Banaqa CFR	Production block (CFA1) ≠	1	13	-	-	1974-5	E. mic. (AB)	80%	4-6.0 15 cm girth	Flood channel but not irrigated for last three months due to pump failure.	Some E. tereticornis and E. camaldulensis mixed. Fence flattened. Possible goat damage (old). Signs of drought stress in leaves.
Wad Banaqa CFR	Production block (CFA2) **	2	7	-	-	1975-6	E. mic. (AB)	90%	2.0		Signs of drought stress in leaves. No fence, cattle running free.
Wad Banaqa CFR	Production block (CFA2)	3	25	-	-	1977 to Feb 1978	E. mic. (AB)	90%	1.0	Irrigated once a week when able, but none for 3 months as above	Some loss of turgidity in leaves. A further 447 feddan is available for planting, but slopes unsuitable for irrigation
Gandato	Village strip (Village)	1	-	3	1	1957	Prosopis (Bc 1)	100%	6.0	No longer irrigated by flood: Rain fed only	Planted by villagers under supervision. Healthy seedlings spreading by natural means (goats eat pods) over 20 feddan without irrigation.
Saiyal	El Guba (Project) ≠≠	1	95	2.1	80	1978 (Jan)	Prosopis (B7)	80%	0.8-2	Flooded every 14 days for first 2 months then monthly for 3 years (not irrigated in March and April)	Shelter for canal from west against wind-blown sand. Land difficult to irrigate for agricultural crops of wheat and onions (9000 feddan). Goat damage evident.

See footnote at end of table

APPENDIX 4 (Continued)

Location	Name (agency)	Block no.	Size of belt			Date plant	Species (soil type) *	Stocked (%)	Av. ht. metres	Irrigation system	Remarks (purpose, area protected, crops grown, damage to trees etc.
			Area fed	Length km	Width rows						
Saiyal	El Guba (Project)	2	20	2.1	80	1978 (Jan)	E. cam. (B7)	75%	1.20	Flooded every month over full rotation except March and April	Production forest for poles and fuel. Top height of trees near canals is 1.40 m. Some root collar deformation.
Saiyal	El Guba (Project)	3	5	2.1	80	1978 (Jan)	E. mic. (B7)	80%	1.20		As above. Some Acacia dealbata and A. farnesiana, showing good growth
Keli	Windbreak (CFA1)	1	30	1.5	40	1974	E. mic. (B7)	55%	5.0	Flooded every month over full rotation except March and April	Shelter for canal from west against wind-blown sand. A salinity problem is suspected. 40% of belt died of drought last year due to competition with farm crops for water in a drought period. A 5 feddan nursery is to be installed. Eucalyptus are in fruit
Keli	Windbreak (CFA1)	2	20	1.5	40	1975	Prosopis (B7)	80%	3.0	Flooded every month, except for March and April, for first 3 years of rotation	Shelter for agricultural scheme. Most of plants survived last years severe drought. Irrigation due to cease next March. Growth uneven

APPENDIX 4 (Continued)

Location	Name (agency)	Block no.	Size of belt			Date plant	Species (soil type)*	Stocked %	Av. ht. metres	Irrigation system	Remarks (purpose, area protected, crops grown, damage to trees etc.
			Area fed	Length km	Width rows						
Zeidab	Abu Salim FR (Project)	1	123	10.5	25	1977 (July-Oct)	Prosopis (C)	80%	2.0	Flooded every 14 days for first 3 months, then monthly, except for March and April until 1980	Shelter of canal and farm crops from East against windblown sand. Cotton, sorghum and broad beans grown over some 29 000 feddan. Very saline coarse gravel and clay soil. 60 feddan due to be planted this month
Zeidab	Umm Tayour (CFA1)	2	68.5	11.5	7	Aug 1972 July 1973	Prosopis	95%	5.5	No irrigation since 1976 except for hill run-off	Shelter from East against windblown sand. Good growth in very saline conditions indicates deep root system. Natural regeneration from browsing by goats
Aliab	Bridge No. 7 (CFA1)	1	4	75 m	25	1974	E. mic. (B1)	95%	6.0	Flooded every month except March to May. Will cease in 1984	Good even growth with few gaps. The block acts as a wind deflector. Crops grown are wheat, beans and sorghum. Some coppiced Neem (Azadirachta indica) also planted
Aliab	Bridge No. 7 (CFA2)	2	0.5	-	-	1976	E. umbellata (B1)	70%	4.50	Flooded every month except March to May will cease in 1985	The block is L-shaped to act as a wind deflector. Crops as above

APPENDIX 4 (Continued)

Location	Name (agency)	Block no.	Size of belt			Date plant	Species (soil type)*	Stocked %	Av. ht. metres	Irrigation system	Remarks (purpose, area protected, crops grown, damage to trees etc.
			Area fed	Length km	Width rows						
Aliab	North belt No. 1 (CFA1)	3	8 (part)	1	9	May 1974 Beaten up 1977	Prosopis (B1)	75%	3	Flooded once every 2 months Irrigation stopped in July 1978	Shelter for canal from west against wind-blown sand. Crops are 6000 feddan of wheat, beans & sorghum. All but the 2 rows nearest the main canal died from water shortage and were beaten up. Ground is high and difficult to irrigate
Aliab	North belt No. 2 (CFA1)	4	8 (part)	1	9	Dec 1973	Prosopis (B1)	95%	5	As above, but probably monthly flooding	As above but better growth from better soil and water supply
Aliab	South belt (CFA1)	5	8 (part)	1	9	Dec 1973	Prosopis (B1)	?	?	As above	Not visited
El Hassa	El Hassa (CFA1)	1	55	7.7	5 2 2	1972	Prosopis E. mic Conocarpus lancifolus	85% 50% 10%	6 4 2.5	Pump fed on high ground. Flood on low ground. When water available area irrigated every 20 days but now infrequent	Shelter for canal from East against wind-blown sand. Crops wheat, sorghum and beans Conocarpus growth poor and 20 feddan needs beating up. Bad Stem-borer attack in 1972 Prosopis area

APPENDIX 4 (Continued)

Location	Name (agency)	Block no.	Size of belt			Date plant	Species (soil type)*	% Stocked	Av. ht. metres	Irrigation system	Remarks (purpose, area protected, crops grown, damage to trees etc.
			Area fed	Length km	Width rows						
El Hassa	El Hassa (Project)	2	25	1.53	15	Jan 1978	Prosopis	-	-	As above	Not seen

*Soil type taken from Roseires Soil Survey, see Section 3.1.3. and Appendix 10.
/CFA1 refers to Central Forest Administration Aforestation Section
**CFA2 refers to Central Forest Administration Shelterbelt Division which succeeded Afriestation Section
//Project refers to joint CFA/SCC Shelterbelt Project

E. mic. = Eucalyptus microtheca
E. cam = Eucalyptus camaldulensis

APPENDIX 5 PLANTING PROPOSALS AND COST CONTROL FORM

APPENDIX 5 PLANTING PROPOSALS AND COST CONTROL FORM

Location	Forest year, 1977/78				Forest year, 1978/79				Forest year, 1979/80				Forest year, 1980/81				Forest year, 1981/82			
	Estimate		Actual		Estimate		Actual		Estimate		Actual		Estimate		Actual		Estimate		Actual	
	Area (F)*	Cost (L.S)*	Area (F)	Cost (L.S)	Area (F)	Cost (L.S)	Area (F)	Cost (L.S)	Area (F)	Cost (L.S)	Area (F)	Cost (L.S)	Area (F)	Cost (L.S)	Area (F)	Cost (L.S)	Area (F)	Cost (L.S)	Area (F)	Cost (L.S)
Saiyal	120	7 865	120		100	12 856			150	17 167			100				100			
Zeidab	86	10 375	123		103	14 246			25	9 591			-				-			
El Hassa	7	3 635	25		50	3 255			25	8 690			25				25			
Keli	-		-		60	6 491			67	9 863			91				94			
Gandato	-		-		50	8 329			25	9 421			-				-			
Banaqa	-		-		25	2 506			24	4 640			25				25			
Kabushiya	-		-		-	-			100	17 239			183				174			
	213		268		388				417				424				418			

APPENDIX 6 ESTIMATED COST OF IRRIGATION WORKS

A. Gandato belt (Permanent pump scheme over 73.8 feddan 21 km long by 15 metre wide)

Particulars	Quantity	Unit	Rate LS/Unit	Total LS
1. Bush clearance and site levelling	75	fedd.	15	1 125
2. Survey for setting out basin system	75	fedd.	5	375
3. Construction of levels for basin	75	fedd.	15	1 125
4. 4" Pumps, each with 4" suction and delivery steel pipes 50 m long with 4" elbows	3	pumps	1 200	3 600
5. Excavation of Abu Ishrin (A/xx) by ditcher	9 000	m^3	0.1	900
6. Supply and lay 0.35 m steel pipes (10 x 1 m length) in canals, complete with door liners. Fill with proper compaction (F.O.P)	8	canals	160	1 280
				8 405
Plus 5% contingencies				420
Total				8 825

B. Kabushinya (Permanent pumps schemes over 475 feddan with 25 canals)

Particulars	Quantity	Unit	Rate LS/Unit	Total LS
1. Bush clearance and site levelling	475	fedd.	12	5 700
2. Survey for setting out basin system	475	fedd.	1	475
3. 4" pumps, each with 4" suction and delivery steel pipes 50 m long with 4" elbows	4	pumps	1 200	4 800
4. Excavating of Abu Ishrin (A/xx) by ditcher	25	canals	150	3 750
5. Supply and lay 0.35 m steel pipes in canals, complete with door liners. Fill with proper compaction.	26	canals	600	15 600
				30 325
Plus 10% contingencies				3 032
Total				33 357

C. Kabushiya (Temporary pump scheme over 475 feddan)

Particulars	Quantity	Unit	Rate LS/Unit	Total LS
1. Bush clearance and land levelling	475	fedd.	12	5 700
2. Survey for setting out basin system	475	fedd.	1	475
3. 4" Portable pumps each with 4" suction and delivery plastic pipes 50 m long with 4" elbows	4	pumps	1 000	4 000
4. Excavation of Abu Ishrin (A/xx) by ditcher	25	canals	150	3 750
5. Protection of A/xx by pitching in 4:1 cement unions	25	canals	100	2 500
				16 425
Plus 10% contingencies				1 642
Total				18 067

APPENDIX 7 REGISTER OF NILE PROVINCE FOREST RESERVES

	Name	District	Area feddans
1.	Wad El Nur*	Shendi	56
2.	Abu Higlig*	Shendi	318
3.	Wadi El Arous	Shendi	2 570
4.	Wadi El Kirbikan	Shendi	1 748
5.	Wad Golai	Shendi	3 720
6.	Es Salama(P)	Shendi	796
7.	Wad Banaga	Shendi	492
8.	El Awateib(P)	Shendi	836
9.	Wadi El Banat	Shendi	2 200
10.	Wadi El Fazara	Shendi	900
11.	Dolo'a*	Shendi	1 032
12.	El Hawad*	Shendi	1 738
13.	Kaboshia	Shendi	284
14.	Um Gurad	Shendi	4 047
15.	Abu Saleem	Shendi	700
16.	Abu Karmat	Shendi	2 700
17.	El Hilgi*	Atbara	1 745
18.	Goz el Halag*	Girsi	1 125
19.	Um Dubei'a*	Atbara	1 751
20.	North Atbara (Shelterbelt)(P)≠	Atbara	980
21.	South Atbara (Shelterbelt)(P)≠	Atbara	2 700
22.	Wadi El Shakkaia	Shendi	730
23.	Wadi El Sheikh	Shendi	1 200
24.	Wadi El Dabi	Shendi	1 500
25.	El Maghaweir	Shendi	1 100
26.	Wadi El A'agir	Shendi	1 600
27.	Wadi Hallouf	Shendi	1 300
28.	Wadi Kassala	Shendi	1 400
29.	Wadi El Bihairriya	Shendi	1 500
30.	Um Sayala	Atbara	850
31.	Kaoli and Um Rouce	Sidon	719
32.	Kalalab and Salalab	Sidon	964

* Final gazette notification completed
≠ Proposed for reservation
The remainder are in the process of being gazetted
(P) Provincial Forest Reserve, the remainder are all Central Forest Reserves

Name	District	Area feddans
33. El Shababeit	Sidon	360
34. Um Ba'asheem and Um Handal	Sidon	1 428
35. Khor El Fiel	Sidon	1 738
36. Abu El Kheil	Sidon	1 809
37. Talshan	Sidon	2 000
38. Um Bairbir	Sidon	3 500
39. Tamsharaf	Sidon	3 000
40. Erat	Girsi	500
41. El Baroneit	Girsi	450
42. Ashoul	Girsi	400
43. El Sahagi	Girsi	600
44. El Shigil	Girsi	1 000
45. El Toan	Girsi	1 500
46. El Marzouga	Girsi	1 500
47. Gaili	Girsi	2 000
48. El Shinkeinta	Girsi	1 200
49. Booria	Girsi	500
50. Kalhada	Girsi	2 000
51. Shangareit	Girsi	3 000
52. El Dagag	Girsi	2 500
53. Um Guroud	Girsi	2 500
54. Tomri	Girsi	2 000
55. Ambloreib	Girsi	1 500
56. El Geir	Sidon	1 500
57. El Sowana	Sidon	800
58. El Makabrab	El Damer	812
		85 310

* Final gazette notification completed
≠ Proposed for reservation
The remainder are in the process of being gasetted
(P) Provincial Forest Reserve, the remainder are all Central Forest Reserves

APPENDIX 8 LIST OF VEHICLES AND TRACTORS IN USE BY CFA-SCC SHELTERBELT PROJECT

Reg. No.	Vehicle	Stationed at, and date bought		Duties
KB 2890	Land Rover SWB Pick up	Atbara	Nov 1976	Accountant
KB 2891	Land Rover LWB St/Wagon	Khartoum	Nov 1976	Project Manager
KB 2892	Land Rover SWB Pick up	Shendi	Nov 1976	FO Shendi
KB 2893	Land Rover SWB Pick-up	El Damer	Nov 1976	FR Damer
KB 9443	Bedford lorry	El Damer	Nov 1976	North section
KB 9442	Bedford lorry	Shendi	Nov 1976	South section
1057)	Massey Ferguson Deisel	El Damer	Nov 1976	Damer nursery
1065)	152, Perkins AD3 Tractors	Shendi	Nov 1976	Shendi nursery
KB 9950)	Ford Deisel 4600 Tractors	El Damer	Aug 1977	North section
KB 9886)	with trailers	Shendi	Aug 1977	South section

Note:

A reconditioned D8 Bulldozer arrived at Port Sudan in August 1978, its eventual delivery to Atbara by rail was the subject of negotiations between Ministry of Transport and Ministry of Agriculture at the time of this visit. It is hoped that the following ancillary equipment can be supplied by the Swedish Free Mission

1. Ditcher (ABU XX) Werklust
2. Hyster 60 tons (US) Low Loader to transport the bulldozer by use of a 7 ton lorry.

APPENDIX 9 ITINERARY M J BERRY 2 OCTOBER - 5 NOVEMBER 1978

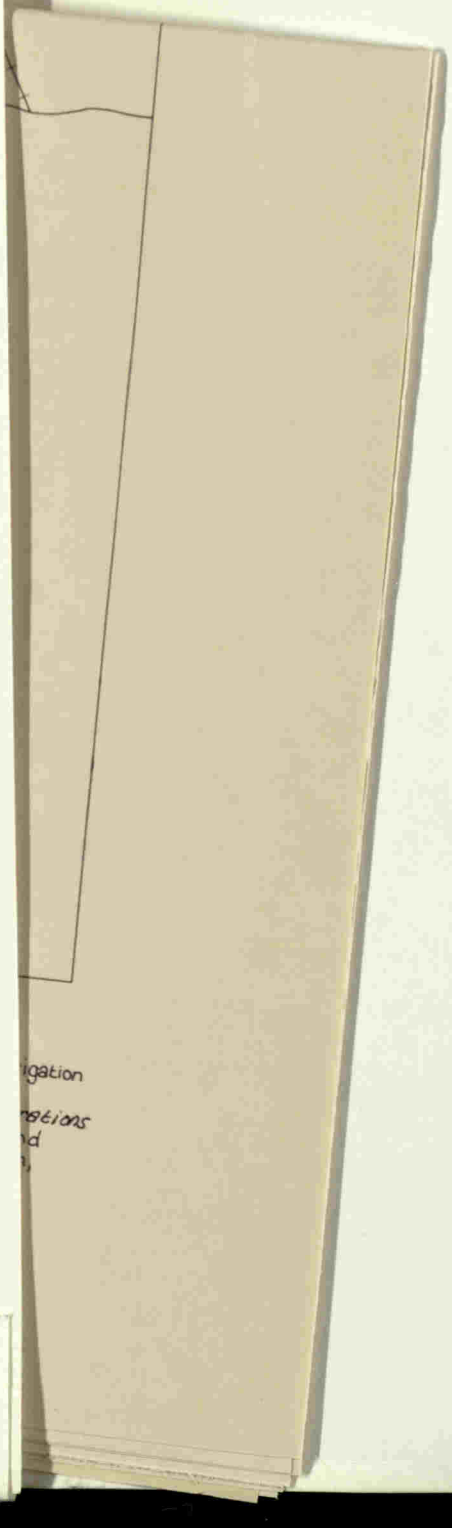
Monday 2 October	Left London, Heathrow airport 1700 hrs, arrived Khartoum 0310 hrs, to Excelsior Hotel.
Tuesday 3	To British Embassy to see First Secretary Aid Mr Gordon. To see Mr Rodney Self, Administrator of Sir M Macdonald and Partners. To see Mr Christopher Howse, Resident Manager Hunting Technical Services Ltd. To see Syed A A Bayoumi Director of Central Forest Administration (CFA). Collected various reports.
Wednesday 4	To Embassy briefly to arrange transport for field visit, through Hunting Technical Services kind offices.
Thursday 5	To CFA on joint discussions on requirements for visit. Meeting chaired by Director, and attended by Syed K O Kalifa, Project Manager on behalf of Sudan Council of Churches: Syed A A Saleem Head of Shelter belt Division CFA and Project Co-manager, Syed E R Zein deputy to Syed Saleem and Syed Mohd A O Karama, my counterpart.
	To Huntings on loan of landrover, driver, petrol drums etc with assistance of Mr Howse.
Friday 6	To airport on currency problems. Rest of day in hotel reading reports.
Saturday 7	Left for the north by Landrover with Syeds Zein and Karama. To Wad Banaga Forest Reserve, and Gandato belt. Night at Shendi as guest of Syed Omran Balilla, Forest Officer seconded to SCC. Arrived 1800 hours.
Sunday 8	At 0715 to Shendi nursery on costings. To see Assistant Commissioner for Nile Province, Southern region, Syed I A El Halim on local problems. To Gandato shelterbelt, El Salama P F R and irrigation scheme. Night in Shendi as before, again most generously entertained. Dinner in Army mess.
Monday 9	At 0700 hrs to Saiyal shelterbelt, on to Keli shelterbelt, Zeidab shelterbelt and Umm Tayour block. To see Assistant Commissioner for Forest Affairs, Nile Province, Syed Gamri Ata. Night in Railway Rest House, Atbara after visit to El Damer nursery.

Tuesday 10 October	Confined to bed all day with fever and severe diarrhoea. Forest department staff most helpful in getting doctor and medicine.
Wednesday 11	Confined to bed until 1100 hrs. To office, but unable to visit El Hassa and Gersi Forest Reserve, which were visited by counterpart. Night in Railway Rest House, Atbara.
Thursday 12	At 0630 to Aliab Shelterbelts on return journey. Reached Shendi at 1330 hrs and decided to continue on to Khartoum some 196 km south, arriving 2000 hrs. Passed Kabushiya site for shelterbelt and Merowe sun temple and pyramids.
Friday 13	In hotel all day writing up notes. Government offices closed.
Saturday 14	In morning to Huntings to return borrowed field equipment kindly lent by Mr Howse. On to CFA head office to start report. Visited Inventory section (Syed Abbas) and Survey office for maps.
Sunday 15 to Thursday 19	CFA all day on report, continued in hotel after 1500 hrs when Government offices close.
Friday 20	Worked in hotel 0900 - 1900 hrs.
Saturday 21	In morning to Forest Research Institute Soba to identify grasses, search for reports and consult staff. Passed Khartoum shelterbelts. Visited Syed Khalifa's SCC office for consultations.
Sunday 22	CFA office all day to discuss financial matters with Syed Kamal Badi.
Monday 23 to Wednesday 25	CFA office all day on report and maps.
Thursday 26	To Sir M Macdonald and Partners on possibility of assistance, to return borrowed reports, to Huntings on the same.
Friday 27	Worked in hotel 0900-1730 hrs.
Saturday 28	At 0730 hrs to office and on by bus to the Gezira scheme with Syed Ali Saleem and Syed Karama to see plantations with Provincial District Officer at Wad Magdoub and Hantoub C.F.R. Eucalyptus grown in Tannery waste water. On to Gezira scheme shelterbelt and production blocks with Syed O M Gashiri. Night in Syed Gashiri's quarters most generously entertained.

Sunday 29	To see Tahamid shelterbelt and Alan Houda production block, this latter on second (coppice) rotation. Visit to Director Projects Division, Ministry of Irrigation, Syed O M Keisir on costs of proposed irrigation systems for Kabushiya scheme, and irrigation cost for existing Shendi Shelterbelts. Returned to Khartoum by bus in evening.
Monday 30	To Sir M Macdonald and Partners to speak to Project Manager Mr Franks, who had just come out, a very useful meeting. Rest of day on report.
Tuesday 31 to Wednesday 1 November	CFA office all day on report and discussions with Mr Franks and Mr Howse
Thursday 2	At 0800 hrs final arrangements with Sir M Macdonald and Partners, and Huntings. At 1200 hrs final meeting with Director CFA. At 1300 hrs to Embassy.
Friday 3	Day off, visiting Museum and War Cemetery with counterpart. Dinner with Forest Department Staff.
Saturday 4	0915 to airport for return to UK.

APPENDIX 10 SOIL MAPPING SYMBOLS, SOIL TAXA AND THEIR SALIENT FEATURES (From 1964 Roseires Soil Survey Hunting Technical Services, Sir M Macdonald and Partners).

Symbol	Taxonomic Group	Characteristics
AB	Complex of a Psammustents and Orthustents	Loosely formed (probably alluvial) soils. Well drained - very dry if not irrigated. Probably deeply developed (at least 50 cm deep). Complex consists of sandy representatives (psamments) and loamy or finer (orthents).
BC1	Complex Natrargids and Natrargidic Orthustents	As above, but: textures predominantly medium range; saline horizon occurs within 50 cm of surface; frequently alkaline reaction.
B1 and B4	Orthic Orthustents and Vertic Orthustents	As for AB except: textures loamy to fine (sometimes clayey topsoils) in lower areas - clay consists of swelling clays which crack severely during the dry season. (NB saline and/or alkaline horizons absent).
B7	Complex Natrargidic and Orthic Orthustents	As for BC1
B13	Complex Lithic and Natrargidic Orthustents	Consists of shallow (<50 cm), stony, medium textured non-saline representatives (lithic), and deeper (>50 cm and probably very much more), predominably medium textured soils. A saline horizon occurs in the top 50 cm, and the soil reaction is alkaline. NB - both representatives are essentially dry (unless irrigated) and freely draining.
C	Natrargids	Probably the most desert - like of the soils in the area: deep loose to consolidated deposits; textures predominantly medium, sometimes fine (occasionally coarse); saline and alkaline; dry and freely draining.



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FOR THE
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