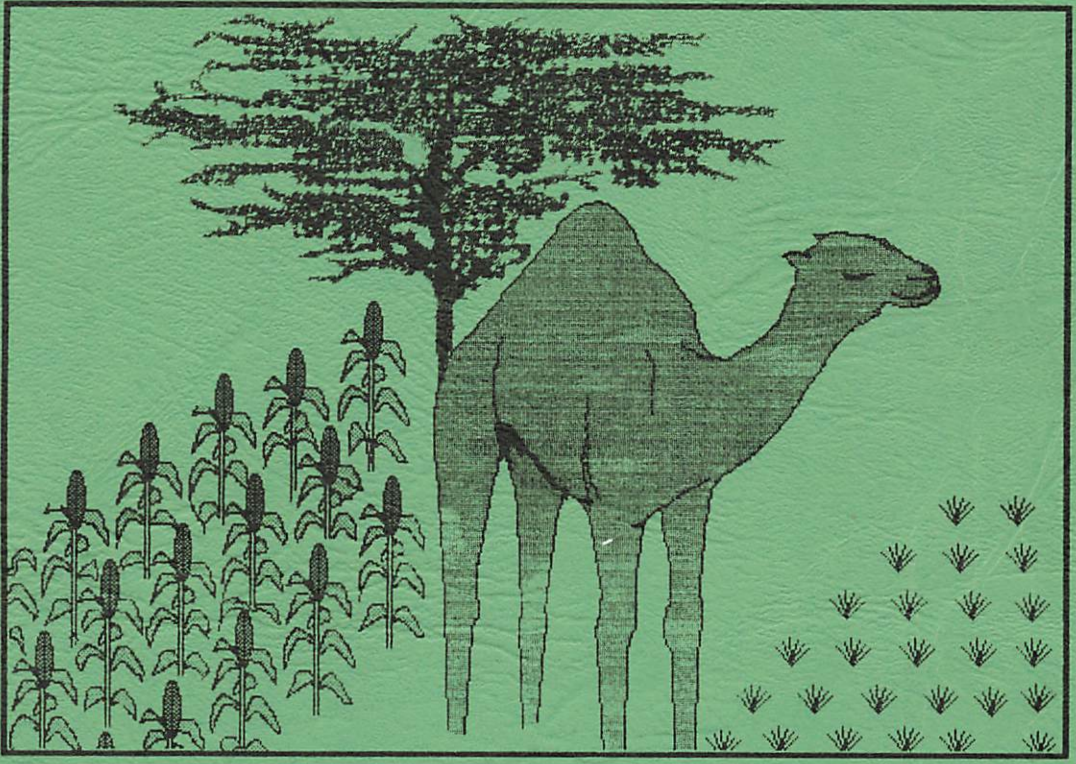
SOMALI DEMOCRATIC REPUBLIC

CENTRAL RANGELANDS DEVELOPMENT PROJECT,
MINISTRY OF LIVESTOCK, FORESTRY AND RANGE

PROMISING TECHNOLOGIES AND APPROACHES FOR SUSTAINABLE RANGE AND AGROFORESTRY DEVELOPMENT IN WARM, ARID AREAS:

RESULTS OF THE AGROPASTORAL DEVELOPMENT PROGRAM IN CENTRAL SOMALIA 1985 - 1988



March 1989
by

Richard Macalister Holt

Chief Extension/Agropastoral Officer
Central Rangelands Development Project

Peter Vervoorn
Business/Systems Analyst
99 Cave Avenue,
Bridgewater SA 5155.

Telephone: (08) 339-5795

28th July, 1989

Mr Dennis Herlocker
c\- 1109 Castleman Drive,
Longview, Washington. . 98632
United States of America.

Dear Mr Herlocker,

Richard Holt has asked me to send you a copy of his report to the Somali Government on the results of the agropastoral development program in central Somalia from 1985 to 1988. He extents his compliments and has asked me to include his business card.

He advises me that he has already sent copies, but believes they may have been mislaid in the local postal system in Lesotho.

Your faithfully,

Vervoorn

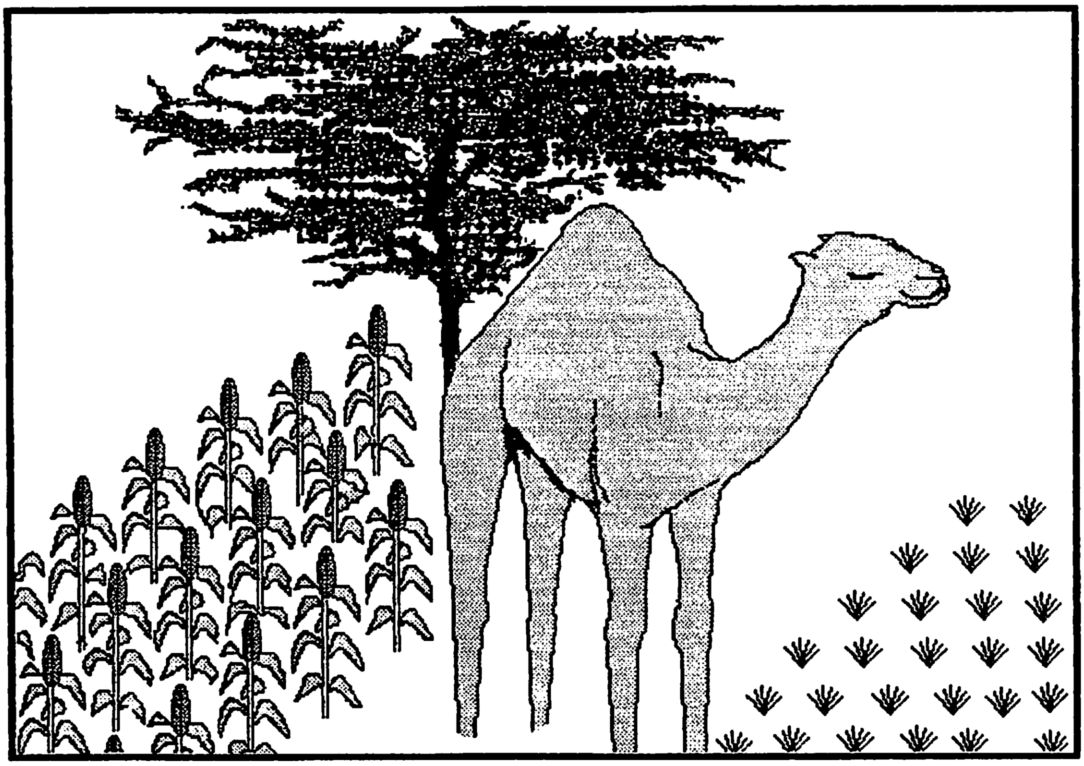
Peter Vervoorn
Managing Director

SOMALI DEMOCRATIC REPUBLIC

CENTRAL RANGELANDS DEVELOPMENT PROJECT,
MINISTRY OF LIVESTOCK, FORESTRY AND RANGE

PROMISING TECHNOLOGIES AND APPROACHES FOR SUSTAINABLE RANGE AND AGROFORESTRY DEVELOPMENT IN WARM, ARID AREAS:

RESULTS OF THE AGROPASTORAL DEVELOPMENT PROGRAM IN CENTRAL SOMALIA 1985 - 1988



March 1989
by

Richard Macalister Holt

Chief Extension/Agropastoral Officer
Central Rangelands Development Project

SUMMARY

By 1985, the large Central Rangelands Development Project (CRDP) had become aware that desertification and rangeland degradation were associated with poor cropping practices in parts of central Somalia. The traditional shifting cultivation system relied on a long bush/rangeland fallow cycle to restore fertility of the soil. As in other parts of sub-Saharan Africa, many recent factors were causing this system to break down. Many of the agropastoral areas in central Somalia are also highly susceptible to erosion, as it is arid and the soils are very sandy. The CRDP thus began to establish an agropastoral component in 1985 to begin to address this problem.

The environment, and the cropping and livestock herding systems in central Somalia are described, based mainly on the results of studies and investigations undertaken during the agropastoral development program. The client demand driven, participatory approach to development adopted by this program is described. It is argued that such an approach facilitates sustainable development.

The report outlines an extensive, integrated, multi-disciplinary, adaptive trial research program to develop improved farming systems, which would be acceptable to local agropastoralists. Both promising local innovations and many from abroad were adapted and evaluated, in a range of environments throughout central Somalia, over a three year period. As the traditional agropastoral system is inter-disciplinary, so too this development project had to be. The trials described thus cover aspects of rainfed cropping, agroforestry, forage production, soil and water conservation, rainwater harvesting and range management.

An anti-erosion strip cropping system was evaluated, which was shown to almost halve the amount of wind erosion on cropped fields. The system uses drought and erosion resistant pasture plants sown in strips to protect adjacent cropped strips. Productive varieties of *Cenchrus ciliaris* and forage legumes were introduced, which produced more than double the quantity of forage than naturally regenerating pasture. The pasture strips could potentially be rotated with the cropped strips too, to create a more sustainable farming system.

New varieties were introduced of the local staple food crop - cowpeas; which consistently significantly out-yielded the local variety at many trial sites. At the Nooleeye trial, the indeterminate cowpea variety TVU 15002 produced 27% and 42% more peas over 5 seasons than the local cowpea variety, under trial and traditional conditions respectively. Later introductions of determinate varieties produced more than 50% higher yields. The results suggest that food production could be considerably increased in central Somalia by the distribution of these varieties and extension of better cropping techniques.

New crops were introduced, which both significantly out-yielded the local cowpeas and proved more drought resistant. Most, like mung beans, were nitrogen fixing, soil improving leguminous species. In this famine susceptible arid area, the improvement of food security offered by the new crops is particularly important.

In the trials it was found that crop and forage production could be significantly increased by manure or phosphorus fertiliser applications. It is suggested agropastoralists should rotate the location of livestock night yards around the cropped fields to improve farm soil fertility.

Agroforestry trials have demonstrated that local bush species, including _Commiphora_ spp. and _Balanites aegyptiaca_, can be used to establish living fence hedges around cultivated fields. This technique promises to reduce the destruction to range vegetation caused by farmers continually cutting branches off bushes to maintain dead thorn branch fences around their farms. Preliminary trials indicate that some valuable multipurpose tree species can be established in a hedgerow, multi-storey cropping system; using low input, direct sowing of seed techniques; or by planting seedlings in microcatchments.

It has been shown that small, very low cost, low input rainwater harvesting systems can be used by individual agropastoralists to improve crop and forage production and potentially reduce erosion. Improvements to traditional rainwater harvesting systems are suggested. A trial also demonstrated how rainwater harvesting techniques can be used to speed the regeneration of denuded range areas.

Acknowledgements

The trials outlined in this report were made possible by the considerable dedication, ability and motivation of the CRDP Agropastoral and Extension Department staff. The author would like to thank them for their outstanding assistance and hard work, which was above and beyond the call of duty, and often conducted under very difficult conditions.

The contribution of those most involved in implementing this program, Abdulkadir Abdulahi Yasin (Bashe), Nuur Farah Mohamed, Abdulkadir Hassan Weheliye, Abdulahi Hassan Husein, and Abdikarim Hassan Osman, is gratefully acknowledged.

Many CRDP staff and local agropastoralists contributed greatly to the success of this program and their assistance is acknowledged.

This research and development program was funded by the World Bank, Somali Government and the International Fund for Agricultural Development (IFAD).

During the period the author worked under contract to the CRDP, November 1981 to October 1988, he was employed by the firm John Bingle Pty. Ltd., 175 Rusden Street, Armidale. N.S.W. 2350. Australia. The author wishes to thank the company for its effective, non-bureaucratic support, which contributed to the success of this program.

The views, conclusions and recommendations found in this report are the author's own, and do not necessarily reflect those of the above, or any other organisations or individuals.

Richard M. Holt,
P.O. Box 8341,
Alice Springs, N.T.,
Australia 5750

Tel: 089 525817
Tlx. 121822,
Quote SY0096

CONTENTS

Tables

Page

List of Maps

List of Figures

1.0 INTRODUCTION

1.1 CRDP Agropastoral Program

The agropastoral investigations, research and extension program described in this report were undertaken as a component of a large integrated rural development project, the Somali Central Rangelands Development Project (CRDP). The agropastoral component was not included in the original design of the project; rather it progressively developed during its course to address problems and potentials identified by the project.

The approach and strategy adopted by this development program were flexible and innovative. It is argued that it has considerable promise for application by agriculture, livestock and range development projects in other similar environments. The purpose of this publication is to record the methodology, results and recommendations of the agropastoral research program; so it can be used to guide future development programs, particularly the second phase of the CRDP; and act as resource material for education and training.

The CRDP was designed in response to the 1974/75 Somali famine, which was particularly serious in the project area. The project was appraised in 1979, and commenced operation in mid 1980. Originally planned to last 6 years, it was later extended to December 1988, with some components continuing to 1990. The multi donor $US 46 million project was financed by IFAD, the World Bank, WFP and the Somali, United States of America, German and Australian Governments. The work described in this report was financed by the World Bank, the Somali Government, and the International Fund for Agricultural Development (IFAD).

The original general objectives of the CRDP were to consolidate and improve rangeland and livestock production and the standard of living of pastoralists, particularly through improved range management, water development and veterinary services (World Bank, 1979). The major components of the project were thus range management, livestock health, livestock water development, soil and water conservation, extension (non-formal education and training), and forestry.

An additional objective was to develop the capacity and ability of the Somali Government to manage and develop the rangelands. Other project components thus included staff training, under which a Range Management Department at the Somali National University was established and infrastructural development which involved the building of a headquarters, and regional and district facilities.

Recently, the Food and Agricultural Organisation (FAO) completed a review of the CRDP, and judged it reasonably successful. (CRDP Completion Report, FAO 1988). One component contributing to this success was the agropastoral program. Although not included in the design of the first phase of the CRDP, it is a major component of the second $US 34 million phase expected to commence in early 1989, with financial assistance from the World Bank and the African Development Bank.

The design of the second phase agropastoral program is based on the experience gained in the first phase, which is summerised in this report. The design is outlined in the CRDP II Project Preparation Report (1986, CRDP II Preparation Committee), and the Central Rangelands Research and Development Project Appraisal Report (1988, World Bank).

Although the original CRDP design documents did not even mention the presence of cultivation in the project area, it commissioned a resource survey, conducted in 1979, before the commencement of the project. It provided the first indication that there was a significant amount of cropping in Central Somalia, and that it was closely integrated with pastoralism. (Watson et.al. 1979).

The project's technical team initiated work in the eastern and southern districts of the project area where most of the agropastoralism is located, soon after arriving in 1982. By 1983, extension and ecological investigations had begun to show that a majority of pastoralists in some districts were actually agropastoralists.

The term is used to describe people who practice cropping and pastoralism in an integrated manner. D. Herlocker and A.M. Ahmed, the ecologists who conducted intensive ecological surveys of this area, found that much of the arable bushland and range had been affected more by the cropping cycle than by nomadic livestock grazing. (Herlocker, D. and Ahmed, A.M. 1985).

The project was at a loss how to improve range management in the agropastoral areas, so requested the Extension component, which had the only available agronomic technical expertise, to investigate the production systems and develop recommendations.

Initial investigation results were detailed in a report on agropastoralism in Ceel Dheer District (Holt, R.M. 1985). The agropastoral development program subsequently evolved out of the Extension Department, greatly influencing the approach and strategy adopted. As the project formally had no agropastoral component, it had no resources; so used those of the Extension Department, and relied heavily on assistance from local agropastoralists.

The trial program, begun in 1985, was initially very small, and located on private co-operating agropastoralists' fields. In 1987 the trials were considerably expanded, with the appointment of a graduate and 3 technicians to specifically work on agropastoral development. A series of project controlled trials were initiated in Ceel Dheer, Bula Burti and Ceel Buur districts. On-farm trial/demonstrations too were rapidly expanded, until by mid 1988, the end of the period covered by this report, 25 were underway.

The agropastoral investigations and adaptive trials described in this report suggests ways the agropastoral system can be modified to make it less ecologically destructive of rangeland and more sustainably productive. The program described is interdisciplinary, integrating aspects of rainfed agronomy, soil and water conservation, agroforestry, livestock husbandry, range management and extension methodology.

1.2 General Objectives

The general objectives of the agropastoral program were to improve the conservation of natural resources, the sustainable productivity of agropastoral areas and the welfare, living standard, food and financial security of the local people.

The general unifying hypothesis to be tested by the agropastoral program described in this report is thus:

> *'The conservation of natural resources, the sustainable productivity of agropastoral areas, and the welfare, living standard, food and financial security of agropastoralists can be improved by the introduction of a range of appropriate techniques including; improved crop varieties, a wider range of alternative leguminous crops, anti-erosion strips, more productive pastures and living fence hedges.'*

The many trials described each have a specific objective and hypothesis or series of hypotheses which are treated individually.

1.3 Rationale for the Agropastoral Program

1.3.1 The Problem

During the course of the CRDP, it became apparent that agropastoralism is a much more important land use within the central rangelands than was originally thought by the project designers. Watson (M. Watson et.al. 1979) estimated that cropping was directly providing possibly a third of the food needed by the inhabitants of Central Somalia from 370,000 ha of cropped or recently cropped land.

Intensive ecological studies by the project found that in the agropastoral zones, which cover approximately 20% of Central Somalia, farming is probably as much, or more of an influence on range condition than use by livestock. (Herlocker, D. and Musa, A. 1985, Kuchar, P., et.al 1985, Herlocker, D.1986). Much of the agropastoral zones are in various stages of regrowth following farming, with plant species of low palatability often being abundant pioneers of recent bush fallows.

Extension investigations found that the inhabitants of the sandy agropastoral zone widely believed that many of the inland active sand dune had been formed over the last 200 years by periods of intensive farming followed by drought. (R. Holt, 1985, 1986) Community elders were able to describe how, when and where each sand dune formed, due to a well developed oral system, which records events based on genealogical histories.

While range condition is usually lower near old established major livestock watering points, in the agropastoral zones ground surveys suggested the situation was particularly serious, due in part to the high stocking pressure in this area. A series of ground water bores were established in the sandy agropastoral zone 15 to 25 years ago, and since then active sand dunes had begun to form where farms had been concentrated near to the water point. (R. Holt, 1985) The local communities at such locations including Nooleeye, Jacar, Bargan, Gal Hareeri, Degaan and Haradhere were very concerned about this problem and requested assistance from the project.

Trends were also disturbing. Many more water bores were being drilled or planned, and there was a widespread belief amongst local communities that agropastoralism was increasing, with larger areas of land being enclosed privately.

1.3.2 Integration of Range and Agropastoral Development

Within the agropastoral zones, farms are scattered throughout the rangelands. Much of this rangeland is a mosaic of old farms, at various stages of regrowth. Almost all farmers are also pastoralists, owning livestock. They graze their animals both on the farms, and on the surrounding rangelands in an integrated manner.

The rangelands are grazed during the wet seasons when feed is abundant, then the high quality crop residues are consumed after harvest. In the late dry season, when there is little palatable range vegetation left to consume, the farmers' livestock graze the agropastoral enclosures. The enclosures thus act as private seasonal reserves. The agropastoralists' livestock thus require access to the farms.

The project implementers were thus faced with a dilemma. Agropastoral practices were apparently causing deterioration in the condition, and thus the productivity of rangelands, yet the project did not know how to fulfill its objectives and improve range condition and sustainable productivity of the agropastoral areas.

In non-agropastoral range areas, the project was developing large grazing reserves in an attempt to fulfill these objectives, however these could not practically be implemented where the inhabitants depended on an integrated farming / livestock system for their livelihood. It thus became apparent to project management that the only practical way to improve the condition of the rangelands in agropastoral zones was through improvements to the farming system.

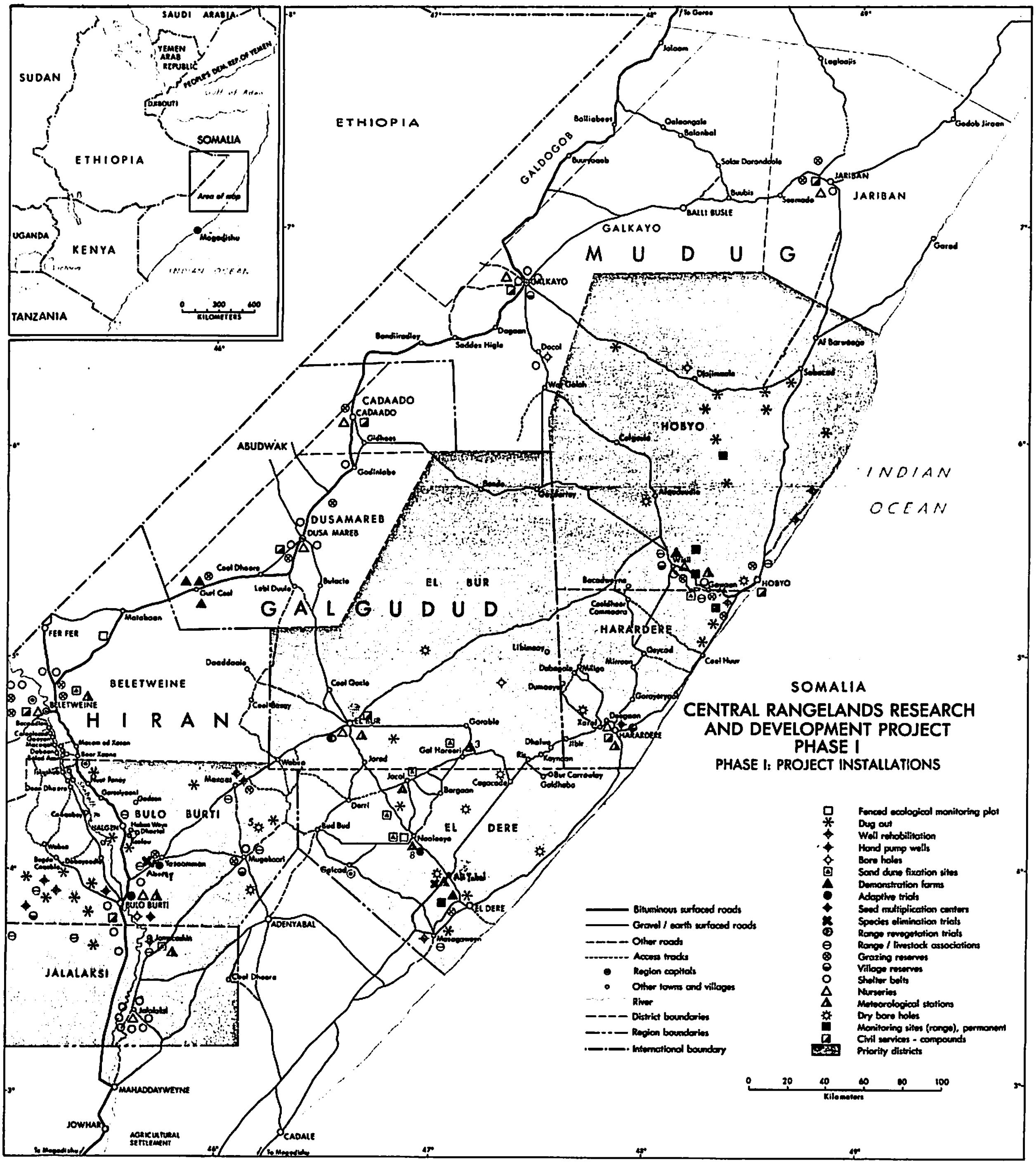
1.3.3 Development Potential Created by Agropastoralism

The agropastoral system has many opportunities for development. Agropastoralists are able to control the stocking rate inside their fenced enclosures. Many technologies such as improved pastures, agroforestry and soil conservation measures thus become possibilities.

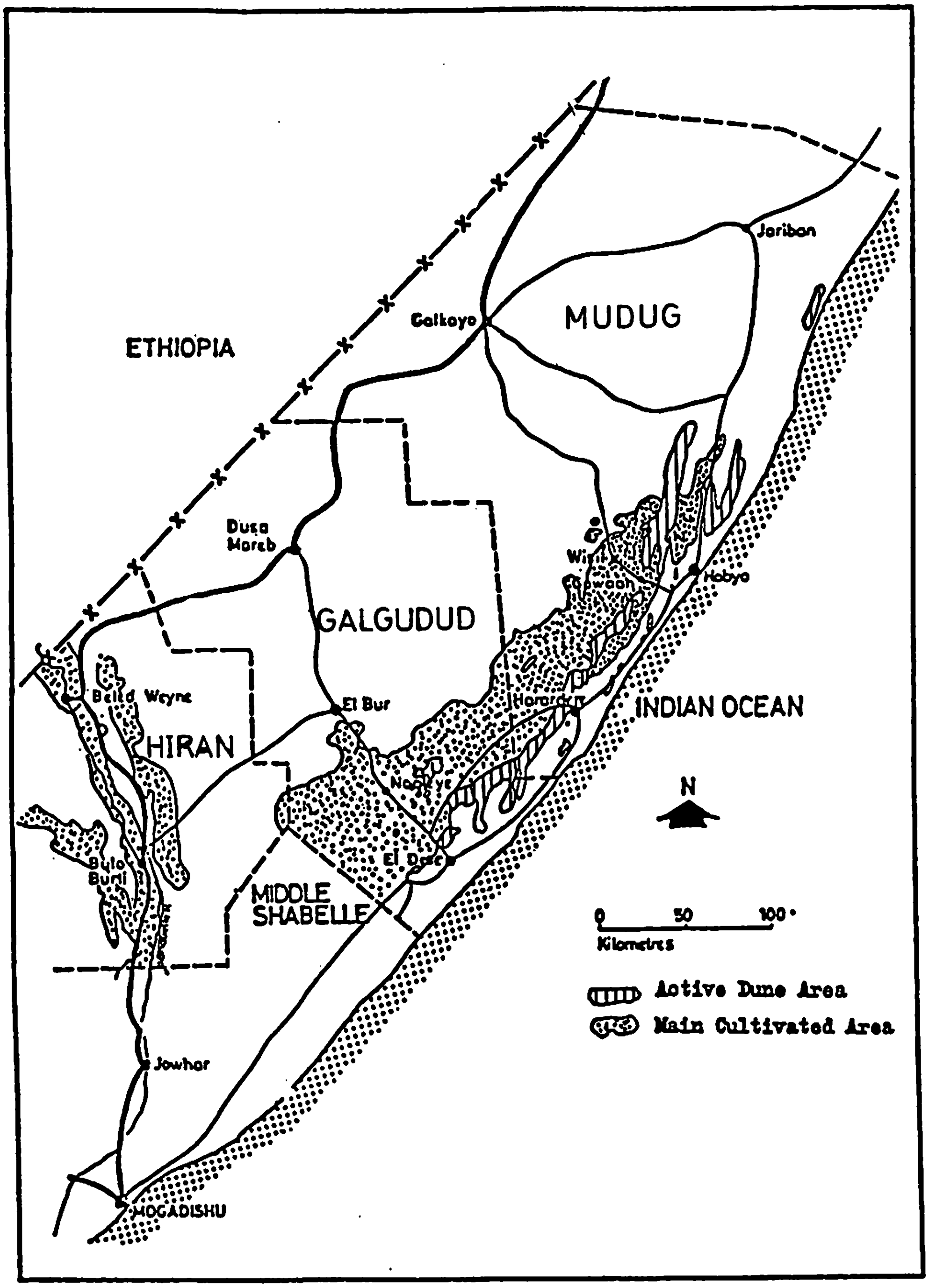
As agropastoralists own the land privately and can pass it onto their descendants, there is also an incentive for families to conserve and improve the sustainable productivity of this land, if they are shown how. Agropastoralists are also more sedentary than pastoralists, and thus easier for extensionists to contact.

Early contact with agropastoralists suggested many were motivated to try promising innovations. Once they accepted technology which benefited them, this should be sustained without external support. The role of the agropastoral program was thus to take advantage of this development potential, fulfilling the project's objectives by identifying and disseminating suitable technology which would be adopted by agropastoralists.

Map 1: Location of the Central Rangelands Development Project



Map 2: Location of Regional Boundaries, Main Cultivation Areas



Source: Adapted from Watson et. al 1979 and Holt 1986

2.0 AGROPASTORAL ZONE ENVIRONMENT

2.1 Location

The CRDP area, as shown on map 1, is located in the central portion of Somalia, between latitudes 3 degrees 10 minutes north, and 7 degrees 40 minutes north, and is bordered on the east by the Indian Ocean, and to the west by the defacto border with Ethiopia. It encompasses an area of almost 160,000 square kilometres, which is just over 25% of the country's land mass.

The project area consists of 3 administrative regions, Mudug, Galgudud and Hiraan, as shown in map 2. The agropastoral zones are located in areas with arable soil and higher rainfall. There are 2 main zones, as shown in map 2.

The sandy agropastoral zone is located in a 50 to 100 km wide strip of land parallel to the coastal plains along the eastern boundary of the project area. It extends from 70 km north of Hobyo port south west to the southern boundary of Ceel Dheer district. It actually continues uninterrupted at least another 300 km south west outside the project area to the national capital, Mogadishu.

The Hiraan agropastoral zone, the other main agropastoral area, is located in Hiraan region. It is generally characterised by having heavier soils and a higher rainfall than the sandy agropastoral zone. In these agropastoral zones, which together comprise about 20% of Central Somalia, 1 to 25% of the land is currently in a cultivation cycle.

There are very low densities of cultivation over most of the rest of Central Somalia, however these are usually associated with settlements or localised depressions. Even the edges of active sand dunes are cultivated. The only areas with no cultivation are the sandy coastal plains, some areas with dense surface limestone and the extremely dry far north. The areas with Yicib, *(Cordeauxia edulis)* a highly valued evergreen shrub, have also traditionally not been cultivated.

2.2 Climate

2.2.1 Rainfall

As with other components of climate, there is little reliable, quantitive data available on rainfall in Central Somalia. The CRDP had planned to improve this situation by establishing a network of automatic climate recording stations in the project area, however, these did not arrive until mid 1988.

Watson et.al. (1979) summarised available climate data during his resource survey of Central Somalia. Table 1 lists annual rainfall records from ten villages in Central Somalia, and Map 3 depicts Watsons' estimate of the rainfall distribution based on available information.

The climate is arid to semi-arid, with the annual rainfall varying from an average of 100 mm. in the north to 300 to 350 mm. in the south. Of apparently critical importance to determining the location of agropastoralism, a spur of higher rainfall, from 250 - 350 mm. extends in a strip north east just inland from the coast to north of Hobyo port. This strip of higher rainfall appears to be, at least partly, associated with an escarpment 200 - 450 mm. high located about 20 km. from the coast.

This area includes most of the sandy agropastoral zone. Similarly almost all the Hiraan agropastoral zone is located in the higher 250-350 mm. rainfall area.

Table 1: Rainfall Records for Stations in the Central Rangelands.

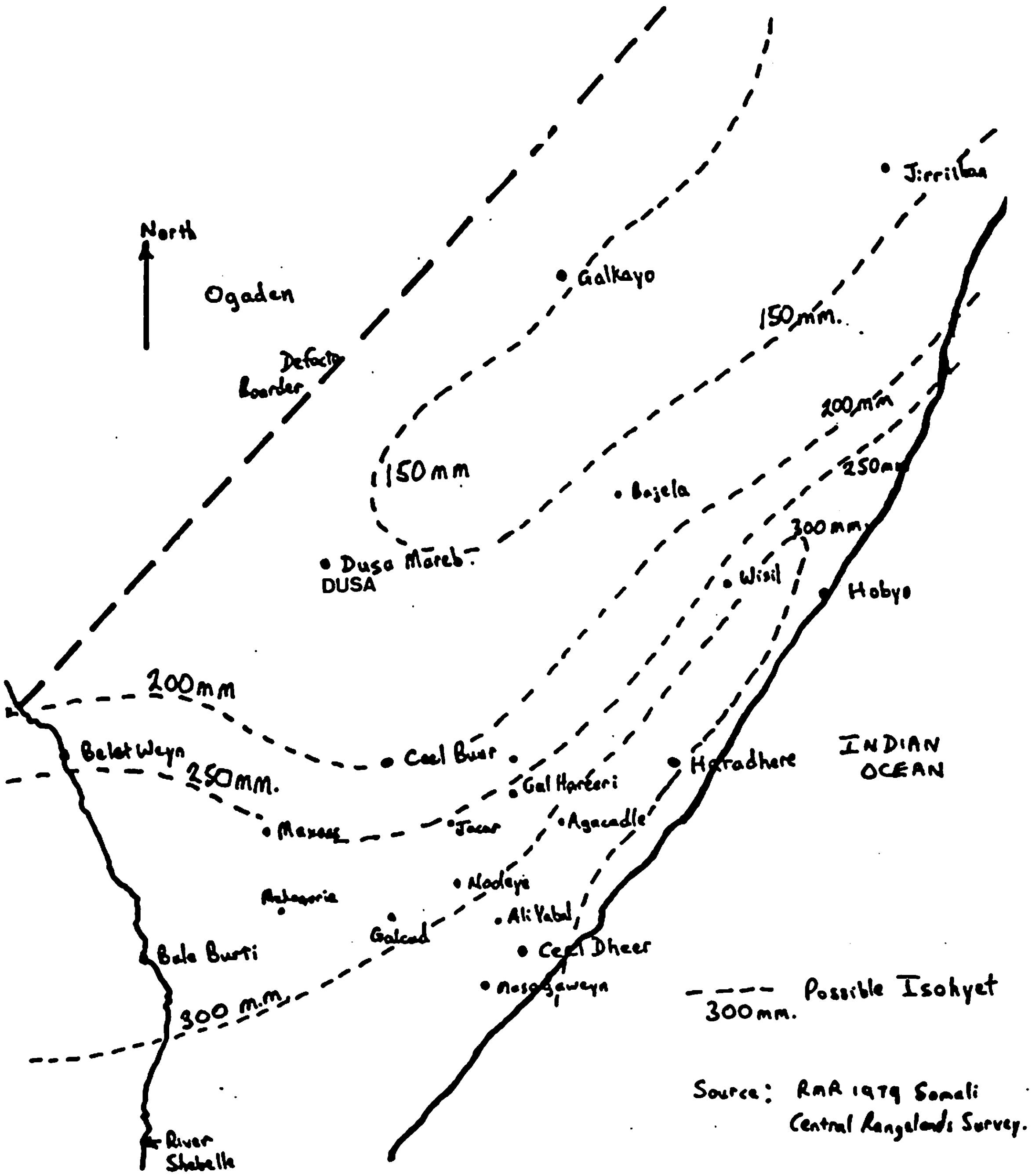
Station	Altitude	No. of yrs with complete record	Period	Mean Annual rainfall	Wettest year	Driest year
Belet Weyne	182	39	1926-76	248	553	44
Beyra	328	5	1953-58*	220	373	93
Cadaado	315	5	1953-58*	123	327	28
Ceel Buur	150	28	1930-76	191	408	20
Dhuusa Mareeb	253	5	1953-58*	126	250	15
Galinsoor	340	6	1953-58*	115	221	21
Galkayo	285	15	1933-58	154	448	33
Hobyo	12	15	1954-76	224	447	81
Mareer Guur	273	4	1953-58*	109	182	58
Matabaan	428	5	1953-58*	136	247	44

Note 1: The period 1953-58 falls in a dry spell and these means, even assuming perfect records, will be below the long term mean.

2. The period 1958-76 seems to have been wetter than the 1926 -1958 period.

Source: Watson et.al. 1979

Map 3: <u>Rainfall Distribution in Central Somalia</u>

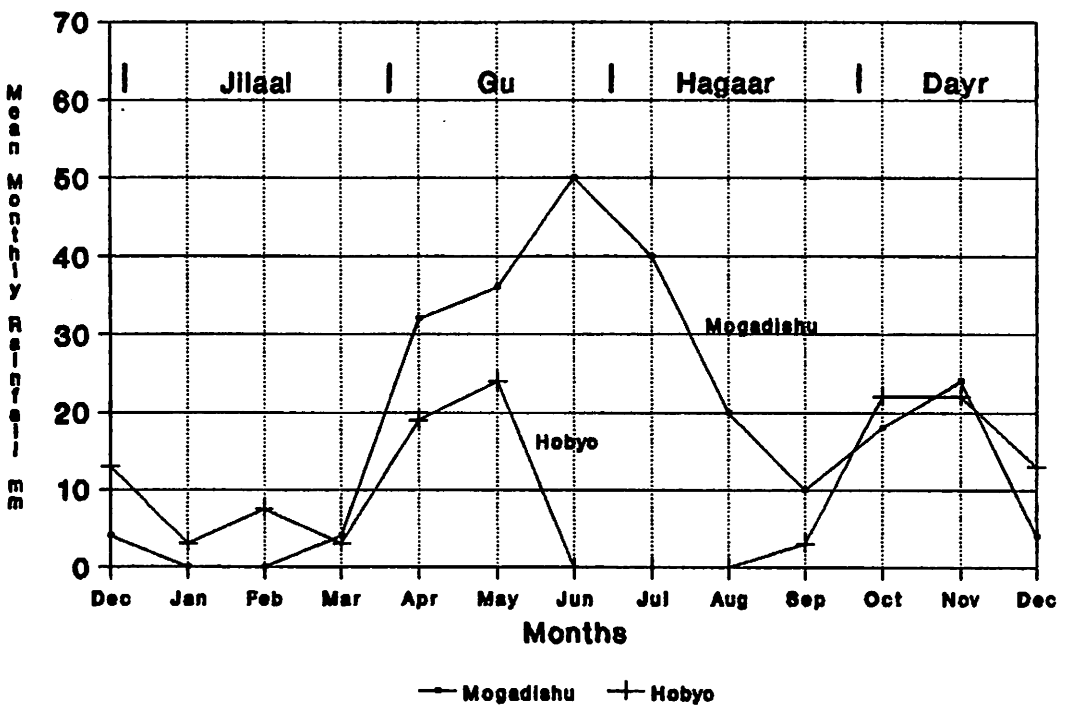


The rainfall is also erratic, a typical characteristic of arid areas. This is demonstrated by the example of Ceel Buur township, the site (3 km away) of one of the range regeneration trial described in this report. As shown in table 1, over 28 years, the mean annual rainfall was 191 mm, however, the wettest year had 408 mm, and the driest, 20 mm. Personal observations over 7 years, and opinions gained from many agropastoralists suggest this variability is not so extreme in the higher rainfall agropastoral areas.

In Central Somalia, there are two distinct wet and dry seasons each year. Agropastoralists thus have a chance twice a year to produce a crop, which is considered a very important factor in determining the viability of cropping under these marginal conditions. In other hot tropical areas, it is rare for cropping to extend into such arid areas. Similarly, the bimodal annual rainfall pattern is felt to be a major factor allowing the rangelands to carry the abnormally high stocking rates.

The monthly distribution of rainfall for Hobyo port, in the project area, and Mogadishu, the national capital 300 km to the south of the project, are shown on figure 1.

Figure 1: Mean Monthly Precipitation, Hobyo and Mogadishu 1955-74



Source: Adapted from UNSO 1984.

The annual distribution of rainfall throughout Central Somalia resembles the Hobyo situation more than Mogadishu, with the main rainy seasons being the March to June Gu season and the October to December Dayr season. In most of Central Somalia, the Gu season rainfall is slightly higher, more reliable and extends longer than the Dayr season. It typically though is not as extreme as at Mogadishu and in much of southern Somalia, where the Gu season rainfall is much higher.

The most extreme dry season is the Jilaal, which extends from December to late March, usually with no rainfall. The less severe dry season, the Hagaar extends from July until September.

In the southern and eastern part of the project area, particularly near the coast, Hagai showers sometimes fall during the Dayr season, which promotes the valuable ratooning of crops, and growth of green forage for livestock.

Table 2: Seasonal Rainfall at Agropastoral Adaptive Trial Sites.

Rainfall Recording Site	Seasonal Rainfall, m.m.							
	1985		1986		1987		1988	
	Gu	Dayr	Gu	Dayr	Gu	Dayr	Gu	Dayr
Nooleye (Ceel Dheer District)	-	-	77	124	291	189	108	27
Ceel Burr Trial (3 km SW Ceel Buur)	-	-	-	-	-	-	152	121
B/Burti Fodder Site Trial (2km N. of B/Burti	-	-	-	-	153	124	129	20
Aborey Trial (Bula Burti District)	-	-	-	-	142	111	192	5
Ali Yabal (Ceel Dheer District)	-	-	-	-	294	181	175	10

Figure 2: Wind Regime at Hobyo (1955-57 and 1967-72)

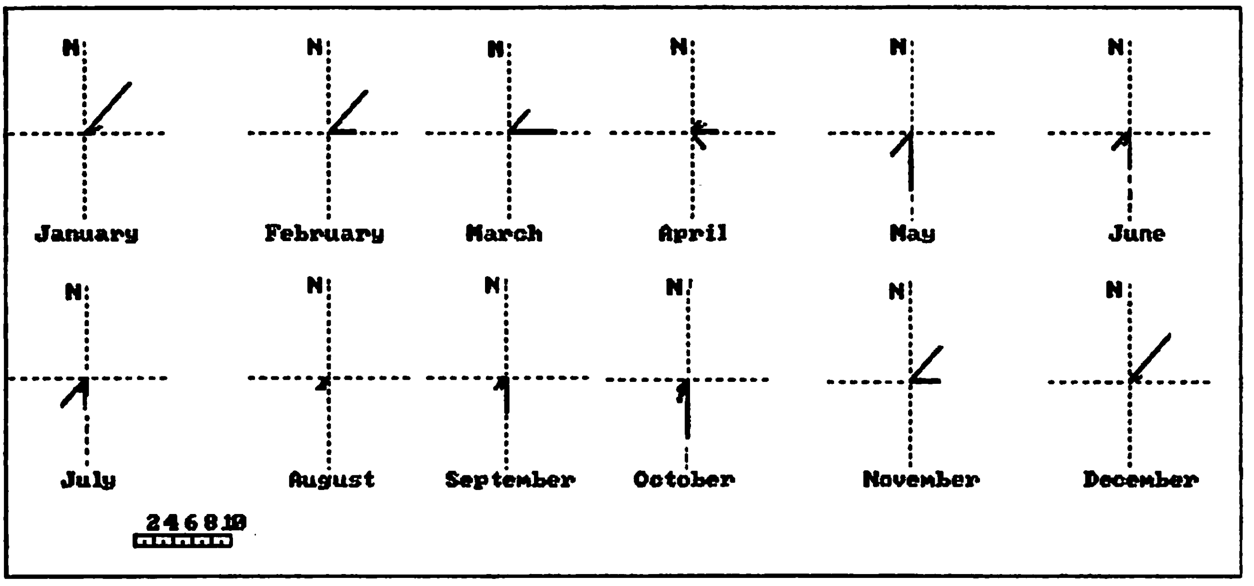


Figure 3: Monthly Wind Velocity at Hobyo, (1954-1976)

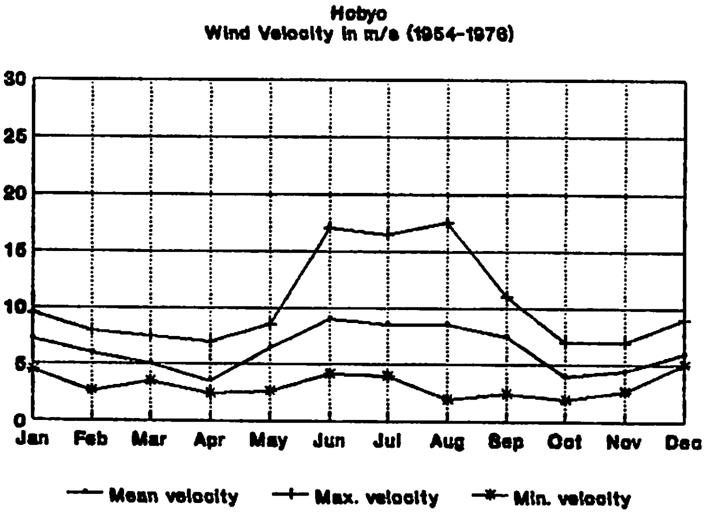


Figure 4: Wind Regime at Mogadishu (1954-1976)

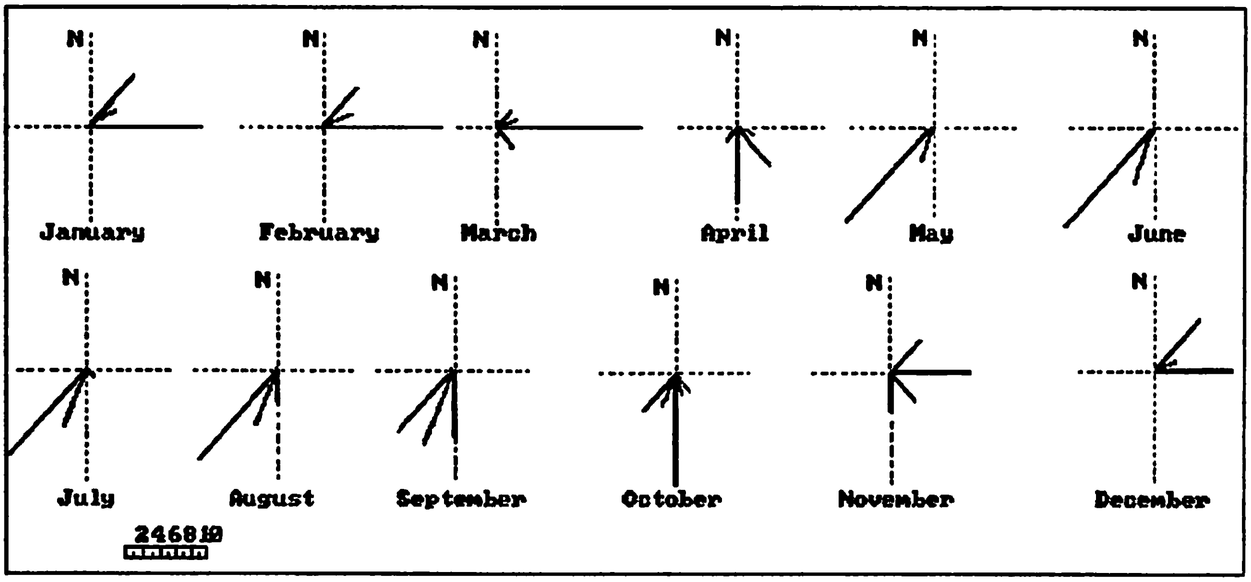
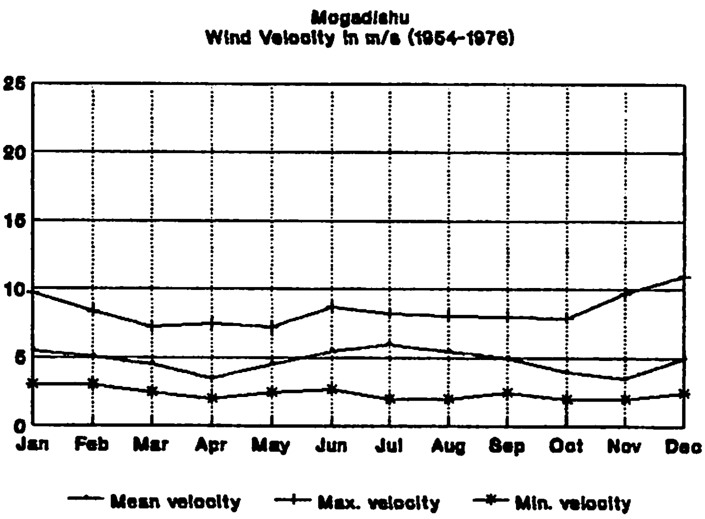


Figure 5: Monthly Wind Velocity at Mogadishu, (1954-1976)



2.2.2 Wind

Wind is the most serious erosive force in Central Somalia, particularly in the agropastoral zones. Current agropastoral practices often stimulate serious wind erosion, especially in the sandy agropastoral zone, where clearing, weeding and grazing strips the highly erodable soil of natural protection. The agropastoral program thus focused on techniques to reduce wind erosion, although in localised areas of the Hiraan agropastoral zone with some slope, water erosion alleviation techniques were tested too.

Central Somalia is generally a relatively windy area, with the strong north-east monsoon dominating the area during November to March, and the even stronger south-west monsoon being the prevailing wind from May to October, as shown in figures 2 to 5. There are two short interseasons from March to April and October to November when the wind speed declines considerably, and the direction turns around through the east.

The potential of the wind to cause erosion in Central Somalia is dramatically illustrated by the monthly maximum wind velocities at Hobyo (figure 3) and Mogadishu (figures 5). In Hobyo they range from 6 metres/sec. in the interseasons to 17 m/s in June to August. In Mogadishu the range is from 7.5 to 11 m/s (at 2 metres above ground level).

Significant wind erosion usually requires a wind speed of 6 to 7 m/s. Then erosion rapidly increases with wind velocity: a wind speed of 16 m/s, for example potentially eroding eight times more sand than a speed of 10 m/s, (Bagnold, 1941) and 10 m/s four times more than 7 m/s (Bagnold, 1941).

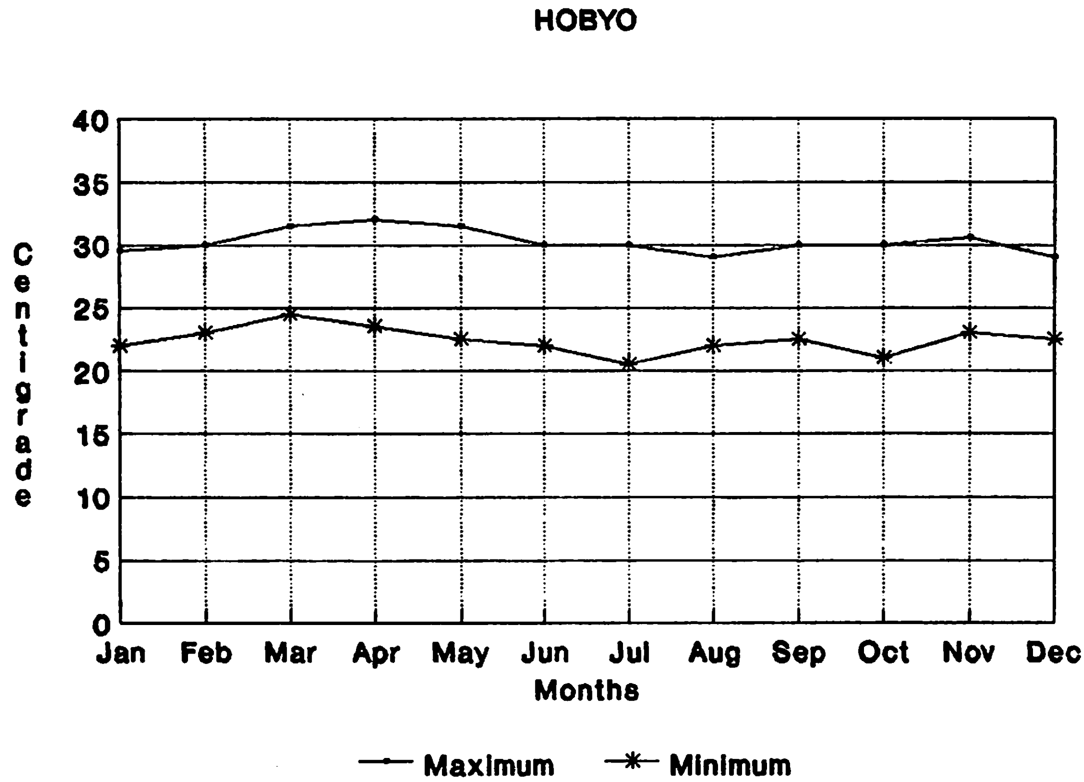
During the windy seasons, the wind velocity at Hobyo is constantly high. As shown in Figure 3, the monthly mean wind velocity is above 6.5 m/s during May to September and December to January. While wind speeds are probably a little lower in the agropastoral areas than at Hobyo, the potential of wind as a major erosive force in the area is clearly illustrated.

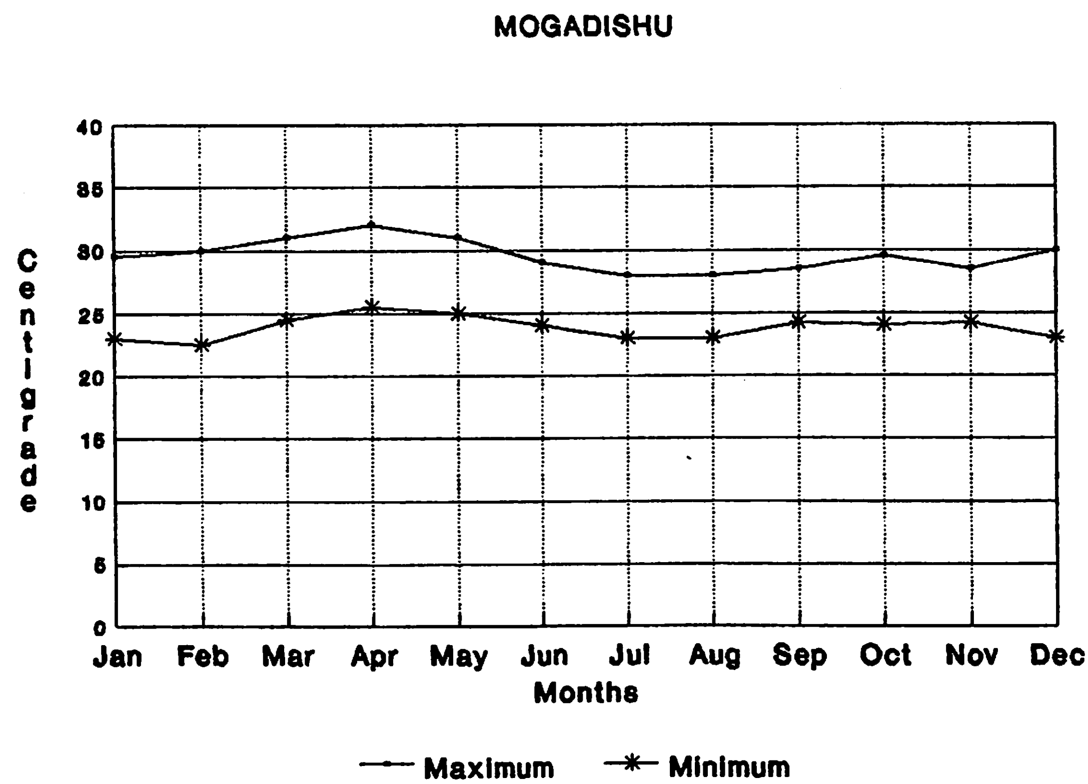
2.2.3 Temperature

As Central Somalia is located only 3 to 8 degrees north of the equator; and the elevation is relative low - only 0 to 450 metres above sea level; temperatures are high throughout the year. The monthly mean maximum temperature varies from only 29° to 32°C and the monthly mean minimum temperature varies from 20° to 24°C at Hobyo, as shown in figure 6. The pattern is very similar at Mogadishu too (Figure 6); however both these sites are on the coast, and the climate is less mild inland in the agropastoral areas. Spot recordings by the authorities indicate that maximum temperatures are higher, and minimum temperatures lower by at least 2° to 3°C inland.

There is a slightly cooler period in mid year from June to September and to a lesser extent from November to February.

Figure 6. Monthly Mean Temperatures for Hobyo and Mogadishu





2.2.4 Humidity

One of the distinctive features of Central Somalia, is that the relative humidity is constantly high throughout the year despite the aridity of the climate. At Hobyo and Mogadishu the mean monthly relative humidity stays between 70 and 80 percent all year long. (UNSO 1984) Undoubtedly, the proximity of the ocean and sea breezes would tend to increase the level and moderate changes in the humidity at these coastal sites, and conversely, inland the humidity would often be lower and more variable.

There is clearly a need to obtain reliable quantitative climatic data throughout Central Somalia to guide future research and interventions. Such recordings should include evaporation rates for which no information could be located.

2.3 Physiography and Sand Dunes

Central Somalia is principally a relatively flat, featureless plain; rising slowly from the Indian Ocean north-west towards the Ethiopian border; where the elevation is 300 to 400 m. In the far north-west, the land rises slightly faster, to a height of 600-700 m. In the south-west, the Shebelle River; which originates in Ethiopian Highlands; flows south through a wide valley, lined in places by an abrupt escarpment.

The only other significant geographic feature is a 200 to 450 m. high limestone and sand ridge lying about 30 km inland from the coastline, which extends from the southern boundary of the project area north-east to peter out 80 km north of Hobyo township. This ridge, which actually extends through southern Somalia, past Mogadishu, 500 km south-west to Kisamayo, effectively blocks the natural inland drainage patterns from flowing into the sea. Even the Shebelle River is diverted south-west near Mogadishu by the ridge, and only occasionally flows into the sea near Kisamayo.

By blocking the natural south/south-east drainage channels, the ridge has caused the formation of some small salt lakes and developed gypsic and anhydrite soil inland from the ridge.

Active sand dunes are one of the distinctive features of the central rangelands. There are approximately 3,500 square kilometres of active sand dunes in Central Somalia, about 70% of Somalia's total. These sand dunes attract a lot of political attention as they are a very obvious manifestation of desertification.

In localised areas too, they cause economic damage and hardship, blocking roads, covering houses, wells, farms, rangeland and polluting the air.

There are 3 main active sand dune areas. Firstly there are relatively small coastal barkan, crescent type sand dunes on the coastal plans. They are composed almost completely of limestone particles, and originate from the shore. These can be clearly seen from the air to be moving in a net northerly direction inland, where eventually they join the limestone ridge.

Along the limestone ridge lies the second and main active sand dune zone, the extensive sand dune fields. They are a mixture of silicious orange sand and white calcarious sand originating from the shore. The two main sand fields in the central rangelands, as shown in map 2, are each about 100 km long and 5 to 15 kms wide. Like the other sand dunes in central Somalia, they move from a few metres to 500 metres (observed by the author near Gowan) each year in a net northerly direction, due to the dominating influence of the strong south-west monsoon.

The third sand dune category are smaller continental type, orange coloured, silicious sand dunes, often with a barkan shape; which are recently reactivated sand dunes, situated inland to the west of the ridge within the agropastoral zones.

The unusually strong prevailing winds in central Somalia are a major factor causing the formation of the dunes. The fine sandy soils, are also highly susceptible to wind erosion. Under natural processes though, plants and algae usually stabilise the dunes; however, if their protective influence is destroyed by overstocking, cultivation or other disturbances, the dunes are re-activated.

While the formation of the coastal dunes is a natural process, it appears the process is being exasperated by the heavy stocking and resulting poor range condition along the coastline, due to the presence of numerous livestock water wells. These dunes migrate to feed the inland sand fields.

Wind erosion in the inland sand fields is also stimulated by localised overstocking often associated with shallow wells which are located in small perched aquifers fed by rain absorbed by the sand fields. This process can be observed at sites like Degaan and Bacaad Weyne in Haradhere district.

Numerous observations and discussions with local agropastoral elders confirm that shifting cultivation is also contributing to the activisation of the sand fields. It is not known, however, whether the sand fields are currently increasing in size. It has been planned that the second phase of the CRDP will determine this using serial aerial photography and satellite imagery.

The smaller, inland continental sand dunes, such as those in the Bargan, Gal Hareeri, Jacar and Nooleeye areas of Ceel Dheer district, and Dumaaye area of Haradhere district, have all been caused by shifting cultivation and associated grazing practices over the last 200 years, according to the local inhabitants. Observations by the author, who has seen active dunes form there over the last 7 years, tend to confirm this view. This was one of the findings of the CRDP extension surveys which instigated the agropastoral program.

2.4 Soils

There are no relatively great geographic or climatic differences within central Somalia, except to some extent rainfall. Rather it is differences in soil type, which have a profound influence on the creation of land use systems, ecological zones and arable areas. As with other components of the environment, there has been no comprehensive scientific study of central Somalia's soils. The following characterisation is based on Watson's resource survey (Watson et.al. 1979) and subjective observations.

Shallow Sandy Soils

Generally the most common soil type, they are shallow, sandy, slightly alkaline, with a middle and upper Eocene limestone base, and are white to orange, reddish brown in colour. They cover much of inland central Somalia. There are many sub soil types.

In some localities the soils are very shallow with massive limestone rocks covering 10 to 50% of the surface. Some of these 'dagaar' (stony) orange sandy soils are cultivated, as for example in the area between Wabho, Ceel Buur, Deri and Bud Bud in Ceel Buur and Ceel Dheer districts, where small, more sandy areas are cleared and opportunistically cropped. In the drier areas to the north though, it appears not to be worthwhile to cultivate this soil type.

Another sub-type is the 'carro cad' (white soil), which is considered the most fertile of the sandy soils. It is the most intensively cultivated soil type in the sandy agropastoral zone. This soil type is located in a north-east, south-west strip parallel to the coast, inland from the coastal ridge; although it is not distinct, often grading into the less fertile orange sandy soil.

The white sandy soils, which are typically found in the Nooleeye, Bargan and Gal Hareeri areas, are calcareous, usually 1 to 3 metres deep, and overlay limestone gravel parent material, rather than rock. This is the soil type at the Nooleeye agropastoral trial site. It is highly susceptible to erosion once disturbed, having a more fertile 'A' horizon composed of finer sand particles, organic matter and silt. The surface is often bound by algae/fungal filaments in the undisturbed state. Cowpea (*Vigna sinensis*) is the crop which thrives in this area, and the Ceel Buur. Cowpeas (digir) are a famous export to other regions of Somalia.

The carro-guduud (orange/reddish sand) soil type is another important sub soil type. It is typically found in inland areas of low stabilised sand dunes. While it is characteristically at least as deep, or deeper than carro-cad, the sand particles are mainly quartz, reflecting its origin. The soil basement in this case is usually massive limestone rocks within 1 to 3 metres of the surface, and occasionally outcropping. The carro-guduud soil type is widely considered by agropastoralists to be less fertile than the carro-caad soil, although it is still often cultivated.

The coastal plain soils (the 'deex' soils) are white, calcareous, very sandy soils of coastal origin. They are typically loose unstructured sands with few fine particles, and have a very low water holding capacity. They are not cultivated.

Deep Sandy Soils

The ridge lying to the west of the coast plain is usually covered by a deep, fine grained, silty and sandy, orange coloured soil, which is highly susceptible to wind and water erosion. It has been cultivated for hundreds of years, although agropastoralists do not consider it as fertile as the carro-caad soil. The Ali Yabal tree species elimination and growth trial is located in this soil type.

A large area of eastern Hiraan region is dominated by the deep Haud type, orange-to-reddish, sandy loam soil. It has coarse to medium sized quartz sand particles, with some silt and clay. This area has traditionally not been cultivated. Watson (1979) has suggested that the southern area of this soil type, lying in Jalalaksi district, has potential for cultivation. It is not known whether the soil is fertile enough to support cultivation. Elsewhere this soil type is dominated by the valuable fodder/food bush, Yicib, (*Cordeauxia edulis*) which requires preservation.

Between this soil zone and the Shebelle valley to the west is a band of deep alluvial, orange, fine-to-coarse quartz sand, which is very mixed, as it originated as alluvial fans washed down from the Yasoman sandstone escarpment. It is mixed in a complex with sandy loam and orange/brown alluvial, silty clay soils.

This soil complex is often cultivated; usually with the aid of traditional runoff rainwater harvesting techniques. The area around Aborey, the site of a tree species elimination and growth trial, and a water harvesting crop species trial, is dominated by this soil type. The sandy loam soil at the Gowan agropastoral trial site, near Bula Burti is a similar alluvial soil type. They have a long history of cultivation, are generally slightly alkaline, and the lighter soil sub-types are not very fertile.

Gypsum and Anhydrite Soils

These soils are only cultivated in localised depressions, or near settlements. They range from shallow sandy gypseous silts, through to alkaline saline gypseous clays, mixed with silts. The latter is the soil type at the Ceel Buur range regeneration trial site.

Clay Soils

Various types of arable clay soils are common in Hiraan region. The Shebelle valley alluvial plain has a range of deep pale, silty clays, and clay loam soils, derived from limestone and gypsum. They are typically alkaline and saline. They have been periodically cultivated and heavily grazed for at least 300 to 400 years, and are often in a degraded, infertile state. This is the soil type at the Ugg agropastoral trial site near Bula Burti.

In western Bula Burti and Belet Weyne district is a relatively fertile zone of dark, chestnut-brown silty clays which are often mixed with lateritic gravel and basalt. These soils often have a cracked surface. Over the last 20 years, there has been a rapid expansion of cultivation in this zone.

In western Belet Weyne district is a large area of very deep fine silty clay loams and silty clays. There is little cultivation of this soil type.

2.5 <u>Water</u>

To reduce work and improve quality of life, agropastoralists tend to congregate as close as practical to good supplies of quality livestock and human water resources. Thus the distribution, abundance, quality and permanence of water supplies influences the density and locality of cropping.

<u>Surface Water</u>

Surface water supplies are not abundant in central Somalia, with the Shebelle River being the only permanent river/stream. Other streams run for a few hours each year. There are some natural seasonal water ponds ('ballis'), mainly in Galgudud and Mudug regions, which store runoff water for 1 to 3 months in some wet seasons. These promote some opportunistic, localised shifting cultivation.

<u>Groundwater</u>

The main source of drinking water throughout central Somalia is groundwater, although even these are more than 20 kms apart in some areas. Shallow hand-dug wells, up to 35 m. deep are the most important water source. Most are permanent, although some are only seasonal, particularly in the drier areas. The most dense concentration of these wells is along the coast line, where a shallow lens of brackish water floats on top of sea water on the edge of the beach.

Historically camel trains were used to haul water 50 - 100 kms inland to supply drinking water to agropastoralists tending crops during the growing season. Now however, there are many water bores in the central rangelands. They have encouraged recent sedenterisation and the concentration of cultivation nearby. There are only a few springs in central Somalia, and these are not in arable areas.

Flooding

Some limited, opportunistic, flood recession agriculture is practised along the banks of the Shebelle river, and when it floods over the banks. In the last 2 years, a recently built flood diversion channel has diverted floodwater into western Jalalaksi district, stimulating a large increase in flood recession cropping.

Rainwater Harvesting

In Hiraan region, agropastoralists have traditionally practised runoff rainwater harvesting and flood water harvesting to increase the water available for crop growth (Holt, 1987 Oct., Dec.). This practice is outlined in section 5.8.

2.5 Vegetation and Wildlife

The rangeland vegetation varies from a dwarf shrub grassland in the arid north, to dense woodland in the higher rainfall south/south-western areas. Characteristically, it is a browse area, with woody plants providing much of the palatable available fodder. Grasses and herbs though, are locally important, particularly on the coastal plain, which is dominated by a productive, dense, dwarf herb grassland.

Generally the rangeland vegetation is woody, deciduous and thorny. There is a particularly large number of tree and bush species in most range sites, and strongly dominating species are uncommon. The woody species appear to be particularly resilient and well adapted to heavy grazing pressure.

Range condition is overall fair, ranging from poor, near water points, to very good in understocked areas at least 15 kms from water points. After studying the vegetation of Hiraan and Galgudud regions for 6 years, the CRDP ecologists Peter Kuchar and Dennis Herlocker feel the high livestock numbers are causing a steady decline in range condition. (personal communication, 1988).

Wherever cultivation has been practised, the composition of the rangeland vegetation is greatly affected for at least 20 years into the fallow period. It became increasingly apparent during the course of the CRDP, that much of the existing arable bushland was actually secondary regrowth in some stage of a bush fallow, following cultivation. As the fallow period is usually at least 30 years, often 50 years or more, trees are fully mature and plant succession well advanced.

Detailed descriptions of the range of vegetation have been published in the CRDP Technical Report Series by Herlocker, Kuchar and Nailer. A description of typical plant successional stages following a cultivation cycle in the *Acacia nilotica* range site in Ceel Dheer has been published by Herlocker and Thurow (19XX).

Wildlife resources have been greatly reduced over the last 90 years, with species such as giraffe, elephant and rhinoceros no longer present. In 1979, Watson estimated from aerial surveys that larger wildlife species were 1.3% of the total livestock/wildlife biomass. These species include Spekes Gazelle, plentiful on the coastal plain; Ostrich, Sommerings Gazelle and Warthog.

Representatives of most of the original scavenger species are still present, though greatly reduced in numbers due to shooting, trapping and poisoning. These include lions, hyena and jackals. The second phase of the CRDP plans to establish 4 wildlife conservation areas to protect rare and other wildlife resources (World Bank, 1988). These are all in uncultivated areas.

2.7 The People and Their Organisational Structures

The people who inhabit central Somalia, the Somalis, are relatively homogenous, all speak the same language, have a similar culture and social system and all are Muslims. They ethnically and culturally belong to the Hamitic (Cushitic) ethnic group. (Lewis, I., 1980)

There is generally no ethnic or cultural difference or barrier between the agropastoralists and the more numerous pastoral herders. Pastoralists often become agropastoralists and vice versa.

An exception is found in the area along the river Shebelle, where the riverine people are of non-Somali origin. Their origin is not clear, although one theory is that they descent from Bantu slaves. (Kaplan 1977). They are mainly agropastoralists or farmers, speak Somali and are also Muslims.

The population of central Somalia is estimated to be approximately 750,000; based on Watson's 1979 central Somali survey; and his 1985 survey of southern Somalia, which included 10,000 square kilometres of western Hiraan region not included in the earlier study; and projecting for population increases.

Information on the proportion of people who practice agropastoralism is ambiguous, but is estimated to be about 30 percent, or 225,000. In some arid districts such as Jiribaan, Beyra and Abudwak, there is virtually no agropastoralism; most people are nomadic pastoralists, and even the number of people settled in villages is small. CRDP Extension surveys indicate that in arable districts including Ceel Dheer and Haradhere, at least 70% of the livestock-owning population are agropastoralists.

Historically a number of Somali ethnic groups inhabited central Somalia, and much of the social organisation evolved around these groups. With independence and the unification of the country in 1960, tribalism was outlawed, and government institutions and services were strengthened (Lewis, I., 1980).

Somalia is however, one of the poorest of the lesser developed counties, so it has been difficult to allocate sufficient resources for the state to build effective, strong, local organisational structures.

Local institutional frameworks can greatly facilitate development programs. The agropastoral program thus established and maintained regular contact with a number of such institutions; including local district governments, the Party, village committees, government representatives in communities, ('Nabadons'), Muslim religious groups and individual sheiks; and last, but not least, an informal network of respected community leaders.

Some elected representative organisations of the local pastoralists, Range and Livestock Associations (R.L.A's - Holt, 1986) were formed by the CRDP; however, these were primarily developed to manage grazing reserves and were never strongly developed in agropastoral areas.

2.8 The Economy and Infrastructure

The economy of the central rangelands is dominated by the livestock industry, with cropping having a lesser, though crucial, integrated role. It is primarily subsistant in nature, though is becoming increasing market/commercial orientated. Over hundreds of years the Somalis have developed a system to maximise their chance of survival in the harsh, drought prone arid environment.

Most families in central Somalia own four species of livestock; camels, goats, cattle and sheep, to minimise their exposure to the effects of droughts or diseases, and to more fully exploit the range vegetation. Similarly, risks are reduced and the chance of survival increased by producing extra food from shifting cultivation, when the opportunity presents itself.

An additional advantage of cropping in such an environment, is that the food can be stored relatively safely (in the case of sorghum and millet) for years as an insurance against frequent droughts.

The most important food is generally milk, produced mainly by the camels and cattle. This is supplemented by occasional meat, and more importantly, sorghum and cowpeas. The sorghum and cowpeas, if not grown by the family are purchased in small local markets.

Sugar, wheat flour and edible oil are also important purchases, and in the south, maize and millet too are often consumed. Finance for these and other requirements such as clothes, medicines and schooling, comes from selling livestock, to a lesser extent milk, and in the case of agropastoralists, surplus crop production too.

In good seasons, considerable quantities of cowpeas and sorghum are exported to other regions; especially Mogadishu, according to CRDP extension surveys. Cowpeas are an important seasonal trading product; because they are a major crop; and due to their short storage life, which encourages producers to sell them quickly. This is reflected in the price, which is usually twice as high in the late dry season and early wet season, than a few months later at harvest.

Central Somalia is a net importer of food grains, particularly rice and wheat products (flour, spaghetti), and an important exporter of livestock. All the wheat, and much of the rice and edible oil has to be imported from overseas, using scarce foreign currency. Local crops to some extent replace these imports as alternatives.

The infrastructure of central rangelands is poorly developed and is a serious constraint to development. The one sealed highway extends from Mogadishu, north along the Shebelle river to Belet Weyne; then north-east, connecting the other 2 regional centres - Dusa Mareb and Galkayo - on the way to northern Somalia. This road provides good access to a narrow strip along the Shebelle valley and the western arid areas of central Somalia.

Elsewhere, including most of the sandy agropastoral zone, is served only by a network of largely unmaintained, rough, bush dirt tracks. These tracks are generally either very rocky, or soft sand; so access by vehicles is difficult and expensive.

The potential benefits from ocean and air transport are only being exploited to a very limited extent at present. There is a small seasonal trade in livestock, food and other goods through the undeveloped Hobyo port. There is one sealed airstrip (at Galkayo) and 7 unsurfaced airstrips in Central Somalia; though these are not often used.

Development of the very limited communication facilities would potentially increase trade, develop the economy and improve the quality of life for the inhabitants. Agropastoralists would stand to gain, as they have seasonal surpluses to trade. Telephone and post facilities are generally limited to a few centres along the sealed road. Radio communication is limited to district and regional police radios, and a few installed by the CRDP to service its main centres of activity.

Banking, and service facilities which are able to supply fuel, farming inputs and hardware supplies, are restricted to Mogadishu; and to a lesser extent, a few of the bigger towns. The sandy agropastoral zone has no such accessible service centre. The lack of infrastructure restricts the development of a commercial economy and encourages such practices as investing money from surplus crop production in more livestock, encouraging overstocking.

2.9 Land Tenure and Enclosures

The land tenure system is a critical aspect of any agropastoral development program; as it exerts a strong influence over the location, size, period, value and security of the farm. If a land tenure system is weak, agropastoralists have no incentive to invest time and money in improvements, including anti-erosion measures.

In central Somalia, the agropastoral land tenure system is confused, as the authority to issue agricultural leases is vested in the Ministry of Agriculture; yet central Somalia is considered rangelands and agricultural leases are normally only issued in irrigation areas close to the river Shebelle. The land tenure situation in this area has been covered by Hoben (1985) and Holt (1985).

The Agricultural Minister can issue 50 year leases to up to 60 ha of rainfed land per individual. It can not be sold, and must be partially cultivated within 2 years. (Hoben, 1985).

There is a strong historic, traditional land tenure system which allows all Somalis relatively free access to graze all range areas; however, if any individual or group expends effort to fence and cultivate an area, their ownership and that of subsequent generations to this land is respected. This tenure system is operating in a de-facto manner, although a portion of agropastoralists, about 10 - 30%, also register their land with the local district government and pay a small tax (25 So.Sh).

Resources are not available to map and properly register agropastoral land, so it is difficult to organise an adequate tenure system. Under law, the State owns all land, (Law No. 73, Oct. 1975) and occasionally attempts are made to destroy unregistered, uncultivated farms. Generally through, the State appears to respect people's right to ownership of a fenced enclosure, if part of it is being cultivated; even if the land is unregistered.

Private enclosure of rangelands is a controversial issue which is of central importance to the future of rangelands in the agropastoral zones. In the sandy agropastoral zone, local elders and government authorities widely consider that the area of rangelands privately enclosed, but not necessarily cultivated, has greatly increased over the last 20 years. This apparent trend is supported by aerial and ground observations and by Herlocker, (personal communication, 1988), who compared areas enclosed and cultivated in 1986 to 1960, in selected sample areas, using aerial photography. The area enclosed around Nooleeye township was particularly dramatic, increasing from 20-25% to 65-70% over this period.

The reasons for this trend are complex and not fully understood. They include development of many water bores, which led to increased settlement, and a sharp increase in the value of enclosed land near these population centres. Other factors include a growing awareness of the advantages of maintaining enclosures as private dry season grazing reserves; the development of specialised livestock fattening operations; apparent increase in human population and resulting pressure on range resources; and the snowballing effect of people joining the trend so their family and descendants would not miss out.

In the Hiraan agropastoral zone, there has been a strong trend to increase the area under cultivation over the last 20 years; although in this case, most agropastoralists do not fence their fields. In the dry seasons, the unfenced fields are open to communal grazing. Thus there is not such a pronounced trend in this case for agropastoralism to reduce the area of rangeland available for grazing. If fields are not fenced, the boundaries are often marked by growing *Aloe* and *Commiphora* plants. Even so, disputes over land ownership here too are common.

In the long term, there is a need to develop a well-planned agropastoral land tenure system, which will give people security over land; provide an incentive to conserve and invest in it; and a disincentive, such as lease forfeiture, if it is not used properly. Such a tenure system could also restrict agropastoralism in areas highly susceptible to erosion, such as near active sand dunes.

2.10 Pastoralism

The livestock industry is the largest in Somalia's economy, comprising about 70% of the exports, and supporting the majority of the population. Central Somalia is one of the main livestock areas, providing about a quarter of Somalia's exports. (CRDP, 1986). It has about 42% of the nation's goats (7,187,000), 23% of the sheep (2,409,000), 22% of the camels (882,000), and 11% of the cattle (417,000). (CRDP, 1986). The density of livestock ranges from about 8,000 kg/km^2 livestock biomass (32 Tropical Livestock Units (TLU)/km^2 - 32 TLU/km^2) in the wetter areas, to 1,000 kg/km^2 (4 TLU/km^2) in the driest areas. (Watson, 1979).

Most livestock families in central Somalia are nomadic pastoralists who herd a mix of livestock species. The proportion of each is adjusted to adapt to the local vegetation type. While most own a proportion of all 4 livestock species; on the coastal plains, for example, there is a much higher proportion of sheep. In the wetter south, cattle are more common; while in the dry north, camels and goats predominate.

Seasonal livestock movements are normally limited to a radius of 20-30 kms, despite the often erratic rainfall. In times of drought however, the livestock; particularly the camels; may be herded hundreds of kilometres to better pastures. Livestock are normally grazed within a traditional use area, called a "degaan'. These are based primarily on the area which can be conveniently grazed from one central permanent water source; though contributing factors are also social and economic ethnic ties, and access to services. While the livestock are normally grazed in a degaan, pastoralists do not hesitate to herd livestock to another degaan close by, if it has superior grazing and the family has labour available.

The livestock husbandry system practised by both nomadic herders and agropastoralists is highly adapted; maximising the utilisation of the local vegetation to produce milk and meat, and minimising exposure of the family to droughts. The quality of the pasture is constantly assessed by monitoring milk production and livestock condition.

The pastoralists have developed a comprehensive knowledge of the identity, palatability and relative value of the available plant species. They are extremely sensitive to the fact that green, growing plants are much more nutritious than comparable dry plants and quickly shift livestock to areas where the best forage is available. In this arid area, the rain often falls in an erratic, isolated, patchwork-like manner, so pastoralists keep moving livestock to wherever rainfall has recently fallen.

Typically herds are grazed far from the heavily utilised permanent waterpoints during the wet seasons, using temporary water ponds and shallow wells to water their livestock; thus enabling rangeland still in good condition to be exploited. They progressively return from these wet season grazing areas, until by the mid dry season, all animals water at the permanent water point.

If labour is available and the season not good the herds are often split, with the boys and young men taking the very mobile animals far from degaan to where good feed is available. This dry herd is normally composed of camels, with a few milking females providing food for the herders. In the drier areas where rainfall is more variable, nomadism and movement between degaans is greater.

Exceptions to this general grazing system are localised transhumance caused by biting flies and a localised free ranging system. Outbreaks of biting flies for a few weeks during the wet season force livestock (and herders!) to move from the coastal ridge bushland, and near the coast to adjacent areas. This forces a wet season/dry season transhumance.

In parts of Ceel Dheer and Ceel Buur districts the campaign to kill all livestock predators has been so successful recently, that cattle, donkeys and occasionally camels are left to graze in a free range system.

2.11 Agropastoralism

This section is based on information collected during the CRDP agropastoral study, unless otherwise stated. Aspects have been further detailed in other publications (R. Holt, 1985,1986,1987)

Pastoralists in central Somalia, practicing shifting cultivation for at least 300 to 400 years, have developed an innovative system which is closely integrated with livestock production, and highly adapted to exploit the very low rainfall and poor soils available. It was a relatively sustainable system, with short cultivation cycles followed by long bush fallows, which rejuvenated the range vegetation and soil. Areas with dense concentrations of farms were probably few, as there were very few settlements, service centres or permanent watering points.

Recent sedenterisation and population growth has caused localised overgrazing, excessive tree/bush cutting and clearing and a shortening of the bush fallow period. The range vegetation is thus not given a chance to protect and improve the soil, leading to degradation of the rangelands; demonstrated in its extreme form by the formation of sand dunes. Less spectacular, but serious and more extensive, is the decline in the condition (or health) of the rangelands.

The Watson (1979) resource survey estimated there was about 370,000 ha of cropped and recently cropped land in central Somalia, although the surveyors qualified these estimates; as they had difficulty distinguishing the cropped area, and due to survey techniques, sample error was high. The extensive CRDP ecological and extension studies later found that much arable bushland was in a bush fallow system, however the area involved will not be quantified until the CRRDP, (Central Rangelands Research and Development Project - the second phase of the CRDP), completes the next resource survey.

Agropastoral Systems

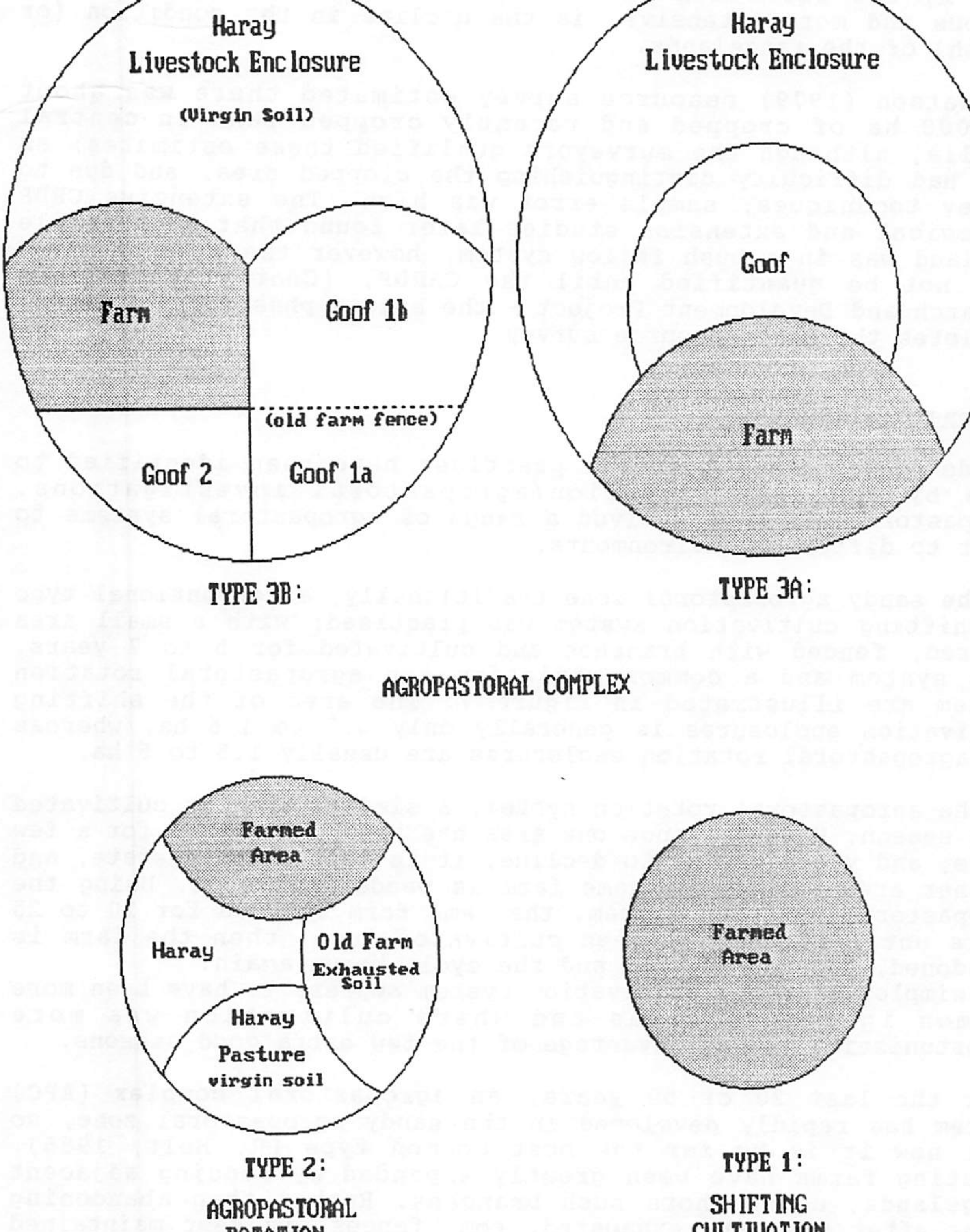
A wide range of agropastoral practices have been identified to date by the CRDP extension/agropastoral investigations. Agropastoralists have evolved a range of agropastoral systems to adapt to different environments.

In the sandy agropastoral zone traditionally, a conventional type of shifting cultivation system was practised; with a small area cleared, fenced with branches and cultivated for 5 to 7 years. This system and a common variation, an agropastoral rotation system are illustrated in figure 7. The area of the shifting cultivation enclosures is generally only 0.5 to 1.5 ha, whereas the agropastoral rotation enclosures are usually 1.5 to 5 ha.

In the agropastoral rotation system, a similar area is cultivated each season. However, once one area has been cultivated for a few years, and yield begins to decline, it is left to revegetate, and another area within the same farm is weeded and sown. Using the agropastoral rotation system, the same farm is used for 10 to 25 years until it has all been cultivated once, then the farm is abandoned, another cleared and the cycle begun again.
The simpler shifting cultivation system appears to have been more common in remote areas and where cultivation was more opportunistic, taking advantage of the few extra good seasons.

Over the last 20 or 50 years, an agropastoral complex (APC) system has rapidly developed in the sandy agropastoral zone, so that now it is by far the most common type (R. Holt, 1985). Existing farms have been greatly expanded by fencing adjacent rangelands, using thorn bush branches. Rather than abandoning farms after they are exhausted, some fences are kept maintained and the field incorporated into a larger APC, as shown diagramatically in figure 7.

Figure 7: Schematic Diagram of Sandy Zone Agropastoral Systems



Source: R. Holt 1985.

The development of the APC system has provided important opportunities to improve the sustainable productivity of the agropastoral system and reduce rangeland regeneration. Features of the APC system which provide such opportunities are:

- One family owns, utilises and passes onto its descendants one continuous area of land for a long period, at least 20 to 30 years. Thus they have an incentive to improve the APC, as they and their descendants can reap the benefits. This only exists if their land tenure is secure.

- The APC's have a boundary and internal paddock fences, so the stocking rate of each paddock (enclosure) can be controlled. This is extremely important, as with control over stocking rates, it is possible to introduce innovations such as rotational grazing, range resting, pasture introduction and agroforestry. In the surrounding rangelands, such control is very difficult and expensive to organise.

- The APC's of 8 to 40 ha, a common size, are theoretically large enough for a permanent farming system to be established with the introduction of innovations such as rotations and improved bush fallows. This potentially would be a more sustainable productive system, with less rangelands cleared and degraded.

- Separate fenced enclosures provide the agropastoralist with the opportunity to improve the husbandry of livestock, and reduce the herding labour requirement. Agropastoralists, for example, often separate special categories of livestock from the herd grazing the rangelands; and graze these sick, young, milking or fattening animals on more nutritious feed within the protection of paddocks.

- The permanency and paddock system offered by APC's enables systems to be established to improve soil fertility; and thus productivity, through rotational night yarding of livestock grazing the APC and surrounding rangelands.

Crops

In the sandy agropastoral zone, the most important crop is cowpeas (*Vigna unguiculata* -syn. Sinesis), followed by grain sorghum (*Sorghum bicolor*). Smaller areas of sesame (*Sesamum indicum*) maize (*Zea mays*), cotton (*Gossypium* sp.) and sour watermelons (a Cucurbit sp.) are also grown. Mung beans (*Vigna mungo*) introduced by the CRDP agropastoral program, are now spreading as an alternative crop.

Typically cowpeas are sown in the Gu season, and both cowpeas and sorghum in the Dayr season. Sesame and maize are generally sown whenever the rainy season has been particularly good.

Agropastoralists say they grew much more sorghum in the past; however, bird damage and diseases including stem borer, had increased so much they were replacing it with a monoculture of cowpeas. They say the sorghum pests and disease problem is worse in the Gu season, so avoid sowing it in this season. The continual sowing of only cowpeas would be expected to increase pests and diseases attacking this crop, and indeed, particularly in Haradhere district, this is a common complaint. It is thus a priority to identify alternative crops.

In the Hiraan agropastoral zone, sorghum is still widely grown, probably even more so than cowpeas, as suggested by the results of a recent sample survey conducted by Salisbury (Salisbury, J., 1988). Maize and sesame are common crops, often grown in depressions, flooded areas, or after very high rainfalls.

Bulrush millet (*Pennisetum typhoides*) is often grown in the Aborey area, though appears to be only a minor crop elsewhere. Sour watermelon, cotton *Gossypium* spp. and peanuts (*Arachis hypogaea*) are other minor crops. Cotton has enjoyed a recent revival as a cash crop, due to the government increasing the controlled price. Sesame too, is an important cash crop, and both are being increasingly sown, especially in the higher rainfall Hiraan region. (J. Salisbury, 1988).

Cropping Practices

A cropping strategy, widely adopted by agropastoralists to increase production under these arid conditions, is the sowing of the major crops into the dry soil just prior to the onset of the wet season. A larger area is then sown subsequently after the rain, if the early rains are heavy.

Dry sowing the seed enables crops to establish quickly, so they have a better chance to reach maturity before running out of moisture. Much larger areas can also be sown using this technique, as the availability of labour limits the area that can be sown during the short period there is sufficient moisture near the soil surface following rain. A major problem with the dry sowing technique is that if the early rainfalls are very light, the seed rots, and has to be resown.

The agropastoral systems in central Somalia require little capital expenditure or external inputs; rather it is labour intensive. All family members work on the farms, with men doing more of the heavier tasks, and women and children the rest.

All agronomic operations, including clearing, weeding, sowing and harvesting, are done by hand; and no fertiliser or herbicides and only very limited pesticide is used. The exception is that over the last 10 to 20 years there has been a rapid expansion in the use of tractors, using small disc ploughs to prepare the seed beds every few years in the Hiraan agropastoral zone. These agropastoralists are progressing from the use of hand tools directly to tractors, without passing through a stage of animal traction.

This transition is very unusual in sub-Saharan Africa (P. Pingali et.al. 1987), and appears to have been stimulated by the availability of tractors and drivers, which can be hired very cheaply. In the Gu 1988 season, at Bula Burti, it cost 650 So.Sh.

(US$2.60) per hour to hire a government agency tractor and driver; and 850 So.Sh. (US$3.40) per hour to hire a private tractor and driver.

For the private tractor, it would cost 1,700/- (US$6.80) to plough one ha; which is about the same cost as hiring casual labour to hoe it. However, the disc ploughs can prepare a better seedbed, turn up deep layers of soil and can achieve better weed control. The tractors are particularly useful in preparing newly cleared land, although considerable extra effort is involved in having to dig out tree roots.

Apart from the tractors, all agronomic operations are undertaken using small hand axes to clear and build the fences, and small, light, short-handled hoes to weed and sow. Occasionally, heavier long-handled hoes and axes are used to facilitate heavy land clearing operations. Cleared vegetation is usually burnt in piles on the farm, although a lot is used in constructing the thorn bush fence.

Intercropping is quite a common practice. Melons are planted with all other crops, and cowpeas and sorghum are often sown together in the Dayr season. Some agropastoralists in central Somalia are aware that yields can be increased by rotating crops; however they have so few crop varieties, there is not much opportunity. In the sandy agropastoral zone, agropastoralists will usually grow cowpeas after one crop of sorghum; however, in the heavier Hiraan agropastoral soils where sorghum is more often grown, it frequently is sown every season in the same soil.

Wind Erosion Prevention Techniques

Wind erosion can be such a serious problem in the sandy zone that it causes agropastoralists economic and social hardship. Innovative agropastoralists have thus devised some techniques to reduce it, although these are generally not widely practised. Such indigenous techniques are particularly important, as they can be built on and improved by development programs, and may be more acceptable than introduced technology.

Probably the most widespread technique is to leave a protective cover of weeds over cultivated areas during the dry season, right through until after the first heavy seasonal rains have consolidated the soil surface. While sometimes this is done to save labour involved in weeding, agropastoralists often claim this is an anti-erosion technique. This technique probably reduces erosion, but it also would often depress crop yields slightly as the weeds compete with the crops for scarce water and nutrients until the first weeding, which usually is not until 2 weeks after emergence.

A labour intensive technique used particularly in the Dumaaye and Aborey areas, is the construction of parallel thorn bush brush lines across the eroding area. The brush lines are typically 8 to 12 m. apart and oriented perpendicular to the prevailing winds. This excellent technique demonstrates the depth of understanding agropastoralists often have for erosion processes. Unfortunately, the technique is environmentally destructive as it requires many branches to be cut. The anti-erosion strips and hedgerow/alley cropping techniques introduced by this program, are essentially improvements on this technique.

A relatively rare technique found in the Nooleeye/Ali Yabal area was the reseeding of fallows with grasses, legumes and tree/bushes. After 5 to 7 years of cultivation, the sand is highly erodable, and the natural seed supply is heavily depleted. The plant seeds are sown to reduce erosion, speed the recovery of a quality fodder for livestock, and to improve the soil.

Probably the most common species sown is *Cenchrus ciliaris* (buffel grass). Other grasses include *Leptothrium senegalense*, *Eragostis cilianensis*, and *Dactyloctenum* sp.. Woody plants sown include the trees *Acacia nilotica*, and *Acacia horrida*, and the small legume bushes, *Indigofera* spp. (including *I. ruspolii*), *Crotalia* spp. (including *C. dumesa*), and a prostrate, spreading perennial, *Rhyncosia* sp. Seeds of these species are typically broadcasted in the late dry seasons. (R. Holt, 1985).

A similar technique, which is probably more common than manual reseeding, is the preservation in the cultivated area of a limited number of plants of a few valued pasture and fodder species. The primary purpose is to provide a seed source for rapid, natural revegetation of new fallow areas. Typically, large tussocks of *Cenchrus ciliaris* are preserved with no apparent spatial organisation.

Rainwater Harvesting and Water Erosion

Water erosion is only a very serious problem in the few areas with appreciable slope and a loamy, silty or clay soil. These conditions are only found along the coastal ridge and the Shebelle valley, which are also the potential areas for rainwater harvesting.

In the Shebelle valley area, agropastoralists have developed an innovative, low-cost, rain water harvesting system to increase crop production and reliability (R. Holt, 1987). While there is no rainwater harvesting along the coastal ridge, there is serious gullying in some areas, particularly in a 140 km long zone from Haradhere to Hobyo. While the origin of these spectacular gullies, some 100 to 150 m. deep, is not known, it is postulated their recent formation was associated with agropastoralism.

The steep sides of these gullies, worn through the highly erodable, fine, silty loam soil, indicates the gullies are of recent origin; although most now are stabilised with a young *Acacia* woodland that appears to be in an early stage of succession. From the air it is possible to see the outline of a dense network of old agropastoral enclosures, though few are maintained now. It is thus speculated that the erosion was at least greatly expanded in the recent past during a phase of dense clearing, cultivation and grazing.

Possibly half of the agropastoralists in the Hiraan agropastoral zone harvest runoff rainwater, or construct micro-catchments using small 15-50 cm dirt banks to increase the water available for crop growth. The banks are constructed by hand using 2 man shovels, or occasionally conventional shovels. Generally they are located to catch runoff rainwater, then direct it to the farm, which is surrounded by a network of similar banks to impound the water on the farm.

While runoff water harvesting is a common technique which has been practised for hundreds of years in arid areas such as North Africa and the Middle East, (Crichley, W. 1986) the Hiraan rainwater harvesting system is unique in some respects. It is practised where there is little slope (0.05 to 2.0%); so small, low-cost, dirt banks, often located far apart (20-200m, can be used.

In practice though, the banks often break, causing localised erosion. They break because they are often located in the wrong position, as agropastoralists have no technology to measure land level. As with other agropastoral systems, the rainwater harvesting agropastoral systems cannot be considered in isolation from range management, as an area is only cropped for 5 to 10 years before it is allowed to revert to rangelands.

Stream diversion is a rainwater harvesting system occasionally practised in the Halgan/Aborey areas of Hiraan region. Diversion banks constructed of wooden poles or dirt are used to divert water that flows for very brief periods down small streams onto one - or more often - a series of farms, lined with banks.

Recent access to bulldozers, which are available occasionally for hire at very low rates (2,000 So.sh/hour - US$8.00), has stimulated a stream tributary damming agropastoral system, in the Halgan/Beer Haano area. Large earth banks, up to 2.5 m. high are constructed without the assistance of levelling equipment to dam small tributary streams, so crops can be grown in the moisture stored in the soil behind the dams. These often break, causing considerable localised erosion.

All the rainwater harvesting systems would greatly benefit from the extension of simple contouring, soil conversation engineering and agroforestry principles.

Livestock Husbandry and Agropastoralism

Livestock production and cultivation are closely integrated in the agropastoral system, with crops and enclosures providing high quality stock feed; which is often valued more as a product than the food produced. Almost all shifting cultivators own livestock too. They consume most crop residues following harvest.

Even if the season is poor and the crops produce no food, agropastoralists still benefit greatly, as nearly every season has enough rain to produce a considerable quality of high quality cowpea and sorghum green forage. The uncultivated portions of the APC's produce forage and fodder which can be reserved for use when it is most needed by the livestock in the late dry season.

Crop forage is often used by agropastoralists to save, or improve the health of sick and starving stock. Other categories of livestock which need nutritious feed; including animals being weaned, pregnant and milking livestock; often benefit by being given priority to this feed.

Most crop residues are consumed by these needy livestock classes, or the whole herd immediately after harvest; although some sorghum and maize stalks, crop cleanings and poor quality grain/peas are stored and used later in dry seasons. According to interviews with agropastoralists, the practice of storing crop residues for later feeding to their livestock, or occasionally sale, has increased greatly over the last 20 years, and now is common in Hiraan region.

Only 10% to 25% of the area enclosed in APC's is cultivated at any one time. The rest is used as a private seasonal grazing reserve or for forage harvest.

Agropastoralists graze the bulk of their livestock in the rangelands for most of the year, the bring needy livestock classes, or the whole herd to graze the protected pastures late in the dry seasons, when there is little forage available elsewhere. Some agropastoralists allow relatives to graze their enclosures and a few lease seasonal grazing rights; however the vast majority of grazing is by the APC owners' livestock.

Most agropastoralists manually harvest some of the forage growing on the fallow and virgin land within the APC's, and store or feed this directly to the needy classes of livestock. It is normally harvested and transported by women and children.

Not all aspects of the system benefit livestock production. Cropping demands keep at least part of the family committed to being at the farms for at least a few weeks each wet season; and so during this time, some livestock normally have to be herded on the often poor pasture nearby, so that the family has access to milk. If families have enough labour, they split the herd, sending most to good pasture; which normally is in rangelands, far from agropastoral concentrations.

Livestock have a potentially synergistic effect on cropping by providing manure to fertilise the soil, and by consuming most of the weeds, thus reducing the manual weeding constraint. Weeding is generally the main constraint limiting crop production in traditional, completely manual, cropping systems. These 'weeds' provide a protection against erosion; however they are mainly consumed when most needed by livestock at the end of the dry season; which is when wind velocities have declined and thus the danger of wind erosion is reduced.

For human food availability, livestock and cropping complement each other well. The staple diet - milk, is most abundant during the wet seasons: then as its availability declines, crop harvests provide a new source of food.

Similarly, in terms of labour availability, the two industries integrate well. The greatest seasonal labour demand for cropping is during the wet seasons; whereas for livestock, it is for herding and manual livestock watering in the dry seasons. In the dry seasons livestock have to be taken far from waters to find good feed; yet must be watered more frequently. As surface waters have dried up, they often have to be laboriously watered by drawing buckets from wells.

Preliminary results from the monitoring of the nutritional level of sheep and goats by the CRDP Veterinary component, indicated that the livestock managed under agropastoral systems had consistently higher blood nutrient levels than those managed under pastoral conditions (N. Abdi, 1986). These results support the proposition that agropastoralism benefits livestock production.

Agropastoral herds rely heavily on grazing rangelands, as they usually only utilise the APC's for 1 to 6 months each year (R. Holt 1985, L. Salisbury, 1988), so the availability and quality of the surrounding rangelands is of critical importance. With the apparent trend of increasing enclosure and cultivation of land, livestock will rely more on fallow land, and rangelands will become less available. However, as the soil and rainfall of at least half of central Somalia is not suitable for cultivation, much of the area will remain rangelands, and rangeland shortages will be localised. Here it will be important to improve the quality of fallows, as they revert to rangeland.

2.12 Other Land Uses

Natural wood resources are extensively exploited for fuel and building purposes. The wood is harvested from the natural woodland and bushland. Virtually none is grown for this purpose.

Most of the fuel wood is made on site into charcoal, then exported to Mogadishu by truck. This industry is concentrated in western Jalalaksi and Bula Burti districts. In 1988, local authorities stated there were at least 28 'bosses', or charcoal camps, each with 10 to 40 labourers and 2 to 3 trucks operating in western Jalalaksi. These would have the capacity to export 20,000 tons of charcoal/month; however, accurate figures on production are not available.

Observations and local informants suggest that the wood resources in these range areas are being exploited at a much greater rate than they are naturally regenerating. Areas of at least a 1 to 3 km radius are typically denuded of trees and bushes around almost all permanent watering points in central Somalia, as people rely mainly on wood for fuel, and it is also the most common building material. Some wooden poles of *Terminalia spinosa* are exported to Mogadishu, but most is used locally.

The rangelands are thus able to supply almost all the household fuel and most of the building needs. In agropastoral areas, wood resources within the enclosures are heavily exploited by the owner for these purposes too.

Termite resistant grasses and dwarf, woody perennials, such as *Andropogen kellei* and *Indigofera ruspolli*, are often harvested for building houses. Women make all of the mats used as floor covers and to line the traditional small, dome-shaped, portable nomadic huts ('uckel'). These mats are woven using the stems of grasses such as *Aristida* spp. Most of the containers used to carry milk and water were also traditionally made from woven grass stems. Few other household utensils are owned by agropastoralists and most are made in a similar way, or carved from local wood.

The only mineral resource being exploited in central Somalia is a large mershan clay deposit at Ceel Buur. A small co-operative exports ornaments and household items, such as charcoal stoves carved from this material, mainly to Mogadishu.

Along the Shebelle river, irrigation is used to grow a range of crops, fruit and fodder. Within central Somalia, the irrigated area is small, possibly due to the lack of suitable soils. Only rainfed agriculture was included in this study; however, the irrigated areas do provide some food, fodder and fruit to local agropastoralists in Hiraan region, and the agropastoralists provide some milk and livestock in return. Honey is also produced mainly along the Shebelle River for local consumption and export elsewhere.

Large edible wildlife species are heavily exploited to provide supplementary food and hides. There are small groups of hunters who rely almost completely on hunting for their livelihood.

No data is available on the extent of this activity; however in a rapid survey of 10 villages in 1988, all had small quantities of game meat for sale. The most common species were dig digs (small dwarf gazelles), Spekes and Sommering gazelles and Dibitag. There appears to be a growing local concern that the wildlife resources are being over-exploited.

Fishing is a minor activity, centred mainly at the very small ports of Hobyo, Ceel Huur, Mereeg and Ceego. Only the first two have permanent villages. Almost all agropastoralists and pastoralists do not eat fish. Some dried shark and frozen crayfish is exported to Mogadishu and hence overseas.

3.0 INTEGRATED PARTICIPATORY SYSTEMS DEVELOPMENT STRATEGY

3.1 Defining the Problem

The first strategy adopted in this development program was to define and develop an understanding about the problem(s) to be addressed, and thus to focus future work and the limited resources available where it was most needed.

3.2 Incorporation of Relevant Technical Expertise

A key strategy was to develop an interdisciplinary group with experience. A conventional approach of conducting highly academic systems studies collecting huge volumes of data about the whole system, and subsequently being not sure what it all meant, was not adopted. Instead, practical people who could talk with authority to agropastoralists about their crops, pests, diseases or livestock were used to collect focused information.

Similarly, in subsequent research and extension, this approach was adopted. Researchers and extensionists often shared duties and had to demonstrate they could farm better than local agropastoralists under the same conditions. In addition to their technical expertise, they had to be able to relate and communicate well with local communities.

Technical expertise and experience from similar environments abroad was also incorporated into all levels of the program, including planning, training and technical supervision. Extensive use was also made of appropriate plant genetic material from abroad.

3.3 Characterisation of the Agropastoralists' System

A case study and interview approach was used to develop an in-depth understanding of the agropastoral system. The basic assumption adopted was that it was only possible to develop techniques which would be accepted by agropastoralists as improvements, if first the developers understood the existing system. Such knowledge was also needed to ensure that the interventions recommended did not inadvertently do more damage than good. The strategy was also used for staff to establish credibility with the agropastoralists. It was found that once staff had a good understanding of the local cropping and herding strategies, agropastoralists would respect and tend to listen to them more.

3.4 Identification of Constraints, Priorities and Innovations

The strategy adopted was to determine the main constraints to efficient, productive, sustainable resource use, and establish the priorities for attention and identify local innovations, at the same time as carrying out investigations. The correct identification of constraints is very important, and can be difficult.

The agropastoral staff learnt from the experiences of the nearby Bay Region Agriculture Development Project, where designers had assumed the local sorghum variety was poor. After years of research, concentrating on trying to identify an improved variety with little success, it was found soil fertility was a serious constraint to sustainable production. The CRDP program had the freedom to identify constraints without prior assumptions.

A fundamental strategy was to investigate local agropastoralists' priorities for development, and to seek out any promising local innovations. It was felt that it was more likely technology would be adopted if assistance in this field was requested by the local people. Local innovations could be promising, as they implied a degree of acceptability; even if they had to be modified to make them more effective. Thus a client demand approach was taken.

3.5 Participation for Sustainability

The full participation of all levels of the local agropastoral communities, in all aspects of the agropastoral program, was a fundamental strategy adopted. Agropastoralists were closely involved in the program from the start. Their concerns and ideas were constantly sought and respected. A community development type of approach was thus adopted, with the onus for development put onto the community; with the project participating as a partner, which could mainly help by sharing technical expertise. From the beginning of the program some agropastoralists began testing potential technologies on their farms.

3.6 Identification of Appropriate Technologies

The basic strategy adopted was to identify promising technologies from other similar environments around the world, and from within Somalia, based on agronomic technical expertise, an understanding of the local agropastoral system, and the opinion of local, knowledgeable agropastoralists. It usually involved looking for local solutions for problems identified, such as erosion; then improving these, using internationally available expertise. Technologies were always discussed with agropastoralists prior to testing, to try and ensure they would be appropriate and acceptable.

As the agropastoral program was very extension-orientated, acceptability and sustainability were factors given priority in identifying technologies. Thus generally, technologies were sought which would meet the conservation objectives, but also improve the income of the agropastoralist, reduce or balance work demands and improve food security.

Priority was always given to identifying technologies which would not create dependence on imports, as foreign exchange was limited. Such technologies were not excluded though, if it was felt the potential benefits were very high.

3.7 Testing, Adapting and Evaluating Technology

All identified technology was tested, adapted if necessary, and fully evaluated under local conditions; then if successful, transferred through extension to the local communities. Representative trial sites were chosen within the main agropastoral zones, and surrounding agropastoralists regularly invited to observe and discuss the results and possible adaptations with staff.

Some involved technology, such as rainwater harvesting requires adapting and refining over a few seasons. Even the most promising straight-forward technology, such as a more promising crop variety; was evaluated under controlled local conditions for at least 2 seasons at the trial stations, before inclusion in on-farm trials. A general strategy adopted was to adopt and evaluate technology as soon as possible in on-farm trials, so it was done within typical integrated agropastoral systems.

While the adapting process is often a necessary strategy needed to develop technologies appropriate locally, a period of testing and evaluation is required to ensure their performance justifies introduction. The credibility of the developers is lost if inappropriate technology is introduced on-farm.

3.8 Transfer of Technologies to the Target Group

By involving the local agropastoral communities in identifying, adapting and evaluating technology, a smooth, rapid and efficient transition to adoption was facilitated. A fundamental strategy was to carefully select a few respected, knowledgeable, innovative agropastoralists and give them training and advice on how to establish small private demonstration/trials on a part of their farm.

Their success as extension demonstrations depended upon local agropastoralists perceiving that the demonstration agropastoralist had adopted the technology because it genuinely benefited him, so great care had to be taken not give them artificial incentives such as salaries or food.

Once effective demonstrations were established the final step in the development program, extension of the technology was begun using the methodology described below.

4.0 GENERAL METHODS AND MATERIALS

4.1 Organisation and Management

Until 1985, agropastoral investigations were undertaken by Extension Department staff, as part of their on-going duties. With the initiation of the first adaptive trials in the 1985 Gu season, two field Extension technicians and the District Extension Officer, Ceel Dheer district were given the part time responsibility of supervising these trials. The district CRDP staff technically directed the program, and directly participated in the implementation of all aspects. An in-service training program was initiated for these staff and the Chief Extension Officer's counterparts, to give specific training in arid land rainfed agronomy and agroforestry.

In terms of the CRDP, which employed over 500 staff, the agropastoral program was modest in size, never expanding beyond three technicians and one professional; as no provision had been made in the project design for this activity. The Agropastoral Department was officially formed in 1986, under the technical direction of the author, the Chief Extension/Agropastoral Officer (C.E.O.). One of his counterparts, Abdulkadir Abdulahi Yasin (Bashe) was appointed Head of the new Department, and he subsequently played a key role in implementing the program.

The Department Head and CEO were based in the capital, Mogadishu and made frequent field trips throughout the agropastoral zones to supervise and directly help implement the agropastoral program, often with assistance from other Extension Department staff. One Agropastoral technician was based at Nooleeye in Ceel Dheer district, and another at Bula Burti. In late 1987 a further technician was stationed at Bula Burti.

The Agropastoral program had a heavy wet seasonal work requirement, which was met by hiring local agropastoral labour on a casual basis, and paid the local daily cash salary. This was 150/- ($0.60) for normal work and 200/- ($0.80) for heavy work in the 1988 Gu season.

The system worked very well, although it required constant staff supervision. The casual workers were much more motivated than similar food-for-work workers. The casual workers also gained experience in the technologies under trial, and thus helped to disseminate and popularise it. Local community leaders were consulted to help organise staff recruitment, and all casual staff were employed from the local communities.

From the experience of other projects in Somalia, it had been anticipated that it would be difficult to organise strict control over grazing and other land use at the adaptive trial stations. Although the trials were located near settlements where land use pressure was intense, control was excellent. Two respected local agropastoralists were employed casually to guard and work on each of the trials, and to keep a boundary fence maintained. The boundary fences were not completely stock proof, however they were generally respected by herders.

Land preparation, clearing and weeding usually commenced 6 to 8 weeks before the beginning of each wet season. Most seeds and live fence plant cutting were sown and planted in the last week or two before the first rains. Immediately following the rain, resowing was undertaken, if poor early rain had caused seed to rot.

All treatments were normally weeded twice per season; the first time as early as possible, usually at about the fourth leaf state. Most harvesting took place 55 to 70 days after emergence, although some species ratooned, or had drawn out harvest periods, and required multiple harvests. In the dry seasons, harvest samples were dried, cleaned and weighed and the results compiled before planning and preparing for the next season.

4.2 Research Site Selection

The seven trial sites were selected using the following criteria:

a) The environment of the site must be representative of an important agropastoral zone type. The soils and climate in particular must be representative.

(b) The site should be close to a village, services and a main access road to reduce the cost and improve the reliability and supply of labour, transport, services, and supplies; and provide accessible accommodation for staff. Being close to a village, the transfer of technology to the local community is greatly facilitated too, as many people daily pass the site.

(c) The site would be relatively uniform, with as little variation in slope, soils or vegetation as possible.

(d) Previous cropping history must be carefully traced to select the history of land use sought for the research program. The information available suggested the soil required a minimum of 30 to 50 years of bush fallow to rejuvenate after a cropping cycle. This was the normal minimum criteria adopted. Due to limited resources available to this program and the alienation of most suitable land, it was often not possible to fully fulfill this criteria. Details are given in the specific sections on each trial.

(e) The site and the proposed trial program must be fully supported by the local community.

(f) The site must be large enough for the proposed trials, and allow room for likely expansion during the course of the project.

(g) The project must be able to obtain secure land tenure over the site for at least its likely life cycle.

In practice site selection proved difficult and some of the criteria had to be partially compromised. It is difficult to find land within 3 to 4 kms from settlements in the agropastoral zones, which has not been recently cultivated for many years - and now, presumably, infertile.

Any fertile lands in these desirable areas are owned by someone, even if they are not currently fenced. While the project could have legally taken the land, this would have caused local resentment, which this community development program had to avoid.

In one case, land was purchased, or agreeable compensation paid to the traditional owner (Nooleeye) and this was a good solution. It does require considerable time to locate the site and negotiate the sale, and adequate funds need to be available.

These problems proved a serious constraint in selecting suitable sites for the rainwater harvesting trials. They required additional specific site characteristics of slope, runoff and soil type (R. Holt, 1987), which further complicated site selection. Experience suggests suitable sites are available in areas such as Halgan, for future trials.

4.3 Experimental Design

Although technical, manpower, equipment and financial resources were very limited, trials were designed scientifically to obtain statistically valid interpretable results which would test hypotheses. The only exceptions were small observation plots used for plant varieties for which very limited reproductive material was available. Trial hypotheses, experimental designs and observations are presented individually in section 5.

4.4 Resources and Equipment

4.4.1 Plant Material Selection and Acquisition

The selection and supply of suitable varieties of plant seeds and cuttings adapted to the local conditions was a difficulty requiring a number of approaches to solve. Very little scientific work has been done around the world to select productive plant varieties that are adapted to these harsh, very dry, tropical climatic conditions.

In addition, as the agropastoral program did not have a long term mandate and external financing was due to end in 1986/87, it was not advisable to establish professional relationships with external research organisations to test germplasm. Within Somalia too, this program was the only agropastoral research being undertaken in such arid conditions, although some of the agronomic research results of the Ministry of Agriculture in the wetter areas of southern Somalia proved useful.

Improved varieties of locally grown crops, and suitable varieties of potential new crop species were obtained from commercial sources in northern Australia and from research organisations in Somalia. These included the Bay Agricultural Development and Research Project, the Central Agricultural Research Station at Afgoi, the Homboy Agroforestry Project, and the Semi-Mechanised Agriculture Project. Small quantities of pigeon pea were also obtained commercially in Nairobi, Kenya. Regular contact was made with all the relevant organisations within Somalia to monitor and assess potential varieties.

No research or selection of improved varieties of pasture or fodder crops was being undertaken in Somalia, so the author relied on personal experience and literature to import some well established productive varieties from commercial sources in Australia. Observations suggest that there are many promising indigenous pasture and fodder crop varieties too, which deserve priority in future agropastoral development programs.

Selections of a few varieties were initiated in this program based on the advice of the project's ecologists, D. Herlocker and P. Kuchar, local agropastoralists and personal observations. Some limited testing of local crop varieties from southern Somalia was also undertaken, based on recommendations from the Bay Agricultural Development Research Project.

The selection of suitable varieties of multipurpose tree and bush species proved particularly challenging; requiring much investigation and basic research, as even less performance information was available. Agroforestry under arid and semi-arid tropical conditions has received little attention from researchers, although there are numerous traditional systems, which are beginning to be investigated. (National Academy of Science, 1975, 1979, H. Steppler and P. Nair, 1987).

Many local species appeared to have unrecognised potential, so the author initiated a program to identify varieties with desirable characteristics. As a result, more than half the agroforestry tree and bush species included in the trial program were identified and collected locally.

The selection process involved rating each species for its proposed function, based on many attributes, which included forage production and palatability, (particularly in the dry seasons); wood quality and quantity; growth rate; competitiveness with under-crown crops and pastures; soil improving ability (including nitrogen fixation); longevity; ease of establishment; live fencing and wind break qualities; food and secondary product production (medicines, gums, fibre, aromatic compounds etc.); adaptation to the environment; versatility in soil and climatic requirements; ability to withstand heavy grazing pressure; and last, but not least, the subjective value of the local agropastoralists.

The assumption used was that agropastoralists would only adopt species which would produce substantial benefits and yet be easy and inexpensive to establish and maintain.

The seeds of local tree and bush species were either directly collected locally by staff, or purchased on a contract basis from local agropastoralists. An attempt was always made to select seed from provinces with the most desirable characteristic, when these were apparent. Due to the climate, local seed availability was erratic and unreliable. Future programs will need a systematic collection and storage program.

Similar selection criteria were used to order very small quantities of promising tree and bush variety seeds from northern Australia. These species were all native to environments similar to central Somalia, including northern and central Australia, south and central America and India.

All imported seed was air freighted to Mogadishu, the capital, to improve the chance it would arrive in a viable condition. All seed was stipulated to be supplied free of contaminating seeds, pests or diseases. The system worked well, with the main supplier, *Kimberley Seeds* of 51 King Edward Road, Osbourne Park, Western Australia, regularly supplying seeds within a month of ordering.

The only problem experienced was with a range of saltbush species. The seeds of the *Atriplex* and *Maireana* species did not germinate. Even resupplied seeds would not germinate under experimental conditions in petri dishes supplied with distilled water. These fodder plants were planted twice in the range regeneration trial at Ceel Buur, and in nurseries without success. It is concluded that the seed was probably not viable.

4.4.2 Seed Multiplication

Only very small quantities of seed was available of all plant varieties, except those collected locally, due to lack of supply or restrictions in finance available. Fifty to one thousand grams of most seed was initially available for most varieties, so even for research purposes, the seed needed to be rapidly multiplied.

At the time, no seed multiplication facilities were available within Somalia, so a small 1 ha unit was established near Bula Burti in early 1987 to temporally supply seeds. It was irrigated from a project water bore so good, seed crops could be regularly and reliably produced. Both the soil and water at this site are quite saline, but proved suitable for most of the varieties sown, over the short period it was needed. The long term need to multiply seeds has been recognised, and the CRRDP has allocated considerable resources to establish a large capacity at a more suitable site.

A border check flood irrigation system was built and managed manually by the Agropastoral Department staff to produce the seed required. The seed was sown in small 5 x 5 m. bays so small quantities could be multiplied. A few viable seeds of short season pigeon pea varieties supplied from Queensland University were in this way multiplied into kilogram sized lots and included successfully in subsequent trial programs.

Multipurpose non-competitive (or low competitive) hedgerow tree/bush seedlings or seeds were planted in rows along the irrigation channels next to the crops, to establish seed supplies of these species and to observe their growth. The species grown included *Leucaena leucocephala* var. K8, *Terminalia spinosa* and *Prosopis cineraria*.

Larger quantities of seed were multiplied each wet season under rainfed conditions at most agropastoral trial sites. The demand for seed was greatly increased when varieties were included in the on-farm trial/demonstrations, and later, general distribution to contact agropastoralists. To meet this need, supplementary supplies were obtained by contracting out local private agropastoralists to produce seed on their farms. Both crop and pasture seeds were very successfully produced this way. This activity also stimulated local farmer interest in the new varieties.

4.4.3 Seed Storage

As the agropastoral program rapidly expanded, so too did the number of plant varieties under trial and the quantity of seed needing to be safely stored. Storage is difficult under local conditions, due to the prevalence of pests, including rats and insects (Bruchid beetles), and the high temperatures and humidity.

With the limited resources available, storage was gradually improved by the acquisition of some large plastic airtight containers, bags and storage space in buildings at Mogadishu headquarters, Bula Burti district headquarters and at Nooleeye. Seeds particularly susceptible to insect attack, including cowpeas, mung beans and many of the tree species, needed to be treated with insecticides, or sealed in air tight containers, otherwise would not last more than 2 to 3 months in storage.

All seeds were well air dried prior to storage, then kept in the dry storage rooms. Most were stored in the less humid inland areas.

Seed cleaning and grading was done very effectively by local women labourers using traditional manual methods.

Seed germination was tested by placing 4 samples each of 25 seeds in separate petri dishes provided with distilled water and left in room conditions. Tests were done on samples with a suspected low viability. No or little information was available on the germination of most local forage species included in this trial program, so similar tests were done to provide the necessary cultural information.

If the germination of indigenous forage varieties proved low, as in the case of *Terminalia spinosa*, an important multipurpose tree, standard hot water, sulphuric acid, presoaking and abrasion treatments were tested in an attempt to find suitable propagation techniques, as reported by Abdulkadir A. Yasin (A.A. Yasin, 1988).

Seed testing and storage facilities were inadequate to support this program, however this deficiency has been recognised and resources have been allocated in the second phase to provide the necessary services.

4.4.4 Tools and Equipment

As the strategy was to not increase the dependence of agropastoralists on external inputs, and to achieve maximum acceptability of introduced technology, locally available tools and equipment were used for all operations, with few exceptions. Rather than use project bulldozers and graders to clear land, for example, trial areas were cleared in the traditional fashion using axes and fire.

All sowing and weeding was done manually too, using small short handled hoes ('yambo'). Harvesting was also by hand. As labour is very inexpensive locally, there is generally little incentive to further mechanise. Some intermediate technology improvements in hand tools may prove beneficial though. A hand sower was tested at Nooleeye, but was not suited to the light soils. Further testing is considered justified.

Animal traction is not used in central Somalia for cropping, and may have some potential, especially for weeding. It would fit the strip cropping, row sowing system well. It was not considered a priority for development in this program, as the nearby Bay Agricultural Development Research Project was not having great success with the introduction of the technique.

In Bula Burti district, tractors with small, two disc ploughs were hired to plough the research trial sites immediately following clearing. This is now a common land preparation technique used in the heavier soil areas of Bula Burti district. The same tractor and plough were used to form small earth banks for the staggered contour ridge water harvesting system at Bula Burti (R. Holt, 1987 Dec.).

In the areas where tractors have been introduced, there would appear to be great potential for introducing some appropriate, small, easy-to-maintain agronomic equipment. Tine ploughs would be less destructive of the soil structure than the disc ploughs now used. Disc bunders and ridgers would also be very useful for rainwater harvesting and soil conservation.

4.4.5 Chemicals and Fertilisers

The use of chemicals and fertilisers was minimised as all have to be imported and the crop yield potential under arid rainfed conditions is low. Generally, the incidence of crop pests and diseases is relatively low too, compared to more wet humid areas. In addition, the infrastructure needed to regularly supply such external inputs was poorly developed.

However, very little information was available on soil fertility, which observations by 1987 were beginning to suggest may be more of a limiting factor than aridity under some circumstances; including where extra water is available from runoff water harvesting. Thus when the agropastoral program was greatly expanded in 1987, fertiliser trials were initiated.

Mixed sheep and goat manure was used as a fertiliser treatment in crop trials at Aborey, Bula Burti and Nooleeye. This manure was selected as a priority for evaluation, as it is readily available locally.

All agropastoralists yard their sheep and goats in a small enclosure ('yerro') every night. As these yards are located near, or in the farm enclosures for a few months each year, an under-utilised manure source is normally available close to the cropped area.

This manure is normally periodically burnt to destroy ticks and other diseases. As an alternative, the manure in all these trials was aged for 6 to 12 months prior to application on crops, to both break the tick cycle and allow the process of nitrification to stabilise.

In the crop manure trials, the manure was applied at a level of 600 kg/ha. At the loamy clay (Ugg) trial site near Bula Burti, in the Gu season of 1988, three levels of manure were evaluated; 400, 800, and 1,200 kg/ha. The sorghum yield response to the manure levels was compared to 3 levels each of nitrogen fertiliser, (TSP - Triple-super phosphate) and phosphorus plus nitrogen fertiliser, (DAP - Di-ammonium phosphate); 33.3, 66.7 and 133.3 kg/ha).

In all trials, the method of fertiliser application was to place a pro-rata quantity of fertiliser under each seed during sowing. A measured quantity of fertiliser was placed at the bottom of a hole dug with a hoe, then 1.5 to 3 cm of dirt kicked in over it, before placing the seeds on top and completely filling the hole with dirt. The dirt layer was placed between the seed and fertiliser to try and avoid any toxic affects on germination and early growth. The fertiliser was placed close to the growing roots to improve the efficiency of utilisation, and thus reduce the amount of fertiliser needed.

As in the surrounding agropastoral systems, pesticides and herbicides were not used in any of the trials. Observations on the effectiveness of some pesticides to control stem borer in sorghum and caterpillars on cowpea crops were initiated in on-farm trials in Haradhere district. A natural insecticide/repellent was made by grinding fresh, dried seeds of the *Azadcirachta indica* tree (neam) to make a powder, (using the same mortar and pestles used to grind sorghum), then sprinkling the powder on plants directly, or mixing it with water then spraying the plants. The concentration of the solution used was 10%. Neam is a common shade tree in local villages.

4.4.6 Nurseries, Seedling Production

Tree and bush seedlings for the trials were produced at small project village nurseries situated at Bula Burti, Belet Weyne, Ceel Buur and Ceel Dheer townships. To reduce the need to transport the seedlings long distances, the Bula Burti nursery produced most of the seedlings for the nearby Bula Burti and Aborey trials, the Ceel Buur nursery supplied the Ceel Buur range regeneration trial, and the Ceel Dheer nursery the Ali Yabal and Nooleeye trials. The main nursery at Belet Weyne provided back up reserve supplies of seedlings.

All nurseries were constructed from local wooden poles, with fine bush wood on the roof providing about 50 to 60% shade cover, and 1 to 2 metre high stick brush wood walls providing shelter from wind.

The seedlings were grown in black polythene plastic bags (8 x 20 cm) supplied with drainage holes in the bottom 3 cm. The pots were filled to within 3 to 4 cm of the top to allow space for watering. The general potting mix used was a mixture of a third each of coarse silicon sand, loam and clay. If only heavy clay was available, or the clay supply limited, the proportion was reduced and medium to fine sand substituted. Experience in growing seedlings for other project activities was used to develop suitable mixes.

Seeds were given soaking, hot water or abrasion pre-treatments prior to sowing, according to variety recommendations. Sowing rate was varied according to seed viability from 2/pot for *Prosopis* spp. to 10/pot for *Terminalia* spp.. Pots were weeded to one seedling per pot two weeks after emergence.

Pots were watered twice daily until emergence, then once per day until the plants were well established. Watering was progressively reduced to every 3 or 4 days, and adjusted to climatic conditions to avoid plant stress.

Three to four weeks prior to planting, when the seedlings were 3 to 4 months old, they were progressively placed in positions exposed to the sun and wind for hardening off. The seedlings were transported to the trial sites in the early morning, evening or night, tightly packed together in the back of trucks. They were watered heavily prior to transport to further reduce disturbance to the roots during transportation.

Holes were dug for the seedlings just before the first rain, so extra rain water would accumulate in the root zone. Seedlings were planted into these holes, which were just big enough for the root bole, as soon as possible after the first 100 mm rainfall for the season had fallen.

All seedlings were planted within a microcatchment, as detailed in the trial section (No. 5) below. No extra water was added at planting or thereafter, as the plants were being evaluated for inclusion into the local agropastoral production system in which it would be neither practical nor economic to transport water to the farms.

Seedlings were subsequently protected from livestock grazing, and a radius of 0.5 m. kept weeded. The survival rate and height were periodically recorded to evaluate performance.

5.0 RESEARCH PROGRAM

5.1 Anti-Erosion Crop and Fodder Strips

5.1.1 Introduction

In the sandy agropastoral zone, preliminary case studies and observations gave strong indications that localised wind erosion on currently cropped fields was a common serious problem. The erosion was often spectacular. Although most crop fields were only 100 to 150 metres in diameter, small sand dunes 1 to 3 metres high were often accumulated on the surrounding thorn bush fence.

Soil profile examinations suggested that wind erosion was often rapidly removing the shallow top soil layer of finer sand with a higher organic matter content. Agropastoralists complained that the lower layers of soil were less fertile, so rapid erosion made it necessary for them to abandon the field, sometimes even after just 2 years, rather than the more normal 7 to 10 years.

After abandoning the field, they would clear another area of rangelands and the cycle would be repeated. More rapid cropping cycles were thus increasing the degradation of the rangelands. Observations also suggested that heavily eroded fields required much longer to regenerate naturally.

Wind erosion prevention techniques usually involve wind breaks and/or soil surface protection treatments. As agropastoralists graze livestock on their fields, and need to weed them during the wet seasons, it is impractical to establish a protective cover on the soil surface, so windbreaks were considered.

Narrow alternating strips of crops and pasture is one possible system, in which the pasture strips act as wind breaks, as well as providing fodder; and perhaps may also improve the soil. This system was given priority for development, as it appeared to have a good possibility of being accepted by local agropastoralists too.

Consequently, the hypothesis established for testing was:

> *'Cropping practices are causing wind erosion which can be reduced by establishing anti-erosion pasture strips.'*

5.1.2 Methods and Materials

At the Nooleeye trial site, 30 parallel strips were marked out adjacent to each other in a north-west, south-east direction (315 degrees). The strips were numbered and the boundaries marked with wooden posts. While the length of all the strips was about 120 m., the widths were varied to determine the optimum size.

Five strip widths were evaluated; 2, 3, 4, 5 and 6 metres wide. Six replicate strips of each width were marked out adjacent to each other in a block, with 3 sown to pasture and 3 cropped. The position of the 5 blocks of 6 strips was randomised, and the 3 pasture and 3 crop strips of each particular width under trial treated as a replicate.

To measure erosion and soil deposition, a grid of 1 metre long galvanised steel pegs were hammered into the soil, the soil surface position then marked on each peg at the beginning of the trial and compared to the soil surface at the end of the trial. Erosion or deposition was thus measured at two positions, 20 m. apart in the middle of each pasture and crop strip. Similar measurements were recorded at two positions, 20 m. apart at the boundary edge between all the pasture and crop strips.

For control comparisons, 6 grid positions were recorded in an adjacent traditionally cropped area, and another 6 on an adjacent area of natural pasture. The traditional cropped area had a similar cropping history to the area under trial, and was cropped each season by a local farmer. It was only 50 m. across, so erosion may not have been as great as on large fields. The natural pasture was an area in which all trees and bushes had been cleared, but the pasture, dominated by the short woody legume *Indigofera ruspolli*, had not been disturbed by cultivation for at least 50 years.

The portion of land covered by the anti-erosion strip trial had been continuously cultivated since it was cleared 6 to 7 years previously. The agropastoralist who had farmed the land said the crop yields had been declining, and the soil fertility was now nearly exhausted.

In the Gu season of 1987, and in the subsequent Dayr 1987 and Gu 1988 seasons, local variety cowpeas were sown in the crop strips. In the 1987 Gu season, the pasture strips were sown to *Cenchrus ciliaris* (buffel grass) var. Gayndah and U.S.A., and *Stylothanses scabra* var. Fitzroy and Seca.

These *C.ciliaris* varieties are large perennial tussock grasses, and the *S.scabra* is a leguminous woody fodder bush which grows 0.5 to 2 m high. Both were imported from northern Australia where they are extensively sown as improved pastures in arid/semi tropical conditions. They were established by broadcasting the seed by hand just prior to the first seasonal rains. The seeds were lightly covered by dragging a thorn bush branch over the soil surface. The *S.Scabra* seed was inoculated prior to sowing with the recommended inoculum, however, it probably would not have survived the hot dry conditions.

The pasture strips were only very lightly grazed over the period of the trial, to give it a chance to establish well under the abnormally dry season conditions. Crops were weeded twice each season and crop plants were removed soon after harvest to simulate grazing or crop residue harvesting. Thus the crop strips were completely bare during the dry seasons, which is the typical situation locally.

The traditional cropped control area was treated very similarly to the crop strips, with the same crops sown, and similar agronomic practices applied. The natural pasture control area received the same light grazing as the pasture strips.

5.1.3 Results

After 24 months, the spatial distribution and degree of erosion and deposition over the trial area was quite dramatic. As shown in table 3, pasture strips with a width of from 5 to 2 metres significantly reduced the erosion of the adjacent, similar-sized, cropped strip. Erosion was progressively reduced as the width of the pasture and crop strips was reduced, with there being less than half the erosion in 2 m strips than in the adjacent traditionally cropped control area.

Table 3: The Effect of Anti-Erosion Pasture Strips on Soil Erosion and Deposition, Dec. 1986 - Dec. 1988, at Nooleeye.

Strip Width	Centimetres Erosion or Deposition (Mean of 6 positions)			
	Pasture Strip	N/E Strip Edge	Crop Strip	S/W Strip Edge
2 metres	2	3	- 2.9 *	1.6
3 metres	2.5	6.1	- 4.1 *	3.4
4 metres	2.3	9.3	- 4.3 *	5.9
5 metres	2	10.8	- 4.8 *	6
6 metres	1.7	11	- 7.2 n.s.	7.2
Traditionally cropped area	- 7.5 cm (mean of 6 positions)			
Natural control Pasture	0.3 cm (mean of 6 positions)			

Summary Anova (Erosion of cropped strips with 6 widths)

Source	SS	df	MS	F	Significance (5%)
Cropped strip width	98.73	5	19.75	9.92	*
Within	59.58	30	1.99		
Total	158.31	35	-		

Note 1. The complete data is presented in appendix tables 1 and 2.
2. Dunnetts t statistical test indicated erosion in the cropped strips 2,3,4,5 metres wide was significantly less than in the traditionally farmed area. The 6 metre wide strips though, were not significantly different.

The traditionally cropped area lost a mean of 7.5 cm of top soil over the 18 months, whereas the 2m. strips lost only 2.9 cm.

Much of the top soil eroded from the cropped strips was deposited on the adjacent pasture strip, as shown diagramatically in figure 8. While soil was deposited right across the pasture strips, deposition was greatest at the edges, with more on the north-east strip edge than the south-west edge.

5.1.4 Discussion

The hypothesis proposed has been proven under the trial conditions; as it has been shown quantitatively under controlled conditions that typical traditional farming methods can cause rapid wind erosion, 7.5 cm in the 24 months of the trial; and that this can be very significantly (statistically) reduced by adopting an anti-erosion strip crop/pasture system.

Pasture strips reduce the erosion of neighbouring cropped strips by reducing the velocity of the wind. The effectiveness of wind breaks depends on its height, width, shape and permeability. Generally, an effectively designed windbreak will protect an area 7 to 15 times its height downwind, and a much smaller area immediately upwind.

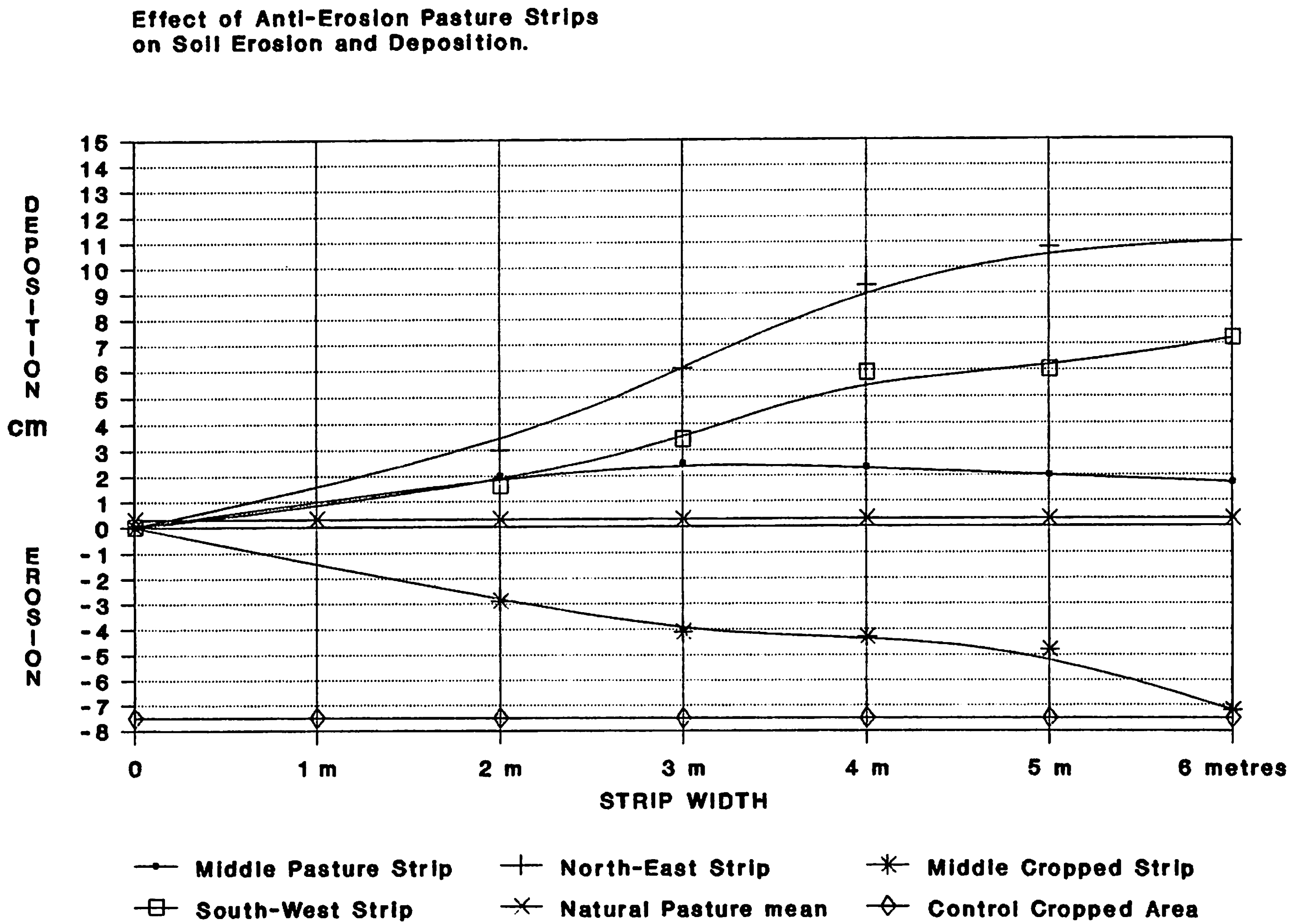
Applied to these pasture strips, it was thus anticipated that a *C.ciliaris*, *S.scabra* pasture with a typical height of 30 - 40 cm could protect a cropped area of up to 6 m. wide. This generalisation has proved valid in this experiment, although the windbreak effect was only very small at 6 m. Strips of less than 5 m. are required to significantly reduce erosion.

As shown in figure 8, wind erosion is reduced by 50 to 75% by reducing strip width from 6 metres, progressively to 3m. A width of 5 m. was chosen as the preferable recommendation to agropastoralists as it was the widest strip possible which still greatly reduced erosion. Extensive discussions with agropastoralists participating in the trial program indicated that wider strips were strongly preferred, and as some competition between pastures and crops for scarce water and nutrients could be anticipated, this recommendation appeared logical.

Although the 2 to 5 m. wide strips greatly reduced wind erosion, significant erosion was still caused by the cropping; although much of the eroded soil appeared to be deposited in adjacent pasture strips, where it would be available for use in a future cropping cycle.

The pasture and crop strips in each block had intentionally been allocated the same width, so they could be rotated periodically. Thus in addition to any anticipated soil improvements from organic matter accumulation, nitrogen fixation and other factors, the pasture strips were shown to accumulate significant quantities of valuable top soil. Unfortunately the trial had to be terminated before the next stage, where the performance of a rotation would have been evaluated.

Figure 8: Effect of Anti-Erosion Pasture Strips on Soil Erosion and Deposition



Deposition and erosion in centimtres.
0 - original soil surface. Natural
Pasture (Mean 0.3) Control (Mean 7.5)

The build up of ridges of accumulated sand on the edge of each pasture strip, shown diagramatically in the top two lines of figure 8, was a very noticeable physical feature caused by the decline in wind speed, due to the wind break effect of the pasture. Wind erosion increases enormously with every increment increase in wind velocity above a threshold speed of approximately 6.5 metres. (H. Hadgedorn et.al. 1977). When wind breaks reduce speed sufficiently, transported particles are deposited.

There are 3 main types of grain motion involved in wind erosion. Fine grains of organic matter, clay and silt are transported by suspension considerable distances. Most sand particles are transported by saltation, a jumping movement along the soil surface. Some sand too is transported by reptation, which is the creeping and rolling of larger particles caused by the saltation impact of smaller grains. (H. Hagedorn et. al. 1977) The sand accumulating as ridges along the edge of the strips could be expected to be transported mainly by saltation and some reptation.

Almost twice as much sand accumulated on the north-east edge of cropped strips than the south-west edge, as shown in figure 8. This is a quantitative demonstration that the south-west monsoon winds were stronger than the north-east monsoon over this 2 year period, causing a net movement of sand in a northerly direction. While no wind data is available for the trial site - at Hobyo, 300 km north-east - the south-west monsoon has been shown to be stronger, as shown in figures 2 and 3. At Mogadishu, 300 kms south-west, the velocities of the 2 monsoons are quite similar (Figures 4 and 5), so the wind regime at Nooleeye is probably more similar to Hobyo.

Although anti-erosion strips from 2 to 5 metres wide produced a large, significant reduction in wind erosion, erosion was still considerable; so means to improve the system need to be considered. The pasture strips were successfully accumulating much of the eroded sand, where it could subsequently be cropped again; however at least some of the find sand, silt and organic matter particles were probably being lost in suspension, and these are particularly important for soil fertility.

Taller pasture species than the *C.<u>ciliaris</u>* and *S.<u>Scabra</u>* varieties used would potentially improve the windbreak effect of the pasture strips. Identification of suitable alternative species is difficult. Very few pasture species adapted to these harsh conditions have been released commercially internationally; so beginning in 1985, the author surveyed local plant communities for possible suitable species, and began evaluating some.

The preliminary results, outlined in section 5.3 below, indicated that at least one indigenous species, *<u>Indigofera</u>* *<u>coerula</u>* had potential. It has many characteristics required for an anti-erosion pasture strip:

- perennial, evergreen species
- palatable, resistant to heavy grazing
- fast growing
- easy to establish
- legume, so may improve the soil
- erect habit, growing to a height of 50 to 60 cm
- resistant to droughts
- grows in a range of soil types including infertile old farms
- deep rooted, not very competitive with adjacent crop plants

E.coerula and other promising species should be further evaluated.

It was observed that some of the erosion of the cropped strips was caused by the occasional east to southerly winds which blew in the periods when the monsoon winds were changing direction, in March to May and October to November. The trial strips had been oriented at 315°, so they would be at right angles to the two strong monsoons, after studying the wind diagrams in figures 2 to 5. According to the wind diagrams, this orientation should be the most effective.

The erosion down the strips could be reduced by sowing additional north-east, south-west pasture strips, to form a checkerboard pattern. This would further reduce the area available for cropping though, and may not be acceptable to local agropastoralists.

Another method to improve the anti-erosion strips would be to plant at least 1 metre high fodder bushes, rather than pastures in the windbreak strips. This is effectively a hedgerow system, which is discussed in section 5.6 below.

By the end of this program, at least 25 local agropastoralists were known to have adopted the use of 5m. wide anti-erosion *Cenchrus ciliaris* pasture strips, and numerous others, including over 40 in Haradhere district, had requested technical assistance and seed to establish strips. The acceptability of the anti-erosion strips partly depended on the popularity of the introduced buffel grass varieties, Gayndah and U.S.A.

Local varieties are valued pasture plants, so apparently more productive varieties were easy to accept. The abundant seed is easy to harvest, store and sow; however careful technical advice must be given to aid a good establishment.

An alternative to sowing anti-erosion pasture strips when clearing new land, is to leave strips of natural pasture, just weeding out the larger competitive plants. This possibility deserves evaluation.

Anti-erosion strips would appear to halve the area available for cropping; however in practice this is rarely the case, as the agropastoralists invariably have spare land adjacent within their enclosure, which they were planning to crop in the near future.

Often agropastoralists adopt the strip farming system on land near exhaustion, then clear an adjacent area to crop. Once they have observed the benefits of the strips for a few seasons, it is hoped they will leave strips of natural pasture when clearing new areas in future.

5.2 Crop Production Trials

5.2.1 Introduction

Range development programs in areas with shifting cultivation need to address the cropping system, as it is effecting income and human welfare, livestock production and the land which will subsequently become rangeland. Extension work in agropastoral areas also benefits greatly from transferring improved cropping technology, as improving crop production is one of the highest priorities of agropastoralists. Such valued assistance establishes vital credibility, facilitating the transfer of other technologies including conservation strategies.

The crop trials were thus seen as another tool to achieve the objectives of the project, an important component of an eventual integrated technical extension package. Other leguminous crops could be introduced to stem the decline in soil fertility, to provide nutritious fodder and some production in drought periods. Other crops too would open the possibility of rotations.

Finally, the preliminary investigations and case studies had indicated a void in this area, as agropastoralists generally depended almost completely on just 2 crop species, sorghum and cowpeas.

The crop trials were undertaken as an integrated component of the whole research program, so some trials are outlined in other sections, particularly section 5.7, the manure and fertiliser trials.

Crop improvement programs abroad in similar climatic environments have selected a range of high producing varieties, some of which may have potential in central Somalia, where no recent introductions have been made. The hypotheses developed for testing were thus:

Ho.1 *'Improved varieties of cowpeas can produce more human food than the local varieties under the same conditions in arid central Somalia.'*

Ho.2 *'Suitable varieties of other leguminous crops can produce as much or more human food as local cowpea varieties when grown under the same conditions in arid central Somalia.'*

Sorghum was given a low priority in this development program, as the Bay Region Agricultural Development Project had a very extensive sorghum trial nearby at Baydoha, which had yet to find a variety superior to the local ones.

5.2.2 Materials and Methods

The first agropastoral adaptive trial site was selected near Nooleeye village, 60 km north-west of Ceel Dheer district centre, using the standard selection criteria and methodology. The site was on the southern edge of the village and next to Ceel Dheer main road. It met all the selection criteria, and had distinct areas with different, known cropping histories and included at least 10 ha of land which had not been cultivated for at least 50 years according to local informants.

This was an ideal situation for developing technologies adapted to current farms and newly fallowed areas. The land was owned by a prominent local agropastoralist, Mohammed Dugow, who was paid compensation for the project's acquisition. He was then employed on a part time basis to guard the facility, repair fences and help run the trials, an arrangement which worked well.

In March 1985, a series of parallel strips 100 to 150 metres long and 5 metres wide were cleared, orientated north-west to south-east direction, at right angles to the strong prevailing winds. Each strip was separated by a similar pasture strip.

In the Gu and Dayr seasons of 1985 and 1986, whole strips were planted to cowpeas. Both the local indeterminate variety and an introduced variety, TVU15002; which was obtained from the Semi-Mechanised Agricultural Project in southern Somalia; were sown. These varieties and a few promising new crop varieties were also sown in 5 x 5 metres observation plots, with 2 randomly located replicates per variety.

In 1987, new similar strips were cleared on previously uncultivated land and the replication of each crop variety increased to 6 plots, each 5 x 5 metres; with each of the six plots randomly located in one of 6 strips (block), creating a randomised block experiment. In the Gu season, 6 varieties were included in this trial, and in the Dayr season and the Gu season of 1988, this was further expanded to 12 varieties.

The yield of all varieties was compared against an internal control of the local variety of cowpea, and an external control of traditionally grown cowpea on an adjacent area with the same cropping history.

In the 1985 Gu season, the crops were sown late - 3 weeks after the first rain. In all other seasons, and at all other trial sites, they were sown just before the rainy season and immediately resown if germination rates were low. All crops were sown manually using a small hoe at a rate of approximately 26,000 plants/ha, except for 40,000 plants/ha for the smaller mung beans and safflowers.

In Bula Burti district, two trial sites were selected 800 metres apart within the Bula Burti fodder farm, which is a seasonal grazing reserve located on the northern edge of the township, next to sealed northern highway. The 2 sites were chosen to represent some of the main soil types in Hiraan region; one being a sandy loam area and the other a loamy clay. The area had been cultivated 7 to 9 years previously, though the agropastoralists who farmed it maintained the areas were still fertile and able to produce good crops.

Each 2.5 ha site was prepared in the standard manner and disc ploughed in March 1987. Each site was divided into 3 sections, one for crop and fodder variety trials, another for hedgerow cropping trials, and the third for live fence hedge trials. The crop and fodder area at each site was divided into 2 blocks, and 5 metre wide parallel trial strips marked out across each block in a north-west to south-east direction.

In the Gu season of 1987, a randomised block experiment containing 7 crop varieties sown in 2 blocks at the 2 soil types was sown. In the following Dayr season this trial, which had a large plot size of 5 x 50 metres, was reduced to 4 crop varieties. An additional large, randomised block variety trial was sown in the Dayr 1987 and Gu 1988 Seasons using smaller 5 x 5 metre plots, replicated twice in each block. This 2 block x 2 soil type x 2 replicate trial evaluated 29 crop varieties in the Dayr 1987 season and 30 in the Gu 1987 season.

The method and materials for the crop variety trial at Aborey is outlined in section 5.8.3, as this was principally a rainwater harvesting trial. A randomised block experimental design was used, with one 20 x 5 metre plot of each variety randomly located in each of 4 blocks. In the 1987 Gu and Dayr seasons, the yield of 6 crops were compared, and in the 1988 Gu season, 7 crops were included.

5.2.3 Results

The summerised yields of the main varieties under trial over 7 seasons is presented in table 4. All crops failed to yield in the 1986 Dayr season, and the 1988 Gu Season due to low seasonal rainfall.

In both 1985 seasons, the crops sown in the main trial strips were badly damaged by bush squirrels and rats. The yield of the 2 varieties presented in table 4 for these seasons were taken from undamaged 5 x 5 metre trial plots.

Mean yields of the same 5 introduced cowpea and mung bean varieties, compared to the controlled local cowpea variety in the 1987 Dayr season is shown in table 5. These yields are from the expanded randomised block experiment, and are the mean of 6 plots. Variation between plots was so high that the large difference between the yields of the varieties was not quite significant at the 5% level.

Table 4: Summerised 1985 to 1988 Seasonal Crop Variety Yields, Nooleeye Trial Site.

Crop Variety	Mean Seasonally Crop Yield (kg./ha. beans/peas)							% Yield Diff. From Local Cowpea
	1985		1986		1987		1988	
	Gu	Dayr	Gu	Dayr	Gu	Dayr	Gu	
Cowpea (local var.) (traditionally grown)	592	209	128	0	131	65	0	-13%
Cowpea (local var.)	664	240	145	0	151	75	0	0
Cowpea (var. TVU15002)	720	400	180	0	183	111	0	+27%
Cowpea (var. Caloona)	-	-	253	0	200	122	0	+55%
Cowpea (erect var.)	-	-	302	0	225	72	0	+61%
Mungbean (var. Thai)	-	-	250	0	345	123	0	+32%
Mungbean (var. Berkan	-	-	295	0	312	104	0	+91%

Note: The local variety cowpeas grown in a traditional fashion were grown by a local farmer immediately adjacent (adjoining) the trials. Yields quoted are a mean of 10 random one metre samples

Table 5: Cowpea and Mungbean Variety Yield Results, Gu 1987 Season, Nooleeye Trial.

Crop Variety	Mean Crop Yield Kg/ha	Percent Increase In Yield Above Local Cowpea
Cowpea (local var.)	151	0
Cowpea (TVU 15002)	183	21
Cowpea (erect var.)	225	49
Cowpea (var. Caloona)	200	32
Mungbean (var. Thai)	345	128
Mungbean (var. berkan)	312	107

Note
1. Yields are mean of six 5 x 5 metre plots
2. Yield of traditionally grown local cowpea was 131 kg/ha
3. Complete results and statistical analysis shown in appendix table 3.

The results of a small trial determining the effect of soil cropping history on crop yields during the 1987 Gu season at Nooleeye is shown in table 6. All the yields are the means of 4 randomly located replicate 5 x 5 m. plots.

Table 6: <u>**Effect of Soil Cropping History on Crop Yields at Nooleeye, 1987 Gu Season**</u>.

Crop Variety	Mean Crop Yields Kg/ha Beans/Peas		Percent Decline in yield
	Cropped for 2 previous years	Cropped for 6 previous years	
Cowpea (local var.)	127	44	289
Cowpea (var. TVU15002)	186	51	364
Mungbeans (var. Thai)	494	60	823

Note: 1. Bulrush millet (Aborey var.) was included in this trial, but gave no yield.
2. Complete results and statistical analysis found in appendix table 4.

<u>Summary Anova</u>

Source	d.f.	F.	Significance (5%)
Varieties	2	64.95	*
Cropping history	1	218.46	*
Var. x C.hist.	2	55.29	*
Within	18	-	
Total	23		

The mean yield of 4 cowpea and 4 mung bean varieties grown in the randomised block variety trial at Nooleeye in the 1987 Dayr season is shown in table 7.

The yields listed are means of 6 replicate plots. Four other crops also included in this trial gave no yield. These were local sorghum, an early maturing sorghum, (variety GSA 5559), peanuts (var. virginia) and pigeon pea (var. QLP hunt). There was a significant difference between the yields of the producing crop varieties, with the most productive varieties, cowpea (var. IT84S 223115) and mung bean var. filsen producing significantly more food than the other varieties.

Table 7: Crop Variety Yield Evaluation Results, Dayr Season 1987, Nooleeye.

Crop Variety	Mean Yield kg/ha Beans/Peas	Percent Difference from local Cowpea
Cowpea (loc. var.)	75	0
Cowpea (erect.var.)	72	- 4
Cowpea (var.TVU15002)	111	+ 48
Cowpea (IT84S-223115)	139	+ 85
Mungbean (Baydoha var.)	126	+ 68
Mungbean (var.berkan)	104	+ 39
Mungbean (Mog.mark.var.)	67	- 11

Summary Anova

Source	d.f.	F.	Significance (5%)
Varieties	7	3.46	*
Within	40	-	
Total	47		

Newman - Keuls test of Significantly Different Means (5%)

8 $\underline{2 \quad 1 \quad 7 \quad 3 \quad 5}$ 6 4 Variety number

Any 2 means not underlined by the same line are significantly different. Any 2 means underlined by the same line are not significantly different.

Note: Detailed results and statistical analysis is presented in appendix table 5.

The first season's crop variety trial results at the Aborey rainwater harvesting trial site are shown in table 8. There was a significant difference between the mean yields of the crop varieties, with the local sorghum producing significantly more grain than the 2 lowest yielding varieties, local sesame and cowpeas.

Table 8: Crop Variety Trial Results in the 1987 Gu Season at Aborey.

Crop Variety	Mean Crop Yield kg/ha grain/beans
Sorghum (loc.var.)	395
Cowpea (loc.var.)	164
Cowpea (var. TVU 15002)	292
Cowpea (var.Thai)	223
Bulrush millet (loc. var.)	243
Sesame (loc. var.)	88

Summary Anova

Source	d.f.	F	Significance (5%)
Blocks	3	1.30	n.s.
Varieties	5	4.38	*
Within	15	-	
Total	23		

Note: 1. Yields are means of 4 plots each 20 x 5 metres.
2. Complete results and statistical analysis presented in appendix table 6.

In the following season, the 1987 Dayr season, both the yield of grain/peas and forage residues of 5 crops varieties under evaluation at Aborey, is shown in table 9. There was a significant difference in the yield of both grain/peas and forage residues. The forage yield of the intercropping treatment was not recorded.

Table 9: <u>The Comparative Yield of Grain/Peas and Forage Residues from 5 Crop varieties at Aborey, 1987 Dayr Season</u>.

Crop Variety	Mean Crop Yield, kg/ha	
	Grain or peas	Forage (dry matter)
Sorghum (loc.var.)	190	1908
Cowpea (loc. var.)	152	947
Cowpea (var. TVU 15002)	257	797
Mung beans (var. Thai)	162	546
Bulrush millet (loc. var.)	470	1632
Intercrops - Sorghum	141	-
plus - Cowpea	145	-

<u>Summary Anova</u> (Yield Grain/Peas)

Source	d.f.	F	Significance (5%)
Blocks	3	0.47	n.s.
Varieties	5	8.78	*
Within	15	-	
Total	23		

<u>Summary Anova</u> (Yield Forage Residues)

Source	d.f.	F	Significance (5%)
Blocks	3	2.16	n.s.
Varieties	4	40.38	*
Within	12	-	
Total	19		

Note: 1. Each figure is the mean of 4 replicated plots, each 10 x 5 metres in size.
2. Detailed results and statistical analysis presented in appendix tables 7 and 8.

The comparative yields of 7 crop variety treatments repeated at the Aborey trial in the 1988 Gu season is shown in table 10. There was again a significant difference between crop variety yields.

Table 10: Aborey Crop Variety Trial Results, Gu Season 1988.

Crop Variety	Mean Yield, kg/ha peas/grain
Sorghum (loc.var.)	110
Cowpea (var. TVU 15002)	101
Cowpea (loc. var.)	120
Bulrush millet (loc. var.)	175
Mung beans (var. Thai)	113
Sesame (local variety)	39
Intercrops - Sorghum	53 } 108
- Cowpea	55

Note: 1. Yields listed are means of 4 plots, each 10 x 5 metres square.
2. Complete results listed in appendix table 9.

Summary Anova

Source	d.f.	F	Significance (5%)
Blocks	3	7.9	*
Varieties	6	7.7	*
Manure	1	11.9	*
Var.x Manure	6	0.9	n.s.
Within	39	-	
Total	55		

At the Bula Burti fodder farms site, the results of the first seasons variety trials (1987 Gu), is shown in table 11. There was a highly significant difference between the yields of the varieties, but no significant effect of soil type on crop yield.

Table 11: Seven Drought Resistant Crop Yield Comparisons at Bula Burti Fodder Farm Trial Site, Gu Season 1987.

Crop Variety	Mean Crop Yields of Peas/grain kg/ha		
	Sandy loam site	Loamy clay site	Mean Yield
Cowpea (local var.)	183	84	133
Sorghum (local var.)	443	533	488
Sesame (local var.)	-	220	220
Bulrush millet(loc. var.)	198	215	206
Mung Beans (var. Thai)	313	409	361
Cowpeas (var. TVU15002)	342	348	345
Safflower	46	161	103

Note: 1. Yields are means of 2 plots, 1 per block, each 50 x 5 metres in size. Sesame was not sown in the light soil so is not included in statistical analysis.

2. Complete results are listed in appendix table 11.

Summary Anova

Source	d.f.	F	Significance (5%)
Varieties	5	27.45	*
Soils	1	1.94	n.s.
Var.x soils	5	1.71	n.s.
Within	12	-	
Total	23		

Sign. difference between variety means = S.E. x t(0.05) d.f.12
= 41.14 x 2.18
= ± 89.7 kg/ha

In following 1987 Dayr season, both pea/bean and crop residue production from 4 crop varieties grown in the same large 50 x 5 metre strip plots is shown in table 12. There was a significant difference between varieties in the production of both. There was a considerable and significant difference between the soils in terms of crop production. Crop residue production data is only available from the sandy loam site where there was also a significant difference between block production.

Table 12: Comparative Yield of Beans/Peas and Fodder Residues from Four Crops Grown at the Bula Burti Fodder Farm Trial Sites in the 1987 Dayr Season.

Crop Variety	Mean yield kg/ha beans/peas		Mean Yield kg/ha crop residues (d.matter)	
	Sandy loam site	loamy clay site	sandy loam site	loamy clay site
Cowpea (loc. var.)	21	20	423	-
Mung bean (var. Thai)	72	149	366	-
Mung bean (var. filsen)	82	153	163	-
Cowpea (var. TVU15002)	73	131	417	-

Note: Yields are means of 2 randomly replicated plots.
Detailed results and statistical analysis in appendix tables 7 and 8

Summary Anova Beans/Peas Production

Source	d.f.	F	Significance (5%)
Varieties	3	27.48	*
Soils	1	32.50	n.s.
Var.x soils	3	3.97	n.s.
Within	8	-	
Total	15		

S.E. difference between variety means x t(0.05)8 d.f.
= 12.71 X 2.31
= ± 29.36 kg/ha

Summary Anova Crop Residue

Source	d.f.	F	Significance (5%)
Blocks	1	20.34	*
Varieties	3	18.39	*
Var.x blocks	3	1.59	n.s.
Within	8	-	
Total	15		

S.E. difference between variety means x t 8 d.f.
= 32.26 X 2.306
= ± 74.39 kg/ha

In the 1987 Dayr season, the large variety trial at the 2 Bula Burti fodder farm sites evaluated 29 drought resistant crop varieties including 6 mung bean varieties, 5 cowpeas and 3 sorghums,including all the main local crop varieties as controls.

Although the seasonal rainfall was poor, eleven varieties had a mean yield of 4 plots, including 2 at both soil types, of over 100 kg/ha. These were:

• mung bean var. VC 3300A	339 kg/ha
• pigeon pea var. QPL 131	273 kg/ha
• mung bean var. Thai	258 kg/ha
• mungbean var. Baydoha	216 kg/ha
• mung bean var. VL 3500A	215 kg/ha
• mung bean var. berkan	178 kg/ha
• mung bean var. filsen	152 kg/ha
• cowpea var. TVU 15002	142 kg/ha
• guar. var. P1 Sel.20	124 kg/ha
• guar var. P3 Sel.36	116 kg/ha
• bulrush millet local variety	106 kg/ha.

The local staple food varieties of cowpeas and sorghum produced only 32 and zero kg/ha respectively. The detailed results are listed in the appendix table 14.

The following 1988 Gu rainy season at Bula Burti fodder farm trial sites was even worse for crop growth, with none of 27 drought resistant crop varieties producing over 100 kg/ha. Three varieties produced over 50 kg/ha. These were:

• guar. var. P3. Sel36	71 kg/ha
• guar var. P1 Sel.20	65 kg/ha
• guar var. P2 sel.3	55 Kg/ha.

The local sorghum variety produced 42 kg/ha, while the local cowpea only produced 1 kg/ha. Tepary beans (*Phaseolus acutifolius*), a drought resistant leguminous crop from Mexico, produced 49 kg/ha. Detailed results are listed in the appendix table 13.

5.2.4 Discussion

The crop adaptive trial's cropping component has proven to be a particularly successful part of this farming system's development program. A number of new drought resistant short season crop varieties and even new species of crops have been introduced, mainly from Australia; which have been shown to out produce the local staple food crop cowpeas, over many seasons of testing.

Not only do some of the introduced varieties promise to considerably increase food production in central Somalia; as many of the new varieties are more drought resistant than the local cowpea or sorghum varieties; they thus promise to improve food security. Most of the new varieties introduced, including cowpeas, mungbeans, guar, pigeon pea, jack bean and tepary bean, are legumes and thus also promise to improve biological conservation through rotations, nitrogen fixation and other positive effects on the soil.

The first new cowpea variety to be introduced, TVU15002, consistently outyielded the local variety at Nooleeye over 5 productive seasons. Over this period it produced 27% more peas than the local cowpea included in the trial plots, and 42% more than the same local cowpea variety grown adjacently in the traditional manner.

The difference between trial and traditional yields was probably due to improved weeding, plant population and row cropping. The TVU 15002 proved highly acceptable to local people as they felt it had similar properties to the traditional variety while having slightly higher resistance to storage insects pests, and longer pods. It too is an indeterminate variety which produces considerable fodder.

Two erect, determinate short season varieties of cowpeas introduced from Australia in 1986 greatly out-produced the local variety at Nooleeye. Over the 3 productive seasons since the 1986 Gu season, variety Caloona and erect var. ex. sanora, produced 55% and 61% more peas respectively.

Mung beans are a new leguminous crop introduced to central Somalia by this agropastoral development program, which show considerable promise. Since they were introduced at Nooleeye in the 1986 Gu season, varieties Thai and Berkan produced 32% and 91% respectively more peas/beans than the local cowpea variety (table 4). The mung beans proved a highly acceptable food, and in the nearest major market, Mogadishu, they enjoy a price premium of 30-40% over cowpeas. They do however, produce less forage residues for livestock.

The success of these introduced varieties of cowpeas and mung beans was considered sufficient to begin multiplying seed and disseminating samples to local agropastoralists. This was begun near the end of this trial program, and at least 200 agropastoralists throughout the sandy agropastoral zone had started to use these varieties.

In the 1987 Dayr season, some additional crop varieties tested at Nooleeye produced relatively very well. A very short season cowpea variety, IT84S-223115, out produced local cowpea by a huge 85%. A very short season mung bean variety, filsen, introduced from the Bonka research station, produced 68% more beans/peas than local cowpeas. These very promising varieties should continue to be evaluated, particularly in better wet seasons.

Overall crop yields were generally fairly low, probably due mainly to the poor rainfall seasons. When good falls were received, it was almost all received early in the season, causing the growing season to be very short.

Crop yields have also been shown to reduce rapidly with the number of seasons soil has been consecutively cropped at Nooleeye. As shown in table 6, soil only 10 metres apart, which had been cropped for the past 6 years produced less than an eighth of the mungbeans (Thai var.), and a 1/3 of the cowpeas (local variety and TVU 15002) than soil cropped for only the last 2 years.

These results support the information collected from the case studies which suggested that the very sandy soils in the sandy agropastoral zone were capable of producing crops for only 5 to 7 years, or occasionally 10 years, before needing a long restorative bush fallow. The results also suggest the Thai mung bean variety may be more sensitive to soil infertility caused by continuous cropping than the cowpea varieties used.

At the Aborey rainwater harvesting trial, the TVU 15002 variety of cowpea again produced more than the local cowpea variety in both the 1987 seasons, 78% and 59%. However, in the 1988 Gu season it actually produced 8% less. The Thai variety mung bean similarly produced less than the local cowpea variety only in this season. The reason is probably methodological rather than biological, as the trials were being finalised at this stage.

The local Aborey bulrush millet (pearl millet) variety produced very well in the Aborey trial, relatively better also than at the other trial sites, Nooleeye and Bula Burti. The local sorghum variety produced well in the 1987 Gu season. It also produces large quantities of palatable fodder, and is a popular crop in Hiraan region particularly; partly because of the valuable fodder produced, even if crop yields are low.

In the 1987 Dayr season for example, it produced more than twice the crop residue dry matter than local cowpeas, 1,908 kg/ha dry matter compared to 947 kg/ha dry matter. In the same season bulrush millet produced almost the quantity of not quite as palatable fodder (1,632 kg/ha) and more than twice the quantity of grain. Further evaluation of this and other promising varieties of bulrush millet is justified.

At the two Bula Burti trial sites, the TVU15002 variety of cowpea again greatly out produced the local cowpea variety, 159% in the 1987 Gu season and 385% in the 1987 Dayr season. Rain was too poor in the 1988 Gu season for production from the cowpeas. Mung beans produced relatively excellently in the Bula Burti trials.

The Thai variety produced more than double the yield of local cowpeas in the 1987 Gu season and over four times the yield in the next season. It appears that the superiority of the TVU 15002 variety of cowpea and the mung bean varieties is particularly evident during poor rain fall seasons. Both are quick maturing, drought avoiding varieties, maturing in 60 and 56 days respectively.

Edible oil is one of the main imports purchased by the inhabitants of central Somalia, as it is an important food; and the small amounts of the only vegetable oil crop - sesame, is mainly consumed directed in central Somalia.

Early efforts to introduce safflower (*Carthamus tinctorius*), a likely drought resistant oil seed crop, were not encouraging. Bush squirrels and rats dug up the seed as fast as it was planted. Germination too, was a problem, and only very small yields were recorded in the Bula Burti and Nooleeye trials. It still requires further evaluation.

Potentially improved varieties of short season sesame introduced in the Dayr 1987 season at Bula Burti did not produce, but rainfall was insufficient for the local variety either. Sesame is quite an important crop in Hiraan region, so future adaptive trials should continue to evaluate short season productive varieties.

Peanuts (*Arachis hypogaea*) are a legume oil crop which is grown to a limited extent in southern Somalia for food. In the 1987 Dayr season and 1988 Gu season variety Virginia established well, but with the poor seasonal conditions, suffered water stress before flowering.

The short season, drought resistant varieties of multipurpose legume crops, pigeon pea and guar; grown at Bula Burti since their introduction from Australia in 1987; demonstrated a potential for producing some food when most other crops fail due to low rainfall. The food produced from these crops require longer cooking than cowpeas or mungbean, so may not be acceptable. Insufficient seed was available to test this.

The results from the intercropping treatments at Aborey were encouraging. Further testing of this technique is required. The large intercropping trial; initiated in Bula Burti in the 1988 Gu season to develop intercropping techniques; did not produce, due to the low rainfall.

Overall, the cropping adaptive trial results were very successful. New varieties of cowpeas have consistently produced much higher yields than the local variety. This result alone promises to provide substantial economic and social benefit to central Somalia. Pure seed of the new varieties needs to be made widely available to reap this benefit.

Of perhaps even more importance, the introduction of new, adapted leguminous crops, particularly mung bean, provides agropastoralists with the opportunity to produce more food under adverse conditions; to practice biological conservation of the soil, and to practice food shortage risk aversion strategies.

5.3 Fodder Production

5.3.1 Introduction

The potential of plant varieties introduced into the agropastoral system to produce good quantities of high quality, valuable livestock fodder, was considered in conjunction with other components of this study. Experience and investigations suggested agropastoralists were not normally prepared to plant fodder species just for fodder production, unless fodder was particularly valuable, as is the case near major settlements. Thus fodders were considered as multipurpose pasture strips in the anti-erosion strip trials, as woody perennial hedgerow/alley cropping fodder species, and as a by-product of food and oil crops.

Fodder production is thus indirectly considered in the other components of these trials. In this section, these will be briefly brought together, with emphasis placed on the pastures established in the anti-erosion strips.

Of special concern was the need to establish pastures on currently farmed and newly fallowed land to protect it from erosion and speed the natural regeneration of the rangeland. Very few pasture species with the necessary characteristics have been domesticated. A notable exception is the perennial tussock grass *Cenchrus ciliaris*.

The hypothesis formulated for testing was:

> *'Improved varieties of C.ciliaris can rapidly increase fodder production of fallowed land under rainfed field conditions in the sandy agropastoral zone.'*

Investigations to identify other suitable species were also initiated.

5.3.2 Method and Materials

The methods and materials have been described in the general section 4.4 and under the methodology of other research components. Pasture biomass production was measured by clipping ten randomly located, one metre square quadrants per plot; then drying the samples in ovens to obtain dry matter weights. Lack of resources for drying and weighing plant samples limited the amount of data collected. Limited resources also meant it was not possible to conduct nutrient analysis of fodder samples.

5.3.3 Results

The results of *Cenchrus ciliaris*, lablab and pigeon pea in anti-erosion pasture strips, compared to allowing the previously cropped land to regenerate naturally at various locations, is shown in table 13.

The three pasture species generally produced at least double the amount of forage after one year, than naturally regenerating pastures. The *C.ciliaris* pasture was not weeded, so it was found hard to establish at all sites, unless the site had been cultivated for a few years to reduce competition from naturally regenerating pasture species. The other two fodder species established vigorously. They were weeded, as are potential food crops.

Table 13: <u>Dry matter Forage Production From Three Introduced Pasture Species Compared to Naturally Regenerating Fallow at 4 Localities in Central Somalia</u>.

Location	Dry matter fodder Production kg/ha			
	Naturally Reg. pasture	*Cenchrus ciliaris*	*Lablab purpurens*	*Cajanus cajan*
Bula Burti (Trial Site)	982	-	1,598	2,898
Nooleeye (Trial Site)	504	1,644	1,408	1,222
Ali Yabal (Mohamed Osman farm)	900	2,380	-	-
Nooleeye (Ali Ciid farm)	586	2,148	-	-

Note: 1. Yields were all measured one year after sowing.
2. Yields are the mean of 7 to 10 one square metre random quadrants.

Two of the most productive, commercially available *C.ciliaris* varieties introduced from Australia, Gayndah and U.S.A. varieties, gave the yields listed in table 13. Both the Highworth lablab variety and a long season variety of pigeon pea imported from Nairobi did not flower. At Bula Burti most of the pigeon pea plants kept growing for 2 years, reaching a height of 2 metres.

The fodder production from sorghum, cowpea, bulrush millet and mungbean varieties at Aborey and Bula Burti is shown on tables 9 and 12, in section 5.2.3. The effect of applying sheep and goats manure at a rate of 600 kg/ha to local varieties of sorghum and bulrush millet at Bula Burti is shown in table 14. The growing season was too short to produce a crop, but large forage yields were still produced, and the manure increased yields by 29% and 35% respectively.

Table 14: <u>Increase in Sorghum and Millet Forage Production with the Addition of Manure at the Bula Burti Sandy Loam Site, Dayr 1987</u>.

Crop Variety	Crop Forage Residues Dry Weight kg/ha		
	No Manure	Manure Applied	Percent Increase
Sorghum (local variety)	1175	1510	29%
Bulrush millet (local var.)	1342	1812	35%

5.3.4 Discussion

The results have shown that it is possible and practical to establish very productive fodder crops on fallowed farm land under arid, rainfed conditions in central Somalia. At a number of locations, including 2 privately owned farms, it was shown that improved varieties of *C.ciliaris*, lablab and pigeon pea were able to more than double the production of the plant biomass produced by naturally regenerating range species. The varieties of lablab and pigeon pea introduced were however not suitable, as they did not set seed. Other varieties with suitable day length requirements should be tested.

The Gayndah and U.S.A. varieties of *C.ciliaris* are large, tussock perennial grass varieties which appear well adapted. Many agropastoralists have already begun sowing anti-erosion strips on their farms using these varieties. Large quantities of seed and an effective extension service will be needed to greatly spread the technology.

Establishment is often difficult, as it is susceptible to competition from other plants; so must be grown in recently fallowed land which has been cultivated for some years. Establishment in Bula Burti in 1987 was poor because these conditions were not available. In addition, the seed requires soaking with rainwater for 2 - 3 days to establish well, so small rainfalls cause establishment failures.

Observations were made on establishing other potential fodder species. *Stylosanthes scabra*, varieties Seca and Fitzroy established, persisted well and set seed at all trial sites (except Ceel Buur). Growth though, was slow.

Local species of the legumes *Indigofera*, *Crotalaria*, *Rhyncosia* and *Tephrosia* were collected and sown. Some show promise, but the time and resources were not sufficient in this program to develop them. There is a great need for domesticated, fast-growing, perennial legume fodder species adapted to warm arid areas.

One of these local species which shows particular promise is *Indigofera coerula* (var. Nooleeye). The Nooleeye variety appears reasonably palatable, and this is 1 metre high woody variety established reasonably well at Nooleeye, Aborey and Bula Burti in observation trials. In the first season it grows fairly slowly; however after a year, one plot at Aborey produced 1,058 kg/ha of palatable forage.

Data presented from the cropping trials has shown that the main crops grown in central Somalia produce large quantities of palatable livestock fodder. In the Aborey trial for example, local varieties of sorghum and bulrush millet produced 1,908 and 1,632 kg/ha of dry matter in the 2 month long 1987 Dayr season (Table 9). It is clearly advantageous for agropastoralists to grow multipurpose fodder/crop species. It is the challenge of the agropastoral program to identify more sustainable varieties, such as pigeon peas.

5.4 Live Fence Hedges

5.4.1 Introduction

One of the main constraints facing improved management of range and farm land in Somalia and many other developing countries is the difficulty of controlling stocking rate, overgrazing and the over-utilisation of the vegetative resources. Living fence hedges are a promising technique which can both control the movement of livestock and provide a physical and mental barrier to humans.

In developed countries, capital intensive fencing techniques, such as steel wires are extensively used for this purpose. Where labour costs are low and capital and foreign exchange scarce; such as with small scale farming in developing areas; wire fences are not economically justifiable, and living hedges may be a practical alternative.

Hedges have been extensively used in Europe and England for fencing for hundreds of years. In Africa hedges have been occasionally used for fencing, usually in villages, or where the population density is high and pressure on resources great.

A range of *Commiphora* bush species have been used to a very limited extent in Somalia for live fences; and probably over the last 50 years, *Euphobia tirucalli* and *Opuntia* spp. (cactus) have also occasionally been used. Almost all fences in Somalia are constructed from cut thorn bush branches. With the rapid expansion of private fencing of the rangelands over the last 10 to 20 years, in areas such as central Somalia and around Mogadishu, the time is right to develop a more appropriate, less environmentally destructive fencing technique.

The most degraded areas in central Somalia are generally those near water points or settlements. In these range areas, overcutting of woody perennials for fuel, building material and to build thorn branch fences has often created an eroded, dusty, treeless areas; in which it is not possible to build thorn branch fenced enclosures, as the branches have to be transported too far. In these circumstances hedges are one of the few possible techniques available that has promise to improve land management.

Traditional Somali *Commiphora* live fence construction techniques involve the planting of a 70 to 150 high *Commiphora* spp. branches in the soil just prior to the rainy season. The cost of establishing 1 km of such a fence at the Aborey trial site was 4,000/-/km or U.S. $22/km, which compares very favourable to a cost of about US $1,000/km for a wire fence with similar stock security. The cost of the Aborey fence did not include transport costs however, and sufficient large branches are often not available near farms.

As arid area farms generally are not very productive, it was considered that for the live fencing technologies to be widely adopted, techniques needed to be developed to reduce the cost and labour of establishment even more. The lack of transport, and high cost when available, also suggested that a further objective of the agropastoral program was to develop techniques to reduce live fencing transport requirements.

If small branches of _Commiphora_ sp. could be used to propagate bushes, and a range of common species were suitable, costs could be reduced; so hypotheses formulated for testing were:

> *'A range of _Commiphora_ and _Euphobia_ spp. can be vegetatively propagated under arid rainfed 250-350 mm. field conditions.'*
>
> *'Common _Commiphora_ sp. in central Somalia can be vegetatively propagated under arid rainfed conditions using small cuttings.'*

Another cultural technique which could potentially improve live fencing is propagation by the direct sowing of seed along the fence line. To test this, the hypothesis formula for testing was:

> *'Live fence hedges can be propagated by direct sowing of appropriate seed along fence lines under arid rainfed conditions.'*

5.4.2 Method and Materials

At both of the two main trial sites at Nooleeye and Bula Burti fodder farm, a cleared area was established for live fence hedge trials, observations and demonstrations. Two replicates were set up at Bula Burti, one at the sandy loam site and the other at the loamy clay site.

Two replicates were also established at Nooleeye. In this case, one was located in virgin soil which had not been cultivated for at least 50 years, whereas the other adjacent replicate was in soil abandoned after being exhausted by a cropping cycle only about 5 years before. The first trials were initiated at Nooleeye site for the Gu season of 1986, then extended to Bula Burti the next year.

At each site many replicated parallel fence lines, 5 metres apart were marked out in a north-west, south-east direction, and 2 metre wide strips kept weeded during the trial period. Rows of live fence treatments were planted or sown down the middle of the cleared strips, with each row being 23 metres long.

Two main plant spacing treatments were adopted. For observation and demonstration purposes, a spacing trial was designed to determine plant spacing recommendations for each species and cultural treatment. The plants were sown or planted at a range of spaces beginning at 10 cm apart at one end of the hedgerow, and progressively becoming wider, to finish at the other end with a 2 metre spacing for each of the species and cultural techniques under trial.

Seeds for the direct sowing treatments were collected from trees growing in Ceel Dheer and Bula Burti districts, and sown 2 to 5 cm deep just prior to the first seasonal rain.

Seedlings were raised using the standard techniques outlined in section 4, and planted out immediately after the first good seasonal rain. Many different types of vegetative cuttings were harvested from local plants, and these were given a range of treatments for trial purposes.

5.4.3 Results

The survival rate of 7 multipurpose, potential live fence plant species 2 years after they were planted or sown at Nooleeye under arid rainfed conditions in April 1986 is shown in table 15. these results are compared to the establishment performance of *Acacia nilotica*, a common native tree at the Nooleeye range site.

Table 15: Results of Propagating Multipurpose Live Fence Plant Species Compared to Acacia nilotica Over a Two Year Period Under Rainfed Conditions at Nooleeye.

			1/4/88 Percent Growing Plants	
Plant Species	Source	Propagation Method	Old Farm	Virgin Soil
Acacia nilotica	C/Dheer	Seedling, 4 months old	0	4
Prosopis chilensis	B/Burti	Seedling, 4 months old	91	95
Parkinsonia aculeata	B/Burti	Seedling 4 months old	24	31
Opuntia sp. (prickly pear cactus)	B/Burti	Cactus pads planted	100	96
Euphobia tirucalli	B/Burti	1m long branches planted	28	15
Euphobia spinescens	B/Burti	1m long branches planted	0	6
Balanites aegyptiaca	B/Burti	Seeds, 9 per position	16	14
Terminalia spinosa	C/Dheer	Seeds, 9 per position	0	2

Note: 1. All seeds and *Euphobia* and *Opuntia* vegetative cuttings were planted in dry soil just prior to the first seasonal rains on the 21/4/86. The seedlings were planted the day after the rain on the 30/4/86.

2. Number of plants per plot was normally 26, sown in a hedge line.

The effect of cutting size, trimming and soil cultivation history, and thus presumably soil fertility, on the vegetative propagation of 3 *Commiphora* species common in the Nooleeye/Ceel Dheer area is shown a year after planting in table 16.

Table 16: Effect of Cutting Size Trimming and Soil Cultivation History on the Propagation of 3 Commiphora Bush Species Under Rainfed Conditions at Nooleeye, 23/4/87 - 18/4/88

Propagation Treatment	Percent Commiphora Cutting Alive					
	Commiphora (xagas)		*Commiphora (sagaarasal)*		*Commiphora (Incisa)*	
	Old Farm	Virgin Soil	Old Farm	Virgin Soil	Old Farm	Virgin Soil
Large branches, 1.5 m high	48	34	96	100	96	100
Medium branches, 1.0 m high	3	5	76	69	33	56
Small Branches, 0.5 m high	3	7	37	41	22	28
Medium Branches, trimmed laterals	0	7	9	22	4	15

Note: 1. Number of cuttings per plot (n) was 54 except for the large branch plots, in which it was 50.

2. Cuttings aged for 1 day before planting 10-15 cm deep on the 23/4/87. First seasonal rain one week later. (No water added).

Just prior to the 1988 Gu season, many *Commiphora* live fence propagation treatments were planted at Nooleeye, including the untrimmed large branch (1.5 m high) *C.Incisa* treatment again, which was used as a control. Almost all were dead by December 1988, after a period of poor seasonal rainfall.

The results of vegetatively propagating a live fence hedge by planting trimmed branches of *Euphobia tirucalli*, just before the Gu season at the 2 Bula Burti trial sites, is shown in table 17. Results were much poorer than expected, so in the following Dayr season, the trial was repeated exactly, except the *E.tirucalli* branches were not trimmed, and these results are also shown in table 17.

The results of a range of treatments on the success of vegetative propagation of 3 *Commiphora* bush species common in the Bula Burti area is shown in table 18. The results of cutting treatments, recording dates and *Commiphora* species on cutting survival were all significant, as were all interactions.

Table 17: Establishment of a Euphobia tirucalli Live Fence Hedge Using Trimmed and Untrimmed Cuttings Under Rainfed Arid Field Conditions at Bula Burti.

Plant Spacing	Percent Growing cutting 14/12/88			
	Trimmed cuttings planted 26/4/87		Untrimmed cuttings planted 29/9/87	
	Sandy loam	Loamy clay	Sandy loam	Loamy clay
26 Plants/Pot, each 10 to 2000 cm apart	8	15	65	65
100 plants/plot, each 22 cm apart	4	4	57	82

Note: 1. All *E.tirucalli* cuttings were of similar length (1.2 - 1.5 m.) and width (2-4 cm).
2. All were cured (aged) for 1 day before planting 10-15 cm deep just prior to the first seasonal rain.

Table 18: Effect of Cultural Techniques and Soil Types on the Vegetative Propagation of 3 Potential Commiphora Live Fence Hedge Species at Bula Burti, 26/4/87 - 13/12/88.

Plant Species	Soil Type	Percent Growing Plants 13/1288			
		Treatment A	Treatment B	Treatment C	Treatment D
Commiphora incisa (rahanreb)	Sandy Loam	0	0	73	0
	Loamy Clay	46	26	96	8
Commiphora hodai (hothai)	Sandy Loam	10	29	74	13
	Loamy Clay	7	4	17	0
Commiphora oddurensis (gar goy)	Sandy Loam	4	4	83	0
	Loamy Clay	4	3	19	0

Treatment A: 26 cuttings, 70 cm. long, trimmed and planted 10 - 200 cm apart.
Treatment B: Same as A, except 90 cuttings, each 25 cm. apart.
Treatment C: Instant fence. Same as A, except untrimmed branches 1.2 - 1.6 m. high
Treatment D: Same as A, except terminal shoot untrimmed and half width, 1.2 - 2.0 cm.

Note: All treatments cured for one day prior to planting 10 - 15 cm. deep. Complete results and analysis shown in appendix table 14.

In the Gu season of 1988, vegetative cuttings of *C.incisa*; one of the most common, promising live fence species; were treated in 12 different ways, and the results are shown in table 19.

Table 19: Results of Testing Factors Affecting the Vegetative Propagation of a Range of Potential Life Fence Hedge Commiphora Species: Bula Burti, 1988.

Treatment	Plant Species	Cutting Length(cm)	Percent Cuttings Alive			
			01/08/88		14/12/88	
			Sandy Loam	Loamy Clay	Sandy Loam	Loamy Clay
1, Untrimmed, untreated stick cured one day then planted	*Commiphora incisa*	30-40	37	2	0	0
2, 10 - 15 cm deep, 6-7/4/88.	"	69-70	88	23	16	14
3, " "	"	90-100	70	4	12	4
4, " "	"	120-130	67	13	12	4
5, Lateral branches trimmed	"	90-100	86	25	2	17
6, Bottom 10 cm. stem bruised	"	" "	-	23	-	0
7, Planted at angle of 45°	"	" "	53	13	0	2
8, Stem double thickness	"	" "	74	16	21	2
9, Stem triple thickness	"	" "	-	53	-	14
10, Planted immediately after cut	"	" "	88	13	7	7
11, Planted after aged for 1 week	"	" "	-	55	-	19
12, Planted after 10 days aging and first seasonal rain	"	" "	-	41	-	4
13, As treatment 1	*Commiphora hodai*	" "	-	0	-	0
14, " " "	*Commiphora myrrh*	" "	-	39	-	10
15, " " "	*Commiphora rostrata*	" "	-	0	-	0
16, " " "	*Commiphora oddurensis*	" "	-	46	-	37

Note 1. Some treatments only in the loamy clay site due to lack of resources.
Note 2. Somali names for the plants tested are: *C.incisa* = Rahanreb, *C.hodai* = hothai, *C.myrrh* = malmal, *C.rostrata* = jinow sheere, *C.oddurensis* = gar goy
Note 3. n, the number of cuttings per plot was 43 for all treatments and species.

Also given in table 19 is the result of propagating 4 other likely *Commiphora* species found in Hiraan region. Rainfall during the trial period was fair to poor, 129 mm and 20 mm in the Gu and Dayr seasons respectively.

Seventeen months after rows of *Parkinsonia aculeata* and *Balanites aegyptiaca* tree seeds were directly sown in April 1987 at Bula Burti, just prior to the Gu season, 75% of the *B.aegyptiaca* and 62% of the *P.aculeata* plants had established well at the loamy clay site. Establishment was significantly poorer in the lighter sandy, loam soil, with 50% of *B.aegyptiaca* growing, but no *P.aculeata* survived. *B.aegyptiaca* thus performed significantly better than *P.aculeata*. Both species grew about 1 metre high during this period. Detailed results and statistical analysis is presented in the appendix table 15.

5.4.4 Discussion

The trials, demonstrations and observations have shown that 'instantly' functional live fence hedges can be propagated vegetatively under arid field conditions using large untrimmed branches of a range of *Commiphora* bush species, and *Euphobia tirucalli*.

E.tirucalli grew well at Bula Burti in both sandy and clayey soils, when large branches did not have terminal shoots trimmed. Under better growing conditions in the previous season, the propagation of similar, trimmed branches was poor. It thus appears trimming the *E.tirucalli* cutting reduces vegetative propagation. Untrimmed *E.tirucalli* branches established poorly at Nooleeye, probably due to more dry, very sandy conditions. *E.tirucalli* is a promising hedge species, which is used in some arid areas of Kenya. It is grazed slightly and has some medicinal use.

Euphobia spinescens is another spiny, potential live fence species, which is native to central Somalia. It is widely used to provide fibre for weaving milk and water containers. Unfortunately growth from vegetative production at Nooleeye was poor. It was planted just before the rainy season, like all the other treatments. Local agropastoralists say it propagates better if planted into wet soil, so this should be tried in future.

At this preliminary stage of research, some *Commiphora* species are the most promising living fence hedge plants; as they are abundant throughout central Somalia, established well from cuttings, are resistant to heavy grazing, have a suitable growth form, and can be used to build an 'instantly' functional fence.

There is only a relatively small quantity of *Euphobia tirucalli* in Central Somalia, mainly in Bula Burti district, and it does not appear to grow well in the drier sandy areas; so its potential for live fencing is probably restricted in the near future.

For similar reasons the immediate potential for using prickly pear cactus (*Opuntia* sp.) is also low. It did however, survive extremely well at the dry, sandy Nooleeye trial site, though growth was slow. It is being used to a limited extent to fence enclosures near Masagaweyn and Galcad villages in Ceel Dheer district, where it has shown a tendency to spread and become a serious weed, as it has abroad. For this reason, spiny forms are not recommended for use.

The variety grown at Nooleeye was a spineless, palatable form found near Galcad. Such varieties are important, very productive fodder plants for arid areas abroad in areas such as southern Africa. The second phase should expand the evaluation of spiny cactus varieties for both fodder and fencing purposes.

An ideal live fencing plant would establish vigorously and grow fast from very small reproductive material, which is easy to transport and store, such as seed. The trials demonstrated that 2 species can be successfully used to establish living fence hedges from seed under field conditions in the heavy soils of the Bula Burti area.

B.aegyptiaca performed the best and is the most desirable species, as it is native and has many valuable uses. It also germinated and established quite well (50%) in the sandy loam site at Bula Burti, so appears quite versatile in its soil requirements. Under the dryer, more sandy conditions of Nooleeye it does not appear to be suitable though.

While the other species, *Parkinsonia aculeata* introduced from South America, established well in the loamy clay soil at Bula Burti, it is not recommended for use when a more suitable alternative is available. Direct sowing treatments should be expanded in future to consider other potential plants, including *Commiphora* species.

Prosopis chilensis is another tree species which could possibly be used for live fencing, as it has a spreading form; however it has weedy characteristics. At arid Nooleeye, an amazing 93% of *P.chilensis* seedlings were well established 2 years after planting without any irrigation (table 15), in contrast to only 20% of the local, tough tree, *Acacia nilotica*. After 2 years though, it had only grown about half a metre high, so may be too slow growing in this arid area.

The trial results at both Nooleeye and Bula Burti suggests that the hypothesis is incorrect that living *Commiphora* bush fences can be practically established using small branch cuttings under rainfed field conditions. In all the trials the larger 1.2 - 1.5 metre high untrimmed branches of the various *Commiphora* species tested established the best.

The only exception was in the final fencing trial planted in 1988 at Bula Bula. These results are not considered reliable, as the rainfall was poor, and all treatments performed poorly.

Often a reasonable proportion of small cuttings did grow though; for example at Nooleeye, 25% compared to 98% of large branches of *C.incisa* were growing a year after planting. Given the great savings in transport costs and reduction in bush felling if small cutting could be used, trials should continue to evaluate techniques that may increase propagation rates.

It was observed that *Commiphora* cuttings usually root only from where the branch is cut. Thus treatments cutting the epidermis along the stem placed in the ground may improve rooting. Due to the poor season in 1988, it was not possible also to determine the best periods for cutting, storing and planting the cuttings.

The trials have demonstrated that there is considerable difference between *Commiphora* species in their ability to vegetatively propagate, and in their soil requirements. At Bula Burti, for example, *C.incisa* established significantly better than *C.hodai* and *C.oddurensis*, and it grew best in the heavier loamy clay soil. By contrast both the latter two species established better in the sandy loam soil. (Table 18).

At Nooleeye, both *C.incisa* and an unidentified local *Commiphora* species called 'sagaarasal' had an excellent 98% establishment rate from 1.5 metre cuttings, whereas similar cuttings of another common local *Commiphora* species, 'xagar' had only a 41% success rate.

Under very arid conditions in 1988, 37% of the cuttings of *C.oddurensis* grew compared to 10% of *C.myrrh*, while no cuttings of either *C.hodai* and *C.rostrata* grew. Some species are multipurpose having valuable uses in addition to fencing. *C.myrrh* is the most famous and valuable of these as it produces the gum, myrrh. It is thus encouraging that some of these cuttings grew under poor conditions.

It is recommended that the second phase of the CRDP should speed and expand the living fence trials by using pot trials. Special consideration should be given to developing techniques to grow small cuttings of *Commiphora* species, to identify the best species to use in the different environmental zones, and to testing multipurpose species such as *C.myrrh*.

The trial program at this preliminary stage has demonstrated that a range of *Commiphora* species can be successfully propagated under arid field conditions by planting large 'cut branches'. When planted, interlacing in a staggered manner, as a boundary fence around the Aborey trial, it was observed that the fence was immediately very effective, capable of keeping out all camels, cattle, sheep and goats. As the *Commiphora* plants are long lived, it is expected the live fences will require little maintenance.

After a number of field days demonstrating live fencing techniques, it was observed in 1988 that a number of agropastoralists had begun to build new living *Commiphora* fence hedges around their farming enclosures in Bula Burti district. This can be taken as an indication that the technique is practical and cost effective.

5.5 Tree and Bush Species Elimination and Growth Trials

5.5.1 Introduction

Woody perennial plants have a vital role for both conservation and human sustenance in most arid and semi arid warm areas, and in central Somalia their current and potential contribution is particularly great. Very little information is available about the attributes, environmental requirements, silviculture and growth of valuable multipurpose species under these climatic conditions, and even less is known about potentially useful African species. Researchers have tended to focus on higher rainfall areas where woody species are much easier to establish, and where their potential growth is substantially greater.

During long dry seasons, woody perennial plants usually provide the only ongoing source of livestock and human food. These areas, including central Somalia, are usually the most susceptible to droughts and famines. Thus woody perennials have a unique, crucial role, which is further increased by their contributions of wood, shade, shelter, and soil conservation and improvement.

In central Somalia, wood provides all household fuel for cooking, and most of the building material. Many species are also used to provide widely used traditional medicines, dyes, gums and aromatic substances.

As the current agropastoral systems in central Somalia were causing considerable destruction of native woody perennials; yet their potential contribution was great; research was needed to develop methods to incorporate them into the agropastoral systems. It was assumed that agropastoralist would only adopt agroforestry systems if the potential benefits to them substantially out weighted the cost and effort involved.

This preliminary research program thus focused on identifying adapted species which promised to provide substantial benefits at little cost. Specifically, methods to reduce two of the major costs involved - establishment and competition with crops and pasture - were investigated.

The hypothesis established for testing in this experimental program was thus:

> *'Valuable multipurpose trees can be established under rainfed conditions without irrigation in both the sandy and hiraan agropastoral system of arid/semi-arid central Somalia'.*

In this section, trials to scientifically evaluate the establishment and growth of a range of multipurpose species from seedlings is described. In Section 5.6 this hypothesis is further tested using an even less costly establishment technique; direct sowing.

5.5.2 Method and Materials

The research program was divided into two components: the identification of potentially adapted, valuable multipurpose woody perennials; and the systematic testing of their establishment and growth under local conditions. International literature was searched to identify potential species with the necessary attributes, including environmental requirements.

This search was not as comprehensive as desirable, due to limited local availability of scientific literature. Publications from the National Academy of Science (U.S.A.) and the International Council for Research in Agroforestry (Kenya) were particularly useful.

Locally, every opportunity was taken to inspect and investigate any potential indigenous agroforestry species. Thus during years of conducting field days, workshops, doing agropastoral case studies, holding discussions with knowledgeable agropastoralists and making personal observations, a bank of information was built up.

This was supplemented by the considerable personal knowledge of the CRDP's ecologists Dennis Herlocker and Peter Kuchar, and the international literature,. Some promising local species were thus identified and incorporated into those and the hedgerow trials. Many other promising species were still under investigation at the end of this trial program.

To test the hypothesis, two trial sites were selected, one in the Hiraan agropastoral zone at Aborey, next to the rainwater harvesting trial; and the other, at Ali Yabal in the sandy agropastoral zone. The criteria outlined in section 4.2 were used to select the sites. Limited time and resources, such as soil testing equipment, were available; so the criteria requirements could not be completely filled.

The Aborey site, next to the tiny village of Aborey, 20 km north-east of Bula Burti district centre, met all the selection requirements, except that there was some doubt about the fertility of the coarse sandy loamy soil, and the potential for expansion was not definite. The sandy loam soil type was only one of the important agropastoral soils in the Hiraan agropastoral zone; however, it was selected as the site for this initial trial, so that woody plant species could be identified to support the improved rainwater harvesting systems under development at the same site.

The Ali Yabal site was located 1.5 km south-west of the tiny village of Ali Yabal, 20 km west of the district centre of Ceel Dheer. Both sites had good access. The Ali Yabal site was next to the Ali Yabal to Mogadishu main road, and the Aborey trial next to the main Bula Burti to Ceel Buur road.

The soil at the Ali Yabal site was a more fine, deep sandy loam, with a high content of fine silt and sand particles. Lack of soil fertility at this site was not considered to be a major problem, as investigations indicated it had been in bush fallow for at least 30 years, and it supported an almost mature stand of dense *Acacia nilotica* and *Terminalia polycarpa* trees. The Aborey site, located within a dense agropastoral area, had by contrast been in bush fallow for only 7 to 9 years. It was covered by a degraded immature *Commiphora/Cordia* bushland.

It was estimated from the limited rainfall information available, summerised in map 3, that the approximate annual rainfall of the Aborey trial site was 275 mm, and Ali Yabal 300 to 350 mm. Both sites were in the relatively high rainfall areas of central Somalia, where agroforestry could be expected to have greater potential.

The Ali Yabal site was partly chosen because it lies at about 300 metres above sea level, near the top of the coastal ridge, in a zone where the appearance of the range of vegetation suggests a higher rain fall than the surrounding lowlands. The site chosen also appeared fairly typical of the extensive ridge zone. The Aborey site lies at an elevation of about 100 metres, 4 kms below the Yasoman sandstone escarpment, which marks the edge of the wide Shebelle river valley.

Both sites were selected, cleared and prepared in January to March 1987. The sites were cleared manually, and all vegetation burnt on site. At Ali Yabal, some thorn branches were used to build a strong 2m high boundary fence. As detailed in section 5.8, a live fence constructed from *Commiphora* bush species was built around the Aborey trial site.

To conduct a scientific evaluation of the tree and bush species, which could be compared with results at other sites, an extensive replicated, randomised block, experimental design was adopted. Both trials were divided into 4 blocks, and a plot of 25 tree seedlings of each species randomly located within each of the 4 blocks. Thus 4 x 25, or 100 seedlings of each species were planted at each site.

Twelve species were planted in the Ali Yabal trial and 10 in the Aborey trial. The seedlings were prepared using the standard techniques outlined in section 4, then planted out in a grid fashion, 3 metres apart.

To assist the establishment and growth of the seedlings, small rainwater microcatchments were built. At Ali Yabal, a simple basin system was considered most appropriate for the sandy soil with little structure. Basins 100 to 80 cm across and 25 to 30 cm deep were dug by hand prior to the first rain to collect rainwater.

A tractor was available at the Aborey site, so a 4 sided 3 x 3 metres Negerim type microcatchment system was constructed, also before the first seasonal rainfall. The Negerim catchment ditches were about 20 cm deep, and the ridges 20-30 cm high, orientated so the slope drained rainwater runoff into one corner of each catchment.

Seedlings were carefully planted in the wettest portion of the microcatchments, within hours of the first 1987 Gu seasonal rainfall event of more than 25 mm. This was on the 30/4/87 and the 1/5/87 for the Aborey and Ali Yabal trials respectively. They received no subsequent treatment, except weeding twice per season. Plant survival and height was then periodically recorded.

A boundary fence and guarding system was used to ensure the plants were not grazed. Some minor grazing by small gazelles was still noticed, though considered not sufficient to affect the trial results.

In the Gu season of 1988, a further 4 tree and bush species were planted similarly in the Ali Yabal trial. It had been originally planned that 20 species would be evaluated at each site in the Gu season of 1987, and these would be supported by repeated planting in at least another season to test seasonal differences. It was also planned that the trial would include direct sowing treatments, but limitations on seed and other resources restricted activities.

5.5.3 Results

The results of the Aborey species elimination and growth trial are presented in table 20. There was a highly significant difference between the species in both survival and height, 13.5 months after planting. To check which species were significantly different, a Newman-Kuels test for significant difference among a set of means at the 5% probability level was applied and the results shown at the bottom of table 9. The survival and growth of species 9 and 10, *Shinus molle* and *Brachychiton gregorii* respectively, were omitted from the analysis due to the failure of these species to survive.

The summarised results of the Ali Yabal rainfed species elimination and growth trial are presented in table 21. There was again a significant difference between the survival of the 12 species, however in this case, difference between growth was not quite significant, due to the high variance. The Newman-Keuls test of significantly different means was applied to mean survival of each species, and the results are shown at the bottom of table 21.

5.5.4 Discussion

The results of the two tree and bush species elimination and growth trials have shown that a range of potential, valuable, multipurpose trees can be established from seedlings, without the application of water or other external inputs under the arid conditions found in both major central Somalia agropastoral zones. The results though are preliminary, as the trials were ended after 14.5 months, and future poor rainfall seasons could kill more plants before they become fully established.

Table 20: The Survival and Growth of Ten Multipurpose Tree/Bush Species Seedlings Grown Under Arid Rainfed Conditions at Aborey, Bula Burti District.

Tree/Bush Species	Source	Percent Survival			Height (metres)	
		26/07/87	20/02/88	17/06/88	20/02/88	17/06/88
1. *Acacia nilotica*	C/Dheer,Somalia	96	62	36	0.54	1.07
2. *Leucaena leucocephala* (v.K8)	Australia	97	71	35	0.67	1.14
3. *Acacia victoriae*	Australia	55	50	40	0.24	0.47
4. *Terminalia spinosa*	C/Dheer,Somalia	47	42	31	0.11	0.39
5. *Balanites aegyptiaca*	B/Burti,Somalia	100	66	42	0.34	0.43
6. *Prosopis chilensis*	B/Burti,Somalia	96	94	87	0.78	1.41
7. *Prosopis juliflora*	Mauritania	93	77	46	0.56	0.82
8. *Acacia ligulata*	Australia	76	51	36	0.31	0.61
9. *Shinus molle*	North Somalia	20	4	0	0.18	-
10 *Brachychiton gregorii*	Australia	7	0	0	-	-

Note: 1. All figures mean of 4 plots each of 25 plants, a total of 100 seedlings/species.
2. The Australian source was a commercial company, Kimberley Seeds, Perth.
3. *Prosopis chilensis* and *Shinus molle* seed was collected from trees growing in Somalia. Neither are native to Somalia.
4. Complete results and statistical analysis is detailed in appendix table 16.

Summary Anovas

% Alive 7/6/88 (arc sin $\sqrt{x}$ transformation)			
Source	d.f.	F.	Significance (5%)
Blocks	3	0.35	n.s.
Species	7	11.37	*
Within	21	-	
Total	31		

Height 7/6/88			
Source	d.f.	F.	Significance (5%)
Blocks	3	0.03	n.s.
Species	7	23.85	*
Within	21	-	
Total	31		

Newman-Keuls Test of Significantly different Means (5%)

Survival 7/6/88 4 2 1 8 3 5 7 6 species no.

Height 7/6/88 4 5 3 8 7 1 2 6 species no.

Any 2 means not underlined by the same line are significantly different. Any 2 means underlined by the same line are not significantly different.

Table 21: <u>The Survival and Grown of 12 Multipurpose Tree/Bush Species Seedlings Grown under Rainfed Arid Conditions at Ali Yabal, Ceel Dheer District</u>.

<u>Tree/Bush Species</u>	<u>Source of Seed</u>	Percent Survival		Height (m.)
		24/07/88	12/06/88	12/06/88
1 *Cordia sinensis*	Mogadishu,Somalia	100	96	0.75
2 *Ziziphus mauritania*	Afgoi,Somalia	98	93	0.68
3 *Terminalia spinosa*	C/Dheer,Somalia	83	83	0.33
4 *Leucaena leucocephala* (v.K8)	Australia	97	83	1.68
5 *Acacia nilotica*	C/Dheer,Somalia	92	47	0.55
6 *Acacia liqulata*	Australia	93	83	1.68
7 *Tamarix aphylla*	Shalembod,Somalia	88	37	0.70
8 *Parkinsonia aculeata*	B/Burti,Somalia	94	61	0.77
9 *Balanites aegyptiaca*	B/Burti,Somalia	93	62	0.34
10 *Prosopis cineraria*	Australia	88	70	0.27
11 *Acacia victoriae*	Australia	83	66	0.37
12 *Sesbania grandiflora*	Haradhere,Somalia	64	10	2.57

Note: 1. All figures are mean of 4 plots of 25 plants, a total of 100.
2. Complete results and statistical analysis detailed in appendix table 17.

<u>Summary Anovas</u>

Tree/Bush Survival 12/6/88 (2 arc sin $\sqrt{x}$ trans)			
Source	d.f.	F.	Significance (5%)
Blocks	3	0.64	n.s.
Species	11	7.21	*
Within	33	-	
Total	47		

Tree/Bush Height (m)			
Source	d.f.	F.	Significance (5%)
Blocks	3	0.15	n.s.
Species	11	1.26	n.s.
Within	33	-	
Total	47		

Newman-Keuls Test of Significantly Different Means (5%)

Survival 12/6/88 12 7 5 9 8 11 10 6 3 4 2 1 species No.

Any 2 means not underlined by the same line are significantly different. Any 2 means underlined by the same line are not significantly different.

Under such arid conditions, rainfed tree establishment trials results would be expected to be highly dependent on the actual seasonal rainfall received during the establishment period. The results are very good considering the rainfall received (table 2).

At the Ali Yabal site, the survival of the tree and bush species was excellent, with 9 of the 12 species having over 60% of all seedling survive, even considering that the rainfall received in their first 12 months, 475 m.m., was above the estimated average. At Aborey, two unadapted species did not survive, while over 30% of seedlings of all the other 8 species survived, which is considered a good result considering the rainfall for the first 12 months of establishment was 303 m.m., near the estimated average.

One tree species, _Acacia_ _nilotica_ was included in both trials as a reference species, as it occurs naturally at both sites. While it provides valuable forage and wood, it is apparently competitive with shallow rooted crop and pasture plants, so was not included for potential on-farm application.

Information available suggested that of the other 15 species in these 2 trials, 10 had useful multipurpose characteristics, including low competitiveness with crops and pastures. Five - _Shinus_ _molle_, _Parkinsonia_ _aculeata_, _Acacia_ _ligulata_, _Prosopis_ _juliflora_ and _Tamarix_ _aphylla_ - were induced for their potential drought resistant, multipurpose windbreak or shade species characteristics. They could be planted around the boundary of enclosures, or near houses, but not on farms.

In the Aborey trial, _Prosopis_ _chilensis_ both survived significantly better and grew significantly higher than all other species. The mean survival of 87% and growth of 1.41 metres was very good for the limited 303 mm of rainfall received.

While this species appears more deep rooted than the competitive, weedy, _Prosopis_ _juliflora_, the degree to which it competes with shallow rooted plants is not yet clear. Given the success of this species, trials to evaluate its agroforestry potential would appear justified. Caution should be exercised in introducing this central American species, as it has possible weedy characteristics. While the wood is good, and pods both palatable and nutritious, the leaves are not very palatable, and it has been observed that this plant is rapidly spreading over rangeland near Belet Weyne, a drier area 100 km north of Aborey.

The situation is complicated by the difficulty in using botanical methods to separate _P.chilensis_ from _P.juliflora_, their ability to interbreed, and the widespread recent use of _P.chilensis_ in Somalia for shade, shelter belts and sand dune fixation.

The Aborey trial results indicate that only 2 species should be considered for elimination from further evaluation at this stage; _Shinus_ _molle_ and _Brachychiton_ _gregorii_. All the other 8 species showed promise, including 3 which are potentially very valuable multipurpose trees; _Terminalia_ _spinosa_, _Balanites_ _aegyptiaca_ and

Leucaena leucocephala. These 3 species would appear to be potential hedgerow species, as they apparently do not compete greatly with crop and pastures, provide valuable fodder in the dry season, and yield good wood. While the growth of the former two species was not encouraging, in the adjacent rainwater harvesting trial, their growth was reasonable.

In the Ali Yabal trial, 5 potentially valuable hedgerow cropping species had a survival rate above 80%. This was higher than the other 7 species tested at this site, where all except *Sesbania grandiflora*, had a survival rate above 37%. *Cordia sinensis* and *Ziziphus mauritania* performed outstandingly with survival rates of 96% and 93% respectively.

The mean survival and growth of *Leucaena leucocephala* var.K8, introduced from central America via Australia, at 83% and 1.68 metres was surprisingly good, considering this variety is normally grown in higher rainfall areas. Given the promising results, more drought resistant varieties should be obtained for further evaluation, as this is a valuable multipurpose hedgerow fodder species.

The survival of *Prosopis cineraria*, a widely used multipurpose hedgerow species from India, at 70% was good; however, its growth was slow. *Sesbania grandiflora* grew very fast - an average of 2.57 metres high in this 14.5 month period; however, it was short lived, and at the end of the trial only 10% were alive. This leguminous multipurpose hedgerow species was introduced from northern Australia and Asia. It probably ran out of moisture, and should be used in moister areas or where there is a high water table.

The very good results from the Ali Yabal trial suggest many useful species can be grown from seedlings without irrigation in this area; however, the trial should be repeated in other season and for longer periods, and other useful, adapted varieties considered.

5.6 Alley and Hedgerow Cropping

5.6.1 Introduction

Trees are a vital component of a sustainable, productive, low input agropastoral system that conserves natural range resources. The cropping aspect of the central Somalia agropastoral system is essentially a typical slash/burn, shifting cultivation system; which relies on a long, 30 to 50 year bush fallow to restore the soil fertility that was depleted with only 5 - 7 years of cropping.

In central Somalia, agropastoralists typically clear all trees on their farms, or occasionally leave one or two large non-competitive trees, such as *Dobera glabra*, mainly for shade. There is no well-developed, organised, sustainable agroforestry system such as the *Acacia senegal* system practised in Sudan, or the West African *Acacia albida* systems. (National Academy of Science, 1983).

The Somali agropastoral system is a de facto agroforestry system, which relies on the naturally regenerating trees, bushes and pasture to restore the soil during the bush fallow, range cycle. With recent sedenterisation and the increase in pressure on natural resources, the bush fallow cycle was often being shortened, which could be expected to result in a decline in crop production and range condition.

In this integrated development program, the anti-erosion strip trials (section 5.1) developed methods of including pastures as a component of the farming system. This series of trials, together with the tree species elimination and growth trials (section 5.5), aimed at identifying and developing techniques to grow appropriate trees on the farms during the cropping cycle.

The main reason agropastoralists give for clearing trees from their farms is that they feel they compete with the crops for the scarce water and nutrients. However, some trees such as *Acacia albida* and *Prosopis cineraria* have been shown to actually promote the growth of crops grown under their canopies. (Steppler, H.A. and Nair, P.K.R., 1987). Thus in this program, investigations were conducted to identify local trees with no or low competitive characteristics, while at the same time introducing adapted species with this attribute from abroad.

On farms which have been cleared, the opportunity exists to plan the spatial arrangement of the trees to be planted or sown. In some countries the trees are established in parallel rows, separated by strips of crop or pasture. This system has come to be called *alley cropping*, or sometimes *hedgerow cropping*. While the terms are often interchanged, in this publication alley cropping is used to denote system which use rows of low density large trees, while hedgerow cropping refers to systems which use rows or strips of dense hedges.

In areas suffering from wind erosion, the rows could be orientated against the prevailing winds to create a windbreak. They could be used similarly to potentially reduce water erosion. Thus trials were initiated to develop alley and hedgerow multi-storey cropping systems for central Somalia. It was hoped that they would reduce erosion, help to improve or maintain soil fertility, while at the same time provide valuable products such as fodder and wood.

As the central Somali agropastoral areas generally have a low productive potential, agropastoralists could not be expected to adopt measures which cost much in time, effort or money. Thus rather than use seedlings, trials were needed to evaluate whether it would be possible to use low cost direct sowing of seed establishment techniques in the local harsh, arid conditions. The hypothesis formulated to test was:

> *'Hedgerows of valuable multipurpose trees can be established by the direct sowing of seed under arid rainfed conditions in central Somalia.'*

5.6.2 Method and Materials

Small alley and hedgerow cropping, direct-sowing trials were established at the Nooleeye and Bula Burti Fodder farm rainfed trial sites, and the Aborey and Bula Burti fodder farm rain water harvesting trials. For observation and to provide seed, alleys and hedgerows were also sown and irrigated at the Bula Burti seed multiplication farm.

At Nooleeye two rows of *Terminalia spinosa* were sown 8 metres apart and 100 metres long in the 1986 Gu Season, followed by another 2 rows 6 metres apart in the 1987 Gu season. In 1986, 7 seeds were sown at each position, 4 metres apart along the hedgerow, at a depth of 3-4 cm, just before the first seasonal rain. The sowing rate was increased to 15 seeds per position in the 1987 Gu season. In the 1987 Gu season, 2 rows of *Prosopis cineraria* were also sown. Ten seeds were sown at each position, with a plant spacing of 4 metres, and 6 metres between rows. With the very sandy soil at this site, no water harvesting treatment was possible.

In April 1987, 2 rows each of the multipurpose trees *Leucaena leucocephala*, *Balanites aegyptiaca* and *Terminalia spinosa* were sown next to the banks lining the ponds in the Aborey rainwater harvesting trial, as shown in figure 10. The rows were 80 metres long, with 10 metres between the rows of the larger *B.aegyptiaca* and *T.spinosa* species, and 5 metres between the rows of *L.leucocephala*. Eight seeds of *L.leucocephala* and the *B.aegyptiaca* and *L. leucocephala* were grown as hedgerows, with a within row spacing of 0.5 metres; whereas the *T.spinosa* were sown 4 metres apart to form alleys. *B.aegyptiaca* and 15 seeds of *T.spinosa* were sown at each position 3-5 cm deep on the 14/12/87 just prior to the first rain of the season. All rows were divided into 4 blocks, which were watered by separate rainwater harvesting irrigation channels. Crops and pastures were grown next to each row. The design is shown in figure 10.

In October 1987, one hedgerow of *B.aegyptiaca* was similarly sown next to the ponding banks, across both the staggered contour ridge and staggered contour rainwater catchment water harvesting systems, at the Bula Burti fodder farm. The seeds were sown 2 metres apart to form hedgerows. To stabilise the earth banks and to provide a windbreak and fodder, the seeds of an indigenous woody legume fodder bush, *Indigofera coerula* (Nooleeye variety) were sown along all the banks of the staggered contour rain water harvesting system, and on top of every third staggered contour ridge.

An extensive hedgerow cropping trial was initiated at the Bula Burti fodder farm trial sites in early 1988. The trial was replicated at 2 sites, 800 metres apart, the sandy loam site, and the loamy clay site. Two replicated, 54 metre long rows of 11 multipurpose agroforestry trees were randomly located in parallel lines from 8 to 6 metres apart at each site. The within row spacing of all species was 4 metres, except for *Leucaena leucocephala* and *Balanites aegyptiaca*, in which it was 1 metre. The species sowing rate varied from 3 to 15 seeds depending on availability and prior germination tests.

The Bula Burti fodder farm hedgerow/alley cropping trial was designed and established as a component of an intercropping, internal catchment rainwater harvesting trial. A bench/furrow (or ridge/ditch) internal catchment rainwater harvesting system was constructed in a similar fashion to the staggered contour ridge rainwater harvesting system. Ploughing was done in opposite directions with a double disc plough to create parallel benches 30 to 40 cm high and 2-2.5 metres wide, with adjacent channels 20-30 cm deep and 30-50 cm wide.

A tied ridge system was created by pushing up dirt with a two-man shovel to fill in the channels every 4m or 1m, depending on plant spacing. The tree seeds were then sown in the channels next to each tie. Rainwater was then expected to run off the benches and be concentrated in the ponds created in the channels by each tied ridge. Sorghum, cowpea and mung bean crops were then sown between the hedgerows.

All the trees grown in the various hedgerow trials were not given any special treatment, such as weeding, to emulate the on-farm situation. They were all automatically, at least partially weeded when the adjacent crops were weeded twice per season.

5.6.3 Results

In the Nooleeye alley cropping trial, the emergence of *Terminalia spinosa* and *Prosopis cineraria* was poor, being 18% in 1986 and 25% in 1987 for *T.spinosa* and 5% in 1987 for *P.cineraria*. In July 1988, the survival rate of the *T.spinosa* was 13% for the 1986 sowing and 20% for the 1987 sowing, so most of the plants which emerged survived despite the low rainfall. Only 2% of the *P.cineraria* seedlings survived.

The results at the Aborey rainwater harvesting trial are shown in table 22. They were recorded on the 14/12/88, 17 months after the tree seeds received the first rainfall. Significantly more *Balanites aegyptiaca* seedlings were alive than the other 2 species, while the growth of *L.leucocephala* was clearly the best.

Table 22: Growth of Three Multipurpose Tree/Bush Hedgerows Using Direct Sowing and Rainwater Harvesting Techniques at Aborey After 17 months.

Tree/Bush Species	Source	No. Positions Sown	Mean Percent Survival	Mean Height (metres)
Leucaena leucocephala (v.K8)	Australia	320	22%	1.8
Balanites aegyptiaca	B/Burti	320	67%	0.7
Terminalia spinosa	C/Dheer	40	35%	0.5

Note: Detailed results are presented in the appendix table 18.

The results of the Bula Burti hedgerow establishment trial are shown in table 23. Rainfall was less than average in the 1988 Gu season, and was light, resulting in no runoff from the rainwater harvesting scheme to assist tree growth.

Table 23: Establishment of Eleven Directly Sown Multipurpose Tree/Bush Species in Hedgerows Under Very Arid Rainfed 1988 Seasonal Conditions at Bula Burti.

Tree/Bush Species	Source	Percentage of Positions with Growing Plants					
		Sandy Loam Site		Loamy Sand Site		Mean	
		Emergence	6 months	Emergence	6 months	Emergence	6 months
Terminalia spinosa	C/Dheer	0	0	0	0	0	0
Ziziphus spinacristie	Mogadishu	30	11	30	4	50	7
Prosopis cineraria	Australia	0	0	0	0	0	0
Acacia albida	Australia	0	0	0	0	0	0
Dobera glabra	Baydoha	21	7	36	18	29	29
Prosopis chilensis	B/Burti	0	0	0	0	0	0
Cordia sinensis	Mogadishu	0	0	0	0	0	0
Leucaena leucocephala	Australia	76	0	52	0	63	0
Cordia suckserti	B/Burti	36	0	43	11	43	7
Balanites aegyptiaca	B/Burti	79	62	96	94	88	79
Sesbania grandiflora	Australia	-	-	36	0	36	0

Note 1. Detailed results appear in appendix table 19.
2. Figures are a mean of 2 replications.

5.6.4 Discussion

The trial results have demonstrated that some valuable multipurpose tree species can be established by the low cost direct sowing of seed method under very arid, hot conditions; without expensive, labour intensive irrigation. The best results were obtained at Aborey, where the rainwater runoff harvesting system supplied the plants with a little extra water. Under arid conditions, the success of tree establishment is highly dependent on the amount and timing of rainfall received; so any methods, such as rainwater harvesting, that can increase water availability at a low cost, will be useful.

At Nooleeye the germination and emergence of the two species sown, *T.spinosa* and *P.cineraria* was relatively low. This appears to have been due to both the low viability of the seed and unsuitable germinating and emergence conditions in the very sandy soils; as germination tests indicated that only 10 to 15% of untreated *T.spinosa* seed germinated; whereas soaking could raise this to 25%; yet emergence in the field was lower.

In the sandy agropastoral zone other more well adapted species and appropriate establishment techniques should be evaluated. Establishment techniques worth evaluating in future include sowing pre-treated seed directly after rainfall and placing manure beneath the seed to store extra water and supply nutrients.

The growth of the hedgerows in the Aborey rainwater harvesting trial are particularly encouraging. The plants were grown close together at a 50 cm spacing. 67% of plants grew to an average of 70 cm high after 17 months, creating dense hedgerows which promise to be good multipurpose windbreaks within 1 - 2 years.

B.aegyptiaca is a very useful deep-rooted, evergreen, drought resistant tree, which occurs widely in sub-saharan Africa. It is a good forage species, providing palatable green fodder during the dry season; though is armed with long thorns and resists heavy grazing. It produces very useful wood; and the fruit, often called 'desert dates'; are readily eaten. Inside the fruit is a nut which has a 30% oil content, which can be used for cooking. Many parts of the tree have medicinal and other uses.

While no record is known of their use as a multi-storey cropping agroforestry species, in central Somalia agropastoralists consider it is only mildly competitive with crops grown under the canopy, and it is one of a few species occasionally left on cultivated fields.

It is proposed that once the hedgerows of species such as *B.aegyptiaca* and *T.spinosa* reach about 1.5 metres high, lower branches of some hedgerows would be trimmed in the dry season to allow more light to penetrate the tree canopy for crop growth, and to provide fodder and wood products. The *L.leucocephala* var.k8 grew well at Aborey, reaching a mean height of 1.8 metres; however many of the 22% surviving plants were water stressed; so more drought resistant varieties of this species should be sought.

The rainfall was too low in the 1988 Gu season for the germination and establishment of most of the both local and introduced trees included in the Bula Burti fodder farm trial. *B.aegyptiaca* however, again performed well with an emergence and six months survival rate of 88 and 79% respectively. Considering that insufficient rainfall in this season caused poor crop yields and crop failures at this site, and that other woody perennial species native to this range site, *T.spinosa* and *Cordia suckserti* performed poorly, *B.aegyptiaca* has proven to be very drought resistant.

Although the rainfall in this season was too light to cause runoff, observations suggest this is an unusual seasonal situation. The results of this and other trials support the proposition that appropriate rainwater harvesting techniques should be used whenever feasible to promote the establishment and growth of hedgerows under these arid conditions. This trial needs to be repeated in a season providing rainfall sufficient for crop production before the performance of these 11 multipurpose trees can be properly evaluated.

5.7 Fertilizer and Manure Trials

5.7.1 Introduction

Manure trials were initiated in the 1987 Dayr season at Nooleeye and Aborey, then followed by a large fertiliser and manure trial at the loamy clay (Ugg) Bula Burti trial site in the 1988 Gu season. At Nooleeye, the manure trial was located in an area which had been continuously cropped for the last 7 to 9 years, and crop yields had declined to very low levels. If the readily available sheep and goats manure could increase the productivity of these old farmed areas ('goofs'), considerable benefit could accrue to the industry. The hypothesis established to test this possibility was thus:

> *'Crop production from infertile old farmed areas can be increased by adding moderate amounts of locally available sheep and goat manure.'*

Extra water provided by the rainwater harvesting system at Aborey would potentially increase crop production, if soil fertility was not a limiting factor. Post crop yields indicated soil fertility may be low, so manure trials were initiated, with the hypothesis:

> *'Manure fertilisation increases the yield of common crops provided with additional water from a rainwater harvesting system.'*

In the absence of resources to conduct soil or plant chemical analysis, crop response to fertilisation is a very useful way to test for nutrient deficiencies. Observations and the little information available suggested the major plant nutrients phosphorus and nitrogen may be deficient. The hypothesis formulated for testing was:

> *'Local sorghum production is reduced by soil nutrient deficiencies that can be at least partially overcome by the application of phosphorus, nitrogen or manure fertiliser.'*

5.7.2 Methods and Materials

At the Nooleeye trial site, a section of exhausted farm land was chosen immediately adjacent to the crop variety trials. It had been continuously cropped by the project for the last 2 seasons, and by the agropastoralist who previously owned the land for 6 to 8 years before that. A small randomised block (strip) trial/observation was sown to four of the main crop varieties under evaluation in the 1987 Dayr season. Four 5 x 25 m. plots of each crop variety were sown, 2 in each of 2 blocks, with one plot in each block having manure added (4 varieties x 2 manures x 2 blocks).

In the same season, a similar preliminary manure observation trial was implemented at the Aborey rainwater harvesting trial site. In this case 8 plots of each of 3 crop varieties - cowpeas, bulrush millet and mung beans - were sown, 2 plots in each of 4 blocks, one with manure added, one without. (3 crop varieties x 2 manure levels x 4 blocks). The same quantity (600 kg/ha) of sheep and goats manure was added. This trial was part of a larger water harvesting and crop variety trial. Each of the 4 blocks was separated by earth banks, and supplied opportunistically with additional runoff rainwater from separate catchment drainage channels. (Figure 10)

In the 1986 Gu season, the Aborey manure trial was repeated with the number of crop species expanded to 6 and a sorghum/cowpea intercrop treatment added. Again, manure was added at the rate of 600 kg/ha.

At the Bula Burti fodder farm, loamy clay trial site ('Ugg'), a randomised block fertiliser trial was initiated in the 1988 Gu season. Ten treatments were evaluated in terms of sorghum yields. A control with no added fertiliser or manure was compared to 3 levels each of manure, phosphorus and phosphorus plus nitrogen fertiliser. Each of the 10 treatments was replicated 4 times, with one 5 x 5 metre plot randomly located in each of 4 blocks.

A wide range of fertiliser and manure rates was chosen, with the lowest rate being the estimated minimum amount needed to obtain significant yield responses under local conditions. The manure treatment levels were 400, 800 and 1,200 kg/ha. Higher rates than normal were used, as the local, aged goat and sheep manure is typically impure. Observations suggested it was composed of about half sand, half manure.

Three rates of each of the fertilisers were also evaluated; 33, 66 and 133 kg/ha. The two fertilisers were granulated triple super phosphate [TSP - $Ca(H_2PO_4)_2$] and di-ammonium phosphate [DAP - $(NH_4)_2HPO_4$], both of which have 19% to 22% phosphorus. DAP also contains nitrogen, (18%-21%). Thus the fertiliser treatments supplied similar quantities of phosphorus, but in the case of DAP, nitrogen was provided too.

The fertiliser and manure was applied using the standard procedure of individual spot placement below each seed at sowing. The local variety of sorghum was sown at a spacing of 50 x 75 cm to give a plant population of 265,600/ha.

5.7.3 Results

Nooleeye 1987 Dayr Season Goof Manure Trial

As shown in table 24, the goof (old exhausted farmland) soil was so poor, the cowpeas and mung beans gave no yield without treatment; whereas all 4 crop varieties produced small yields when manure was applied. The manure treatment only increased yields to 4 to 18 kg/ha, far less than the 67 to 111 kg/ha produced on adjacent soil which had only been farmed for the previous 2 years.

Table 24: Crop Yield Response (kg/ha) to Application of 600 kg/ha Manure on Exhausted Farmland, Nooleeye 1987 Dayr Season

Crop Variety	Soil Cropped Previous 7 - 9 Years						Soil Cropped 2 Years
	No Manure Applied			Manure Applied			
	Strip 1	Strip 2	Mean	Strip 1	Strip 2	Mean	Mean Yield
Cowpeas (loc. var.)	0	0	0	8	0	4	75
Cowpeas (var.TVU 15002)	0	0	0	6	6	6	111
Cowpeas (var.erect)	0	0	0	8	14	11	72
Mung beans (Mog.market var.)	0	0	0	20	16	18	67

Note: 1. Each crop allocated a random position in each strip (block).
2. Plot size 125 metres square.
3. Crop yields on the soil only cropped for the previous 2 years is the mean of six 25 metre square randomly replicated plots.

Aborey 1987 Dayr and 1988 Gu Season Manure Trials

The application of 600 kg/ha of manure in the 1987 Dayr season significantly increased the yield of sorghum, bulrush millet and mung beans by 34%, 33% and 27% respectively, as shown in table 25.

Table 25: Increase in Crop Yield by the Application of 600 kg/ha of Manure in Aborey Water Harvesting Trial, Dayr Season 1987.

Crop Species	Mean Crop Yield kg/ha grain/beans	
	Without Manure	600 kg/ha Manure Applied
Sorghum (local variety)	190	254
Millet (local variety)	470	626
Mung beans (var. Thai)	162	205

Note 1. Manure significantly increased yield at 5% confidence level.
F for manure treatment = 6.04, F.5% 1,15d.f. = 4.54. s.d. 5% ± 93.
2. Each figure in the table is the mean of four 25 metre square plots.
3. Detailed results including statistical analysis are in the appendix table 7.

The yield of the fodder residues from these plants was also significantly increased by the application of manure, as shown in table 26, although it was lower: 12%, 19% and 13% respectively for sorghum, millet and mung beans.

Table 26: Increase in Crop Residue Fodder Yield from the Application of 600 kg/ha of Manure in the Aborey Water Harvesting Trial, Dayr Season 1987.

Crop Species	Mean Crop Forage Residue Yield kg/ha Dry Matter	
	Without Manure	600 kg/ha Manure
Sorghum (local variety)	1,908	2,297
Millet (local variety)	1,632	1,936
Mung beans (var. Thai)	546	682

Note: 1. Manure significantly increased crop residue yield at the 5% confidence level. F for manure treatment was 12.41, F.05 1,15 d.f. = 4.54, sd.05% = ± 202.

2. Each figure in the table is the mean of four 25 metre square plots.

3. Detailed results including statistical analysis are in the appendix table 8.

In the 1988 Gu season, the manure application again significantly increased the yield of the 6 crops under evaluation, as shown in table 27. While the yield increases were considerable; generally ranging from 20 to 100% depending on the crop variety, as in the 1987 Dayr season; overall production was low, due at least partly to the poor rainfall.

Bula Burti Fertiliser and Manure Trial, Gu Season 1988.

All levels of manure and fertiliser applied increased the yield of sorghum, as shown in table 28. The lower rates of manure almost doubled the sorghum yield, and at 1,200 kg/ha of manure, yield was tripled. While higher applications of both the TSP and DAP similarly increased sorghum yield, the yield at the highest level of DAP was only half that at the medium rate.

5.7.4 Discussion

The yield of crops in all four trials was consistently improved by the application of sheep and goats manure, indicating that soil fertility at the 3 trial sites is a factor limiting crop yields.

Table 27: Stimulation of Crop Production in the 1988 Gu Season Aborey Water Harvesting Trial.

Crop Variety	Mean Crop Yield kg/ha	
	Without Manure	Kg/ha Manure Applied
Sorghum (local variety)	110	175
Cowpea (local variety)	120	152
Cowpea (var. TVU15002)	101	156
Bulrush Millet (loc.var)	175	223
Mung beans (var. Thai)	113	157
Sesame (local variety)	39	47
Intercrop - Sorghum	53	104
plus - Cowpea	55	115
Control : Sorghum	73	86
: Cowpea	46	56

Summary Anova

Source	d.f.	F.	Significance (5%)
Blocks	3	7.9	*
Varieties	6	7.9	*
Manure	1	11.9	*
Var. X Manure	6	0.9	n.s.
Within	39	-	
Total	55	-	

Note 1. The control sorghum and cowpea plots were grown without additional water from rainwater harvesting.

2. Complete results listed in appendix table 6.

Table 28: Stimulation of Sorghum Production by Manure and Fertiliser at the Bula Burti Fodder Farm Ugg Site, Gu Season 1988.

Fertilizer Manure Type	Quantity Applied kg/ha	Mean Sorghum Yield (kg/ha)
Control (No treatment)	0	34.5
Manure	400	62.0
	800	62.5
	1,200	105.0
Phosphorous (TSP)	33	42.0
	67	79.5
	133	97.0
Phosphorous + Nitrogen (DAP)	33	49.0
	67	122.5
	133	60.0

Summary Anova

Source	d.f.	F.	Significance (5%)
Blocks	3	6.36	*
Fertilizer, Manure Type	2	0.05	
Fertilizer, Manure Level	2	3.54	*
Type X Level interaction	4	2.16	
Control vs all others	1	3.94	
Within	30	-	

Note: 1. Each sorghum yield is the mean of 4 plots, randomly located in 4 blocks.
2. Complete results and statistical analysis is presented in the appendix table 20.

As manure is an unutilised, readily available local resource; and these trials indicate it can be used to considerably increase crop yields; these results may have important practical applications. Further evaluations are required though, as the rainfall seasons were poor, the general crop productivity low, and the manure used diluted with sand.

As rainfall was low in the 1987 Dayr and 1988 Gu seasons at these trial sites, lack of water would have limited crop production. Crop response to manure and fertiliser application would be expected to be much greater in good seasons than when water shortages limit plant growth.

This was demonstrated in the water harvesting trial, where sorghum and cowpea yields were increased much more in plots supplied with a small amount of extra runoff rainwater than rainfed control plots. (Table 28).

An agronomic technique, which could be applied to reduce the labour requirement and increase the effectiveness of manure application, would be to only apply the manure with the seed when sowing after very good rainfall events, fairly early in the season.

The tripling of sorghum yield with the application of 1200 kg/ha of manure in the Bula Burti trial indicates that the level used in other trials (600 kg/ha) may have been too low for the impure manure used. Higher rates require much more work, so would be less acceptable to agropastoralists. Thus more pure manure samples should be evaluated in future.

A simple, appropriate technique to take advantage of these results, which have shown that manure significantly increasing crop yields, would be to establish an integrated livestock/cropping system with the livestock night yards regularly rotated around the farmed field. This technique would reduce the labour requirement and decrease manure loss by seepage and erosion.

Agropastoralists have given a positive response to this proposal in initial discussions. They have widely adopted the practice of shifting the night yards frequently when they are located outside the enclosures. They do this to reduce livestock diseases and pests. Very little additional effort is thus required to adopt a system of systematically shifting the night yard around the land to be cropped. Given the success of these trials and the potential of a night yard rotation system to increase the sustainable production of the agropastoral system, it should be given priority in future adaptive trial programs.

The Bay Agricultural Research and Development Project (BARDP) undertook trials to evaluate the effect of sheep and goats manure on sorghum production at the Bonka Research Station, Baydoha, southern Somalia, in the 1988 Gu season. Very similar manure application techniques were used, and observations near harvest suggested the results were very positive. These are the only other trials with manure known to have been conducted in Somalia. The CRDP second phase should maintain the close exchange of technical information with this project, initiated by the author.

Crop yield increases of 20 to 100%, and at the highest manure application level, 300%, may be particularly important under the marginal, arid, semi-subsistance conditions of central Somalia; where food availability in times of the frequent droughts and famines is critical. In this integrated agropastoral system, livestock would also benefit from crop manure application, as demonstrated in the Aborey trials (Table 25), where manure significantly increased the production of crop residues. As the high quality crop residue fodder is normally selectively fed to milking and weak animals, increases in production may be particularly important.

The fertiliser and manure trial results at Bula Burti is the first confirmation of a soil phosphorus deficiency constraining sorghum yields, and that phosphorus fertiliser can at least partially overcome this deficiency. It appears that there is also a nitrogen deficiency.

At the application rate of 67 kg/ha, the phosphorus fertiliser (TSP) increased yield by 130% whereas the phosphorus plus nitrogen fertiliser (DAP) which supplied the same amount of phosphorus, and additional nitrogen, increased yields by 266%. However, at double the fertilizer application rate, 133 kg/ha, the DAP yield was lower than that for TSP.

The apparent reason for this was that the highest rate of DAP greatly depressed crop emergence, which was estimated to be 75% to 80% for TSP compared to 25-30% for DAP. Nitrogen fertiliser is known to depress germination and emergence if it is placed in contact with seeds, so in these trials the fertiliser had been separated from the seeds with a 2-3 cm layer of soil.

Clearly this was insufficient at the highest fertiliser rate, possibly due to the seasonal rainfall, which would tend to reduce nutrient movement in the soil and leave a concentrated solution of nitrogen near the fertiliser and thus the seed. This theory is supported by observations of the nearby BARDP trials, where using similar techniques in a dark, clayey soil, and similar rates of DAP did not suppress emergence under higher rainfall conditions.

While the fertiliser and manure treatments increased crop yield in the Bula Burti trial by 22 to 266%, depending on the application level, this increase was not quite significant at the 5% level (F 3.99, f.05, 1,30, = 4.17), due to high variability of yields between replicated plots. The mean yields of 2 treatments was significantly increased at the highest manure level, and the medium DAP level.

Variability between the control plots was much lower, so it is suggested that the uneven surface allowed rainwater to congregate on certain plots and not others. Sorghum growing on control plots with additional runoff water would have been constrained by nutrient deficiency, at least partially overcome on similar plots with fertiliser or manure applied.

The considerable increase in sorghum yield from fertiliser application would probably not be economically justified under the poor rainfall conditions of the 1988 Gu season (129 mm), as the control yield, 34.5 kg/ha, was so low. Even if the beneficial residual effects of the fertiliser, and crop residue responses were allowed for, applications of fertiliser over the range tested would possibly not be justified.

If these fertilisers raised yields by similar proportions in good seasons, their use may be viable. Thus trials should continue to evaluate them in better seasons, when water was not such a limiting factor to crop growth.

High rates of DAP should be placed deeper under the seeds at sowing. As in the case of manure, opportunistic fertiliser application should be tested, applying the fertiliser under the seed at sowing only after heavy early rains have fallen.

5.8 Rainwater Harvesting

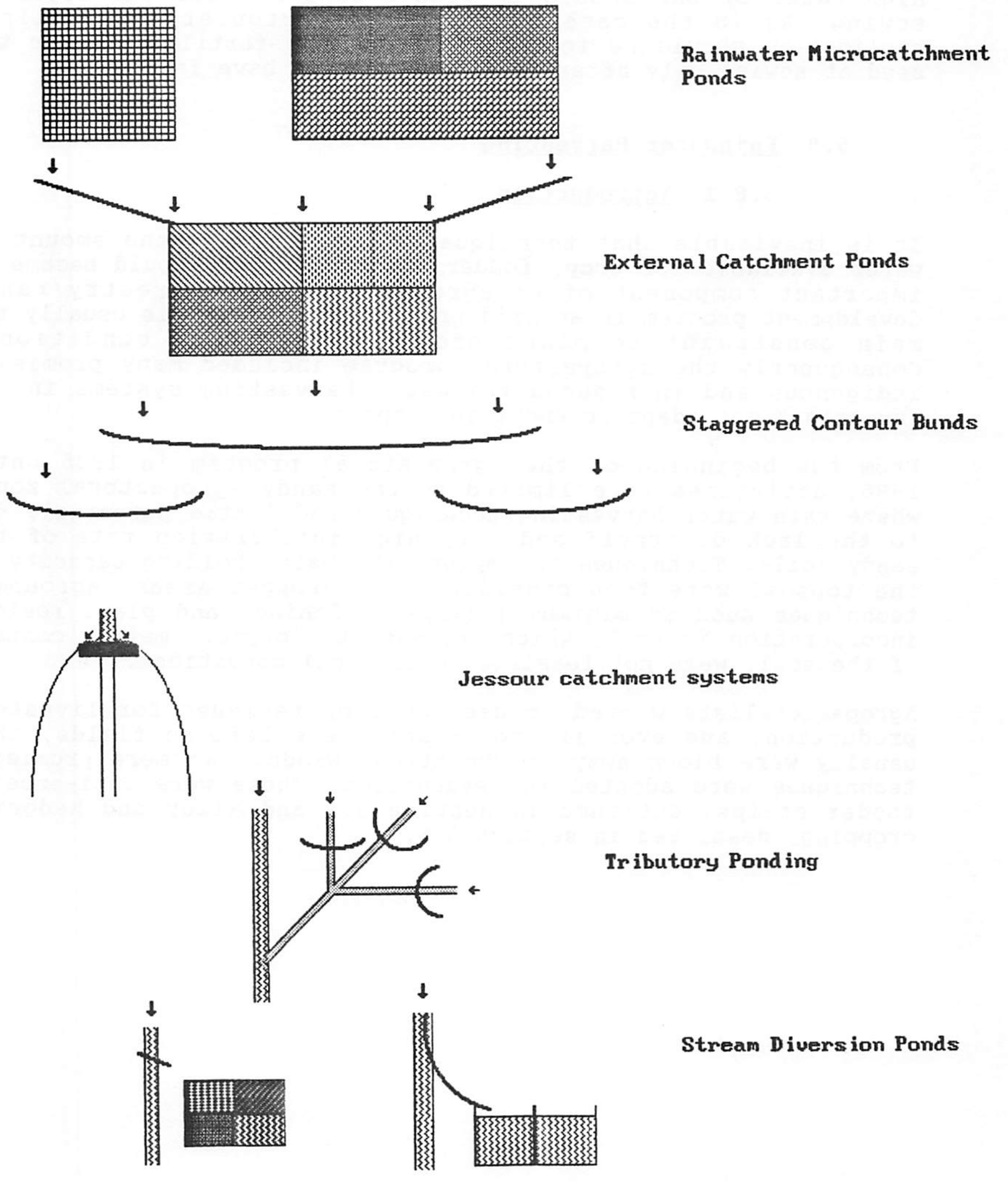
5.8.1 Introduction

It is inevitable that techniques which increase the amount of water available for crop, fodder and tree growth would become an important component of an agropastoral/agroforestry/range development program in an arid area. Lack of water is usually the main constraint to plant growth under these conditions. Consequently the agropastoral program included many promising indigenous and introduced rainwater harvesting systems in its investigation, adaption and trial program.

From the beginning of the agropastoral program in 1985 until 1986, activities were limited to the sandy agropastoral zone, where rain water harvesting techniques had little potential, due to the lack of runoff and very high infiltration rate of the sandy soils. Techniques to improve the water holding capacity of the topsoil were then considered. In cropped areas, agronomic techniques such as minimum tillage, mulching, and plant residue incorporation in soil, which increase the organic matter content of the soil, were not feasible under local conditions.

Agropastoralists wanted to use the crop residues for livestock production, and even if crop plants were left on fields, they usually were blown away in the strong winds. Two more promising techniques were adopted for evaluation. These were anti-erosion fodder strips, outlined in section 5.1 and alley and hedgerow cropping, described in section 5.6.

Figure 9: Indigenous Somali Rainwater Harvesting Systems



In late 1986, the first case studies of the Hiraan agropastoral system found that many agropastoralists in Bula Burti and Jalalaksi districts were practicing rainwater harvesting techniques to increase the production of their crops. The Hiraan region agropastoralists have developed a unique, low input runoff water harvesting system, which has potential application in other areas of Somalia and abroad, including many other African countries.

There are many types of rainwater harvesting, which is a general term used for techniques that collect runoff or flood water for humans, livestock, crop, tree or fodder production. Examples of two types were included in the agropastoral adaptive trials.

Runoff rainwater harvesting is described as the collection and impounding of rainfall with the objective of increasing the availability of water for plants in areas where rainfall limits production. (W. Crichley, 1986). The second type, floodwater harvesting, differs only in that the source of water is a temporary rainfed stream or gully. (W. Crichley, 1986).

Within these two types there are many variations, or sub-types, many of which have been practised by traditional farming systems for hundreds of years in parts of north Africa, America and the Middle East. (W. Crichley, 1986, W. Hiemstra, 1986). Over the last 30 years, researchers in Australia, south-west U.S.A., India, Israel and Kenya have begun to improve some of the traditional techniques. (W. Hiemstra et.al. 1986, A. Pacey and A. Cullis, 1986)

The traditional rainwater harvesting systems practised in Somalia, and their potential, has only recently been recognised (R. Holt, et.al. 1987). Six sub-type indigenous water harvesting systems have been identified in Somalia, diagramatically illustrated in figure 9.

Rainwater microcatchment ponds External catchment ponds Staggered contour bunds	Runoff rainwater Harvesting
Jessour catchment systems Tributary ponds Stream diversion ponds	Flood water Harvesting

Two of these systems, staggered contour bunds and 'jessour' type catchment systems have been practised in the undulating hilly areas of north-west Somalia. Types of staggered contour bunds are still used in this area. Short (5-20m) manually constructed earth bunds are built approximately on the contour on slopes, and crops sown behind them making use of extra water stored in the soil.

Recently attempts have been made to improve the system by introducing equipment to determine contours and heavy mechanical equipment to build the bunds. (W. Crichley, personal communication, 1988). There are also remnants of an interesting 'Jessour' Tunisian type of water and sediment catchment system in north-western Somalia (J. Kneeler, personal communication, 1982). It consists of stone and earth dams across small valleys and associated spreader bunds.

The other 4 indigenous Somali water harvesting systems are currently being used in the Hiraan region of central Somalia, and in some cases, parts of southern Somalia. The rainwater microcatchment ponding system is the simplest type. It is an internal microcatchment system, consisting of an earth bank (bund - or 'wonjel') which impounds rainfall falling on an area.

These ponds have a great range of shapes and sizes. In the Afgoi and Janale areas of southern Somalia, a network of small square, or checkerboard ponds are extensively used to impound water evenly on farms and prevent runoff. These typically are from 0.3 x 0.3 metres to 3 x 3 metres in size. The microcatchment ponds constructed in Hiraan region are much larger, irregular in shape, as shown in figure 9, and usually from 20 to 100 metres across. While they also prevent rainwater running off the bare farmed soil, unlike the small checkerboard microcatchments, they do little to help to evenly distribute water over the fields.

The external catchment pond water harvesting system, as shown diagramatically in figure 9, is a more sophisticated system extensively used in Bula Burti and Jalalaksi districts. It is both an internal and external catchment system, harvesting runoff water from higher ground adjacent to the farm. Manually constructed earth banks around the boundary of the farm impound rainwater on the farm, with extra water directed to the farm by similarly constructed wing catchment banks.

This system was selected for adaption and improvement as it appeared to have considerable potential. Alterations were also required to reduce water erosion often caused by the earth banks breaking due to their poor location or construction.

This system can be practised in the extensive areas with little to moderate slope and heavier soils capable of storing the water harvested in the soil profile. It is not generally suitable for areas with slopes over about 2%, as the earth banks have to be big and thus are expensive to build, especially if mechanical equipment is not available. The great advantage of this system is that it can provide crops with additional water for very little cost, as on flat land, only a few small 10 to 40 cm high earth bunds are needed.

The tributary pond flood water harvesting system is practised along some of the small ephemeral streams running down the escarpments lining the river Shebelle valley in Hiraan region. Unlike the external catchment ponds which cover an extensive area and have been practised for hundreds of years, the tributary pond system is limited in area, localised to a few small stream valleys, and has been practised mainly since bulldozers became available. The earth banks are much larger, usually 0.5 to 2 metres high, and consequently hold a much greater depth of water.

As traditional Somali agropastoralists have no land level measuring technology, the poorly constructed banks frequently break, with the considerable volume of water suddenly released, causing serious localised erosion. This system could be greatly improved by the introduction of both simple level measuring equipment and water spreading and ponding techniques used in northern Australia.

Stream diversion flood water harvesting is both located in the same area as tributary ponding and similarly limited in extent. Usually small barriers are constructed across small temporary streams, using wooden poles and sticks. The barriers slow the flood water, raising its level and causing it to flood over an area which is subsequently cultivated. Often only short barriers are built across part of the stream channel, and at an angle downstream, so that water is directed to flood over one bank. Large areas of a few hundred hectares of a farmland and range have been observed irrigated in this manner.

This system was chosen as a priority for improvement, as it appeared to have considerable potential, and it could be constructed by just one household, using local equipment and materials.

Two examples of a similar stream diversion system were observed which required bulldozers. This system is shown diagramatically in the bottom right corner of figure 9. Bulldozers push up a large 2 to 3 metre high earth bank in the middle of a small flat temporary stream. It is build at a gentle angle from the middle of the stream downstream towards one bank, effectively splitting the stream and directing floodwater to irrigate an adjacent area.

To begin to evaluate the potential of appropriate water harvesting techniques while developing improvements to the systems, the hypothesis established to test was:

> *'Low technology small scale rainwater harvesting techniques requiring little external input can economically crop production.'*

Five other water harvesting systems were introduced for observation, evaluation and to support the growth of agropastoral plants. The effectiveness of two of these, pitting and staggered contour catchment ponds, was evaluated in the range regeneration trial, described in section 5.9.

Another two were introduced to assist the growth of multipurpose trees under the arid rainfed conditions in the species elimination and growth trials. These two systems, the four-sided 'negerim' type of microcatchment, and the circular basin microcatchment are outlined in section 5.5. Just before this phase of the agropastoral program ended, another system - a tiered ridge contour bed, ditch system - was introduced to promote tree, crop and forage production. It is described below.

Two other indigenous Somali rainwater harvesting systems are indirectly important, as they often provide the water for the human and livestock components of the agropastoral system.

The first system - cement cisterns, locally called berkeds ('berkedo') - has experienced a dramatically rapid expansion over the last 35 years; to the extent where many villages and communities completely depend on berkeds for human water needs.

Berkeds are built by lining an excavated hole in the ground with stone and cement. They are usually located near where rainwater naturally runs off during rainfall events. Small channels are then dug to drain the runoff water into the berked tank. In sandy areas, roadways often provide adequate catchments. Sometimes runoff water is supplemented by motor tankers carting bore water. Using this system, agropastoralists are becoming more sedenterised. A berked, holding 40,000 - 300,00 litres, is usually built by a wealthy merchant or pastoralist, then relations settle nearby.

Whereas the berked system is a new development, earth dugouts or dams are an ancient technique; in some cases probably a precursor to berkeds. The dugouts were hand dug in locations where they could collect and store runoff water. These are not common in central Somalia, unlike southern Somalia.

Both berkeds and dugouts were techniques adopted by the CRDP during the course of the project to improve livestock and human water supplies, and to provide water to nurseries and shelter belts. The excellent local system was used to construct berkeds. Dugout construction was improved by using land levelling and soil profile testing equipment and bulldozers to speed construction. These 2 systems were not included in the agropastoral research program, so are only briefly described here.

5.8.2 Method and Materials

Aborey Rainwater Harvesting Trial.

Village leaders of Aborey village, 20 km. north-east of Bula Burti township, allocated a site next to their village for agropastoral trials. All the nearby, apparently more fertile areas were privately owned and thus unavailable. The soil was a sandy loam, last cultivated 7 - 10 years ago; and according to local agropastoralists, fertile enough to produce good sorghum crops.

With reservation about soil fertility and the runoff catchment, but lack of an alternative site, a live fence of *Commiphora incisa* and *C.hothai* branches was constructed around the 2.5 ha. site, and the rainwater harvesting system constructed in February to March 1987. The site selection and preparation is fully described in a previous technical report (Holt R. et.al., 1987). The work time and cost of all operations was recorded to assist the evaluation process.

The site was cleared by hand, and a local tractor hired to disc plough the area to be farmed. A border check irrigation system was then designed to accommodate an evaluation of rainwater harvesting, crop and pasture varieties, as well as observations on the potential use of rainwater harvesting for vegetable production and agroforestry.

A randomised block, experimental design was adopted, as shown in figure 10. The 80 x 75 metre experimental area was divided into four 20 x 75 metre blocks with each block irrigated separately. The blocks were divided up into 15 rows, with each block containing fifteen 5 x 20 metre plots. The rows, or strips, were orientated in a north-west, south-east direction to be at right angles to the strong prevailing winds. Rows of crops and pastures were alternated, as shown in figure 10; so that the pastures could act as anti wind erosion strips, and to allow for further crop, pasture rotations.

The rainwater harvesting and irrigation system was constructed using only locally available equipment and materials, to ensure that if successful, it could be readily adopted. Thus, although it would have been more efficient to use land level measuring equipment, local knowledge and observations of where water flowed after rain was used to layout the irrigation system and rainwater catchment wings.

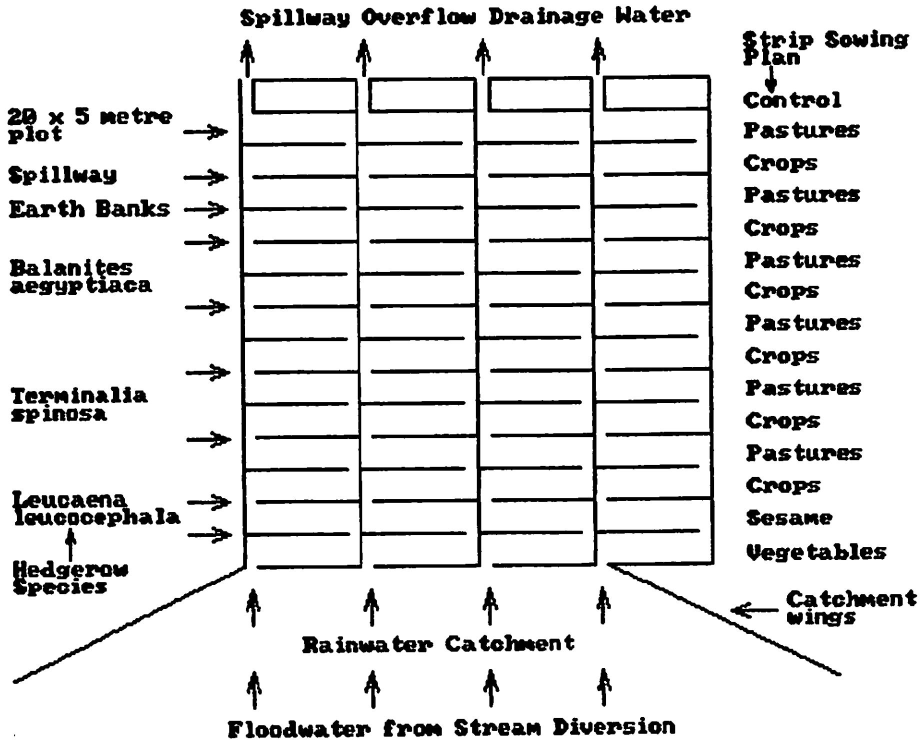
Short handled hoes, conventional shovels and traditional 2 man shovels were used to construct 25 - 30 cm high earth banks around each plot and out to the catchment area to collect runoff water and direct it through the irrigation system. Each plot was designed to be filled to a depth of about 10-15 cm by the runoff rainwater, with each plot individually filled and drained by a system of staggered spillways, as shown in figure 10. Each spillway, 1 metre wide and 10 cm high, was lined with *Commiphora hothai* wood to prevent erosion. Rock would have been a preferable material, but had to be transported a few kilometres to the site.

The total area of the trial ponds was 0.65 ha, and the area of the external catchment from which rainwater was harvested was 2.5 ha, thus the farm to catchment ratio was 1:4. A higher ratio of about 1:10 would be preferable to ensure sufficient water, but was not available.

The opportunity arose to evaluate and demonstrate a stream diversion floodwater harvesting system to provide additional water, as a small, 4m wide temporary stream was located 150 m. from the trial. A stream diversion, floodwater harvesting system was thus constructed to supplement the small external catchment runoff rainwater harvesting system.

A 100 metre diversion channel was manually dug in the soft soil using shovels to direct water from the stream to the farms catchment area, and hence to flow slowly through the farms irrigation system. The small channel, only 30-40 cm wide and grading from 80 cm deep at the stream bank to ground level in the farm catchment area, was dug with little effort in 1½ days by 2 men.

Figure 10: <u>Design of the Aborey Water Harvesting Crop/Fodder Species Trial</u>.



To minimise the possibility of storm damage, it was oriented almost at right angles to the stream near the bank. To reduce the flow of sand from the sandy stream bed down the channel, the diversion outlet was placed 10 - 15 cm above the base of the stream.

In an attempt to raise the level of the water in the stream (but not the sand) and divert more water down the diversion channel in small floods, a brushwood barrier was built across the stream at the diversion entrance. It was built from local poles of green *C.hothai* wood buried 1 metre in the ground. Horizontally woven sticks supported the structure. It was hoped that *C.hothai* poles would shoot, creating a permanent living barrier that raised the level of the storm water a little, but allowed the sand and most of the water to pass.

All the crop and pasture treatments were sown, weeded and harvested using the standard techniques. A range of drought resistant vegetables and a few varieties of promising crops with limited seed available were planted immediately after the first good seasonal rain in the front observation strip which had the best access to harvested rainwater.

At least 6 seedling each of bush tomatoes, pumpkin, sweet red watermelon, jackbean (*Cannavalia* sp), pigeon pea (*Cajanus cajan*) and tepary bean (*Phaseolus acutifolius*) were planted when 2 to 3 weeks old. The first 3 varieties were grown from seed collected from local farm product.

The jackbeans were collected from a few plants of unknown origin growing in Adale township. A long season pigeon pea variety was introduced from Nairobi, Kenya, where it is commonly sold for food. A very short season commercial variety of pigeon pea, QPL Hunt was introduced from Queensland, Australia, and tepary bean from World Vision, Homboy Agroforestry Project, southern Somalia.

The seedlings were all raised in the Bula Burti nursery used for propagating tree seedlings, using the same method and materials. No seed treatment was needed.

Hedgerows of 3 promising multipurpose agroforestry trees were established in lines along the boundary of the trial rows, by direct sowing of the seed. The position of these rows is shown in figure 10.

Seeds of the 3 species, *Leucaena leucocephala* var.K8 (from Australia) and *Terminalia spinosa* and *Balanites aegyptiaca* (local variety) were sown prior to the first seasonal rain in the 1987 Gu season. Two rows of each species were sown, with the *B.aegyptiaca* and *T.Spinosa* hedgerows 10 metres apart, while the *L.leucocephala* hedgerows were 5 metres apart, reflecting the estimated size these plants were expected to grow.

Spacing within rows was 4 metres for *T.spinosa* and 0.5 metres for the other 2 species. The hedgerows were grown next to the pond/plot banks, with trial crops growing on one side and pastures the other. They were given no silvicultural treatments; such as application of fertiliser or water, or weeding.

Bula Burti Rainwater Harvesting Trial.

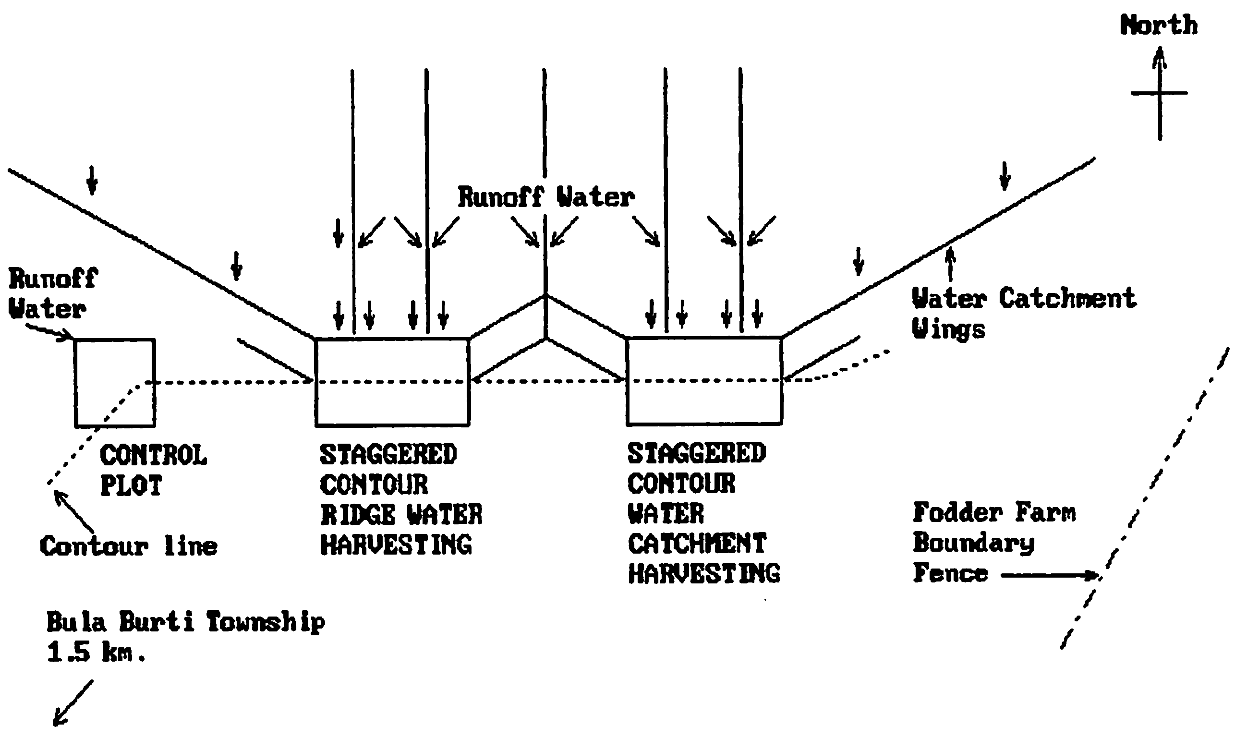
In mid 1987, surveys were conducted to locate a suitable trial site for evaluating technology to improve the traditional external catchment ponding rainwater harvesting system in Bula Burti district. A suitable site was surveyed near the Aborey trial, but it proved not practical to obtain tenure over the land.

Rainwater harvesting is practised extensively in the Halgan area, 60 km north of Bula Burti, and some sites offered by co-operating agropastoralists were surveyed; but an area suitable for a trial could not be located in the limited time available. Finally a site was chosen 2 km north of Bula burti within the CRDP fodder farm.

This site fulfilled all the selection criteria except that the slope was gentle, only 0.05 to 0.15%, and the soil a little light, being a loam. Interviews with local agropastoralists, and observations of old earth banks confirmed that the area had been used for traditional rainwater harvesting farming only 4 to 8 years previously; so contours were established using a dumpy level and line level.

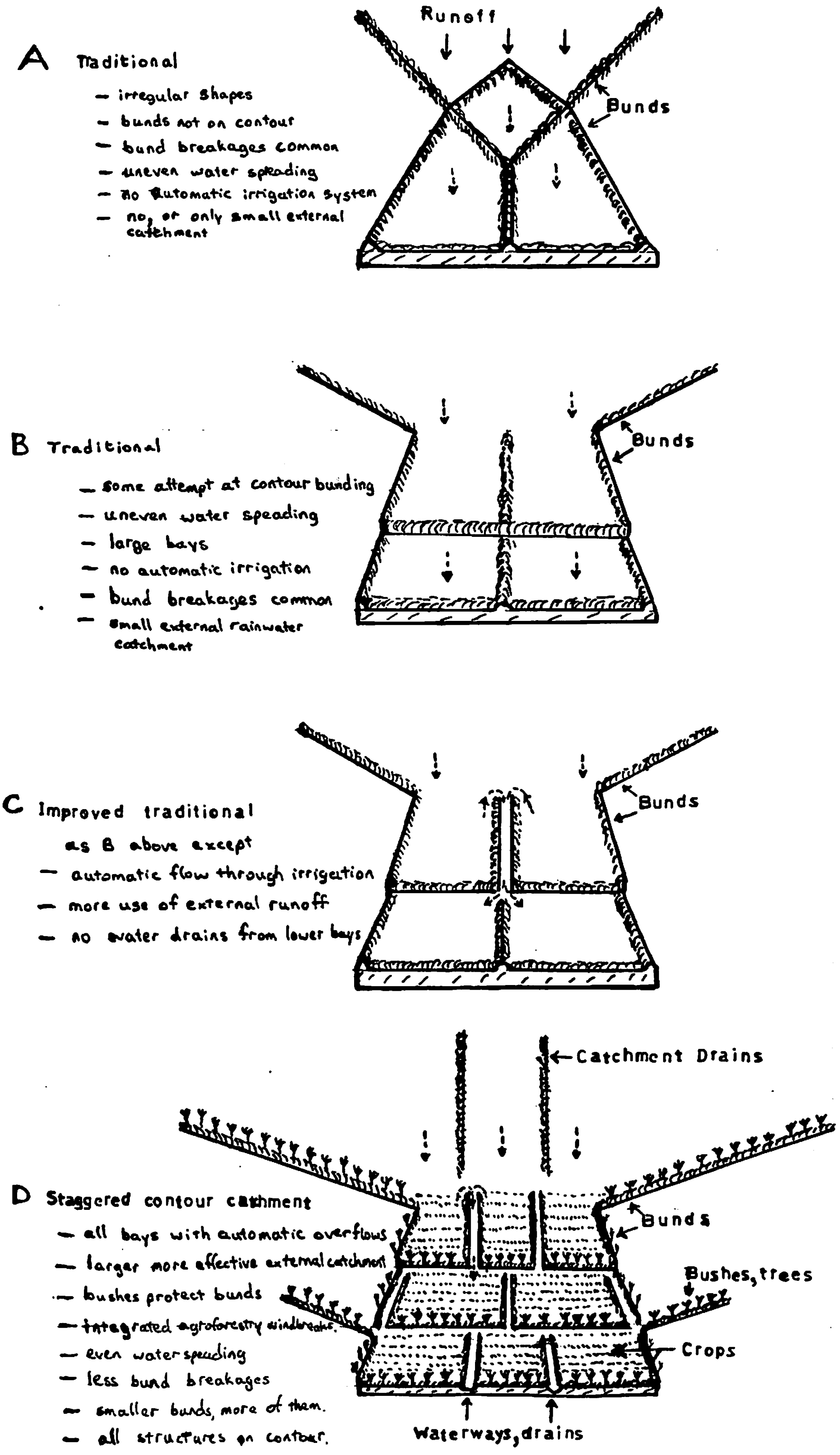
A relatively homogenous flat area with a gentle slope to the south, south-west was chosen. A trial was marked out as shown in figure 11, which incorporated comparisons of 2 potentially improved external catchment ponding systems and a control area with no supplementary rainwater harvesting.

Figure 11: <u>General Location and Plan of Bula Burti Rainwater Harvesting Trial</u>.



The whole area was prepared using local techniques. The land was manually cleared and disc ploughed using a small tractor. The design of the first improved system, the staggered contour rainwater catchment system (SCRC) is shown diagramatically as D in figure 12. The SCRC system was developed as an evolving improvement from the best local traditional rainwater harvesting systems, as shown in figure 12.

Figure 12: Bula Burti Runoff Harvesting Systems.



Next to this, another external (and internal) rainwater ponding system, the staggered contour ridge rainwater harvesting system (SCRRH), was established. This system, shown in figure 13, was designed to exploit the under-utilised potential offered by the recently available small, tractor-drawn 2 disc ploughs.

The two trial systems and the contour plot were located adjacent to each other, on the contour, with 40 metre buffer areas separating them. Both trials had an area of 50 x 50 metres, 0.25 ha., whereas the control was 25 x 50 metres, 0.125 ha.

The SCRC system, shown diagramatically in figure 13, diagram D, was built using similar techniques to those used at the Aborey rainwater harvesting trial. The network of 25-30 cm high ponding banks were constructed using 2 man shovels. Five rows of ponds were constructed, 9 metres long and 9 to 13.5 metres wide, with the wing tips and bases of each pond on the contour so they would fill evenly.

Ponds were separated by 1 metre wide spillways to allow automatic irrigation of all ponds. The spillways were staggered to reduce the likelihood of erosion. All spillway bases were left undisturbed (though ploughed): dirt for the earth banks being pushed up from within the ponds. As the land at the trial site had little slope, the potential water level in the trial was raised by raising the level of the bottom two rows of spillways 10 cm using *C.hodai* wood.

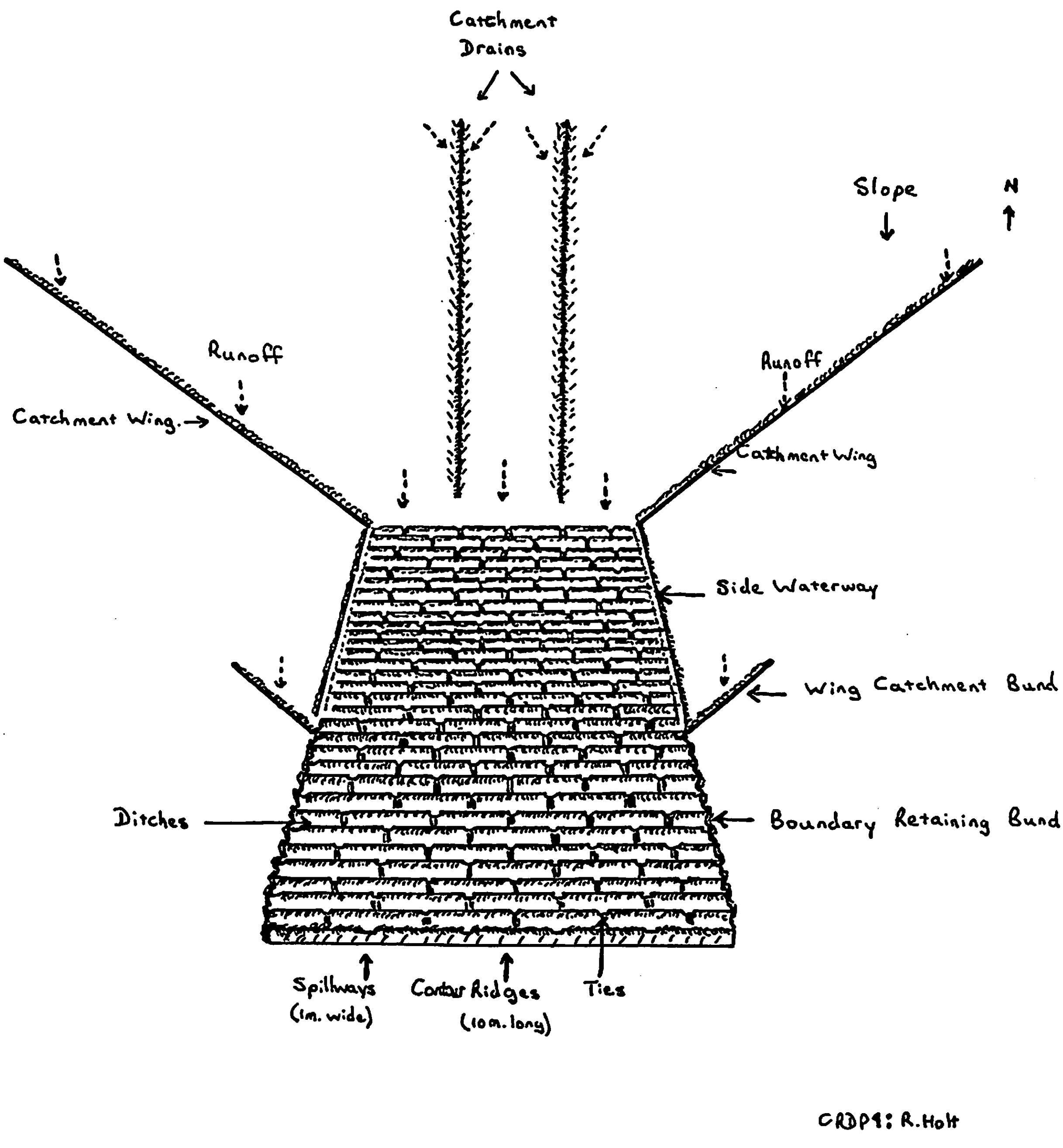
The SCRRH system was very easily constructed by driving the tractor up and down rows to create a series of adjacent ridges (or benches or beds) and the associated ditches (or channels). this internal catchment system would harvest rainwater from the ridges into the channels, potentially allowing crops to grow in the channels, in poor seasons when rainfall was too little to promote crop growth elsewhere.

The contour ridges were 1.5 to 2 metres apart, 1 to 1.5 wide and 20 to 30 cm high. The ridges were separated by ditches, 20 to 30 cm wide, and 15 to 20 cm below ground level. To both evenly distribute water along the channels and to create an irrigation system for addition external runoff harvested rainwater, every 10 metres the ridge was removed for 1 metre to create spillways, and the dirt pushed with 2 man shovels into the adjacent ditch.

The ditches were thus blocked every 9 metres, creating small ponds, often called tied ridges. The spillways, and thus the ties, were offset in a staggered fashion, as shown in figure 13. To hold the runoff water on the trial, earth banks were pushed up along the sides of the trial.

Similar external rainwater harvesting systems were constructed for each of the two trials. Four catchment wings for each trial, at least 200 metres long were built from the catchment area to direct runoff water to the trials. The 40 cm high earth catchment wings, with associated drainage ditches on both sides were rapidly built up by ploughing in one direction then back the other. They were pushed up higher when necessary using a 2 man shovel.

Figure 13: <u>Staggered Ridge Rainwater Harvesting Systems</u>.



To evaluate the rainwater harvesting systems in a quantitative manner, a third of the area of the control and both rainwater harvesting systems were sown to each of the crops, sorghum, cowpeas (local varieties) and mung beans (filsen variety). Each crop was sown in the position best suited to maximise total production from the trial.

In the staggered contour ridge, the crops were grown in rows, with sorghum sown near the bottom of the channels, cowpeas on the edge of the channels at near ground level, and mung beans on the ridges. In the staggered contour catchment system, sorghum was sown again in potentially the wettest area, the bottom third of each pond, cowpeas in the middle third, and mung beans in the driest, highest third.

5.8.3 Results

The comparative yields of local varieties of sorghum and cowpeas grown with and without rainwater harvesting at the Aborey site in the 1987 Gu season is shown in table 29. The rainwater harvesting significantly increased the yield of both crops, increasing sorghum yield by 94% and cowpeas by 59%.

Table 29: Increase in Sorghum and Cowpea Yields from Rainwater Harvesting at Aborey in the 1987 Gu Season.

Treatment	Crop Variety	Crop Yield of Grain/Beans - kg/ha				Mean Yield
		Block 1	Block 2	Block 3	Block 4	
No Extra Water	Sorghum	121	197	253	245	204
	Cowpea	78	92	110	131	103
Rainwater Harvesting	Sorghum	200	532	367	480	395
	Cowpea	153	284	111	124	164

Summary Anova

Source	d.f.	F.	Significance (5%)
Blocks	3	2.36	n.s.
Varieties	1	17.92	*
Rainwater Harvesting	1	10.91	*
Varieties X Water	1	2.64	n.s.
Within	9	-	
Total	15		

Note: Plot size 5 x 20 metres, randomised block experimental design.

The costs of establishing and operating the rainwater runoff harvesting production system for the 1987 Gu season are detailed in table 30. The cost of establishing the external catchment pond rainwater harvesting system, including all the ponds and the irrigation system was 1,339/- (Us $7.44) for the 0.54 ha unit, or 2,479/-/ha (Us $13.78).

Table 30: <u>Cost of Aborey Rainwater Harvesting Agropastoral/ Agroforestry Production Unit, 1987 Gu Season</u>.

Activity	Rainwater Harvesting		All Operations	
	Man Days	Cost (So.Sh.)	Man Days	Cost (So.Sh.)
Live Fencing	-	-	24	3,600
Clearing	-	-	2	300
Surveying	0.38	56	1	150
Ploughing	-	120	-	2,180
Pond Bank Construction	6.0	900	6	900
Catchment Wings & Spillways	2.0	300	2	300
Stream Diversion	3.0	450	3	450
Sowing	-	-	1	150
Weeding (twice)	-	-	2	300
Harvesting	-	-	0.5	75
TOTAL	11.38	1,826	41.5	8,405

Note 1. Cost does not include part time services of 1 day and 1 night guard/workers (6,000/- per month) as these were only necessary for trial purposes.

2. The commercial exchange rate at the time of the trial was 1 $U.S. = 180 So.Sh. Standard salary for local casual workers was 150 So.sh per day.

3. The construction of a brushwood barrier across a stream added about 500/- to the cost of a stream diversion in the 1987 Dayr season.

Adding the stream diversion marginally increased the cost of rainwater harvesting to 1,826/- (US$10.14) for the 0.54 ha trial, or 3,381/- per ha (US$18.79) This cost is equivalent to only 60 kg of sorghum for the trial area, or 113 kg/ha. Referring to table 29, the rainwater harvesting increases sorghum yields by 191 kg/ha, so a sorghum crop from this first season would have more than paid for the rainwater harvesting system. The increase in cowpea yield would not have been quite enough to pay for the system in this season.

In the following Dayr season, the rainwater harvesting system again significantly improved crop yields, increasing sorghum grain yields by 88% and cowpea yields by 75%, as shown in table 31. The forage residues yield of these same sorghum and cowpea crops was also significantly increased, in this case by 40% and 39% respectively.

Table 31: Increase in Crop Variety Yields and Crop Forage Residue Yields from Rainwater Harvesting at Aborey, Dayr Season 1987.

Treatment	Sorghum		Cowpeas	
	Grain kg/ha	Forage Residues kg/ha dry matter	Peas kg/ha	Forage Residues kg/ha dry matter
No Rainwater Harvesting	101	1,365	87	679
With Rainwater Harvesting	190	1,908	152	947

Note 1. All figures are means of 4 plots, 1 randomly located in each of 4 blocks.
2. Complete results including analysis listed in appendix tables 21 and 22.

Summary Anova

Source	d.f.		F.		Significance (5%)	
	Grain/Peas	Forage	Grain/Peas	Forage	Grain/Peas	Forage
Blocks	3	3	1.90	4.63	n.s.	*
Water	1	1	0.63	129.60	n.s.	*
Species	1	1	5.86	19.44	*	*
Species X Water	1	1	0.16	6.38	n.s.	*
Within	9	9	-	-		
Total	15	15				

As shown in Table 32, in the 1988 Gu season, the rainwater harvesting significantly increased sorghum yield by 51% and 103%, with and without manure respectively; and similarly cowpea by 161% and 171%, with and without manure application respectively.

Table 32: Effect of Rainwater Harvesting and Manure Fertilisation on Mean Crop Yields in the Gu 1988 Season at the Aborey Trial Site.

Crop Variety	Mean Crop Yield kg/ha	
	No Additional Manure	With Manure Applied
1 Sorghum (local variety)	110	175
2 Cowpea (local variety)	120	152
3 Cowpea (var. TVU15002)	101	156
4 Mung beans (var. Thai)	113	157
5 Bulrush Millet (loc.var)	175	223
6 Sesame (local variety)	39	47
7 Intercrop - Sorghum	53 } 108	104 } 219
plus - Cowpea	55	115
8 Control Sorghum	73	86
9 Control Cowpea	46	56
Treatment Mean	98	141

Note 1. Figures are means of 4 plots, each 50 metres square.
2. Control plots provided with no opportunistic water from the rainwater harvesting system.
3. Complete results and statistical analysis in appendix table 9.

Summary Anova

Source	d.f.	F.	Significance (5%)
Blocks	3	7.9	*
Crop Varieties	6	7.9	*
Manure	1	11.9	*
Var. X Manure	6	0.9	n.s.
Within	39	-	
Total	55	-	

During the three wet seasons the Aborey rainwater harvesting trial was conducted, seasonal conditions were relatively poor for crop growth. Local agropastoralists reported that their yields were far below average. This appears to have been due to the lower than average rainfall (table 2) and the abnormally short growing seasons; as most rain fell in the first 3 weeks of each season.

Although the rainwater harvesting greatly increased crop production, seasonal conditions did not favour external catchment, rainwater harvesting. Rainwater was only harvested in the heavy rainfall events occurring early in the season. For the rest of the seasons there was little rainfall, and what there was, was too light to cause runoff. As shown in table 33, harvested rainwater irrigated all the trial site once in the Gu 1987 season and twice in the other two seasons. During the 1988 Gu season, one heavy rainfall event caused some earth banks to burst. As the earth banks are small, and the slope gentle, there was little damage, and repair easy.

Table 33: Effectiveness of Rainwater Harvesting at the Aborey Trial Site, Gu Season 1987 to Gu Season 1988.

Types of Rainwater Harvesting	Number and Success of Rainwater Harvesting Events in 3 Seasons					
	Gu 1987		Dayr 1987		Gu 1988	
	Irrigated Some Ponds	Irrigated All Ponds	Irrigated Some Ponds	Irrigated All Ponds	Irrigated Some Ponds	Irrigated All Ponds
Runoff From Just Farm Catchment			1			
Runoff From Just Stream Diversion			1			
Runoff From Both	1	1		2	1	2

At the Bula Burti fodder farm rainwater harvesting trial, no crop yields were recorded for either the 1987 Dayr season or 1988 Gu season; apparently mainly due to the low rainfall and the slow rate at which the rain fell, which caused little runoff. In both seasons, early growth was very good, and during field days, local agropastoralists were impressed with the rainwater harvesting systems.

Due to the lack of mid to late season rain, all 3 crops - sorghum, cowpeas and mungbeans - died before flowering. In the last season, small yields may have been produced by the staggered contour ridge rainwater harvesting system, which has an internal rainwater catchment system; however, small gazelles (dig digs) damaged growth. Due to rainfall, there was no runoff from the external catchment, so no water was harvested

5.8.4 Discussion

The results of three seasons of trials at Aborey have consistently shown that appropriate rainwater harvesting techniques can be used to produce highly economic and significant increases in the yields of the major local crop varieties, sorghum and cowpeas. Although generally crop yields were low, due to the poor rainfall, and probably infertile soil, over the 3 seasons rainwater harvesting increased yields of sorghum from 51 to 94%, and cowpeas from 59 to 161%.

A single application of 600 kg/ha of manure also significantly increased the yield of these crops, supporting the theory that the fertility of the sandy loam soil at this site is a factor limiting crop growth.

The observation plots of bush tomatoes, sweet watermelon, jackbeans, pigeon peas and tepary beans all yielded well. Jackbean was particularly productive. There thus appears potential for somelimited vegetable production from wetter areas of well designed rainwater harvesting systems.

The large increases in crop production at the Aborey site were achieved using a very low cost, low technology, rainwater harvesting system; which required no external inputs except technical expertise. It has been shown that the cost of establishing this system, which requires little management or maintenance, is very low, and that it can be more than recovered from the increase in sorghum yield in the first season. This low cost system is particularly well suited to arid areas with a low rainfall and gentle slopes.

The cost of the rainwater harvesting and associated irrigation system, 3,381/- per ha. is kept low by using small 25-30 cm high earth banks; whereas larger banks would be needed in conditions with greater runoff. The cost is further reduced by using a tractor drawn disc plough to loosen the soil, and very effective local 2 man shovels to rapidly build the banks.

Observations suggested that the small 20 x 5 metre ponds were much more effective at evenly spreading runoff water than most local traditional external catchment ponds, which are much larger. In the hundreds of traditional ponds examined, runoff rainwater congregated only in the lower portion of each pond.

Larger ponds are also more susceptible to bank breakages, as they are less effective at spreading and reducing the concentration of runoff water. Consequently, larger ponds usually require larger retaining banks.

It is only practical to use smaller ponds if an automatic, low cost method of irrigating all the ponds is available. Of the 3 such systems introduced in these series of trials, the Aborey border check system is potentially the most subject to breakages.

The effectiveness of the system is heavily dependent on the proper functioning of the network of spillways. Carefully built wooden spillways can be effective, although more resistant timber than *Commiphora hothai* should be used. Rock spillways would be more effective, if rock was available nearby. Spillways covered with a creeping perennial grass, such as *Cynadon dactylon*, may also prove successful.

Discussions with agropastoralists indicated that designs which required much management or maintenance to operate would not be acceptable. In this respect, the designs used at Bula Burti are superior.

Although the Aborey rainwater harvesting trial proved successful, the performance could have potentially been improved and breakages reduced if simple land level measuring equipment was used to lay out the ponds. It is felt that the potential benefits would justify the introduction of small line levels, which costs about 1,000/-. A practical alternative would be water hose levels.

The maintenance of the earth banks in all the rainwater harvesting trials was reduced by growing multipurpose perennial plants on the banks. The roots of these plants tend to hold the banks together, while the branches act as a windbreak. These plants can also provide valuable secondary products, such as dry season fodder, food and wood.

The results of sowing such plants in the Aborey trial, discussed in section 5.6, indicate that the indigenous small, woody perennial, *Indigofera coerula* (var. Nooleeye - durgo) is a species showing promise. Reasonable success was also obtained with the direct sowing of the 2 indigenous tree species, *Balanites aegyptiaca* (kulen) and *Terminalia spinosa* (hara). The adaptive trials should continue to develop methods of using these and other promising plants for bank stabilisation.

As shown in table 33, the small stream diversion proved capable of supplying floodwater to the agropastoral production unit at least twice each season. The flood water brushwood barrier, which increased the total cost of the diversion to a very modest 1,000/-, appeared relatively effective; though big floods washed out part of the barrier.

The effectiveness of the system could be economically increased by digging the diversion channel another 10 to 20 cm deep, alleviating the need for the barrier. Alternatively, a more substantial wood barrier could be constructed. Again, rock would be a more suitable material, where it is available.

In addition to harvesting rainwater, observations demonstrated that the harvesting system irrigated the ponds with potentially beneficial alluvial and manure. This phenomenon would vary from site to site. It has been shown in these trials that manure can significantly increase crop production; so over a number of seasons, the accumulation of manure and alluvium from the harvested runoff water may also improve production.

Although rainfall was not sufficient to evaluate two the rainwater harvesting systems at Bula Burti, the early growth of crops and the establishment of hedgerows suggest these innovative designs have considerable promise. They should continue to be evaluated and adapted, preferably at a more suitable site with more slope, a better catchment and heavier soils.

5.9 Range Regeneration

5.9.1 Introduction

In central Somalia, there is serious range degradation around most permanent livestock and human water sources, especially in the more arid areas with erodable soils. Most of the agropastoral program focused on preventative measures, as it was felt this approach is more sustainable and economic; however appropriate techniques needed to be developed to regenerate already degraded areas too.

In agropastoral zones, many of the techniques under development which are outlined elsewhere in this report could also be potentially used to regenerate degraded areas. Valuable bare land and sand dunes near water points for example, could be privately fenced using live fencing techniques, then managed as private season grazing reserves; and perhaps for cropping, using anti-erosion strips, rotations, hedgerows and manure fertilisation. In pastoral land use areas, other range regeneration techniques were required.

Around Ceel Buur township, a district centre near the geographic centre of Somalia, the rangelands are highly degraded; so a range regeneration trial was established to evaluate and develop appropriate revegetation techniques. The soil at this site was a saline, alkaline, gypseous sandy clay, similar to the soils found around many of the inland pastoral settlements, which are often located in gypsum valleys. It was thus hoped that the results of this trial could not only be utilised in the thousands of hectares adjacent, but also could be transferred to many other localities.

There are numerous methods of regenerating very degraded range areas, but most involve treatment to improve the infiltration of rainwater into the soil, and some sort of revegetation. Two such soil surface treatments were chosen for evaluation, which are relatively inexpensive to implement, and are suited to the soil type and flat to gently undulating topography.

Excavated pitting is a technique widely used in the Australia rangelands. Mechanical implements are used to dig small holes, or pits in the soil, which subsequently act as microcatchments, collecting rainwater and seed. Contour staggered tied bunding is another potential technique, in which a network of short ditches and their adjacent bunds (banks) are constructed on the contour to collect runoff rainwater and seed. Thus to evaluate the effectiveness of these techniques under local conditions, the following hypothesis was proposed.

> *'Pitting and bunding soil surface treatments can improve the rapid vegetative regeneration of denuded saline clay rangeland areas.'*

The following section describes a range regeneration trial and observations of various techniques informally evaluated during the CRDP development program. The author was involved in giving in-service training courses to soil conservation and extension staff, in sand dune fixation and range regeneration techniques, from mid 1982 until mid 1988. As the agropastoral department staff gained experience, their expertise was increasingly used to solve local range regeneration problems. Construction observations are thus recorded.

5.9.2 Method and Materials

The site selected to develop and evaluate appropriate range regeneration techniques was first established by the CRDP in 1985. A 5.2 ha area 5 km south-west of Ceel Buur near the main road to Mogadishu, the capital, was fenced in early 1985, under the technical direction of Bill Fobair, the CRDP Soil and Water Conservation Officer.

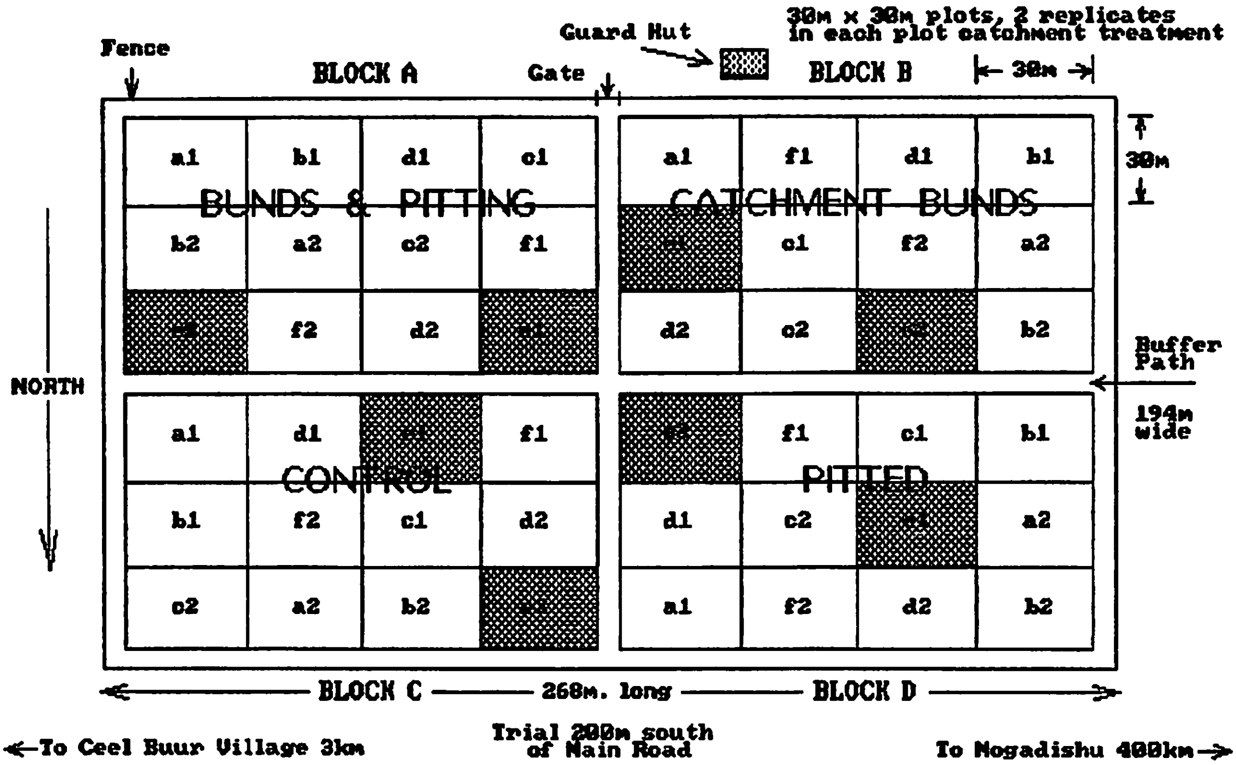
Unfortunately, due to a combination of circumstances, including very poor seasonal rainfall and poor quality seed, no results were obtained, and by early 1987, it was difficult to identify any affect on vegetation. Some pits had been dug, but these were small and had filled in. Various pasture species had been sown, but very few plants remained. The whole trial site, like most of the surrounding landscape, was barren, with only a few isolated Sporabolis plants. Nearby, the few isolated trees or bushes, such as Acacia spp. or Dobera glabra, existed on isolated mounds between eroded claypans.

The original trial design had been a randomised, split plot experiment, with 2 replicates. It had been divided into 4 blocks, 2 being pitted and 2 left as controls. For the current trial, in early 1988, both the previously pitted blocks A and D were again pitted, but with more deep, larger pits.

One of the prior control blocks, block C, as shown in figure 14, was again left as a control; and the other, block B contour bunded. A contour bund treatment was also superimposed over the pitted block A., to create a pitting plus bund treatment. Each of the four block was subsequently divided into twelve 30 x 30 metre plots.

The pits and contour bunds were constructed using a large motor grader, the only suitable machine available. Driven by large rubber tires, the grader minimised soil surface disturbance. Pits 15 to 20 cm deep and wide, and 30 to 40 cm long were dug in a grid fashion about one metre apart using the grader tine plough.

Figure 14: <u>Location and Design of Ceel Buur Range Regeneration Trial</u>.



Three rows of contour bund microcatchments were built across each 30 by 30 metre plot in blocks A and B by using the grader blade set at an angle. Two metre wide spillways were left every 5 to 9 metres to allow rain water runoff to flow from one catchment down slope to the next catchment.

To increase the rainwater catchment capacity of the bund, 5 metre long tied ridges (bunds) were constructed using 2 man shovels at right angles, up-slope from the end of each bund, creating a series of 3 sided rectangular catchments, open up slope. The bunds forming the base and sides of these catchments were 20 to 25 cm high, and the associated ditches were 15 - 20 cm deep.

To evaluate the effectiveness of the soil treatments for establishing a range of pasture, bush and tree species, 6 revegetation treatments were randomly allocated to the 12 plots in each of the 4 blocks. There was thus 2 replicate plots for each revegetation treatment in each block. Details of the 6 revegetation treatments are provided in table 34, and their location is recorded in figure 14.

Treatments a, b and c were various combinations of salt and drought resistant fodder species, with the seeds directly sown just prior to the first seasonal rain in April 1988. Only small quantities of seed was available, so it was sown in the pits, and behind the catchment bunds by hand, using hoes to place the seed 1.5 to 3 cm deep.

Table 34: Ceel Buur Range Regeneration Trial Revegetation Treatments.

Code	Treatment Type	Plant Species	Seed Quantity kg./treatment	No. Seedlings per treatment
a	Direct Seeding	*Atriplex nummalaria*	1	—
		A. rhagodioides	1	—
b	Direct Seeding	Daran (local saltbush)	3	—
		Indigofera (loc. salt res.var.)	1	—
c	Direct Seeding	*A. nummalaria*	0.5	—
		Maireana aphylla	0.5	—
		A. vesicaria	0.5	—
		A. rhagodioides	0.5	—
		A. hamilus	0.5	—
d	Control - Natural Regeneration	—	—	—
e	Planting Salt Resistant Tree/Bush Seedlings	*Conocarpus lancifolia*		32
		Terminalia spinosa		32
		Tamarindus indica		32
		Casuarina equisetifolia		32
		Acacia ligulata		32
		Prosopis tamarugo		32
f	Future Treatment	—	—	—

Note: Each plot was 0.09 ha, with 8 plots per treatment, total area per revegetation treatment was 0.72 ha.

For treatment e, 6 salt and drought resistant tree/bush species with useful characteristics were raised in nurseries, using the standard techniques outlined in section 4.4.6; then planted in all 4 blocks after the first 1989 Gu season rains in April. Four seedlings of each species, a total of 24 seedlings were planted in each of the e treatment plots.

In block D, the pitting treatment, the seedlings were planted in the bottom of the pits. In blocks A and B, they were planted in the wettest positions too, in this case just behind the bottom bund in the ditch.

Treatment d was left as a control, and f reserved for a future treatment. In effect for the period of this trial both treatments d and f acted as controls. During the trial, the plants received no irrigation or other treatments. They were protected from grazing by a boundary fence and guard.

5.9.3 Results

Results from the trial were recorded in December 1988, eight and a half months after planting and sowing. Given that the average annual rainfall of Ceel Buur is 200 to 250 mm, the Gu 1988 seasonal rainfall of 152 mm was quite good. Two storms were heavy, filling almost all the pits and causing considerable runoff. An assessment of the success of the catchment bunds in collecting runoff water is shown in table 35. Twenty percent of the bund microcatchments suffered some degree of breakage in block B, and 12% in block A, during the Gu season.

Table 35: Proportions of Catchment Bunds Collecting Runoff Rainwater in the Ceel Buur Range Regeneration Trial.

Microcatchment Treatment	Replicate	Level of Runoff Water Caught in Catchment (% of Bunds)				
		Empty	1/4 Full	1/2 Full	3/4 Full	Full
Bunds Only	Plot E1	0	0	12.5	12.5	75
	Plot E2	0	0	0	29	71
	Mean	0	0	6	21	73
Bunds + Pitting	Plot E1	0	29	57	14	0
	Plot E2	0	43	43	14	0
	Mean	0	36	50	14	0

None of the seeds sown in treatments a, b and c germinated. Standard germination tests in petri dishes supplied with distilled water indicated that the seed was not viable, despite having only just being imported.

All the soil treatments dramatically improved natural regeneration of vegetation, as shown in table 36. The soil treatments caused a highly significant increase in the number of plants growing per square metre. The bunds plus pitting treatment was significantly the most effective for natural regeneration of vegetation, followed by the bunding treatment and pitting.

Table 36: Significant Improvement in the Regeneration of Degraded Range Vegetation by Pitting and Bunding at Ceel Buur, 1988.

Plot No.	Treatment	Natural Regeneration (plants/square metre)			
		Bund Plus Pitting	Bunds Only	Pitting Only	No Treatment
d1	Control, natural regeneration	8	4	3	1
d2	" " "	9	4	4	2
f1	Future Treatment	10	4	3	1
f2	" "	8	6	5	1
	Mean Plants / Square metre	8.8	4.5	3.8	1.3

Summary Anova

Source	d.f.	F.	Significance (5%)
Blocks	3	0.73	n.s.
Treatments	3	38.90	*
Within	9	0.78	n.s.
Total	15		

Newman-Kuels Test of Significantly Different Means

Bunds Pitting	Bunds only	Pitting only	No Treatment

Any 2 means not underlined by the same line are significantly different. Any 2 means underlined by the same line are not significantly different.

All the range regeneration soil treatments caused an enormous and significant increase in the survival of the tree seedlings planted in revegetation treatment, as shown in table 37.

5.9.4 Discussion

The trial results have shown that excavated pit and staggered contour rainwater catchment pond soil surface treatments rapidly improved the vegetative regeneration of a denuded saline clay rangeland site near Ceel Buur.

After only eight and a half months, there was more than 6 times as many native plants established in the bunds plus pitting treatment than the untreated control. The success of the soil treatments in promoting early tree survival and growth was also enormous and dramatic, with only one tree (2%) surviving in the untreated control, and it looked as it would die soon; whereas 34 seedlings (71%) survived, with almost all growing well in the bunds only treatment.

The bunds only treatment was significantly the most effective for tree seedling establishment; whereas the bunds plus pitting treatment was significantly the most successful for promoting natural revegetation. Observation during storms suggested that the reason for the difference was that the pitting microcatchments collected runoff rainwater; so in the pits plus bunding treatment, less runoff rainwater was available to fill the staggered contour bund catchments, as shown in tables 34.

As all the seedlings in both the bunds only and bunds plus pitting treatments were planted behind the bunds, and the bunds only treatment was most effective in collecting runoff, it appears that the extra water harvested promoted tree survival.

The pitting and bunding treatments had an accumulative effect on natural range vegetation regeneration as the bunds only impounded rainwater over, at a maximum, half of the area of each plot; whereas the pits covered the whole plot area. Observations strongly suggested that both the pits and bunds increased range regeneration by harvesting runoff rainwater, increasing soil water infiltration, and collecting seed, alluvial and debris.

The soil at the trial site lacked structure, probably due to the high gypsum and mershan clay content; so the life time of the soil treatment structures is likely to be relatively short. Under these conditions, higher bunds, deeper ditches and larger, deeper pits than those used would be more effective. While such structures would be more expensive, they could be easily constructed with standard, commercially available range revegetation equipment, which was not available for this trial.

The larger bunds would reduce, or eliminate the breakage of some bunds experienced during this trial. Due to trial design, it was not possible to build all the bunds on the contour, contributing to breakages. Under normal conditions, this would not be a constraint.

While it is disappointing that the seed of the salt and drought resistance saltbush species was not viable, trials should continue to evaluate promising local and introduced productive

Table 37: Highly Significant Increase in Survival of Tree Seedlings Given Bunding and Pitting Treatments Under and Rainfed Conditions at Ceel Buur, 1988.

Tree/Bush Species	Regeneration Treatment Seedling Survival (out of 8/treatment)				
	Bund Plus Pitting	Bunds Only	Pitting Only	No Treatment	Total No Trees
Conocarpus lancifolia	2	7	2	1	12
Terminalia spinosa	3	4	4	0	11
Tamarindus indica	4	7	2	0	14
Casuarina equisetifolia	6	6	3	0	15
Acacia ligulata	2	4	3	0	9
Prosopis tamarugo	3	6	2	0	11
Treatment Mean % Survival	42%	71%	33%	2%	37%

Summary Anova

Source	d.f.	F.	Significance (5%)
Blocks	3	0	n.s.
Species	5	0.72	n.s.
Soil Treatment	3	35.37	*
Species X Soil Treatment	15	1.17	n.s.
Within	23	-	
Total	47		

Note 1. The number of each species per treatment is the total of two replicated plots, each plot having 4 trees planted.

2. Detailed results and statistical analysis presented in appendix table 23.

Seventy one percent of all tree seedlings survived in the microcatchment bunding treatment, significantly more than the next most effective treatment, bunds plus pitting. In the bunds plus pitting treatment, the trees survived slightly, but not significantly better than the pitting only treatment, 42% compared to 33% respectively, whereas without any soil treatment, only 2%, or 1 tree survived.

fodder species for these conditions. Many of the species introduced, sustain millions of livestock in other saline, arid areas of the world.

All 6 tree species planted in the trial grew well, with there being no significant difference between their survival. All 6 species were selected for their usefulness, salt, alkaline and drought resistance, and ability to grow in the local climate.

The water table is high at this site, probably about 4 metres, so it was hoped the trees would eventually tap this source. *Casuarina equisetifolia* and *Tamarindus indica* had the highest survival rate.

C.equisetifolia, a native of the coastal areas of Australia and Asia, produces excellent, valuable poles, which are scarce and highly valued locally. It is a widely used windbreak species with some forage value. *T.indica* is a slow growing, tough leguminous tree, introduced from India for its fruit pulp, which is eaten as food, or drunk. It also produces valuable wood and forage.

Conocarpus lancifolia and *Terminalia spinosa* are two valuable indigenous species. *C.lancifolia* (dumus) produces excellent poles, while *T.spinosa* yields valuable poles, fuel and fodder.

Prosopis tamarugo is a very drought resistant species introduced from Chile, where the nutritious pods and dry leaves support a sheep industry in barren, saline deserts. *Acacia ligulata*, a legume introduced from Australia, has some value for fodder, wood and soil conservation.

Many other promising, useful tree and bush species are available that could potentially grow under these harsh conditions, and trials should evaluate them. Future trials should include more economic, direct sowing of seed treatments, accompanied by more substantial water catchment structures.

6.0 CONCLUSION AND RECOMMENDATIONS

The adaptive trial research program has developed appropriate farming systems which are much more productive, less environmentally destructive, and potentially more sustainable. These systems would have some combination, or all of the following components.

(1) Rather than shifting from one locality, to clear and crop another every five years or so, a number of soil conservation and improvement measures would be adopted; so that the one farm, often consisting of a number of enclosures, could be continually utilised for a long time.

(2) Four to five metre wide anti-erosion pasture strips have been shown able to substantially reduce wind erosion on farmed fields. They produce larger quantities of fodder, collect blowing soil; and potentially, biologically improve soil fertility. This technique should be widely extended to agropastoralists in the sandy zone. Adaptive trials should continue to improve the technique, by identifying suitable, taller, preferably woody leguminous pasture/fodder species, including *Tephrosia* spp., *Indigofera* spp. and *Stylosanthes* spp.

(3) The use of living fence hedges has been found to be a practical technique to control the grazing of livestock; one of the major problems facing livestock and cropping industries in Africa. They also promise to reduce the need to cut branches to maintain thorn branch fences. The technique has greatest initial application to bring bare land and sand dunes near villages back into production. A range of *Commiphora* spp. *Balanites aegyptiaca* and *Euphobia tirucalli* have beenfound to be suitable living fence species, adapted to certain localities. A priority for future research should be to continue the development of techniques that would reduce establishment costs, including the use of small cuttings and direct sowing of seed.

(4) The agropastoral program introduced improved varieties of cowpeas, which are highly acceptable and produce substantially higher yields of peas than the local variety. Pure samples of these varieties should be multiplied and widely distributed.

(5) A range of additional, leguminous crops were introduced which show great promise to increase yields, reduce the risk associated with the dependancy on only 2 crop species, and improve food security during dry periods. Most are also known to biologically improve soil fertility. The availabilty of additional crops should be used to develop rotations, intercropping and cover crops. Drought resistant varieties of mung beans were the most extensively tested crop introduced by the project. In most seasons they out-yielded local cowpeas, and are now grown by many agropastoralists. Other promising crops, such as pigeon pea and guar, require further evaluation.

(6) Improving forage production and availabilty for livestock in the dry season was an aspect of other interventions; including anti-erosion strips, living hedges, new crop varieties, hedgerow cropping, multi-storey cropping and permanent/semi-permanent farming systems. Improved varieties of *Cenchrus ciliaris* have produced high yields when established in pasture strips, or to revegetate barren, recently falllowed areas. Fodder production should continue to be seen as a major objective of the agropastoral system, and local selections and introductions from abroad should continue to be made.

(7) Valuable multipurpose trees which are compatible with cropping have an important role, and should be retained or established on farms. Agropastoralists should be encouraged, by demonstration and extension, to retain such local trees identified to date; including *Terminalia spinosa*, *T. polycarpa*, *Dobera glabra*, *Balanites aegyptiaca*, and *Cordia* spp. Trials should continue to evaluate and develop suitable establishment techniques under local conditions, both for local species and promising multipurpose species from abroad. Hedgerow and alley cropping should be developed as multipurpose techniques with potential to reduce erosion.

(8) Small scale, low input, rainwater harvesting techniques have been shown to be an economic, practical technique to significantly increase crop and forage production. Adaptive trials are need to refine and improve the traditional systems which often cause water erosion.

A range of techniques have been tested under controlled trial conditions, which have variously been shown to reduce erosion, potentially decrease tree cutting and over-grazing, and increase food and fodder production. Many of these techniques are now being adopted by local agropastoralists. It is thus considered that the general objectives and unifying hyposisis for this program have been fulfilled. In many ways the work has just begun, and it is hoped this program will inspire and guide others.

REFERENCES

Abdi, N.H. — *Seasonal Serum Concentrations of Glucosis and Urea in Small Ruminants in Central Somalia.* Oct. 1986. Unpublished draft article, Central Rangelands Development Project Mogadishu, Somalia, Veterinary component. 7p

Bagnold, R.A. 1941 — *The Physics of Blown Sand and Desert Dunes* London (Referred to in Dune Stabilisation 1977, GTZ, No. 67.

Critchley, W. 1984 — *Runoff Harvesting. Interim Report, Pilot Semi-Arid Area Project, Baringo, Kenya, M.O.A.L.D., Republic of Kenya.*

Critchley, W. 1986 — *Some Lessons from Water Harvesting in Sub-Saharan Africa. Workshop Report*, 13-17 Oct. 1986, Baringo, Kenya, The World Bank, East and Southern Africa Projects Dept. 58p.

CRDP 1986 — *Rangelands Development Project Phase 2 Project Preparation Report*, Dec. 1986. CRDP Project Preparation Committee, Main Report 53p. and Annexes 1 to 10.

FAO — *Central Rangelands Development Project, Somalia, Completion Report*, 1988 FAO Rome.

Hagedorn,H., Giebnerk, 1977 — *Dune Stabilisation: A Survey of Literature*, In Weise, O., Busche, D., Grunert, G. Dune Stabilisation. GTZ publishers (German Agency for Technical Co-operation) Book 194 pages plus bibliography.

Herlocker, D. 1985 and Ahmed, A.M. — *Interim Report on Range Ecology and Management of Ceel Dheer District CRDP*

Herlocker, D. 1986 — *Status of Central Rangelands Development Project.* Executive Paper in Proceeding of Workshop on Future Range/Livestock Strategies for the Central Rangelands of Somalia. March 1986, Mogadishu Somalia, 28p.

Hoben, A. 1985 — *Resource Tenure Issues in Somalia.* Boston University African Studies Centre, U.S.A.

Holt, R.M. 1985 — *Agropastoralism and Desertification in Ceel Dheer District: Preliminary Investigation and Trial Results*. CRDP Technical Report Series No. 3.

Holt, R.M. 1986 — *Agropastoralism and Desertification in Central Somalia*. In Proceedings of the Seminar/Workshop on Future Range/Livestock Development Strategies for the Central Rangelands of Somalia March 1986, Mogadishu. ed. Wieland, R.G.

Holt, R.M. 1986 — *Developing Range and Livestock Associations in Central Somalia*. CRDP Technical Report Series No. 5. 51p.

Holt, R.M. October 1987 — *Aborey Pasture/Fodder/Crop Runoff Water Harvesting Adaptive Trials: Establishment and First Season Results*. CRDP Technical Report Series No. 23.

Holt, R.M. December 1987 — *Runoff Water Harvesting and Agrosilvi Pastoral Techniques to Improve Plant Growth and Reduce Erosion: Bula Burti Trials Interim Report*. CRDP Technical Report Series No. 25.

Lewis, I.M. 1980 — *A Modern History of Somalia*. Book 279p. Longham Group Press, London/New York.

Kaplan, I. 1977 — *Area Handbook for Somalia*. 2 ed. American University. 392p.

Kuchar, P. Omar A.E., and Hassan, A.S. 1985 — *The Rangelands and Their Condition in Eastern Bula Burti District*. CRDP Technical Report Series no. 12. 53p.

National Academy of Science 1975 — *Unexploited Tropical Plants with Promising Economic Value*. Washington D.C. Book, 190 pages.

" " " " 1979 — *Tropical Legumes: Resources for the Future*. Washington D.C. Book, 332 pages.

" " " " 1983 — *Agroforestry in the West African Sahel*. National Research Council, U.S.A., Advisory Committee on the Sahel. National Academy Press. Washington, D.C. 86p.

Pacey, A. & Cullis, C., 1986 — *Rainwater Harvesting: The ollection of Rainfall and Runoff in Rural Areas*. Intermediate Technology Publication, London U.K. Book 216 pages.

Pingali P., Bigot Y., *Binswanger, H. 1987* — *Agricultural Mechanisation and the Evolution of Farming Systems in Sub-Saharan Africa*. The World Bank. Published by John Hopkins University Press. 216p.

Salisbury, L. 1988 — *Agropastoral Crop Production in the Central Rangelands*. Draft report produced for USAID, Mogadishu, Somalia. 21p.

Steppler, H.A. & Nair, P.K.R. ed. 1987 — *Agroforestry - a Decade of Development*, ICRAF Nairobi, Kenya. 337p.

UNSO 1984 — *Inventory of Sand Movement in Somalia*. United Nations Sudano - Sahelian Office. UNSO/DES/SOM/80/001 100p.

Watson, R.M. et. al. 1979 — *Central Rangelands Survey, Somali Democratic Republic Vol. 1-4*. Resource Management and Research, 16B West Central St. London W.C.1.

Watson, R.M. et. al. 1985 — *Southern Rangelands Survey, Somalia*. Resource Management and Research.

World Bank 1979 — *Central Rangelands Development Project, Somalia, Staff Appraisal Report*. Report number 2163-50.

World Bank 1988 — *Central Rangelands Research and Development Project Phase II, Somalia*. Appraisal Report, World Bank.

Yasin, A.A. 1988 — *Seed Germination Enhancement Treatments for Six Agropastoral Crops*. Somali Journal of Range Science. Vol 3, No. 2. Oct. 1988. Somali National University P.24 to 30

LIST OF APPENDIX TABLES

Appendix Table 1. <u>Anti-Erosion Strip Trial: Centimetres Soil Erosion and Deposition Across 2 to 6 Metre Wide strips, 24 Month Period, Dec. 1986 - Dec. 1988</u>.

Strip Width	Pasture Strip	N/E Strip Edge	Crop Strip	S/W Strip Edge
2 Metre Strip	3 2 1.5 2 1 1.5	2 3 2.5 3 4 3.5	- 3 - 4 - 2 - 2.5 - 3 - 3	1 2 1.5 1.5 1 2.5
Total Mean	12 2	18 3	- 17.5 - 2.9	9.5 1.6
3 Metre Strip	2 3 2.5 2 2.5 3	6.5 4.0 8 6 7 5	- 5 - 4 - 6 - 4 - 3 - 3	4.5 5 3 2 4 2
Total Mean	15 2.5	36.5 6.1	- 25 - 4.1	20.5 3.4
4 Metre Strip	1.5 3 2.5 1 3 3	12 9.5 8 11 7 8	- 5 - 4 - 4.5 - 3 - 4 - 5	4 9 7 5 5 5.5
Total Mean	14 2.3	55.5 9.2	- 25.5 - 4.3	35.5 6
5 Metre Strip	2 1 2.5 3 1.5 2	8 13 10 9 14 11	- 5 - 4 - 6 - 4 - 7 - 3	7 4 5 6 7.5 7
Total Mean	12 2	65 10.8	- 29 - 4.8	36.5 6
6 Metre Strip	2 3 1.5 1 1.5 1	10 14 13 10 11 8	- 8 - 9 - 6 - 7 - 8 - 3	9 7 7 8 7 5
Total Mean	10 1.7	66 11	- 43 - 7.2	43 7.2

Appendix Table 2. <u>Anti-Erosion Strip Trial: Centimetres Soil Erosion and Deposition on Control Traditionally Cropped Area and Natural Pasture, 24 months, Dec. 1986 - Dec. 1988</u>.

Recording Position	Centimetres Deposition or Erosion of Soil	
	Cropped Traditionally	Natural Pasture
1	- 6.5	0.5
2	- 9	0
3	- 5.5	0
4	- 7	0.5
5	- 9	1.0
6	- 8	0
Total	- 45	2.0
Mean	- 7.5	0.3

Appendix Table 3. Cowpea and Mung bean Variety Yield Results, Gu 1987 Season, Nooleeye Trial.

Crop Variety	Crop Yields Kg/ha peas/beans						
	Strip Blocks						Yield Mean
	1	2	3	4	5	6	
Cowpea (local var.)	229	60	108	245	90	174	151
Cowpea (TVU15002)	143	110	260	197	176	214	183
Cowpea (erect var.)	396	155	108	455	146	88	225
Cowpea (var.Caloona)	235	204	197	211	193	160	200
Mungbean (var. Thai)	98	467	350	312	338	506	345
Mungbean (var.Berkan)	182	305	512	364	69	440	312
Block Mean	214	217	256	292	169	263	

Note 1. One plot of each variety, 5 X 5 (25 metres square) randomly located in each of the six blocks.

2. The yield of traditionally grown local variety cowpea, grown adjacent was 131 kg/ha. (Mean 10 samples).

Summary Anova

Source	d.f.	SS	MS	F	Significance (5%)
Blocks	5	6187.47	12375.69	0.89	n.s.
Varieties	5	174699.47	34939.89	2.51	n.s.
Within	25	348307.03	13932.28	—	
Total	35				

Appendix Table 4. Effect of Soil Cropping History on Crop Yields at Nooleeye, 1987 Gu Season.

Crop Variety	Crop Yields, Kg/ha Bean/Peas										Mean Crop Variety Yield
	Cropped for 2 Previous Years					Cropped for 6 Previous Years					
	Replicates				Mean of 4 Rep-licates	Replicates				Mean of 4 Rep-licates	
	1	2	3	4		1	2	3	4		
Cowpea (local var.)	118	130	138	120	127	30	70	22	52	44	86
Cowpea (TVU 15002)	240	148	161	194	186	50	64	31	57	51	118
Mungbean (var.Thai)	540	396	489	552	494	44	59	52	85	60	227
Bulrush millet (Aborey variety)	0	0	0	0	0	0	0	0	0	0	0

Note 1. Plot replicate size 5 X 5m. Plots randomly located along anti-erosion strips.

Summary Anova

Source	d.f.	SS	MS	F	Significance (5%)
Varieties	2	168774.08	84387.04	64.95	*
Cropping History	1	283837.50	283837.50	218.46	*
Variety X C.History	2	143671.75	71835.88	55.29	*
Within	18	23386.50	1299.25		
Total	23	619669.83			

Appendix Table 5. Crop Variety Yield Evaluation Results, Dayr Season 1987, Nooleeye.

Crop Variety	Crop Yields Kg/ha beans/peas						
	Replicate Plot Yield						Mean Yield
	1	2	3	4	5	6	
Cowpea (local var.)	116	84	49	60	86	55	75
Cowpea (erect var.)	52	148	38	55	41	97	72
Cowpea (TVU15002)	121	157	91	115	86	98	111
Cowpea (IT84S-223115)	167	187	118	79	161	122	139
Mungbean (Baydoha Var)	90	202	144	84	103	131	126
Mungbean (var.Filsen)	259	137	118	130	81	96	137
Mungbean (var.Berkan)	129	90	125	86	125	70	104
Mungbean (Mog.Market)	70	78	79	57	63	53	67
Cowpea (local, traditional)							65

Note 1. Each crop variety had 6 replicated, randomly located plots, each 25 metres square.

2. In the trial 4 varieties gave no yield. These were the local sorghum, an early maturing sorghum (65A5559), Peanut (var. Virginia) and Pigeon Pea (var QLP Hunt).

Summary Anova

Source	d.f.	SS	MS	F	Significance (5%)
Varieties	7	36572.25	5224.61	3.64	*
Within	40	57347.67	1433.69	—	
Total	47	93919.92			

Appendix Table 6. <u>Evaluation of Rainwater Harvesting and Crop Species in the 1987 Gu Season at Aborey</u>.

Crop Species and Variety	Crop Yields of Grain/Beans Kg/ha				
	Block 1	Block 2	Block 3	Block 4	Mean
Sorghum (local var.)	200	532	367	480	395
Cowpea (local var.)	153	284	111	124	164
Bulrush millet(local var)	67	445	214	245	243
Sesame (local var.)	110	48	90	104	88
Cowpea (TVU 15002)	280	269	225	392	292
Mungbean (var. Thai)	280	116	254	241	223
Control (No extra water)					
- Sorghum (local var)	121	197	253	245	204
- Cowpea (local var)	78	92	110	132	103
Block Mean	161	248	203	245	192

Note 1. Plot size 5 X 20 metres (100 metres square).
2. Four plots (replicates) per crop, one crop located randomly in each of 4 blocks.

<u>Summary Anova</u> (Comparison 6 crop varieties).

Source	d.f.	SS	MS	F	Significance (5%)
Blocks	3	3927.46	13090.49	1.30	n.s.
Variety	5	220031.71	44006.34	4.38	*
Within	15	150637.79	10042.52	—	
Total	23	409940.96	—		

Appendix Table 7. **Effect of Manure Fertilisation and Water Harvesting on Crop Yields: Dayr Season 1987, Aborey.**

Crop Variety	Crop Yields With and Without Manure & Water Harvesting									
	Block 1		Block 2		Block 3		Block 4		Mean Yield	
	None	With	None	With	None	With	None	With	None	With
1 Sorghum (local var.)	108	199	105	220	382	382	165	215	190	254
2 Millet (local var.)	400	680	400	520	480	700	601	604	470	626
3 Mungbean (var. Thai)	217	265	195	240	130	140	105	174	162	205
Mean Block Yield	242	381	233	327	331	407	290	331	274	362
Crops Untreated With Manure										
4 Cowpea (Local var.)	100	NA	200	NA	145	NA	162	NA	152	NA
5 Cowpea (TVU15002)	201	NA	250	NA	292	NA	283	NA	257	NA
6 Intercrop										
- Sorghum (local)	130	NA	150	NA	95	NA	190	NA	141	NA
- Cowpea (local)	195	NA	190	NA	150	NA	45	NA	145	NA
Control (No extra water)										
7 - Sorghum (local)	68	NA	94	NA	120	NA	122	NA	101	NA
8 - Cowpea (local)	59	NA	79	NA	107	NA	103	NA	87	NA

Note 1. Yields in table given in kg./ha per plot.
2. Each crop sown in 8 plots, two located randomly in each of 4 blocks.
3. The plot size in the manure trial was 25 metres square, and for the untreated portion of the trial, including the control, was 100 metres square.
4. The controls received no extra water from the runoff water harvesting system.
5. The six month old sheep/goat manure was placed by hand under each seed hole at sowing at the rate of 600 kg/ha.

Summary Anova

Source	d.f.	SS	MS	F	Significance (5%)
Blocks	3	24845	8281	1.09	n.s.
Varieties	2	642648	321323	42.19	*
Manure	1	46025	46025	6.04	*
Variety X Manure	2	14381	7190	0.94	n.s.
Within	15	114249	7617		
Total	23	842147			

S.E. Crop varieties = 43.64, t.05, 15d.f. = 2.13, s.d. = 92.95

Appendix Table 8A. **Effect of Manure Fertilisation and Rainwater Harvesting on the Yield of Forage Residues from 5 Crop Variations at Aborey, Dayr Season 1987.**

Crop Variety	Forage Residue Yields With and Without Manure & Water Harvesting (kg./ha. dry matter)									
	Blocks with No Manure					Blocks with Manure				
	1	2	3	4	Mean	1	2	3	4	Mean
Sorghum (local var)	1699	1745	2111	2105	1908	2258	2298	2330	2300	2297
Millet (local var.)	1504	1494	1595	1935	1632	1854	1715	2353	1820	1936
Mungbean (var.Thai)	746	515	414	507	546	793	709	542	687	682
Cowpea (local var)	826	1046	916	1000	947					
Cowpea (TVU 15002)	458	687	1060	984	797					
Control - Sorghum	1241	1331	1513	1374	1365					
- Cowpea	588	657	721	748	679					

Summary Anova Manure Trial (top half table)

Source	d.f.	SS	MS	F	Significance (5%)
Blocks	3	87233.66	29077.89	0.81	n.s.
Varieties	2	9774708.08	4887354.04	135.33	*
Manure	1	448266.66	448266.66	12.41	*
Variety X Manure	2	61294.09	30647.05	0.85	n.s.
Within	15	541712.84	36114.19		
Total	23	10913215.33	—		

Summary Anova Crop Variety Trial (left side table)

Source	d.f.	SS	MS	F	Significance (5%)
Blocks	3	214586.55	715280.85	2.16	n.s.
Varieties	4	5343743.80	1335935.95	40.38	*
Within	12	397002.20	33083.53		
Total	19	5955332.55			

Appendix Table 8B. <u>Yield of Crop Forage Residues from Four Varieties Grown at the Bula Burti Sandy Loam Site, Dayr Season 1987</u>.

Crop Variety	Crop Forage Residue Dry Weight kg./ha.				
	Block 1		Block 2		Mean
	Sample 1	Sample 2	Sample 3	Sample 4	
Cowpea (local var.)	470	420	410	390	330
Cowpea (TVU15002)	448	491	335	395	417
Mungbean (var. Thai)	430	483	217	334	366
Mungbean (var. Filsen)	222	285	206	139	163

Note 1. Crop Residue includes the complete plants harvested at ground level directly after crop harvest. The forage residue did not include the pods. Plot size was 50 X 5 metres. Ten samples 1 X 1 metre taken (randomly per plot.

<u>Summary Anova</u>

Source	d.f.	SS	MS	F	Significance (5%)
Varieties	3	114,863.69	38,287.90	18.39	*
Blocks	1	42,333.07	42,333.07	20.34	*
Var. X Blocks	3	9,934.20	3,311.40	1.59	n.s.
Within	8	16,652.50	2,081.56		
Total	15	183,783.44			

Appendix Table 9. **Effect of Manure Fertilisation and Rainwater Harvesting on Crop Yields: Gu 1988 Season, Aborey Trial Site.**

Crop Variety	Crop Yield (kg./ha.) With and Without Manure									
	Block 1		Block 2		Block 3		Block 4		Mean Yield	
	None	With	None	With	None	With	None	With	None	With
1 Sorghum (local var.)	94	131	129	164	90	161	126	234	110	175
2 Cowpea (TVU 15002)	46	54	110	161	120	186	128	221	101	156
3 Cowpea (local var.)	94	103	100	121	138	140	146	246	120	152
4 Bulrush millet(loc.var)	172	177	175	196	82	119	274	401	175	223
5 Mungbean (var. Thai)	89	108	126	201	113	117	126	201	113	157
6 Sesame (local var.)	40	47	38	49	36	42	41	50	39	47
7 Intercrop										
- Sorghum (local)	22	72	90	146	60	65	40	134	53	104
plus Cowpea (local)	46	120	82	184	37	44	55	114	55	115
Control										
8 - Sorghum (local)	49	71	85	95	70	79	89	98	73	86
9 - Cowpea (local)	35	42	49	59	42	52	158	70	46	56
Block Mean	77	104	109	153	88	112	120	197	98	141

Note 1. Yields in table given in kg./ha per plot, each 50 metres square.
2. Eight plots of each crop, two located randomly in each of 4 blocks.
3. Controls provided with no extra water from the rainwater harvesting system.

Appendix Table 10. <u>Drought Resistant Crop Yield Comparisons at Bula Burti Fodder Farm Trial Sites, Dayr Season 1987</u>.

Crop Variety	Yield of Grain/Beans Kg./ha.						Mean Yield of 4 Blocks
	Loamy Clay Site			Sandy Loam Site			
	Block 1	Block 2	Mean	Block 1	Block 2	Mean	
Cowpeas (loc. var.)	24	15	20	12	29	21	20
Mung bean (Var. Thai)	156	142	149	82	61	72	110
Mung bean (Var. Filsen)	164	142	153	75	89	82	116
Cowpeas (var. TVU 15002)	136	125	131	102	44	73	102

Note 1. Each of the 4 replicate plots/crop species, randomly located, 1 in each of 4 blocks.

2. Each plot measured 50 X 5m, 250 metres square.

<u>Summary Anova</u>

Source	d.f.	SS	MS	F	Significance (5%)
Varieties	3	24,707.25	8,235.75	25.48	*
Soils	1	10,506.25	10,506.25	32.50	*
Var. X Soils	3	3,848.25	1,282.75	3.97	n.s.
Within	8	2,586.00	323.25		
Total	15	—			

Appendix Table 11. Drought Resistant Crop Yield Comparisons at Bula Burti Fodder Farm Trial Sites, Gu Season 1987.

Crop Variety	Crop Yields of Grain/Beans Kg./ha.						Mean Yield of 4 Replicates
	Loamy Clay Site			Sandy Loam Site			
	Repl. 1	Repl. 2	Mean	Repl. 1	Repl. 2	Mean	
Cowpeas (loc. var.)	93	74	84	177	188	183	133
Sorghum (loc. var.)	469	596	533	520	365	443	488
Sesame (loc. var.)	256	184	220	NA	NA	NA	220
Bulrush Millet (loc. var.)	269	160	215	200	196	198	206
Mung Beans (var. Thai)	402	416	409	392	234	313	361
Cowpea (var. TVU 15002)	369	326	348	345	339	342	345
Safflower	193	128	161	65	27	46	103

Note 1. Each of the 4 replicate plots randomly located, one in each of 4 blocks.

2. Each plot measured 50 X 5m, 250 metres square.

Summary Anova

Source	d.f.	SS	MS	F	Significance (5%)
Varieties	5	464,546.71	92909.34	27.45	*
Soils	1	6,567.04	6567.04	1.94	n.s.
Var. X Soils	5	28,862.71	5772.54	1.71	n.s.
Within	12	40,623.50	3385.29		
Total	23	540,599.96	—		

S.E. for difference between means of varieties at 5% level = ± 41.14 kg/ha

Appendix Table 12. **Yields of 29 Potentially Productive Drought Resistant Crop Varieties at the Two Bula Burti Fodder Farm Trial Sites in the 1987 Dayr Season.**

Crop Variety	Yields of Grain/Beans Kg./ha.						Mean Yield of 4 Blocks
	Loamy Clay Site			Sandy Loam Site			
	Block 1	Block 2	Mean	Block 1	Block 2	Mean	
1 Bulrush Millet loc. var.	184	240	212	0	0	0	106
2 Safflower	16	0	8	4	0	2	5
3 Guar var. P2 Sel.3	160	200	180	18	16	17	96
4 Sesame var. CPI85656	0	0	0	0	0	0	0
5 Pigeon Pea QPL Hunt	32	110	71	12	130	71	71
6 Cowpea IT845-2231-15	40	80	60	23	12	18	39
7 Mung Bean (var. Thai)	360	280	320	150	240	195	258
8 Peanut var. Virginia	0	0	0	0	0	0	0
9 Sorghum var.GSA556	0	0	0	0	0	0	0
10 Tepary Bean	80	40	40	120	120	120	90
11 Mung Bean var Filsen	240	192	216	128	46	87	152
12 Jack Bean	0	0	0	0	0	0	0
13 Mung Bean VC3300A	440	400	420	320	196	258	339
14 Guar var. P3 Sel.36	120	340	230	0	4	2	116
15 Guar var. P1 Sel.20	240	240	240	16	0	8	124
16 Mung Bean var. Berkan	88	200	144	320	104	212	178
17 Cowpea (var.TVU15002)	200	120	160	144	102	123	142
18 Cowpea (loc. var.)	0	60	30	64	4	34	32
19 Sesame (loc. var.)	0	0	0	0	0	0	0
-	0	0	0				
20 Cowpea IT845-22464	43	30	37	0	2	1	19
21 Sorghum (loc. var.)	0	0	0	0	0	0	0
22 Pigeon Pea var. QPL 131	328	200	264	82	480	281	273
23 Sesame CPI 85657	0	0	0	0	0	0	0
24 Mung Bean VL 3500 A	160	300	230	80	320	200	215
25 Sesame CPI 8300	0	0	0	0	20	10	5
26 Bulrush Millet local var.	0	0	0	0	0	0	0
27 Mungbean (Baydoha var)	70	360	215	90	344	217	216
28 Sorghum GSA 5559	0	0	0	0	0	0	0
29 Cowpea var. Caloona	2	2	2	100	190	145	74

Note 1. Each of the 4 replicate plots of each crop variety randomly located, one in each of 4 blocks.
2. Each plot had an area of 5 X 5 metres.

Appendix Table 13. <u>Yields of 27 Potentially Productive Drought Resistant Crop Varieties at the Two Bula Burti Fodder Farm Trial Sites in the 1988 Gu Season</u>.

Crop Species		Crop Yields Kg./ha.								
		Loamy Clay Site				Sandy Loam Site				Mean
		Replicate Plots				Replicate Plots				
		Block 1		Block 2		Block 1		Block 2		
		A	B	C	D	A	B	C	D	
1	Peanut var. Virginia	0	0	0	0	0	0	0	0	0
2	Tepary Bean	10	52	18	110	110	34	2	56	49
3	Mung Bean (var. Thai)	60	5	0	0	0	0	20	0	11
4	Bulrush Millet loc. var.	0	0	0	0	0	0	0	0	0
5	Pigeon Pea QPL Hunt	4	0	0	40	4	3	14	4	7
6	Safflower	0	0	12	0	0	0	6	0	1
7	Guar var. P2 Sel.3	54	80	54	0	34	2	230	92	68
8	Mung Bean var Filsen	0	6	0	0	20	0	0	0	3
9	Mung Bean VC3300A	0	0	30	0	6	0	0	0	5
10	Guar var. P3 Sel.36	78	36	64	126	12	56	0	36	51
11	Guar var. P1 Sel.20	64	66	54	234	0	22	52	60	69
12	Jack Bean	0	0	0	0	0	0	0	0	0
13	Pigeon Pea var. QPL 131	0	10	0	4	0	2	15	2	4
14	Cowpea (var.TVU15002)	0	6	6	0	0	0	0	0	2
15	Cowpea (loc. B/Burti var)	0	0	0	0	0	10	0	0	1
16	Sesame (loc. B/Burti var)	0	0	0	0	0	112	12	0	16
17	Mung Bean var. Berkan	0	0	0	0	2	0	0	0	0
18	Sorghum loc. B/Burti var	0	0	0	0	54	80	100	100	42
19	Mungbean (Baydoha var)	0	0	0	0	0	14	22	16	7
20	Cowpea (var. Caloona)	0	0	0	0	0	0	0	0	0
	Guar var P1 Sel.20	10	54	30	70	48	47	178	44	60
21	Mung Bean VC3500A	0	0	44	24	26	0	2	0	12
	Guar var P2 Sel.3	0	0	0	106	0	0	160	64	41
	Guar var P3 Sel.36	6	8	104	152	120	22	168	150	91
22	Sorghum var. Hegari	0	0	0	0	0	0	0	22	3
23	Cowpea var. IT-82D-716	0	0	0	0	0	0	8	0	1
24	Sorghum var. PP-290	0	0	0	0	0	0	0	0	0
25	Cowpea IT-845223115	0	0	0	0	2	0	0	0	0
26	Sorghum var. LV-175	0	0	0	0	0	0	0	0	0
27	Sorghum GSA-5559	0	0	0	0	0	0	0	0	0

Note: Eight randomly located plots of each crop variety tested, 4 each at the sandy loam site, and 4 at the loamy clay site. Each plot 5 X 5 metres. Three guar varieties were repeated.

Appendix Table 14. **Effect of Cultural Techniques and Soil Types on the Vegetative Propagation of 3 Potential Commiphora Live Fence Hedge Species at Bula Burti: Percent Growing Plants.**

Plant Species	Recording Date (planted 26/4/87)	Treatment A		Treatment B		Treatment C		Treatment D	
		Sandy Loam	Loamy Clay	Sandy Loam	Loamy Clay	Sandy Loam	Loamy Clay	Sandy Loam	Loamy Clay
Commiphora incisa (Rahenreb)	01/07/87	8	73	3	66	100	100	75	83
	28/02/88	8	50	0	51	96	96	33	15
	03/04/88	8	46	·0	26	86	96	30	15
	13/12/88	0	46	0	26	73	96	0	8
Commiphora hodai (hothai)	01/07/87	71	77	73	77	98	100	95	98
	28/02/88	10	8	36	22	74	50	25	15
	03/04/88	10	8	34	4	74	50	25	0
	13/12/88	10	7	29	4	74	17	13	0
Commiphora oddurensis (gargoy)	01/07/87	23	69	16	38	100	100	80	95
	28/02/88	8	8	4	13	86	23	3	15
	03/04/88	8	8	4	3	83	19	3	0
	13/12/88	4	4	4	3	83	19	0	0

Treatment A: 0.7m long trimmed sticks. 26 plants, 0.1 - 2m apart.
Treatment B: Same as A, except 90 plants, each 25cm. apart.
Treatment C: Instant fence. Complete branches, untrimmed, 1.2 -1.6m long. Same as A.
Treatment D: Same as A, except terminal shoots left untrimmed & width, half size of A, 1.2 - 2m at base.

Notes
1. All numbers listed in the table are percent surviving, growing plants.
2. The number planted in each treatment was A = 26, B = 90, C = 26, D = 26. There were 2 replications of each treatment, 800 metres apart at the Bula Burti fodder farm site, one with sandy loam soil, the other a loamy clay site.
3. All treatments cured for 1 day after cutting taken, prior to planting 10 - 15 cm deep.

Summary Anova (arc sin $\sqrt{x}$ transformation)

Source	SS	d.f.	MS	F	Significance (5%)
Recording dates	24.6115	3	8.2038	56.42	*
A = Species	2.3264	2	1.1632	8.00	*
B = Cutting Treatment	28.5651	3	9.5217	65.49	*
C = Soil Type	0.0957	1	0.0957	0.66	n.s.
A X B	2.5235	6	0.4206	2.89	*
A X C	4.4832	2	2.2416	15.42	*
B X C	3.0078	3	1.0026	6.90	*
A X B X C	2.0103	6	0.3351	2.30	*
Within	10.0297	69	0.1454	—	
Total	77.6532	95			

Appendix Table 15. Establishment of Balanites and Parkinsonia Live Fence Hedges by Direct Sowing of Seed Under Rainfed Conditions at Bula Burti.

Recording Date	Treatment	Percent Sown Positions with Growing Seedlings			
		Sandy Loam Soil Site		Loamy Clay Soil Site	
		Parkinsonia	Balanites	Parkinsonia	Balanites
03/04/88	26 positions, 10 to 200 cm apart	4	81	81	80
	44 positions, each 50 cm apart	0	75	43	86
20/06/88	26 positions, 10 to 200 cm apart	4	58	81	80
	44 positions, each 50 cm apart	0	53	43	76
13/12/88	26 positions, 10 to 200 cm apart	0	50	81	80
	44 positions, each 50 cm apart	0	50	43	69
13/12/88	Mean Survival After 19.5 months	0%	50%	62%	75%

Note 1. Sowing date 26-27/4/87.
2. All seeds dry sown, untreated just before first rain.
3. 9 seeds of Balanites aegyptiaca sown at each position, 3 in each of 3 holes at a depth of 4 - 5 cm.

Appendix Table 16. <u>The Survival and Growth of Ten Multipurpose Tree/Bush Species Seedlings Grown Under Rainfed Conditions at Aborey, Bula Burti District</u>.

Tree/Bush Species	Block No	Number of Seedlings Alive (n=25/block)			Mean Height/Block (m)	
		26/7/87	20/2/88	17/6/88	20/2/88	17/6/88
Acacia nilotica	Block 1	24	12	11	0.54	1.20
	2	25	25	14	0.64	1.18
	3	22	13	6	0.53	0.98
	4	25	12	5	0.45	0.92
	Mean	24	16	9	0.54	1.07
Leucaena leucocephala	Block 1	24	17	10	0.60	1.13
	2	25	20	8	0.73	1.20
	3	23	17	11	0.75	1.22
	4	25	17	6	0.60	1.01
	Mean	24	18	9	0.67	1.14
Acacia victoriae	Block 1	16	15	15	0.35	0.63
	2	18	15	11	0.29	0.50
	3	16	15	10	0.17	0.52
	4	5	5	4	0.15	0.22
	Mean	14	13	10	0.96	0.47
Terminalia spinosa	Block 1	16	13	10	0.14	0.48
	2	11	10	9	0.12	0.44
	3	17	16	10	0.10	0.36
	4	4	3	2	0.08	0.31
	Mean	12	11	8	0.11	0.39
Balanites aegyptiaca	Block 1	25	16	15	0.26	0.34
	2	25	13	10	0.18	0.34
	3	25	15	13	0.48	0.53
	4	25	22	4	0.44	0.51
	Mean	25	17	11	0.34	0.43
Prosopis chilensis	Block 1	23	22	20	0.56	1.00
	2	23	22	21	0.83	1.54
	3	25	25	24	0.89	1.62
	4	25	25	22	0.84	1.49
	Mean	24	24	22	0.78	1.41
Prosopis juliflora	Block 1	23	14	12	0.70	0.89
	2	22	22	15	0.72	0.91
	3	23	23	11	0.50	0.68
	4	25	18	8	0.31	0.80
	Mean	23	19	12	0.56	0.82
Acacia ligulata	Block 1	20	14	13	0.13	0.48
	2	16	7	6	0.24	0.51
	3	25	17	9	0.45	0.71
	4	15	13	8	0.42	0.73
	Mean	19	13	9	0.31	0.61
Shinus molle	Block 1	5	1	0	0.14	-
	2	4	1	0	0.22	-
	3	8	0	0	-	-
	4	4	0	0	-	-
	Mean	5	1	0	0.18	-
Brachychiton gregorii	Block 1	2	0	0	-	-
	2	3	1	0	0.12	-
	3	1	0	0	-	-
	4	1	0	0	-	-
	Mean	4	0	0	0.03	-

Note: 25 seedlings of each species planted in each plot, 1 plot in each of 4 blocks, so total 100 seedlings/species.

<u>Summary Anovas</u>

Plant Survival (arc sin $\sqrt{x}$ transformation)

Source	S.S.	d.f.	M.S.	F.	Sign. (5%)
Blocks	1.3121	3	0.4374	0.35	n.s.
Species	4.6817	7	0.6688	11.37	*
Within	1.2357	21	0.0588	-	
Total	7.2259	31	-		

Plant Height 7/6/88

Source	S.S.	d.f.	M.S.	F.	Sign. (5%)
Blocks	0.0394	3	0.013	0.03	n.s.
Species	4.0408	7	0.5773	23.85	*
Within	0.5087	21	0.0242	-	
Total	4.5889	31	-		

Appendix Table 17. <u>The Survival and Growth of Twelve Multipurpose Tree/Bush Species Seedlings Grown Under Rainfed Arid Conditions at Ali Yabal, Ceel Dheer District.</u>

Tree/Bush Species	Block No	Number of Seedlings Alive (n=25/block)		Mean Height/Block (m)
		24/7/87	12/6/88	12/6/88
Cordia sinensis	Block 1	25	25	0.42
	2	25	25	1.21
	3	25	24	0.87
	4	25	22	0.50
	Mean	25	24	0.75
Ziziphus mauritania	Block 1	23	22	0.39
	2	25	24	0.36
	3	25	23	1.22
	4	25	24	0.75
	Mean	25	23	0.68
Terminalia spinosa	Block 1	23	23	0.31
	2	22	22	0.39
	3	19	19	0.24
	4	19	19	0.38
	Mean	21	21	0.33
Leucaena leucocephala var. K8	Block 1	25	23	1.63
	2	25	24	2.41
	3	24	16	1.56
	4	23	20	1.11
	Mean	24	21	1.68
Acacia nilotica	Block 1	25	6	0.60
	2	23	16	0.94
	3	23	15	0.22
	4	21	10	0.42
	Mean	23	12	0.55
Acacia ligulata	Block 1	24	22	1.10
	2	22	17	2.29
	3	22	20	1.62
	4	25	23	1.71
	Mean	23	21	1.68
Tamarix aphylla	Block 1	25	18	0.57
	2	25	21	1.07
	3	25	25	0.71
	4	25	24	0.46
	Mean	25	22	0.70
Parkinsonia aculeata	Block 1	23	22	0.69
	2	23	11	0.71
	3	24	10	0.75
	4	24	18	0.92
	Mean	24	15	0.77
Balanites aegyptiaca	Block 1	24	15	0.33
	2	23	17	0.36
	3	22	13	0.30
	4	24	17	0.33
	Mean	21	16	0.34
Prosopis cinesaria	Block 1	21	9	0.19
	2	24	24	0.37
	3	21	17	0.28
	4	22	20	0.23
	Mean	22	18	0.27
Acacia victoriae	Block 1	20	14	0.29
	2	20	19	0.25
	3	22	17	0.41
	4	21	16	0.53
	Mean	21	17	0.37
Sesbania grandiflora	Block 1	20	1	2.00
	2	13	3	2.04
	3	18	3	3.38
	4	13	3	2.87
	Mean	16	3	2.57

Summary Anovas (Table 17)

Plant Survival (arc sin $\sqrt{x}$ transformation)						Plant Height 7/6/88			
Source	S.S.	d.f.	M.S.	F.	Sign. (5%)	S.S.	M.S.	F.	Sign. (5%)
Blocks	0.3749	3	0.1250	0.64	n.s.	0.71	0.24	0.15	n.s.
Species	15.4035	11	1.4003	7.21	*	22.32	2.03	1.26	n.s.
Within	6.4084	33	0.1942	-		53.04	1.61		
Total	19.1868	47				76.07			

Appendix Table 18. Establishment of Multipurpose Tree/Bush Hedgerows Using Direct Sowing and Water Harvesting Techniques at Aborey.

Species of Tree/Bush	Row No.	Number (n) Positions per plot	Number of Positions With Growing Plants				Mean Survival Percent	Mean Height (m)
			Replicate 1	Replicate 2	Replicate 3	Replicate 4		
Leucaena leucocephala	13	40	6	8	8	9	22	1.8
	14	40	7	10	11	12		
Balanites aegyptiaca	5	40	21	32	35	24	67	0.7
	7	40	22	32	24	30		
Terminalia spinosa	9	5	1	2	2	2	35	0.5
	11	5	1	3	1	2		

Note 1. Seeds sown just before first seasonal rain on the 24/4/87. Table recordings were made 17 months after the first rain on 14/12/88.

2. Number of seeds sown per position were: *L. leucophala* = 8, *B. aegyptiaca* = 8, *T. spinosa* = 15.

3. There was no significant difference (5%) between rows or blocks. *B. aegyptiaca* had a significantly higher survival rate than the other two species.

Appendix Table 19. Establishment of 11 Directly Sown Multipurpose Tree/Bush Species in Hedgerows Under Very Arid Rainfed 1988 Seasonal Conditions at Bula Burti.

Multipurpose Tree/Bush Species	Recording Period	Seed Number per Position	Number of Positions with Growing Plants				Mean Number of Positions	Mean % Survival Per Position
			Sandy Loam Site Replicates		Loamy Clay Site Replicates			
			A (n=14)	B (n=14)	A (n=14)	B (n=14)	(n=14)	
Terminalia spinosa	Germination	15	0	0	0	0	0	0
	6 Months		0	0	0	0	0	0
Ziziphus spinacristae	Germination	10	6	8	8	6	7	50
	6 Months		1	2	1	0	1	7
Prosopis cineraria	Germination	10	0	0	0	0	0	0
	6 Months		0	0	0	0	0	0
Acacia albida	Germination	3	0	0	0	0	0	0
	6 Months		0	0	0	0	0	0
Dobera glabra	Germination	3	4	2	6	4	4	29
	6 Months		1	1	3	2	4	29
Prosopis chilensis	Germination	8	0	0	0	0	0	0
	6 Months		0	0	0	0	0	0
Cordia sinensis	Germination	8	0	0	0	0	0	0
	6 Months		0	0	0	0	0	0
Leucaena leucocephala n = 52	Germination	8	37	42	32	22	33	63
	6 Months		0	0	0	0	0	0
Cordia suckserti	Germination	8	4	6	5	7	6	43
	6 Months		0	0	1	2	1	7
Balanites aegyptiaca n = 52	Germination	8	42	42	50	50	46	88
	6 Months		40	24	50	48	41	79
Sesbania grandiflora	Germination	8	-	-	4	6	5	36
	6 Months		-	-	0	0	0	0

Note 1. All seeds sown directly without any treatments in small tied ridge microcatchments. No water supplied from external sources. Estimated catchment area/position is 2 metres square.

2. If more than 3 seeds sown per position, 3 - 4 seeds placed in separate holes 5 - 10 cm apart.

Appendix Table 20. Effect of Fertiliser and Manure on the Yield of Local Sorghum (kg/ha): Bula Burti Fodder Farm Ugg Site Gu Season 1988.

Treatment	Sorghum Yield Kg./ha.					
	Block Number				Total	Mean
	37A	37B	38A	38B		
Control (No Treatment)	26	36	36	40	138	34.5
Manure - 15 gm/plant (400 kg/ha)	44	116	60	28	248	62
- 30 gm/plant (800 kg/ha)	44	94	70	42	250	62.5
- 45 gm/plant (1200 kg/ha)	60	200	80	80	420	105
TSP fertiliser - 1.25 gm/plant (33.3 kg/ha)	28	38	52	50	168	42
- 2.5 gm/plant (66.7 kg/ha)	48	118	60	92	318	79.5
- 5.0 gm/plant (133.3 kg/ha)	108	160	56	64	388	97
DAP fertiliser - 1.25 gm/plant (33.3 kg/ha)	92	40	40	24	196	49
- 2.5 gm/plant (66.7 kg/ha)	52	292	90	56	490	122.5
- 5.0 gm/plant (133.3 kg/ha)	44	56	40	100	240	60
Block Mean Kg./ha.	54.6	115	58.4	57.4		71.4

Summary Anova

Source	d.f.	SS	MS	F	Significance (5%)
Blocks	3	2822.4	9409.5	6.26	*
Fertiliser, Manure type	2	164.7	82.3	0.05	n.s.
Fertiliser, Manure level	2	10658.7	5329.3	3.54	*
Type X Level Interactions	4	13030.7	3257.7	2.16	n.s.
Control vs all Treatments	1	6002.5	6002.5	3.99	n.s.
Within	30	45128.6	1504.3		

Note 1. Plot size 5 X 5 metres.
2. Plots randomly located, one in each of 4 blocks.

Appendix Table 21. Increase in Sorghum and Cowpea Yields from rainwater Harvesting at Aborey, Dayr Season 1987.

Treatment	Crop	Crop Yield kg/ha of grain/peas				
		Block 1	Block 2	Block 3	Block 4	Mean
No Water Harvesting	Sorghum	68	94	120	122	101
	Cowpeas	59	79	107	103	87
With Water Harvesting	Sorghum	108	105	382	165	190
	Cowpeas	100	200	145	162	152

Summary Anova

Source	SS	d.f.	MS	F	Significance (5%)
Blocks	23438.19	3	7812.73	1.90	n.s.
Species	2575.57	1	2575.57	0.63	n.s.
Rainwater Harvesting	24102.57	1	24102.57	5.86	*
Species X Water	663.05	1	663.05	0.16	n.s.
Within	37023.56	9	4113.73		
Total	87802.94	15	—		

Appendix Table 22. Increase in Sorghum and Cowpea Forage Residue Yields from Rainwater Harvesting at Aborey, Dayr Season 1987.

Treatment	Crop	Crop Forage Residue kg/ha dry matter				
		Block 1	Block 2	Block 3	Block 4	Mean
No Water Harvesting	Sorghum	1241	1331	1513	1374	1365
	Cowpeas	588	657	721	748	679
With Water Harvesting	Sorghum	1669	1745	2111	2105	1908
	Cowpeas	826	1046	916	1000	947

Summary Anova

Source	SS	d.f.	MS	F	Significance (5%)
Blocks	336224.19	3	112074.73	4.63	*
Species	3139098.07	1	3139098.07	129.60	*
Rainwater Harvesting	470939.07	1	470939.07	19.44	*
Species X Water	159400.55	1	159400.55	6.58	*
Within	218000.56	9	24222.28		
Total	4323662.44	15	—		

Anova for Simple Effects of Water

Source	SS	d.f.	MS	F	Significance (5%)
Water for Cowpeas	41184.50	1	41184.50	1.70	
Water for Sorghum	589155.12	1	589155.12	24.32	*
Within	218000.86	9	24222.28		

Appendix Table 23. <u>Highly Significant Increase in Survival of Tree Seedlings Given bunding and Pitting Treatments Under Rainfed Arid Range Conditions at Ceel Buur, 1988</u>.

Tree/Bush Species	Regeneration Treatment Seedling Survival (out of plot)								
	Block A Bunds and Pitting		Block B Bunds Only		Block C Control		Block D Pitting Only		Total
	Plot E1	Plot E2	Plot E1	Plot E2	Plot E1	Plot E2	Plot E1	Plot E2	
Conocarpus lancifolia	0	2	4	3	1	0	1	1	12
Terminalia spinosa	2	1	1	3	0	0	2	2	11
Tamarindus indica	2	2	3	4	0	0	1	1	14
Casuarina equisetifolia	4	2	2	4	0	0	2	1	15
Acacia ligulata	1	1	2	2	0	0	2	1	9
Prosopis tamarugo	2	1	2	4	0	0	1	1	11
Total	11	9	14	20	1	0	9	7	72
Treatment % Survival	46%	38%	58%	83%	4%	0%	38%	29%	37%
Mean Treatment % Survival	57%		71%		2%		33%		37%

Summary Anova

Source	SS	d.f.	MS	F	Significance (5%)
Blocks	0.00	3	0.000	0	n.s.
Species	0.232	5	0.046	0.72	n.s.
Soil Treatment	6.862	3	2.287	35.73	*
Species X Soil Treat	1.128	15	0.075	1.17	n.s
Within	1.478	23	0.064		
Total	9.700	47	—		