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Rainfall, Environment and Water Resource Development in Somaliland and the Sahel

by

C.R.Print

"The world contains four types of stomach.
The first stomach is that of the sky,
the second is that of the earth,
the third of livestock
and the fourth people.

When the stomach of the sky is full,
it opens and rains fall upon the earth...
When the stomach of the earth opens to receive the rain,
grass grows in abundance...
When animals graze,
their stomachs open to receive the grass...
When people have plenty of milk and meat,
their stomachs are full...

But if the stomach of the sky is empty there is no rain.
If the stomach of the earth is empty there is no grass.
If the stomachs of the livestock are empty there is neither milk nor meat,
and the people go hungry".

Abdi Awke - Somali elder, 1996

Abstract

This thesis has relevance to any water and/or environment initiatives in both the Somaliland region and the Sahel. It aims to answer the desire among growing numbers of water managers and environmentalists to bring a more lateral approach to the water management debate globally. This thesis explores the general inter-relation between hydrological and man-oriented processes, in relation to current models for water resource development and natural resource management in Somaliland. Extensive reference is drawn to published studies elsewhere in the Sahel.

The Sahel and Somaliland are introduced, along with definitions of drought and land degradation. An understanding of paradigms in development co-operation and sustainable development are shown, through a review of the evolution of guiding principles of water resource development in developing countries, and a statement of their usefulness in water scarce developing countries. The EU guidelines for strategic water resource development are reviewed amongst others.

In the Sahel life and indigenous production systems are shown to depend almost entirely on renewable natural resources. The inter-annual variability of scarce rainfall is the prime mover of the ecological system. An analysis of research data from the Sahel and Somaliland, including the IUCN Sahel studies series, underline the importance of understanding: pastoral production systems, non-equilibrium environmental theory, temporal rainfall variation, drought and the traditional management strategies for coping with water scarcity, if effective development paradigms are to be engineered.

In Somaliland pastoral livelihoods have been under intense pressure during the last century. A transition by many to urban living and an import/export market economy is partly forced, and partly a sign of social adaptation. Water stress remains serious. Famine experience, and the highly uncertain rainfall, underline the need for an efficient early warning system to monitor food and water security. Virtual water imports are shown to be an option for coping; but stress may also be mitigated by improving the indigenous production capacity, and by engineering the development of the water resources.

An analysis of the water resources of Somaliland is presented. A bibliography for water resource development in Somaliland has been researched and the known titles and sources of available data are listed. An overview of the water resources and their potential is offered, based on a review of several key documents. In it the known sources of rainfall data are stated and verified, and an analysis of rainfall series in carried out using a first and second order statistical approach. The topography, geomorphology, geology, hydro-geology and catchment hydrology of Somaliland are described briefly, from which the water resource development potential is outlined according to regional physiographic characteristics. The limits of information available are clearly shown, plus the danger of relying on it to draw definitive conclusions. The importance of data is shown with reference to a water resource and natural resource management seminar held during the fieldwork. How to consolidate the existing knowledge is identified, in relation to the EC approach.

The existing and potential role of remote sensing in the monitoring of the Sahelian environment is reviewed. Remote sensing is capable of playing a significant role in mapping the spatial and temporal distribution of water resources; but is only a useful activity if related to improving the quality of life of man on the ground. An analysis of rainfall estimation by remote sensing, with emphasis placed on techniques for the merging of satellite and gauge data follows. A simple method of gauge/satellite merging by kriging is offered that can be of use in improving the accuracy of the current FEWS/FSAU system used in Somaliland. A recommendation is made for engineering a hydrometric solution to support this method.

The thesis concludes with recommendations for future action in the field of water resource assessments, remote sensing, development co-operation and basic research into water resources in Somaliland.

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ACRONYMS

ACH	Accion Contra el Hambre
ADMIT	Agricultural Drought Monitoring Integrative Technique
ARTEMIS	African Real-Time Monitoring and Information System
ASAL	Arid and Semi Arid Lands
AVHRR	Advanced Very High Resolution Radiometer
AWUM	Agricultural Water Use and Management
BIAS	Bristol University/NOAA Inter Active Scheme
BWSS	Basic Water Supply and Sanitation Services
CCD	Cold Cloud Duration
CIWEM	Chartered Institution of Water and Environmental Management
COOPI	Co-operazione Internationalize Italiano
CRU - UEA	Climate Research Unit of the University of East Anglia
CRC - UEA	Climate Research Centre of the University of East Anglia
CSE	Centre de Suivi Ecologique, Senegal
CVAF	Coefficient of Inter-annual Variations of Mean Annual Flow
CV	Coefficient of Inter-annual Variation
DfID	Department for International Development
EC	European Commission
EPSAT	Etude des Precipitations par Satellite
ESA	European Space Agency
EU	European Union
FAO	Food and Agricultural Organisation (of the United Nations)
FEWS	Famine Early Warning System
FCO	Foreign and Commonwealth Office
FSAU	Food Security Assessment Unit
GDAS	Global Data Assimilation System
GIS	Geographic Information System
GPI	GOES Precipitation Index
GTS	Global Telecommunication System
GVP	Gross Value Product
GWP	Global Water Partnership
ICRC	International Committee of the Red Cross
IGADD	Inter - Governmental Authority on Drought and Development
IRC	International Reference Centre for Water Supply and Sanitation
ITF	Inter-tropical Front
ITCZ	Inter-tropical Convergence Zone
IUCN	International Union for the Conservation of Nature (The World Conservation Union)
IUCN SNRMP	IUCN - Somali Natural Resource Management Project
LANDSAT	Land Imaging Satellite series (originally the Earth Resources Technology Satellite) of the US
LSE	London School of Economics
MAF	Mean Annual Flood
METEOSAT	Meteorological Satellite of the European Space Agency/European Organisation for the exploitation of Meteorological Satellites
MMWR	Ministry of Mineral and Water Resources
MWWS	Municipal Water and Waste Water Services
NERC	Natural Environment Research Council
NOAA	National Oceanographic and Atmospheric Administration
NOAA CPC	NOAA Climate Prediction Centre
NDVI	Normalised Difference Vegetation Index

NGO	Non-governmental Organisation
NRA	National Range Agency
QP	Peak Flow
PERMIT	Polar-orbiter Effective Rainfall Monitoring Integrative Technique
PET	Potential Evapotranspiration
RMR	Resource Management and Range
SACB	Somali Aid Co-ordination Body
SOGREAH	French Consulting Engineers
STEP	South Turkana Ecosystem Project
TAMSAT	Tropical Agricultural Meteorology using Satellite
TIR	Thermal Infrared Imagery
U$D	United States Dollars
UN	United Nations
UNCED	United Nations Commission on Environment and Development
UNDOS	United Nations Development Office for Somalia
UNDP	United Nations Development Programme
UNESCO	United Nations Education, Science and Culture Organisation
UNESCO IHP	UNESCO International Hydrological Programme
UNSO	United Nations Sahelian Office
USAID	United States Agency for International Development
WCED	World Conference on Environment and Development
WES	Water and Environmental Sanitation
WFP	World Food Programme
WHO	World Health Organisation
WMO	World Meteorological Organisation
WRAP	Water Resources Assessment and Planning
WWC	World Water Council

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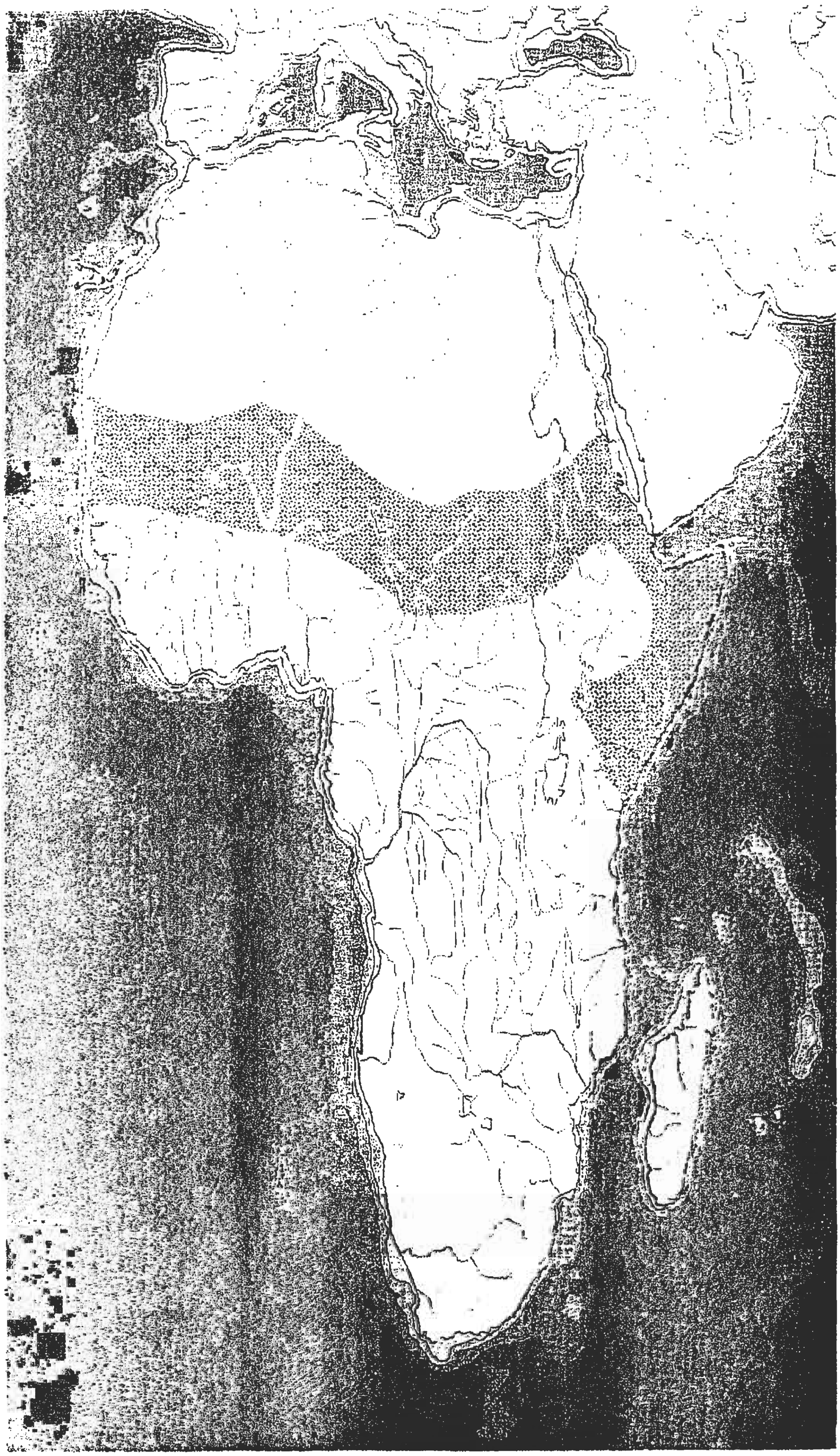
1. Introduction

1.1 Background to the Sahel and Somaliland

The Sahel is the name given to the vast area of Africa South of the Sahara, stretching from Senegal and Mauritania in the west to the Somali lands of the Horn of Africa in the East, crossing the frontiers of several nation states (fig 1). It is synonymous with the world's poorest economies, where the situation is steadily worsened by periodic droughts, by famine, and by varying degrees of warfare. Smillie (1995) succinctly states the causal link; *"Poverty is the key word: the state of being that has contributed more to debt, war, environmental degradation and famine than any other single factor"*.

In the Sahel, the problems of desertification and lack of food, if not outright famine, have received considerable attention (World Bank 1989, 1990). The effects of the great famines of the early 1970s and mid 1980s, exacerbated by severe droughts, did much to catalyse international assistance. Yet programmes to improve resource exploitation and rural development have been unsuccessful, despite the efforts of capable and dedicated people and massive financial inputs over the last three decades (Snrech 1988).

Why these efforts have in the main failed remains a point of considerable international debate. The fragility of the soils of the region, coupled with scarcity of water, variability of climate, and diversity of crops and pests, make efforts in agricultural and ecological development financially and organisationally challenging (IUCN 1986). Also, the global industrial developments of the 19^{th} and 20^{th} centuries have resulted in significant social change within Sahelian communities, leading to rapidly growing populations, increased urbanisation without industrial progress, the widespread degradation of land and the breakdown of traditional coping mechanisms (Markakis *et al* 1993). Exogenous contributing factors, such as global capital and market pressures, or poor indigenous political structures, further inhibit



The Sahel Fig. 1

sensible and sustained development. In fact the crisis in the Sahel is complex and multidimensional, and whatever the underlying causes the Sahelian region remains in the news, when not because of war because of recurrent drought, and famine.

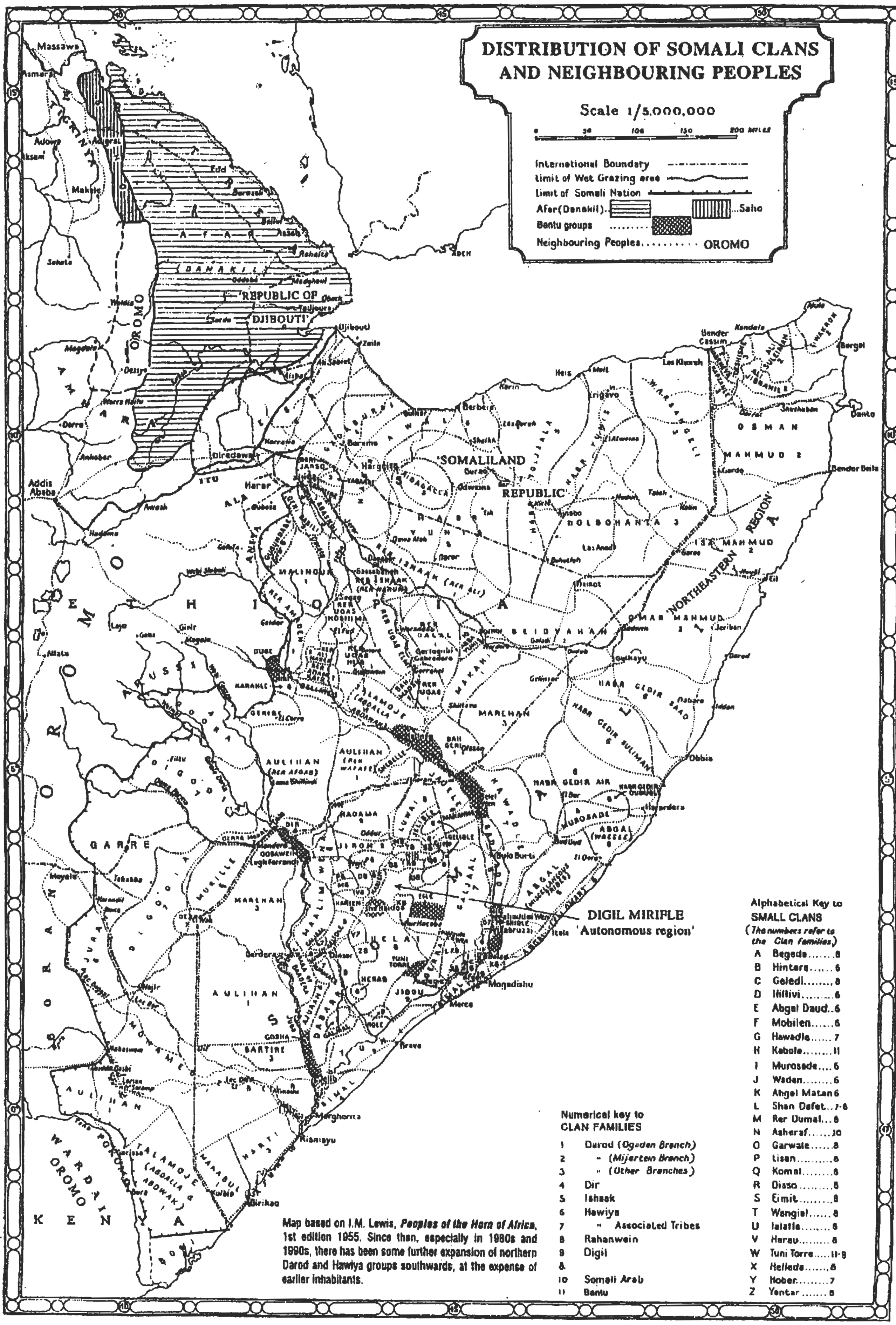
1.1.1 The Collapse of the Somali State

The current problems in Somalia are an extreme example of Sahelian evolution as a whole. The Somali people, their development institutions and their land have suffered much over the recent past. The crisis is one in which institutional collapse, economic failure, decreasing feasibility of traditional livelihood options and environmental degradation are inseparable (Wisner 1994).

The Somali inhabit an area of approximately 1,000 by 500 square miles in the Horn of Africa, running from 2° latitude South to 12° latitude North (fig 2). Traditional Somali society has been characterised as a pastoral democracy (Lewis 1960). It is clan based, in which all decision making is conducted democratically (although formally excluding women), by segmentary groups of kinsmen whose patterns of alliance and confrontation are fluid and inherently unstable. Traditional Somalis are pastoralists and individualists who meet in general assemblies, where all adult male family heads (or elders) seek consensus, as opposed to taking decisions by majority vote. In a situation where so many males can be elders, leadership is often difficult to maintain for long. In this uncentralised, rather than decentralised society, there is no tradition of a centralised state or any set political offices.

There was thus no Somali state before European colonisation, which divided the nation into five parts (French, British, Ethiopian, Italian and Kenyan). This division ultimately served to unite Somalis, giving rise to Somali nationalism, which created conflicts with neighbouring states, especially Kenya and Ethiopia. In 1969 General Mohamed Siad Barre took over in a military coup and quickly developed a highly

Fig 2


DISTRIBUTION OF SOMALI CLANS AND NEIGHBOURING PEOPLES
Scale 1/5,000,000
International Boundary
Limit of Wet Grazing area
Limit of Somali Nation
Afar (Danakil)
Saho
Bantu groups
Neighbouring Peoples.......... OROMO
REPUBLIC OF DJIBOUTI
'SOMALILAND REPUBLIC'
NORTHEASTERN REGION
E T H I O P I A
K E N Y A
DIGIL MIRIFLE 'Autonomous region'
Mogadishu
Alphabetical Key to SMALL CLANS
(The numbers refer to the Clan Families)
A Begeda......8
B Hintare......6
C Geledi......8
D Hillivi......6
E Abgal Daud..6
F Mobilen......6
G Hawadle......7
H Kabole......11
I Murosade....6
J Waden......6
K Abgal Matan 6
L Shan Dafet...7-8
M Rer Dumal...8
N Asheraf......10
O Garwale......8
P Lisan......8
Q Komal......8
R Disso......8
S Eimit......8
T Wangial......8
U Ialatle......8
V Harau......8
W Tuni Torre.....11-9
X Helleda......8
Y Hober......7
Z Yentar......8
Numerical key to CLAN FAMILIES
1 Darod (Ogaden Branch)
2 " (Mijertein Branch)
3 " (Other Branches)
4 Dir
5 Ishaak
6 Hawiya
7 " Associated Tribes
8 Rahanwein
9 Digil
&
10 Somali Arab
11 Bantu
Map based on I.M. Lewis, Peoples of the Horn of Africa, 1st edition 1955. Since then, especially in 1980s and 1990s, there has been some further expansion of northern Darod and Hawiya groups southwards, at the expense of earlier inhabitants.

centralised, totalitarian state inspired by Marxist-Leninism. He applied what he termed "scientific socialism" in an attempt to ban clan behaviour, but in reality he abused the system by manipulating clan rivalry to favour his own clan lineage.

After the crippling 1974-1975 drought the government adopted "command planning" relief measures which displaced many Northern nomads to the south, where they were settled in agricultural and fishing communities. These activities were despised by the nomads and many preferred to survive on food handouts while rebuilding their herds. Barre supported the Ogadeni guerrillas in their secessionist struggle in Ethiopia, which led to all out war in 1977/78. This proved disastrous as the Somali underestimated the strength of external support for Ethiopia and lost the war. Defeat and the enormous number of Ogadeni refugees who fled into Somalia gradually destabilised Barre's regime, which became increasing repressive against sections of the Somali in turn, and led to civil insurrection in the North. With the Soviet Union having abandoned Somalia for the greater prize of Ethiopia, Barre desperately switched allegiance to the West to gain assistance. As Western aid increased to a level of $4.268 billion in 1980-89, the national economy collapsed, and Somalia became dependant on this aid for survival (LSE 1995). In 1991 Barre was overthrown and the unnecessary deaths of hundreds of thousands of Somalis from civil war and famine followed.

Much has been written about the causes of the disintegration of the Somali state, especially by the Somali intelligentsia/diaspora now living outside the nation (Samatar *et al* 1994). In particular clanism, misconceptions about the nature of the state, and international aid are seen as the primary causes (Mansur 1995). International aid was seen as detrimental for three main reasons:

i. Aid was appropriated by the state and was corruptly managed. In particular emergency aid rarely reached the people who needed it, which in turn fostered resentment, and then finally raiding of the state and its assets.

ii. Aid was inappropriate to the needs of the Somali people. For example large scale agricultural projects built on a plantation/export principle did not take account of the strongly decentralised, essentially pastoral cultural base on which Somali society had previously thrived. Ultimately this approach to economic development failed.

iii. Aid finally created a dependency on imported foodstuff, discouraging local production.

In addition, at the local level competition for natural resources, notably - dry season pasture, water resources, productive farmland and fuelwood reserves - are seen as driving forces for civil conflict (Cassanelli 1994). In Southern Somalia this is still much the case; it resonates of traditional land management systems gone terribly wrong, since conflict and co-operation over limited natural resources, including scarce water resources, have always been a major factor in Somali social relations.

1.1.2 The Current Situation in Somalia

Today Somalia remains a least developed country, and in many regions of the South in a state of intractable civil war. International Aid is currently delivered through the auspices of the Somalia Aid Co-ordinating Body (SACB), in which the European Commission (EC) and the United Nations (UN) play a leading role[1]. With regard to EC programming in all areas there is a focus on promotion of peace and stability and in linking relief, rehabilitation and development within the Somali context (EC 1999).

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1 In the absence of an internationally recognised Somali government, the Addis Ababa Declaration of 1st December 1993 has become the basis for a legitimate involvement of the international aid community in Somalia. The Addis Ababa Declaration defines the

The situation in ex Northern Somalia however, encompassing the independent state of The Republic of Somaliland and "Puntland" (North East Region), is that the area is now substantially peaceful enough for the European Commission Somalia Unit to concentrate rehabilitation efforts. At reconnaissance level, this area is essentially homogeneous in terms of geography and hydrology: there are no perennial rivers and there is a background climate characterised by varying degrees of aridity.

1.1.3 The Republic of Somaliland

Somaliland[(2)] occupies an area of 176,000 km^2 (an identical border to the ex British Somaliland Protectorate) and varies in altitude from sea level to 2408m at Shimbir Beris, 19km North West of Erigavo (fig 3). Today in the country there exists a semblance of regional and multi-regional structure of governance that provides for safety and security; a functioning commercial and trade environment; willingness for self-help; ability to absorb rehabilitation and some external development support with a certain degree of sustainability (EC 1999).

The Somali economy is highly unconventional, well over half the population is dependant on nomadic pastoralism for its livelihood and it

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conditions under which assistance to rehabilitation and reconstruction can be provided. It specifies that peace and security and the existence of responsible Somali authorities on a regional and local level are the prerequisites for effective implementation of aid activities in the country. In addition, the Addis Ababa declaration made provision for the creation of a co-ordinating mechanism comprising donors, UN Agencies and NGO activities in Somalia. In application of these provisions, the Somalia Aid Co-ordination Body (SACB) was created in 1994 In February 1995, a Code of Conduct for international rehabilitation and development assistance to Somalia was adopted by the SACB formalising the principles established in the Addis Ababa declaration.

2. On May 18[th] 1991, the people of the North West regions of Somalia revoked the 1960 Act of Union that joined the colonial territories of the British Somaliland Protectorate with Italian Somalia, and announced the secession of the "Republic of Somaliland". With civil war raging across Somalia, the declaration of independence was made without consulting Somalia's numerous other political factions. and consequently Somaliland remains unrecognised by the International community. In contrast to what happened in the Southern Somalia, the declaration of independence ushered in a period of relative stability

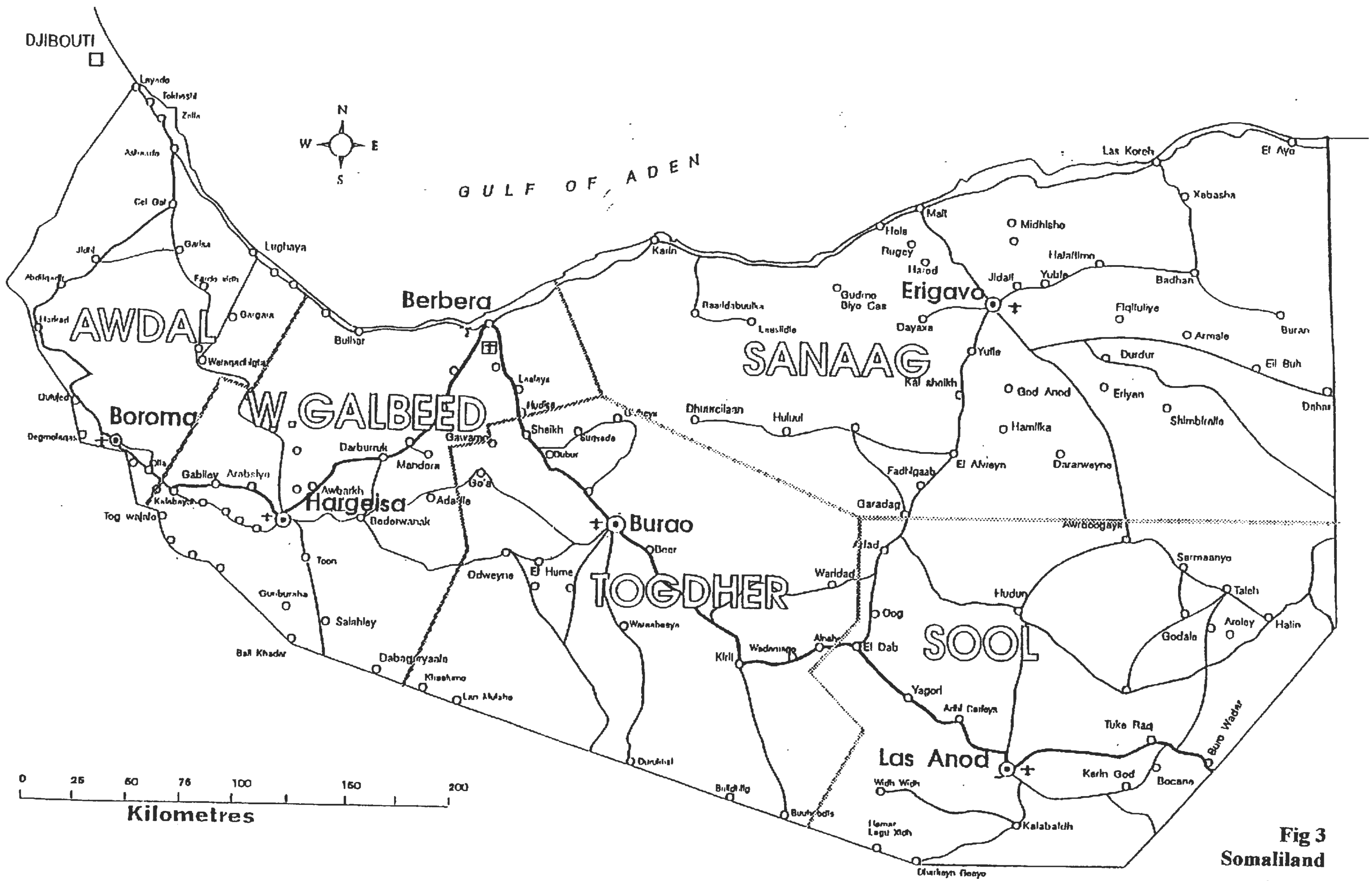

Fig 3
Somaliland

has a hidden economy of significant magnitude in the way of unrecorded remittances from Somalis abroad (LSE 1995, Ministry of Planning 1997). Recipients for the most part use the funds to purchase livestock and agricultural land, and to rehabilitate/construct shelter and water reservoirs (Liban 1997).

From 1993-97 Somaliland's rangelands supported expanding herds of livestock, thanks largely due to the absence of severe drought conditions. During that time livestock exports rose from 54,401,952 kilo liveweight worth 92.5 million U$D to 103,880,925 kilo liveweight worth some 176.6 million U$D (Ministry of Planning 1997). Livestock exports have in the past accounted for 91% of total foreign earnings (Holt and Lawrence 1992). Economically, having proven its export/import capacity with remarkable results in 1997 a downturn occurred with the Saudi Arabian ban on Somali livestock exports in 1998.

However, the relative success of the re-emergence of Somaliland must be tempered with the poverty and "least developed status" that undermines the country's potential. As elsewhere in the Sahel, Somaliland's problems are complex and multidimensional and its authorities and people struggle with severe health and environmental difficulties compounded by water and food insecurity. Understanding the central role of water to the situation in Somaliland may go some way towards assisting in the development of solutions to mitigate these problems; and, no matter how limited the understanding is, the contribution is warranted in relation to the severe development needs of both Somaliland and the Sahel. This challenge marks out the region as

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in Somaliland, and the clans within the North established a good degree of co-operation. This was exemplified by the Borooma assembly of 1993, which prepared the ground for a provisional constitution, an electoral college and a bicameral parliament with an upper and lower house of representatives. Since then, despite some outbreaks of violent interclan conflict, recovery has been slow but constant. The "Republic of Somaliland" therefore remains a defacto reality; there are civil institutions and ministries, supplemented by a judiciary, central bank, currency, police and defence force. See "Somaliland – A Country Report" by Mark Bradbury for CIIR, 1997.

one of the world's the neediest, and most problematic, in relation to water co-operation. It is also this challenge that is addressed, in part, in this dissertation.

1.2 Aims and Structure of the Dissertation

This dissertation addresses the central role of water in the development of Somaliland from the perspective of best practice in Water and Environmental Management (CIWEM 1996), and brings a lateral approach to the water management debate. The dissertation is thus an in depth, critical, real time, review of operations and management found in the workplace of the development engineer in East Africa and Somaliland.

The aim is towards ***a study of current trends and understanding in water and environmental management in the Sahel, with a focus on data and experience from Somaliland.*** This aim is pursued in order to describe the basic processes between man and environment in relation to meeting fundamental water (and subsequently food) security needs.

The study therefore concentrates on elaborating the general inter-relation between two *paradigms*:

Natural Resource Management

and

Water Resource Development in Developing Countries.

Natural Resource Management here implies a way of looking at how natural resources (vegetation, water, soils and fauna) can be used, managed and improved in a sustainable way, combining physical and social considerations (UNSO 1994); and where Water Resource Development in Developing Countries implies a set of practical responses to improving the health, social and economic well being of the worlds poorest populations in a way that is itself environmentally sustainable (DfID 1998).

The study is therefore a combination of focus on

- **Rainfall**
- **Water Resource Development**
- **Pastoral Production Systems**
- **Early Warning Systems**

with reviews and analysis of the following *processes* in support of the two major paradigms:

i. Hydrological
Rainfall, drought, water resource characteristics and potential in arid lands, remote rainfall hydrometry.

ii. Environmental Conditioning of Pastoral Production Systems
The role of rainfall, drought, non-equilibrium environments and water scarcity management

1.2.1 Dissertation Structure

The study brief is thus rather wide ranging. It is tackled in a review and analysis of individual "system elements", which build from basic definitions to a logical focus on Somaliland, and which are then synthesised in the Discussion and Conclusions at the end of the dissertation. The dissertation is organised in the following way.

Chapter 1 provides a basic background to the Sahel and Somaliland and sets out the aims and objectives of the thesis.

Chapter 2 reviews definitions of "drought" and "land degradation" and provides definitions that are used throughout the dissertation.

Chapter 3 then lays the foundation for an understanding of "development co-operation" and "sustainable development" by reviewing the guiding principles in Water Resource Development in Developing Countries, their evolution, the reason for their evolution, and their usefulness in water scarce developing countries.

Chapter 4 is a description, review and analysis of processes common to the Sahel region, with particular reference to pastoral production systems, non-equilibrium environmental theory, temporal rainfall variation, drought and the traditional management strategies for coping with water scarcity. The chapter is based on case studies from the Sahel, including Somaliland in the case of managing water scarcity. It shows how life and indigenous production systems depend almost entirely on renewable natural resources, and how the interannual variability of scarce rainfall is a prime mover in the ecological system.

Chapter 5 focuses on Food and Water Security concerns in Somaliland. It shows how pastoral livelihoods have been in transition over the past century and why there is now a strong need for an efficient food early warning system to monitor food and water security. The chapter details some of the water resource problems faced by Somaliland, and some of the attempts by the Somaliland people and the international community to alleviate those problems. Current prospects for effective development co-operation are explored and the results of a Water Resource and Natural Resource Management seminar held during the fieldwork are presented. The chapter concludes with the importance of data to the development process, and presents known titles and sources of available data for water resource development in Somaliland.

Chapter 6 continues the theme on from the previous chapter by reviewing some key documents, and by presenting an overview of the available water resources and resource potential. The sources of rainfall data are stated and verified, and an analysis of rainfall series in Hargeisa and Berbera presented. The topography, geomorphology, geology, hydrogeology and hydrology are described briefly, from which the development potential is outlined according to regional physiographic characteristics. The chapter clearly shows the limits of information available, and thus the need to consolidate the existing knowledge with further research.

Chapter 7 follows on from the established need for early warning systems identified in Chapter 5. The existing and potential role of remote sensing in the monitoring of Sahelian environments is reviewed. This is followed by an analysis of the early warning systems in Somaliland, which focuses on the role of rainfall estimation within the system, with particular emphasis placed on techniques for the merging of satellite and gauge data. The chapter concludes with ground observations carried out during the fieldwork, in relation to an ideal early warning system described beforehand.

Chapter 8 synthesises the previous chapters into a discussion and set of conclusions.

From this the final chapter makes three basic recommendations for immediate and future activities, including potential research.

1.2.2 Materials, Methods and Institutions

The study is thus essentially a desk study, based on the assessment of relevant information derived from contacting parties in Europe and East Africa and from briefly visiting sites in Somaliland. As relevant information had to be sought from a wide range of sources the first two months were spent in the UK, mainly in archive studies and setting up the work in East Africa. Fieldwork was undertaken in East Africa for a month beginning July 1st. The fieldwork focussed on data collection, institutional feedback and the preparation of the seminar held in conjunction with the Ministry of Water and Mineral Resources, and the Ministry of Environment and Rural Development in Hargeisa, Somaliland. The final month was spent in London, analysing the reports and data and in writing up the dissertation. This basic methodology was based on a flexible approach to the uncertainty of the study, the principle uncertainty being in the availability and reliability of any data.

As part of the project the student was hosted by the IUCN Somali Natural Resource Management Project in East Africa. Reference to best practice in Water and Environmental Management is therefore based to a very large extent on the limits of that working environment. In particular the IUCN "Strategic Framework for Sustainable Natural Resource Management in Somalia" (IUCN 1997) and Sahel Studies series (IUCN 1986, 89, 91, 95), plus the EC's recently published "Management and Development of Water Resources in Developing Countries - Guidelines for Water Resources Development Co-operation" (EC 1998) are key documents. Published accounts of relevant studies and experiences elsewhere in Sub-Saharan Africa or other Arid and Semi-Arid Lands are also analysed.

A basic review of literature is integral to the study and is evidenced by the referencing throughout and the attached bibliography. It is based on the following focus areas:

1. Hydrological processes in arid and semi-arid lands.
2. Remote sensing with reference to hydrological applications.
3. Principles in Water Resource Development in Developing Countries.
4. Water resources development and management in arid and semi-arid lands.
5. Sahelian and related dryland integrated studies.
6. Horn of Africa general information.
7. Horn of Africa specific on hydrology and environment.
8. Somaliland general information.
9. Somaliland specific on hydrology and environment.

The Internet was also used extensively, in search of references, in search of additional sources of information and to trace institutional links in search of data.

2. Definitions of Drought and Land Degradation

The terms drought and land degradation are used throughout the thesis so it is useful to have some agreed sense of meaning at the outset.

2.1 Drought

Drought is a constant threat to the inhabitants of arid lands. If aridity is a climatic term concerned with average conditions, then drought refers to more ephemeral conditions that are abnormal and infrequent. Often drought is treated as simply an abnormal reduction in rainfall with the assumption that this can explain all disasters from famine through to desertification. This emphasis on rainfall does not take into account reductions in supply (irrespective of rainfall) or increasing demand through population or landuse dynamics.

The consequences of droughts are felt most keenly in areas that are in any case arid. However it is manifested, drought adversely affects the economy by reducing, or even eliminating, agricultural production, livestock herds, and domestic and municipal water supply. Developing countries are particularly prone to these adverse effects (Beran 1985).

Various definitions of drought have been analysed by Agnew and Anderson (1992). Dracup *et al* (1985), Russell *et al* (1970), Timberlake (1985) concentrate definitions on rainfall deficiency, or meteorological drought. Yevjevich *et al* (1978), Warrick (1975) consider agricultural drought as related to the reduction of yields in relation to moisture deficits. Agnew (1980,1982) developed a model that calculates the soil water balance in the Sahel on a 5 day time-scale with a reported mean accuracy of 10%; which has been used to distinguish between meteorological and agricultural drought conditions. Subrahmanyam (1967) argues the case for water supply drought, agricultural drought, climatic drought and hydrological drought.

Conditions within a drought may vary considerably in space and time, in accordance with the spatio-temporal irregularity of the rainfall distribution and with the heterogeneity of the hydrological response of the catchments that are affected (Beran *et al* 1985). Drought characteristics therefore differ for different climatological and hydrological regimes, and also differ very much according to the use to which the water is put. For example in the arid part of the Sahel a shortage of rain depth and duration during the rainy season need not much affect the livestock pasture so long as germination and growth is permitted, however grain production may be very much reduced. The effect of drought is therefore more keenly felt by the cereal grower than the pastoralist (Beran *et al* 1985).

Although there is a significant body of work that has been undertaken in the hydrological aspects of drought in the Sahel, eg. low rivers flows, persistence, etc. (see section 4.5) at this point we must accept that droughts in the general sense retain qualitative connotations. It is therefore enough to accept that

"Drought is a condition of moisture deficit sufficient to have adverse effect on vegetation, animals and man..." Warrick 1975

and that drought is a "prime mover" which has attributes or consequences.

This is universally accepted in the tradition of the Somali, who have endured, and developed a resilience to, persistent drought over time, and who regard drought as the worst of all natural disasters. It is an ordeal which, with varying degrees of severity, enters the experience of almost every generation; the impact so keenly felt that each drought is remembered by character. *Xaaraamacune* (early 1910s) "The Eater of Forbidden Food", so called because it caused such famine that some people were driven to break the dietary prohibitions enjoined by Islam; *Siigacase* (early 1950s) "The Blower of Red Dust" named after the frequent sand storms which affected some areas; and *Dabadheer* (early to mid 1970s) "The Long Tailed One" so called because of its long drawn out character (Andrzejewski 1974).

2.2 Land Degradation

The idea of land degradation cannot be separated from that of sustainability. A form of land use is sustainable if it can continue indefinitely; sustainability therefore depends on the properties of both the resource and the way it is managed. The quality of a resource that renders its use sustainable is its resilience, where resilience is defined in relation to a particular, specified, form of land use. Parry (1986) has shown the close relationship between the resilience of land, and the way it is used. Warren *et al* (1986) give examples of the relationship in drylands.

Due to its dual nature (land use and environment) resilience is therefore highly variable in both space and time. A good test of resilience of a resource is its ability to recover from shock, either climatic or through a change in land use. The greater the shock absorbed the greater the resilience. The recurrent shock in arid lands is drought, and it is drought that usually brings land degradation to notice (Warren *et al* 1988). In this sense the definition within this thesis is very simply that;

"any damage to, or loss of, resilience is a form of land degradation".
(Warren and Agnew 1988)

In practice any investigation of the damage to resilience should involve continual iterations between examinations of environment and economy, and between environmental, technological and economic opportunities.

A measure of degradation is the cost of rehabilitation. Damaged resilience can be recovered, even the most degraded soil can be rehabilitated if sufficient capital and technology are available. Williams (1974) provides examples of the recovery of resilience in dryland Australia.

3. A Review of the Guiding Principles in Development Co-operation and Sustainable Development of Water Resources

The concepts of *sustainable development* and *development co-operation* are fundamental to the process of donor assistance to developing countries. Adherence to these principles, and the paradigms they imply, shape the form of "best practice" donor assistance in water resource development. It is therefore necessary to understand exactly what the principles are, and what they mean for the engineer. The aim of this chapter is therefore to review the guiding principles, their evolution, the reason for their evolution, and their usefulness in water scarce developing countries. It also highlights information sources. The chapter is not itself conclusive, but rather lays the foundation on which the focus of development paradigms and processes in the Sahel and Somaliland will be further reviewed and discussed within the following chapters (see sections 4,5,6 and 7) of the dissertation.

3.1 Water Scarcity in Developing Countries

The International Drinking Water Supply and Sanitation Decade 1981-1990, launched by the United Nations General Assembly placed the highest priority on basic needs in the developing world. Yet around 1,300 million people are classified as living in poverty, and more than 1,200 million are without access to safe water supplies (WHO-UNICEF 1996). Coupled with poor hygiene practice and inadequate sanitation the principle outcome is diarrhoea disease; by any reckoning, more than 90% of the benefits of water supplies arise from reduced diarrhoea disease, most of it in children less than five years old (Cairncross 1999). Improved water supplies and sanitation typically reduce diarrhoea incidence by about 25%. In reducing the toll of sickness and death the supply of adequate quantities of water is usually more important than improving its quality. (Esrey *et al* 1985).

Rapid increases in population are anticipated in dry climate areas with a prediction (Rodda 1995) that around 3,000 million people will be living in areas of water shortage by the year 2025 (DfID 1998). The problem of increasing regional water shortages have been highlighted by governments, the UN and the scientific community (eg. Gleik 1993). It has been argued that when the renewable freshwater available per person falls below 1,000 cum/year (the condition of water scarcity), lack of water begins to hamper health, economic development and human well being. Less than 500 cum/year is the water level at which water availability is the primary constraint to life (CIWEM 1998, DfID 1998). When population growth increases, the ability to meet supply needs becomes more challenging as the resource base becomes increasingly stressed. Future predictions highlight the nature of the problem. Health implications in developing countries look serious.

		Year	
Country	**1955**	**1990**	**2025**
Djibouti	147	23	9
Qatar	1,427	117	68
Saudi Arabia	1,266	306	113
Jordan	906	327	121
Yemen	1,098	445	152
Israel	1,229	461	264
Algeria	1,770	689	332
Kenya	2,087	636	235
Burundi	1,339	655	269
Rwanda	2,636	879	306
Malawi	2,839	939	361
Somalia	2,500	980	363

Table 1. Annual renewable fresh water available (in order of availability in 1990). Dimensions - cum/capita/pa based on UN medium population growth for 2025. Source CIWEM 1997

Note that figures for Somalia include the two permanent rivers Shabelle and Juba that run through Southern and Central Somalia, but not through Somaliland, which has no perennial sources other than springs.

The situation in Somaliland is thus more critical, and probably more representative of the situation in Yemen.

3.2 The Sustainable Development Paradigm

The end of the decade and its follow on activities were paralleled by international initiatives concerning the wider water sector and the expanding agenda on environment.

In 1987 the World Commission on Environment and Development produced its report "Our Common Future" (the Brundtland Report), calling for development which meets the needs of the present without compromising the ability of future generations to meet their own needs. The term "sustainable development" thus came into common use; the commission in agreement on what conditions constitute "sustainable livelihood security".

"Livelihood is defined as adequate stocks and flows of food and cash to meet basic security needs. Security refers to secure ownership of, or access to, resources and income earning activities, including reserves and assets to offset risks, ease shocks and meet contingencies. Sustainable refers to the maintenance or enhancement of resource productivity on a long term basis" (WCED 1987)

The Commission's objective was to provide the UN with an environmental perspective to the year 2000 and beyond. In the final analysis it was the linking of environment and development, which were seen as inseparable, and the institutionalising of the sustainable development paradigm, that are the hallmarks of the Commission. But the massive water scarcity threatening millions of Africans a few decades from now went unnoticed, even though it will have profound influences on the relationship between environment and development in the countries concerned (Falkenmark 1989). Loucks (1994) subsequently set out basic principles focussing on sustainability in

Water Resource Management. Alaerts *et al* (1991) proposed five sectoral conditions for achieving it:

1. **Technical** - the effective and efficient design and management of resource development projects involves balancing variable demands and supplies.

2. **Environmental** - there can be no long-term irreversible effects.

3. **Financial** - the costs of all resource development and management projects must be recoverable.

4. **Social** - society must support and be willing to pay for the services provided by development projects.

5. **Institutional** - institutions must have the capacity to plan, manage, monitor and adapt to changing situations.

Pearce (1996) has focussed further on definitions of sustainable development of the water sector in developing countries, but for the engineer this is much less an issue than determining what needs to be done to achieve it. Ultimately sustainable development will rest on the political will to take into account two key concepts:

i. The concept of needs; in particular the essential needs of the worlds poor, to which overriding priority should be given.

ii. The limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs (CIWEM 98).

3.3 The Evolution of International Initiatives

In 1991 UNDP sponsored a symposium "Strategy for Water Resources Capacity Building" at Delft where economists argued that the term "water resources" implied only the supply side, and that without effective demand measurement, goals such as the provision of "drinking water to all" were meaningless (UNDP 1991). The notion of a "Water Sector" to cover issues beyond those understood by water resources was therefore adopted, where managing water and environmental resources were central strategic concepts. Later in 1991 a Nordic initiative focussed on integrated water-resources management in rural communities in developing countries. The resulting Copenhagen statement stressed that water and land resources should be "managed at the lowest appropriate levels", and that water should be considered as an economic good with a value reflecting its greatest potential use (Danida 1991).

Both Delft and Copenhagen provided input to the Dublin International Conference on Water and the Environment in 1992. The Dublin conference established new principles for water resources management, and called for fundamental approaches for the assessment and management of freshwater resources (WMO 1992). The conference agreed that, to reverse the trends of over-consumption, pollution, droughts and floods, action should be based on the following guiding principles (Dublin 1992):

1. **Freshwater is a finite, vulnerable resource, essential to sustain life, development and the environment.**
ie. Since water sustains life, effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems. Effective management links land and water uses across the whole of the catchment area or aquifer.

2. **Water management should be participatory, involving planners and policy makers at all levels.**
ie. The participatory approach involves raising awareness of the importance of water among policy-makers and the general public. It means that decisions are taken at the lowest appropriate level, with full

public consultation and involvement of the users in the planning and implementation of projects.

3. **Women play a central part in the provision, management and safeguarding of water.**
ie. The pivotal role of women as providers and users of water and guardians of the living environment has seldom been reflected in institutional arrangements for the development and management of water resources. Acceptance and implementation of this principle requires positive policies to address women's specific needs and to equip and empower women to participate at all levels in water resource programmes, including decision-making and implementation, in ways defined by them.

4. **Access to clean water at an affordable price is a basic human right, but failure to recognise its economic value in competing uses leads to wasteful and environmentally damaging use.**
ie. Within this principle it is vital to recognise first the basic right of all human beings to have access to clean water and sanitation at an affordable price. Past failure to recognise the economic value of water has led to wasteful and environmentally damaging uses of the resource. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources.

The Dublin conference was of fundamental importance since it consisted largely of professionals, acting in technical and advisory capacities. Unfortunately the consensus achieved did not have governmental backing to the extent enjoyed by other international conventions and protocols (CIWEM 1998).

However, the follow-on was the intergovernmental 1992 UN Commission on Environment and Development (UNCED) - now known as the Earth Summit, and its main outcome was **Agenda 21 - the Agenda for the 21st Century** (UNCED 1992). The broad aspects of freshwater management are contained under Section 2. "Conservation and Management of Natural Resources" in chapter 18. Here the links with other environmental issues; the objectives of water resource management, and the recommendations of Delft and Dublin are divided into seven programme areas:

1. Integrated Water Resources Development and Management.
2. Water Resources Assessment.
3. Protection of Water Resources, Quality and Aquatic Ecosystems.
4. Drinking Water Supply and Sanitation.
5. Water and Sustainable Urban Development.
6. Water for Sustainable Food Production and Rural Development.
7. Impacts of Climate Change on Water Resources.

These programme areas have been widely used as the basis for subsequent reporting.

In 1996 the World Water Council (WWC) was constituted to cover policy issues in the broad field of water resources management, its subscribing members including public and private sector agencies along with UN agencies and donors. The Council acts as a think tank, to promote awareness at all levels of critical water issues and their relationship to environmental sustainability. The WWC held its first "World Water Forum" at Marrakech in 1997 and is currently spearheading the preparation of a *Vision for Water, Life and the Environment.* The Global Water Partnership (GWP) was also formed in 1996 with the aim of facilitating improved implementation of programmes in water resources. The GWP has been looking at gaps in sector knowledge and capacity-building needs in the different sectors, and emphasises information and experience sharing to facilitate a co-ordinated approach.

From the perspective of the hydrologist and water manager one of the most convincing, and longest established, initiatives has come from UNESCO through it's International Hydrological Programme (IHP).

Based on the philosophy that rational water management should be founded on a thorough understanding of water science, its availability and movement, since 1977 the objectives have shifted perceptibly towards a multi-disciplinary approach to the assessment, planning and rational management of water resources. The programme thus now covers not only hydrological processes considered in interrelationship to man and the environment, but also the scientific aspects of multi-purpose utilisation and conservation of water resources to meet the needs of economic and social development (UNESCO 1991).

That global co-operation and international consensus has thus emerged, and continues to be debated and developed following these international initiatives is encouraging. Clearly it represents a logical progression in addressing global water scarcity concerns more holistically, equitably, scientifically, and hopefully in future much more effectively.

3.4 Development Co-operation and the EC Contribution

Most successful development co-operation over the past seven years has thus been driven by the consensus on guiding principles. Guidelines for development co-operation, and for technical and programming issues within the water sector, have been developed at the national level (Swiss Development Co-operation 1994, DfID 1999, WASH 1988), by the UN Agencies, and through NGOs such as Oxfam (Oxfam 1993), WaterAid and the International Reference Centre for Water Supply and Sanitation (IRC 1983, 1991).

In general most overarching guidelines are generic, drawing on examples of "best practice" project specific experience gained in the developing world to reinforce the guiding principles (DfID 1999). As development co-operation is an evolving process, the guidelines will also continue to evolve, as part of a dynamic process of evaluation and subsequent adjustment over time.

In the past year the European Union has contributed through its "The Management and Development of Water Resources: A Strategic Approach – Guidelines for Water Resources Development Co-operation". Specifically the EC guidelines aim to *"improve the quality and impact of the EC's assistance to developing countries in water resources management and the provision of water related services, as part of long term efforts to assist the process of sustainable social and economic development"*(EC 1998).

Within the guidelines six interrelated and inter-linked guiding principles, (that are clearly derived from Alaerts *et al* (1991)):

1. Institutional and Management Principles.
2. Social Principles.
3. Economic And Finance Principles.
4. Environmental Principles.
5. Information, Education And Communications Principles.
6. Technological Principles.

support four focus areas of programme activity

1. **Water Resources Assessment And Planning** (WRAP)

2. **Basic Water Supply And Sanitation Services** (BWSS)

3. **Municipal Water And Waste Water Services** (MWWS)

4. **Agricultural Water Use And Management** (AWUM)

Programming can be at several levels, long term national or regional indicative programmes, annual programming, or project focussed programming. During the programming phase the aim is to determine the place of water resource development within the wider context of national development objectives so as to be able to identify priorities for project support.

This is achieved through four logical steps (EC 1998) with conditions imposed.

1. **Assessing the need for water resources support.**
Condition: All support should be demand driven, fully supported by the partner country, and developed in consultation with the target groups

2. **Determining the absorptive capacity of the country.**
Condition: A water resources programme can only be effectively implemented if there is adequate absorptive capacity to handle the institutional, technical and financial demands contained within it.

3. **Identifying complementary activities in other sectors and by other donors and assessing the compatibility of any proposed programme.**
Condition: Water resources development and management must be assessed with regard to its compatibility with the overall development plans of the country.

4. **Identifying the priority focus areas for support.**
Condition: Prioritising the focus area(s) is based on findings of steps 1,2 & 3, in relation to the optimal use of limited finance available.

3.5 Development Co-operation in Water Scarce Developing Countries

There is a major problem in that development co-operation in water scarce developing countries has been characterised by greater depth of failure than most other development initiatives (IUCN 1989, 1995). The importance of water for life makes it a plausible hypothesis that socio-economic development is particularly difficult to achieve in countries where a hot dry climate does not allow easy access to water for plants or humans (IUCN 1991). There is a growing awareness that water scarcity may complicate the socio-economic growth of countries with rapid population increase and growing megapoles (World Bank

1989). There is thus a critical need to develop a theoretical understanding of the way that such societies cope with water scarcity.

Turton (1999) has proposed that water scarce developing countries are equally scarce in human resources. They lack "social adaptive capacity" and are thus typically unable to mobilise the resources to ameliorate the effects of water scarcity, hence the growing reliance on development assistance. He also argued that developing economies tend to deplete their environmental capital during the pre-industrial phase of development, and as a consequence of their shift to market based economies. When the shift has been made then financial resources are usually reinvested in mitigating the damage to, and improving and managing, the natural environment.

Until recently there were vague ideas about the role of water in the environmental problems of developing countries. Consequently many of the recommendations for development co-operation are not always very convincing; they tend to be limited to protection of landscape features, transfer of environmentally sound technology, and environmental impact assessment of projects, rather than considering the most suitable and efficient use of water resources (Falkenmark 1991).

On the other hand agriculturists have treated water as a hydro-technical issue focussing on irrigation and drainage. Attention has been on irrigable soils and plant water requirements. In spite of the sophisticated level of understanding, prevailing irrigation techniques remain rather primitive in practice with huge losses in canal transfer, widespread overpumping of groundwater aquifers, and major problems with water logging and salinization (Kay 1995). In areas of increasing scarcity, the growing demand for domestic water supply will necessitate reducing existing allocations of high quality water to irrigation systems where it has a relatively low value per cubic metre. The relative amounts involved are illustrated by a general model that a flow of 1l/s is needed to irrigate just one hectare of land, but is sufficient to provide domestic water supply for 1000 people (DfID 1998). Although food security is a high priority in many countries, there is a growing belief that where water is scarce, its security is best achieved through water intensive food imports or "virtual water imports" and storage facilities, and not inadequate hydrological systems (Allen 1997).

The search for appropriate paradigms in Development Co-operation in Water Scarce Developing Countries therefore needs to be based on awareness and critical evaluation of these experiences. Attempts to develop appropriate paradigms have so far been few, the most notable being the UNESCO International Hydrological Programme (IHP) which has initiated a Project theme of "Integrated Water Resources Management in Arid and Semi-Arid Zones" consisting of four project lines;

1. Hydrological processes in arid and semi-arid zones.
2. Water resources assessment in arid and semi-arid zones
3. Water resources management for sustainable development in arid and semi-arid zones.
4. Coping with Water Scarcity.

Although limited mainly to international symposia, plus the publication of technical documents, studies and reports in Hydrology, the exchange of information and experiences within project outputs may provide a useful foundation for future approaches to Co-operation Development in Water Scarce Developing Countries (eg. Hufschmidt *et al* 1991, van Lanen 1998).

4. Focus on The Sahel - A Description and Analysis of Basic Paradigms and Processes in Water and Environmental Management

4.1 Basic Description of the Sahel

The Sahara is the world's largest desert, stretching across the African continent and receiving on average less than 100mm of precipitation per year. The Southern limit of the Sahara is usually considered to be the 200mm isohyet. Immediately South of this is the Sahel, which although conveniently associated with an isohyetal limit is, in *sensu stricto*, the name for a phytogeographical zone, characterised by a semi-arid steppe vegetation (IUCN 1991).

In the Sahel, life and the indigenous production systems depend almost entirely on renewable natural resources. The inter-dependence of man with the environment is clearly seen in the composition of gross domestic and national product, the proportion of the labour force engaged in agriculture, the prevalence of subsistence agriculture and the dependence upon biomass for energy. As a result any form of environmental degradation directly affects the regions ability to meet basic survival needs (IUCN 1991)

Defined on the basis of physical characteristics (climate and vegetation), the Sahel covers the area of large scale pastoralism, and the extreme north of rainfed agriculture. Since livestock and agriculture are dependent on agro-ecological potential their spatial and seasonal distribution coincide to a great extent with known climatic and vegetation zones. The climatic and vegetation zones extend across the continent in narrow west-east bands and can be followed down through East Africa. On travelling South the mean precipitation gradient increases steadily, with the 1000mm isohyet approximately 700km south of the 100mm isohyet. A rainfall deficit in the Sahel proper often coincides with deficits in eastern and southern parts of Africa, although no strict correlation has been established (IUCN 1984). Clearly isohyetal maps can give a misleading impression of rainfall predictability and regularity and thus cannot be taken as an indication of future probabilities. For example, during a drought, the short term means fall, and the Sahelian isohyets move south (or correspondingly inward in the case of East Africa). A reduction in rainfall is thus equivalent to a shift in the isohyets. Transhument nomadic populations used to follow this movement as a routine coping mechanism, but this has become progressively more difficult throughout the 20^{th} century (Agnew *et al* 1992).

4.1.1 Basic Description of The Eastern Sahel

The Red Sea and the Ethiopian highlands form a natural eastern border to the vast Sahara desert of West and Central North Africa. From the East of here is a boomerang shaped strip of arid and semi-arid land that continues south towards the equator. In this region (of more than 1,000,000 km^2), often referred to as the Eastern Sahel, or Horn of Africa due to its prominent protrusion on the Eastern seaboard, average annual rainfall rarely exceeds 500mm. Vegetation is almost universally sparse, being mainly Somali-Masai deciduous bushland or Somali-Masai semi-desert grassland (IUCN 1989).

The zone is a strange climatological phenomenon, a desert (the Somali-Chalbi) on the Eastern coast in tropical latitudes. The extreme aridity is caused by the fact that the prevailing winds during most months of the year have a north-easterly or south-westerly direction, thus making moist air masses over the land an exception rather than the rule (Griffiths 1972).

The Eastern Sahel thus falls within the seven countries (Sudan, Eritrea, Ethiopia, Djibouti, Somalia, Kenya and Uganda) that make up the Intergovernmental Authority on Drought and Development (IGADD). As the name implies IGADD is the principle regional forum through which development and drought related activities are co-ordinated. Recognising that insufficient information was available on crop and livestock production systems to properly analyse some of the advance indicators provided by environmental satellites or by agro-meteorological analysis, IGAAD/FAO Early Warning and Food Information System commissioned a Crop Production Systems Zone Database in 1994. The database brings together information on physical environment, agronomy, livestock and the occurrence of biotic and abiotic hazards to agricultural production in order to interface statistical data by administrative units. Granted access to the database it was possible to produce a series of maps showing normal conditions in the IGAAD sub-region. Note that the extent of the Sahel corresponds roughly to the extent of arid lands within the profiles (figs 4 to 14).

4.2 The Prevalence and Problems of Pastoral Production Systems

The Sahel, and in particular The Horn of Africa, is home to the largest remaining aggregation of traditional livestock producers in the world. The states of the Eastern Sahel - Sudan, Somalia, Ethiopia and Kenya - rank first, third, fifth and sixth respectively in the world in terms of pastoral population size. Though never accurately counted, the size of the population ranges from 6% in Kenya to over 60% in Somalia. Vast expanses of land, 52%in Ethiopia, 66% in Sudan, 72% in Kenya and 75% in Somalia - are pastoralist habitat (Markakis 1993).

Pastoralism thus provides both a living and a way of life to over 25 million people in Africa, and makes a significant contribution to the economies of the region. It is a production system that continues to make more efficient and sustainable use of the dryland resources of Africa than most alternatives that have been tried. At one time considered inefficient and anachronistic, nomadic pastoralism is now seen to be an appropriate system of production for arid land environments. The various components of the production system are adapted to the variable climate and ecology of that environment. It is therefore no coincidence that pastoral systems across the Sahel rangelands display essentially similar characteristics (Behnke *et al* 1993).

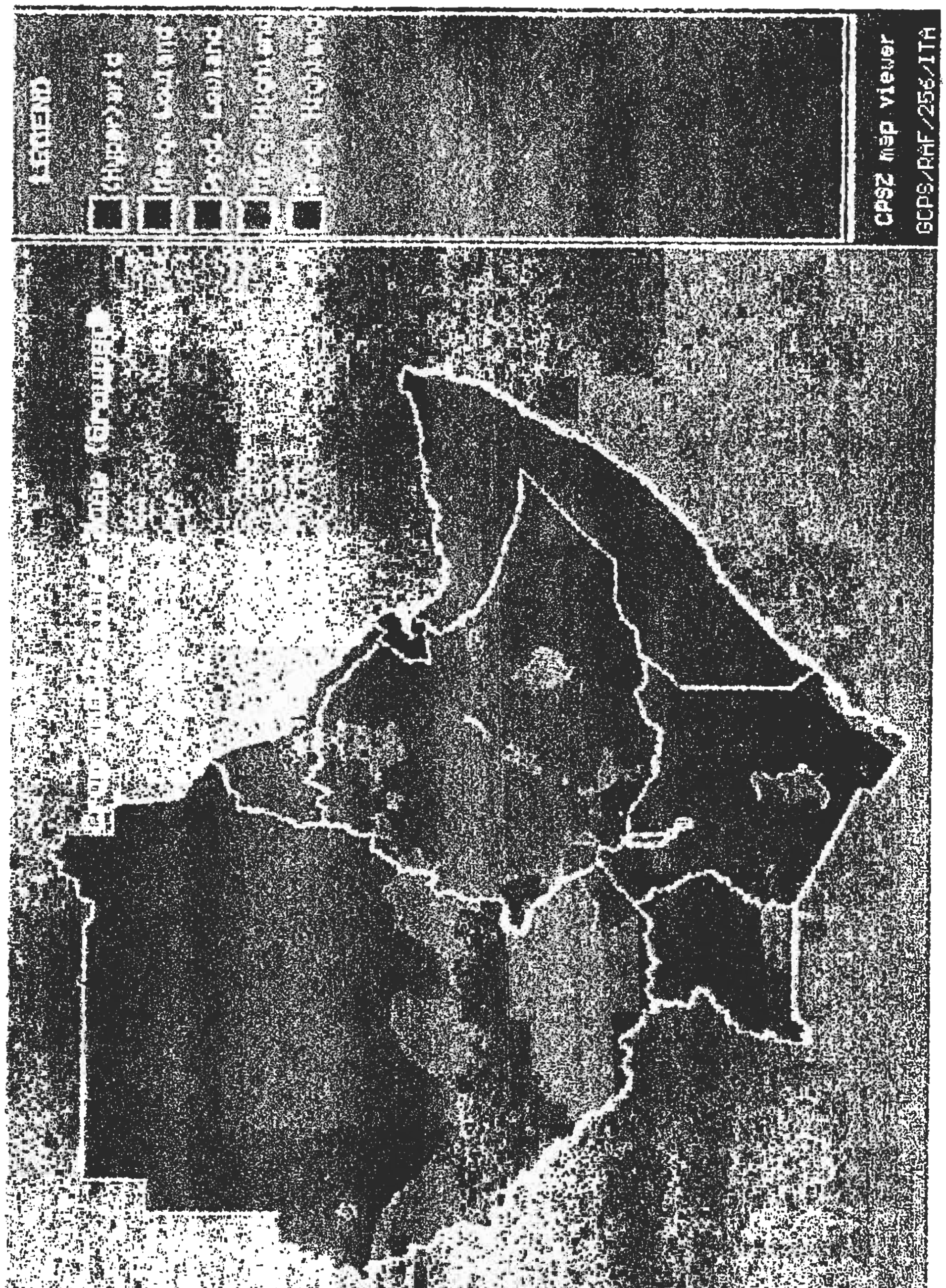


Fig 4
Grouped Crop and Pasture Zones

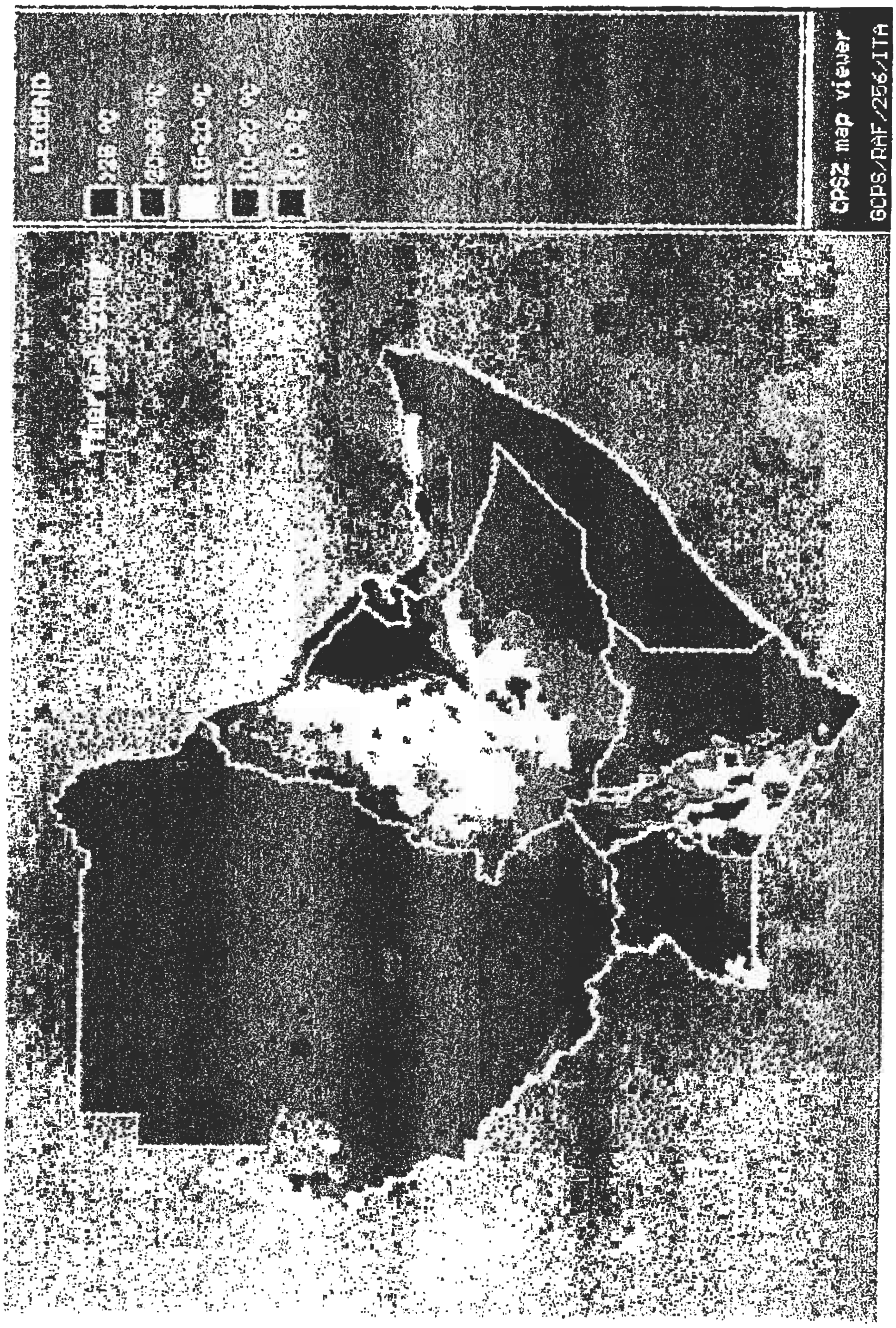


Fig 5
Thermal Zones

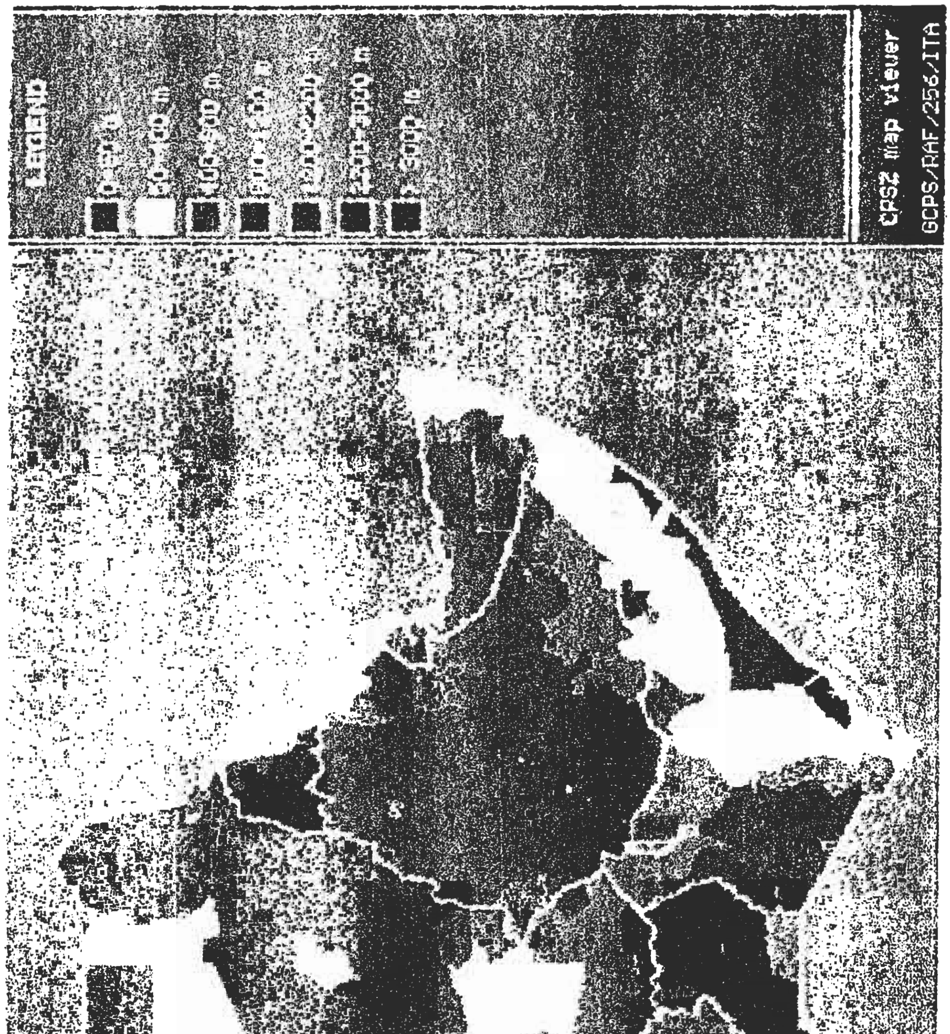


Fig 6
Average Altitude

Fig 7
Average Annual Rainfall

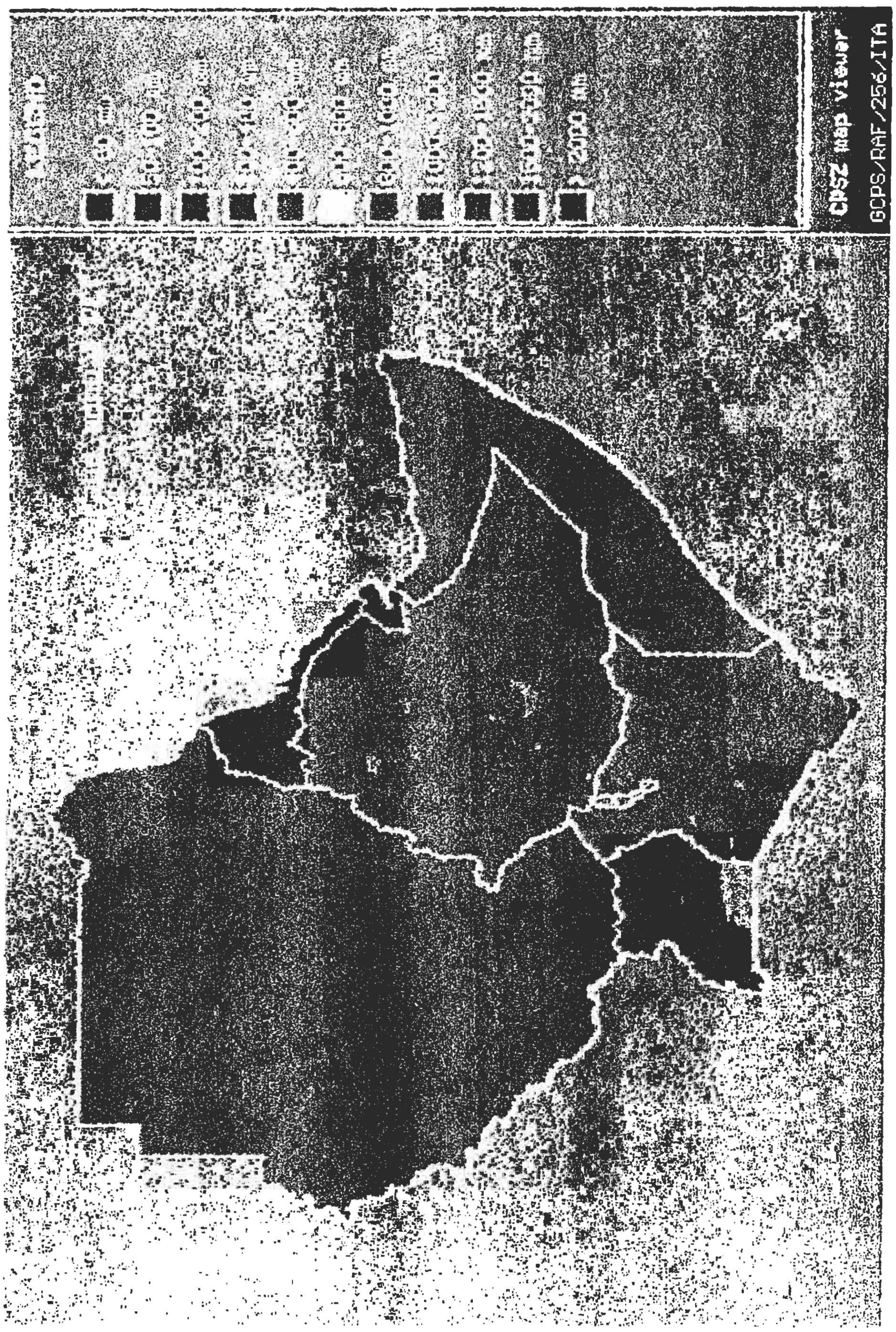


Fig 8
Average Annual Potential Evapotranspiration

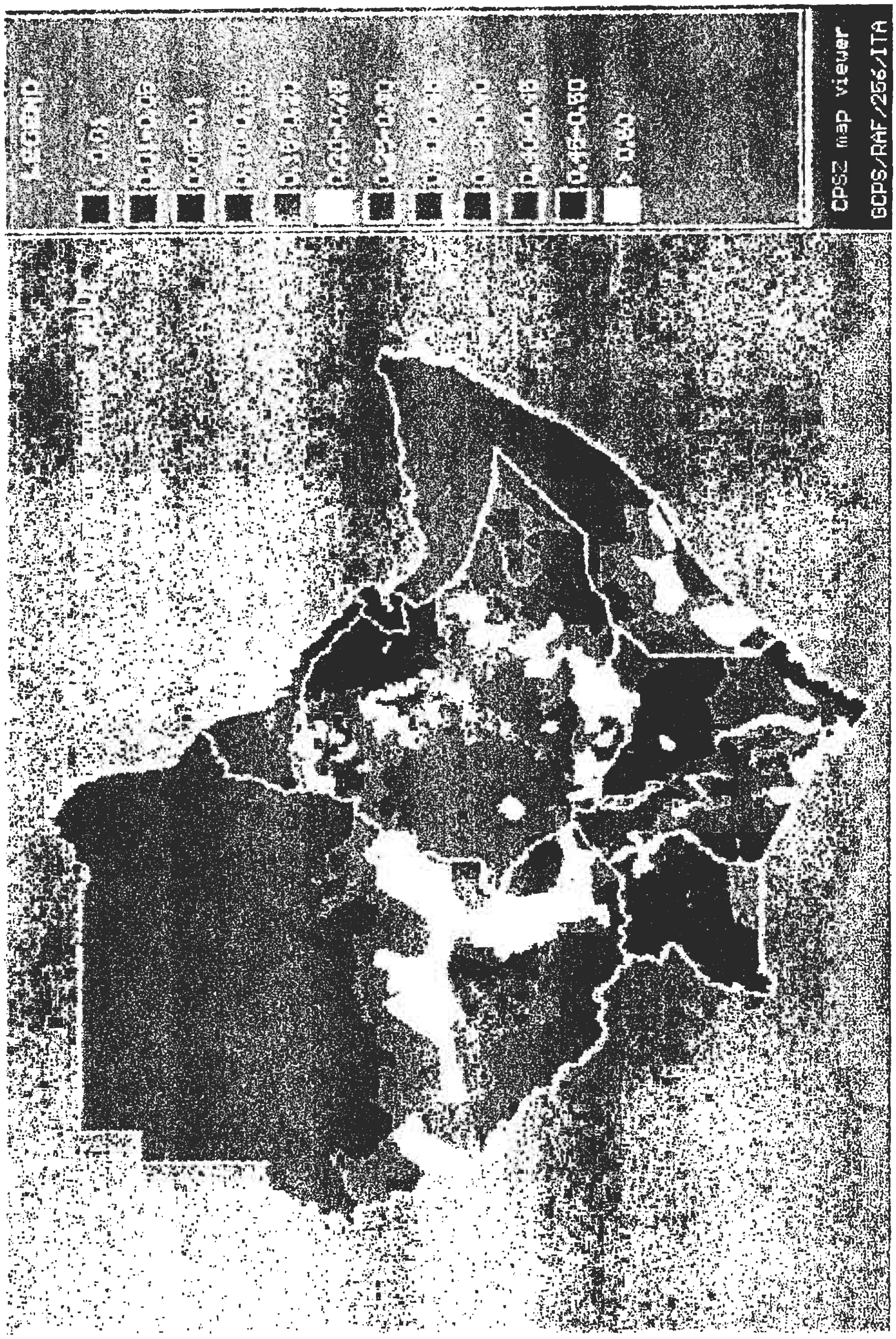


Fig 9
Average Annual Normalised Difference Vegetation Index

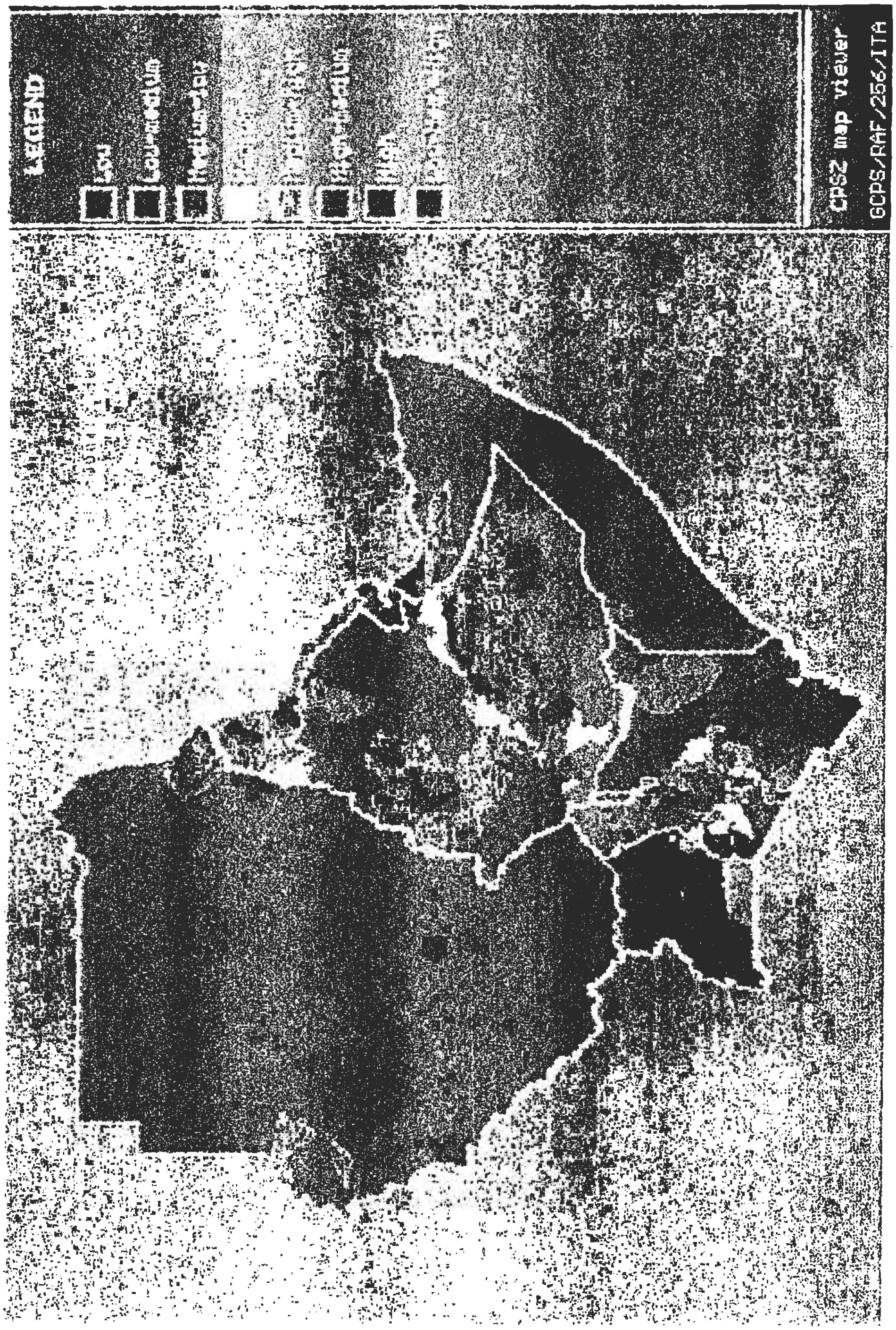


Fig 10
Inherent Soil Fertility Class

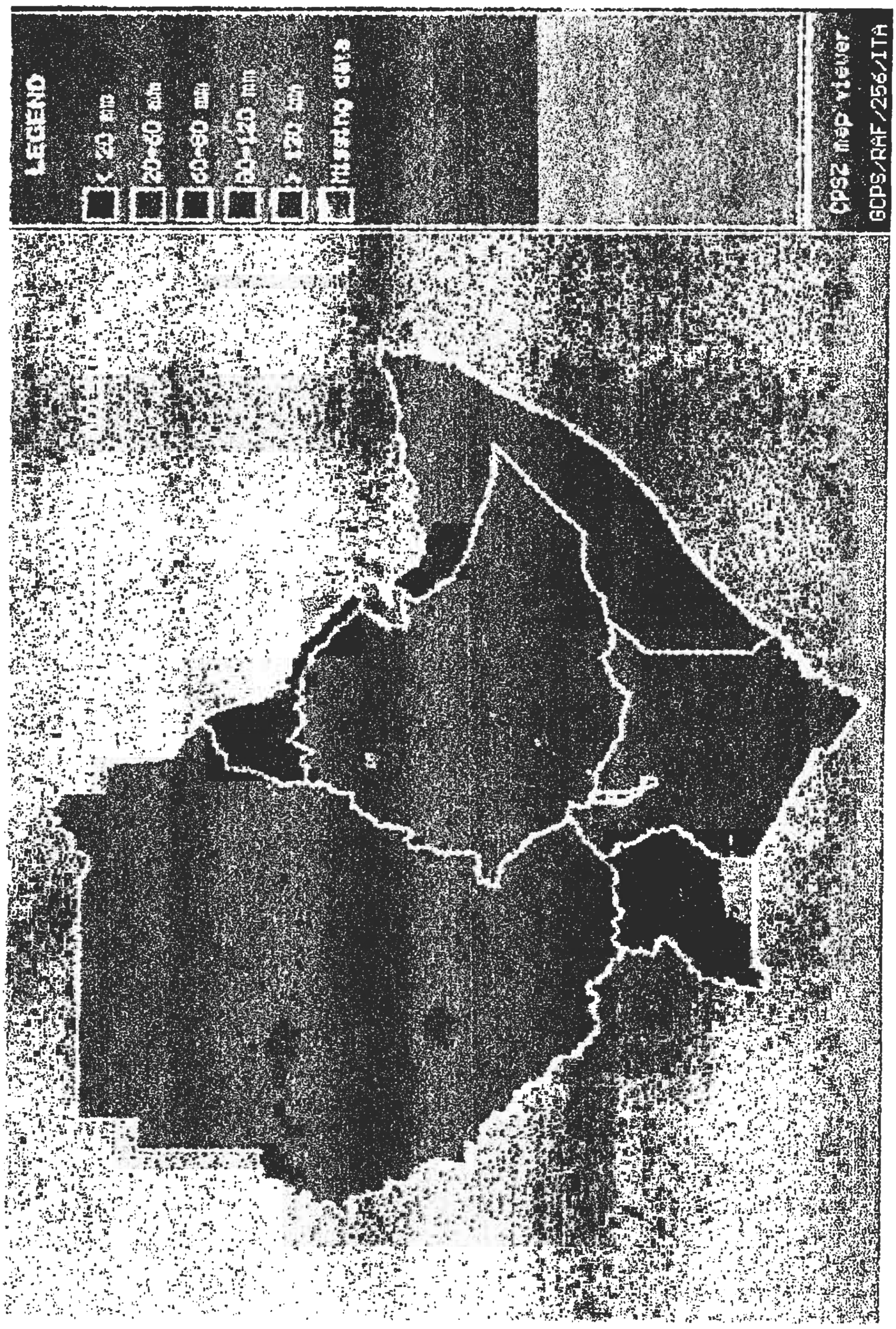


Fig 11
Readily Available Soil Moisture

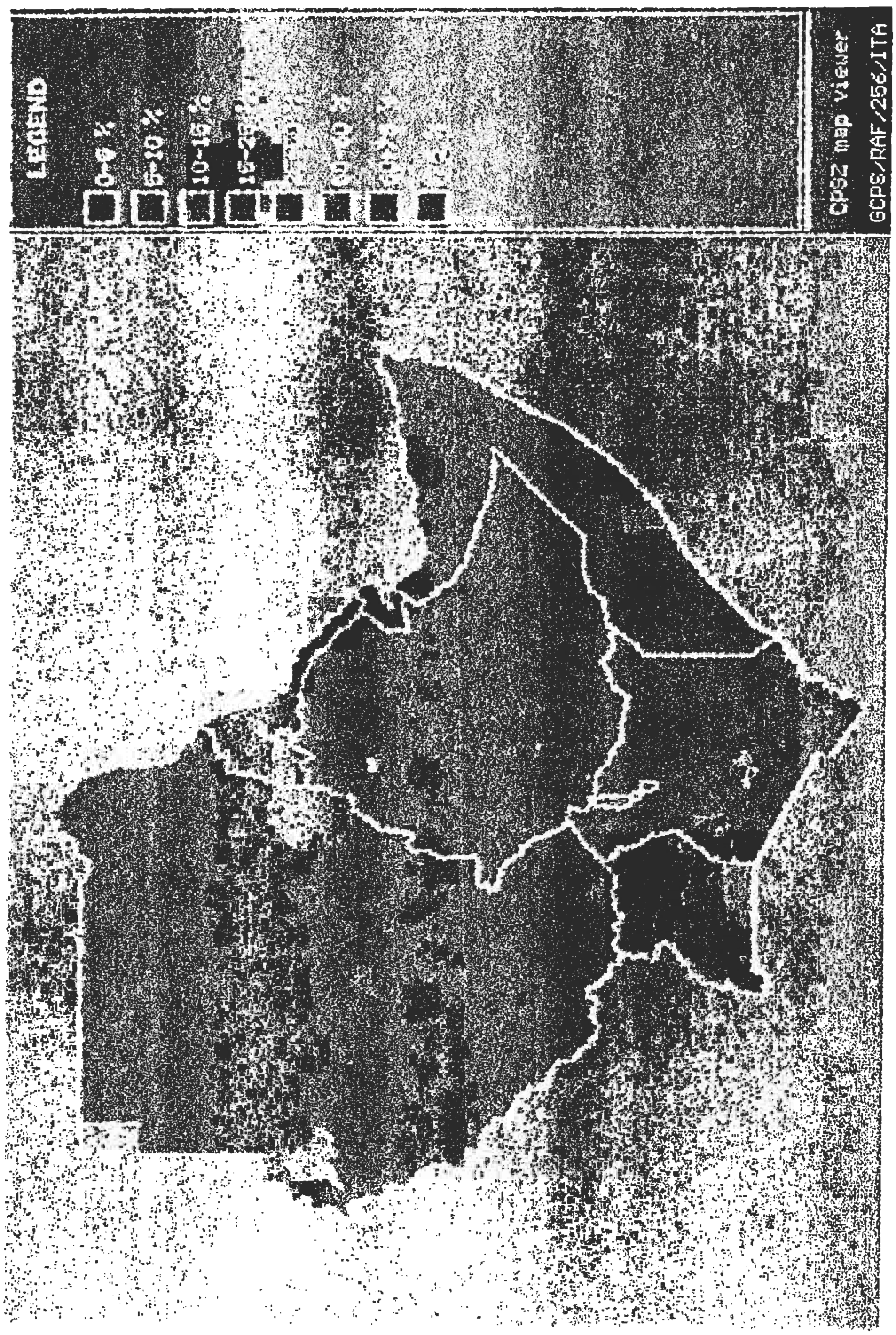


Fig 12
Livestock/Crop Ratio

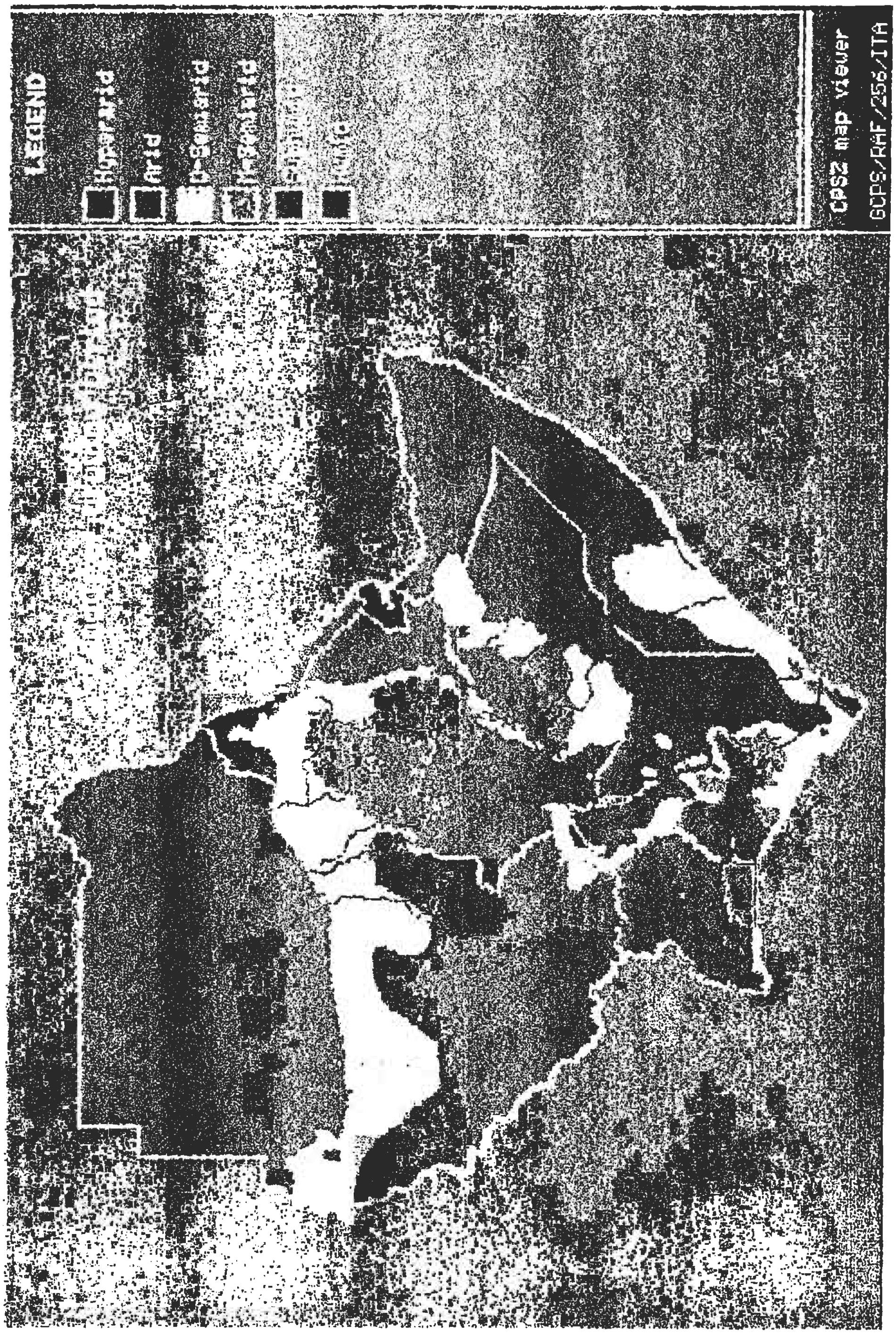


Fig 13
Length of Growing Period

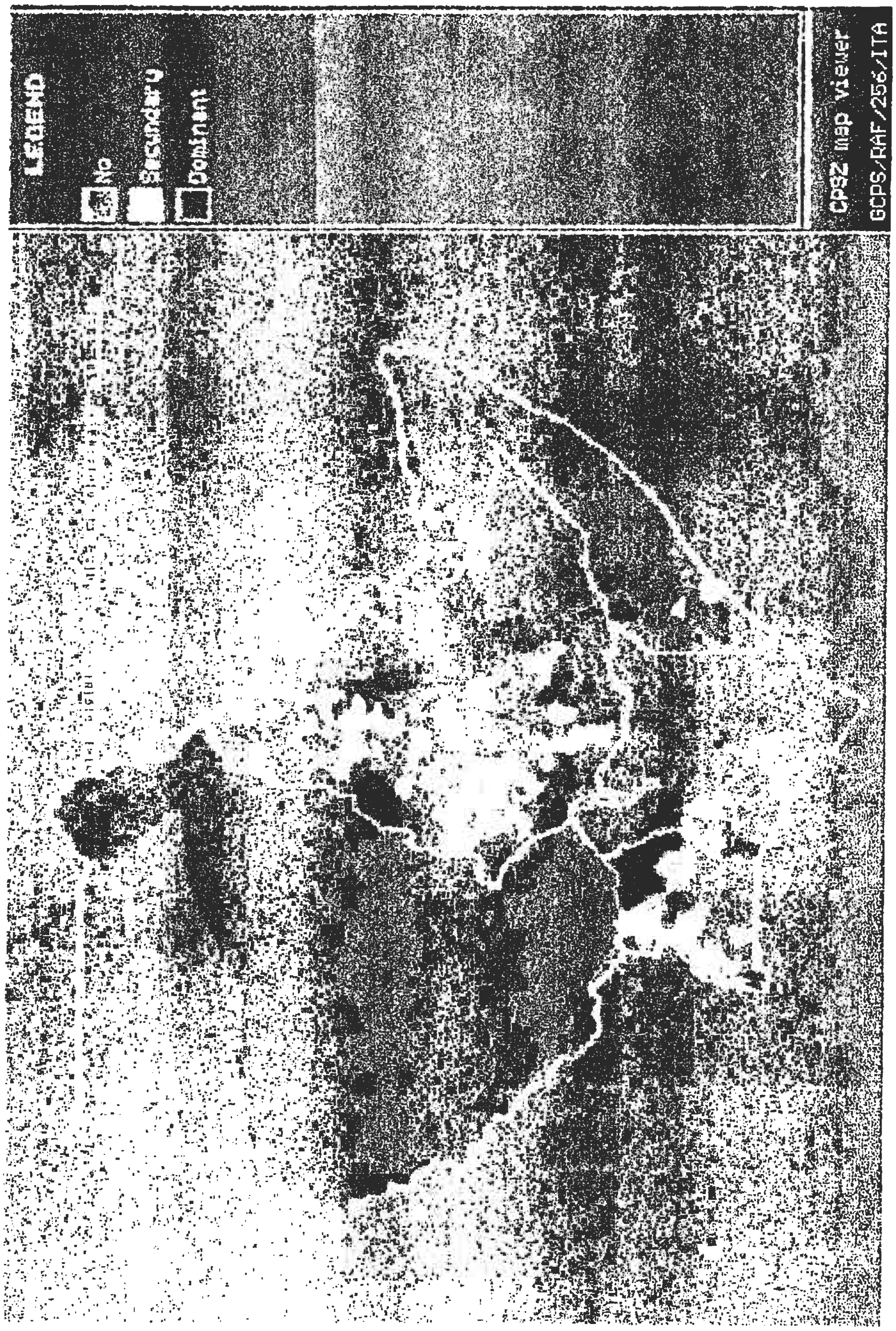


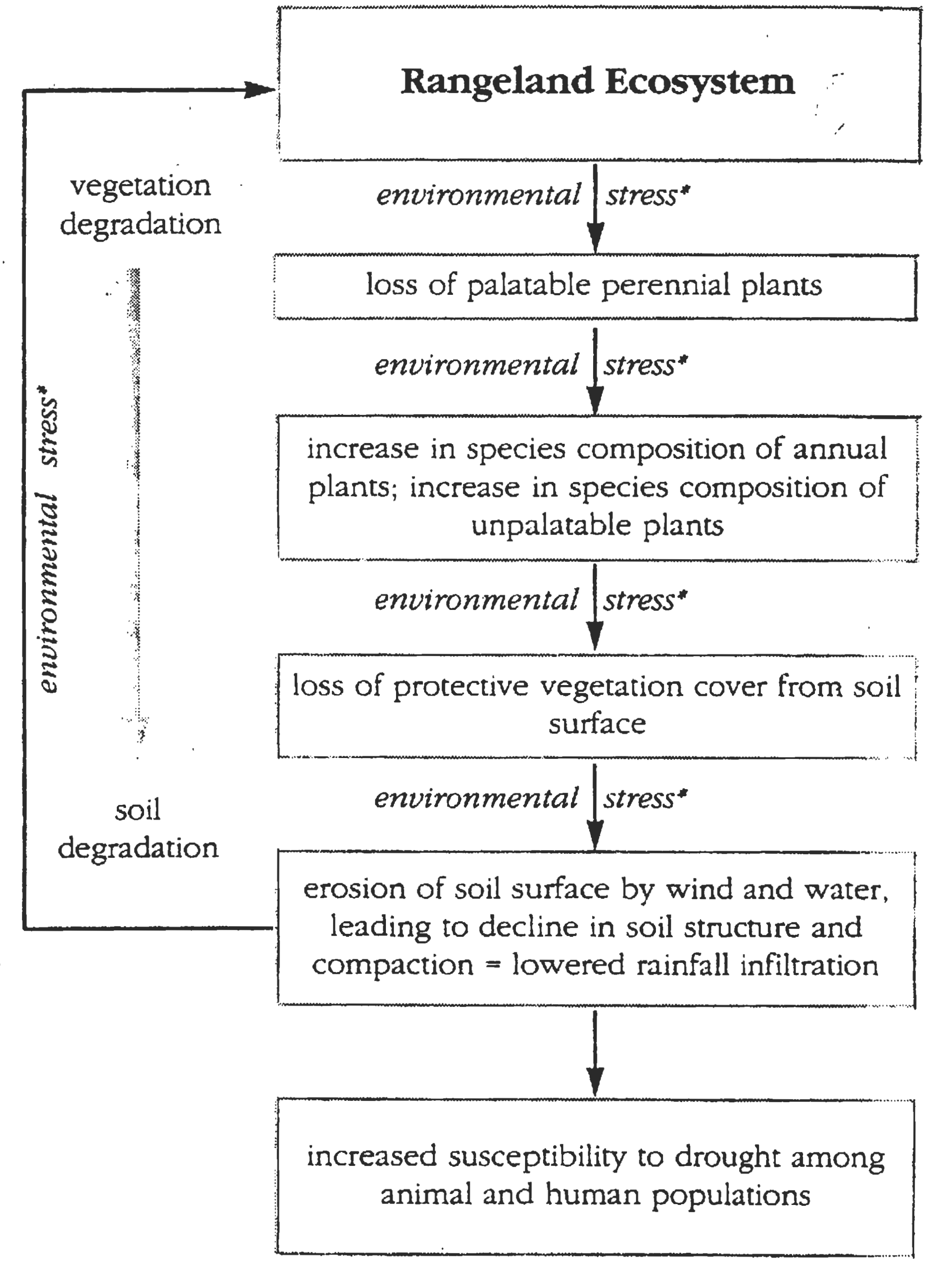
Fig 14
Sorghum in the Cropping System

4.2.1 System Characteristics

A pastoral ecosystem has three main components: people, animals and land. Land degradation leading to a reduction in the primary vegetative yield is the result of a major imbalance between animals and the land. Famine is the result of an imbalance between people and animals (the main means of pastoral production). This imbalance may be in absolute numbers of animals, their relative distribution, or their price relative to other commodities (Swift 1977). The monitoring of these indicators is an important component of Famine Early Warning Systems (FEWS 1999) as will be shown in section 7 (see fig 15).

Pastoral production systems depend on natural forage or "useful vegetation". "Useful rainfall" promotes vegetation growth. It is therefore rainfall which in effect drives the rangeland system. Constant or periodic movement in search of pasture is the underlying feature. Every herd must have access to dispersed, ecologically specialised and seasonally varied grazing lands and water resources, in order to provide for the varied needs of different livestock species, and to afford a margin of safety against uncertain rainfall. The best protection is access to extensive territory, preferably containing a regular supply of water (Scoones 1996). In the Somali pastoral eco-system, human and animal populations are kept in fluctuating and approximate relationships to each other and to the land by a variety of mechanisms. The major threshold limits are set by environmental controls. These include rainfall depth and distribution, drought severity and duration, spatial distribution of scarce surface water resources, etc. (Swift 1977).

Pastoralists mainly perceive their worst problems as being drought and insufficient livestock. Most try to promote rapid increase of livestock numbers between droughts and few attempt to limit numbers voluntarily (Sanford 1983). One reason is security against drought, for various reasons it is rational for herd owners to enter a drought with as many animals as possible, because the chance of a nucleus herd surviving is increased (Abel 1993).



(* e.g. drought or over-grazing)

Rangeland Degradation and Famine: an episodic and iterative process
Fig 15

Pastoralist societies are highly segmented, mobile and have a very low man/land ratio. Pastoral production systems cover large area of relatively unproductive drylands as well as smaller, wetter, more fertile areas. It is the use of wetter areas through the dry season that allows pastoralists to make use of the drylands in the rest of the year. Efficient use of the drylands depends on pastoralists ability to move herds away during the driest periods of the year before they become degraded. The nature of the pastoralists system thus depends on movement, and a relatively non-intensive use of the best land is necessary in order to make any use at all of the poorer lands. If, as is commonly the case, the most productive lands are the first to be converted to agriculture, and if the mobility of the pastoralists is curtailed, the production per unit of "wet" land may rise. However, production in the surrounding drylands will almost certainly fall and environmental degradation will almost certainly take place (IUCN 1989).

4.2.2 Pastoralism under Pressure

Development investment in the livestock sector has seldom been proportionate to its economic contribution: pastoralists are far more likely to be undermined than provided with support, whether unintentionally or not. It seems that nomads in the past were better able to cope, but that pastoralists are now suffering disproportionately in Africa. Rapid population growth, its spill over onto the rangelands, restrictions on migratory movements, alienation of land and the allocation of land for cultivation of crops, and the degradation of land that has been retained in pastoral production are making it increasingly difficult for herders to maintain their mobility. Without this mobility, pastoralists, sedentary agriculturists and even sedentary populations become vulnerable to food insecurity, or may become environmental refugees (IUCN 1984).

That dramatic, irreversible change has taken place in pastoral societies and lands during the last century is evident. In the face of such pressure the traditional practises that maintained such systems cannot, in all probability, be maintained. Pastoral societies will of necessity adapt to survive, and many nomads will cease the traditional way of life entirely. This should not be discouraged where improving the health and quality of life, (and thus improving access to safe water and sanitation in relation to internationally set goals (WHO 1992)) so rightly dominate the development co-operation agenda. But it is equally important to recognise that pastoralism is based on a relatively efficient system of resource management, and that its prevalence and "inherent successes" mark it as a viable production system in its own right. It is therefore vital not to compromise the strengths of the system through the application of inappropriate development co-operation models. It must also be clearly recognised that rangeland management is too complex an undertaking to be codified by outsiders and that pastoralists must be involved in determining the shape of future rangeland management, in relation to overiding development aims. Scoones *et al* (1996) have recommended that development be based on:

1. Recognising that pastoralism is, *de facto*, a viable and productive use of resources.

2. Establishing a better understanding of ecological conditions in areas in which it is practised.

3. Defining the productive capacity through appropriate, scientific modelling and assessment.

4. A careful examination of changing tenure arrangements and their effects, not just on converted lands, but on the whole pastoral system.

5. Establishing mechanisms for conflict resolution.

In particular new thinking on land use in non-equilibrium environments has placed rangeland resources at centre stage in the debate on appropriate tenure regimes for pastoral production in Africa (Benkhe *et al* 1993). Within this thinking the role of rainfall is critical.

4.3 A Synopsis of Non-Equilibrium Studies

The conventional notion of carrying capacity in range management rests on theories of plant succession, defined as orderly and directional process whereby one community of plant species replaces another (Stoddart *et al* 1975). Both succession theory (Clements 1916) and range management practice assumed that a single, persistent and characteristic vegetation, "the climax", would dominate a particular site (depending on the soil and climate of the site) and that the system would therefore be driven by equilibrium conditions. For many years ecologists and other scientists, especially those working in arid environments have questioned this theoretical construct. The dissension has led to the development of an alternative theoretical construct, the non-equilibrial hypothesis, to explain the dynamic behaviour of those dry eco-systems. Results from studies conducted in arid eco-systems in Africa and Australia over the past 20 years offer strong support to the non-equilibrial hypothesis (Ellis *et al* 1996).

There is a high degree of uncertainty in the behaviour of African dryland ecosystems. The most pervasive, source of uncertainty influencing African pastoral and agropastoral production systems is climate variability (Ellis 1995). This makes it difficult to predict the levels of production that the system might yield from one year to the next, or how ecosystem structure may change over time. Ecological systems that demonstrate this type of behaviour, are non-equilibrium systems, and are typified by non-linear or complex dynamics (Prigogene 1961, Holling 1973). Non-equilibrium systems, the complex dynamics they manifest and the resulting uncertainties, may arise because of amplification or positive feedback within the system, or due to external forcing. In the case of dryland ecosystems, external climate forcing is the primary cause of complex dynamics (Scoones *et al* 1996). Severe droughts devastate plant communities and decimate animal populations. Where droughts are frequent, population fluctuations prevent plants and herbivores from developing closely coupled interactions, ecosystem development and succession are abbreviated or non-existent, and ecosystems seldom reach a climatically determined equilibrium point (Ellis *et al* 1996).

A critical nexus in non-equilibrium ecosystem dynamics is the interaction of drought with mortality rates, reproductive rates and the generation time of resident organisms. If the generation time of herbivores is very long, as in the case of camels, then very infrequent but severe "killer" droughts could have large order consequences that might include transitions in ecosystem state. For sheep or goats, generation time is short and population recovery from drought is rapid. So a drought frequency/severity regime that would induce a long term shift in the interactions between camels and browse trees, might have a much more transient effect on sheep and goats and their forage plants. It might therefore be expected that with larger organisms, more severe but less frequent droughts would cause non-equilibrium dynamic response; whereas with smaller organisms, droughts of greater frequency and less severity might suffice.

Predicting the likelihood that non-equilibrium dynamics will occur in a particular ecosystem is thus a difficult analytical task. It requires a detailed analysis of drought patterns and the responses of principle plants and herbivores to drought. In the absence of these analyses it is possible to formulate some crude idea about were drought driven domains of uncertainty may exist, simply by exploring rainfall variability patterns.

Caughey *et al* (1987) analysed interactions between climate variability, plant production, plant species composition and dominant fauna populations during a multi year Australian study. Pasture biomass fluctuated by two orders of magnitude during the study and plant species composition changed dramatically with rainfall patterns. They concluded that strong rainfall variability, with a coefficient of inter-annual variation of 45%, induces a centrifugal, chaotic aspect to system behaviour. They proposed that the threshold to the system dynamics occurs when CVs exceed 33%. The effects of grazing on the system, although weak, induce an element of "centripitality" reducing the chaotic tendencies of the system. They also suggested that where CVs are below 20%, animal populations remain relatively stable and strong feedback will develop between herbivores and plants. The study thus describes the range of climatic conditions that may discriminate equilibrium from non-equilibrium environments.

Ellis *et al* (1988) synthesised the results of the South Turkana Ecosystem Project (STEP), a long term interdisciplinary study of Turkana nomadic pastoralists and their arid eco-system in northern Kenya and arrived at conclusions similar to Caughey *et al* (1987). In Turkana rainfall averages around 200-300mm per year with CVs reaching 60%. Droughts occur on average every five years; severe multi year droughts which decimate livestock occur about once a decade. The STEP study witnessed one such multi-year drought (1979-1980) where roughly 50% of monitored livestock herds died and over 20% of the population temporarily emigrated from the area. In contrast a single year drought (1984) caused no livestock mortality (McCabe 1987, Elis *et al* 1987).

Benkhe *et al* (1993) suggest that non-equilibrium dynamics may be exacerbated or damped, according to the dominant soil type. For example on fertile clay soils, levels of primary production are closely correlated with, and as variable as, annual rainfall levels. This instability results from a combination of adequate soil fertility, which induces high levels of plant growth when water is sufficient, combined with the poor water infiltration and retention capacity of clay, which severely limits plant growth when water is insufficient. Coarse but nutrient deficient soils show the opposite pattern (Dye *et al* 1982). Soil physical and chemical characteristics also influence the way in which different range types respond to grazing pressure, which will in turn influence the resilience of the system.

Abel (1993) developed a rainfall driven model that relates stocking densities in the Central Region of Botswana to their productivity and to the rate of soil lost from their range. He concluded that the costs of dense stocking, in terms of rate of soil loss, appear to be fairly low, in that reducing densities drastically results in only a small decline in the rate of soil loss. However the rate of soil loss is critically dependant on a threshold of vegetation cover, and that once below this the rate of soil loss increases exponentially. He concurred with Harrington *et al* (1984) who suggested that most land degradation occurs in the early stages of drought, when livestock density remains at pre-drought levels but the biomass of vegetation has greatly declined.

Coppock (1992) examined the implications of vegetation and pastoral dynamics on the equilibrium versus non-equilibrium patterns of ecosystem dynamics, through a study within the Borana plateau of the Southern Ethiopian Rangelands. The area is an important dry season watering zone and is thus a key resource focus of many other pastoral groups (eg. Gabra, Somali) beside the Borana. Annual rainfall is bi-modal and in excess of 400mm. Noy-Meir (1973) noted that systems having less than 400mm of annual rainfall are under abiotic control, and Coppock (1992) concludes that non-equilibrial dynamics will prevail in these instances. However, he also concluded that the semi-arid Borana system falls more within the realm of periodic biotic regulation with the frequent occurrence of equilibrium dynamics, and that drought pulses are the cause of temporal perturbations.

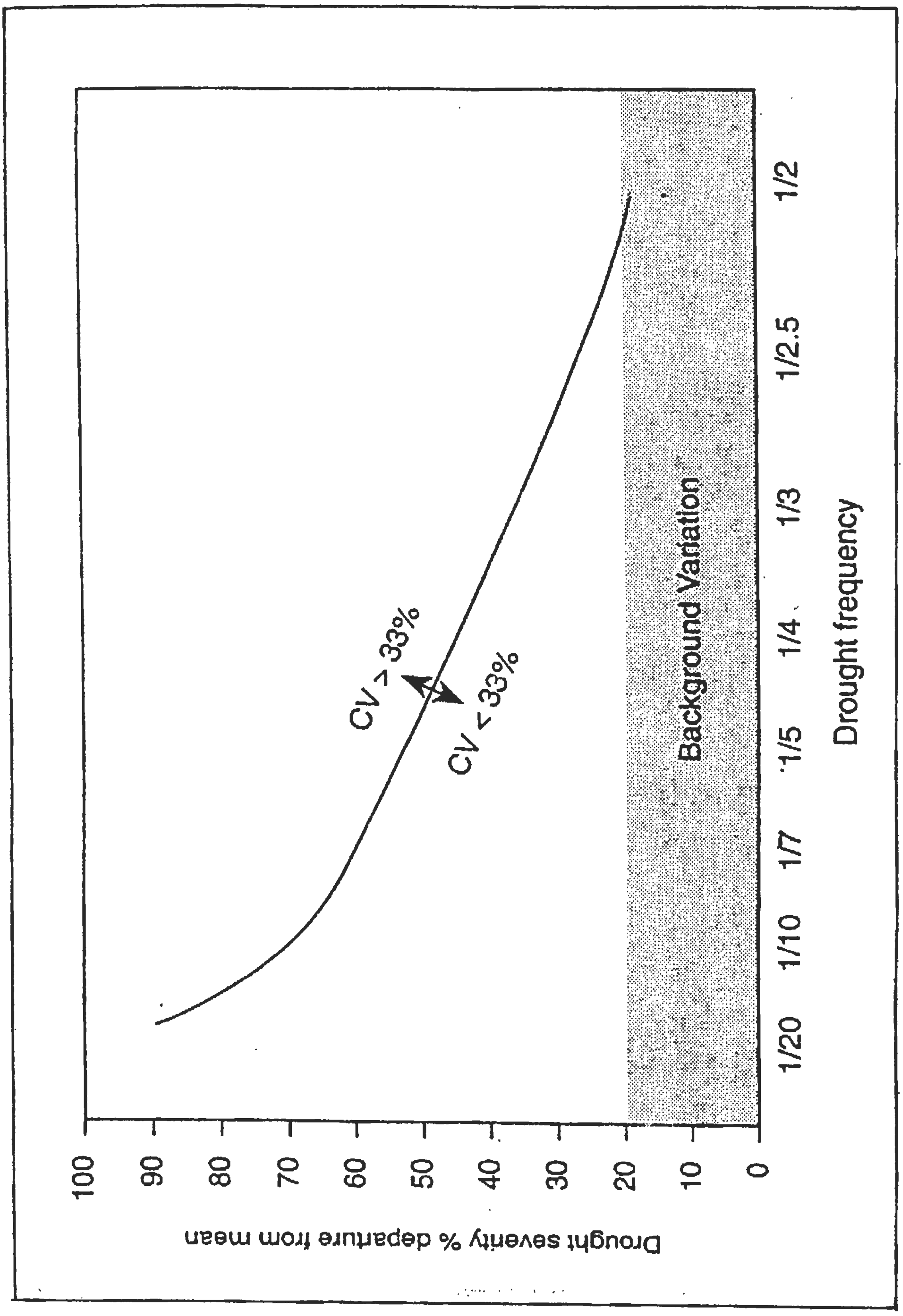
The STEP study and the Australian analysis provide clear evidence of non-equilibrium dynamics. In both cases CVs are high (40-60%) because droughts are both frequent and severe. But non-equilibrium dynamics may also become apparent at lower levels of variability so it is necessary to understand what the measure of rainfall variability implies about drought frequency and severity. Put simply **the**

coefficient of interannual variation is an integrated measure of the magnitude and frequency of departures of annual rainfall from the long term mean. Thus CVs of 33% may occur if positive or negative departures from the mean are frequent, but not too large, or large but not too frequent; if both frequent and large, then CVs may be as high as those observed in Turkana or Australia. In subsequent analysis Ellis (1996) developed a hypothetical relationship between drought frequency and severity for a threshold CV of 33% but recognised that the concept represents idealised values. (see fig 16 - here drought frequency is a return period value. The relationship implies that droughts are more severe the more infrequent they are in relation to a CV threshold curve defined (from unknown data sets) and that as CVs increase, for any given return period, drought severity will increase. In this case for a CV of 33%, a one-in-three year drought corresponds to a negative departure from the mean of about 40%, whereas a one-in twenty year drought corresponds to near 100% departure from the mean.

Our concern remains with droughts that are severe enough to cause mortality in herbivore populations by reducing plant production to the point where herbivore nutrition and health is seriously impaired. In fact experience from the Sahel (Ellis and Swift 1988) shows that very severe droughts may not induce herbivore mortality if the drought persists for a single year, whereas multi year droughts are often lethal. The most important criteria for drought-caused livestock mortality seem therefore to be the length of time over which large negative departures from mean conditions persist.

4.4 Long Term Rainfall Variations in the Sahel

Given the marginal nature of the region in terms of its rainfall amounts and consequent agriculture and pastoralism, any deficit in the primary resource of water has immediate and potentially disastrous effects. As part of the IUCN Sahel studies therefore a study of rainfall variations in 10 Sahelian countries was undertaken in 1988. The principle analysis was undertaken by the Climate Research Unit of The



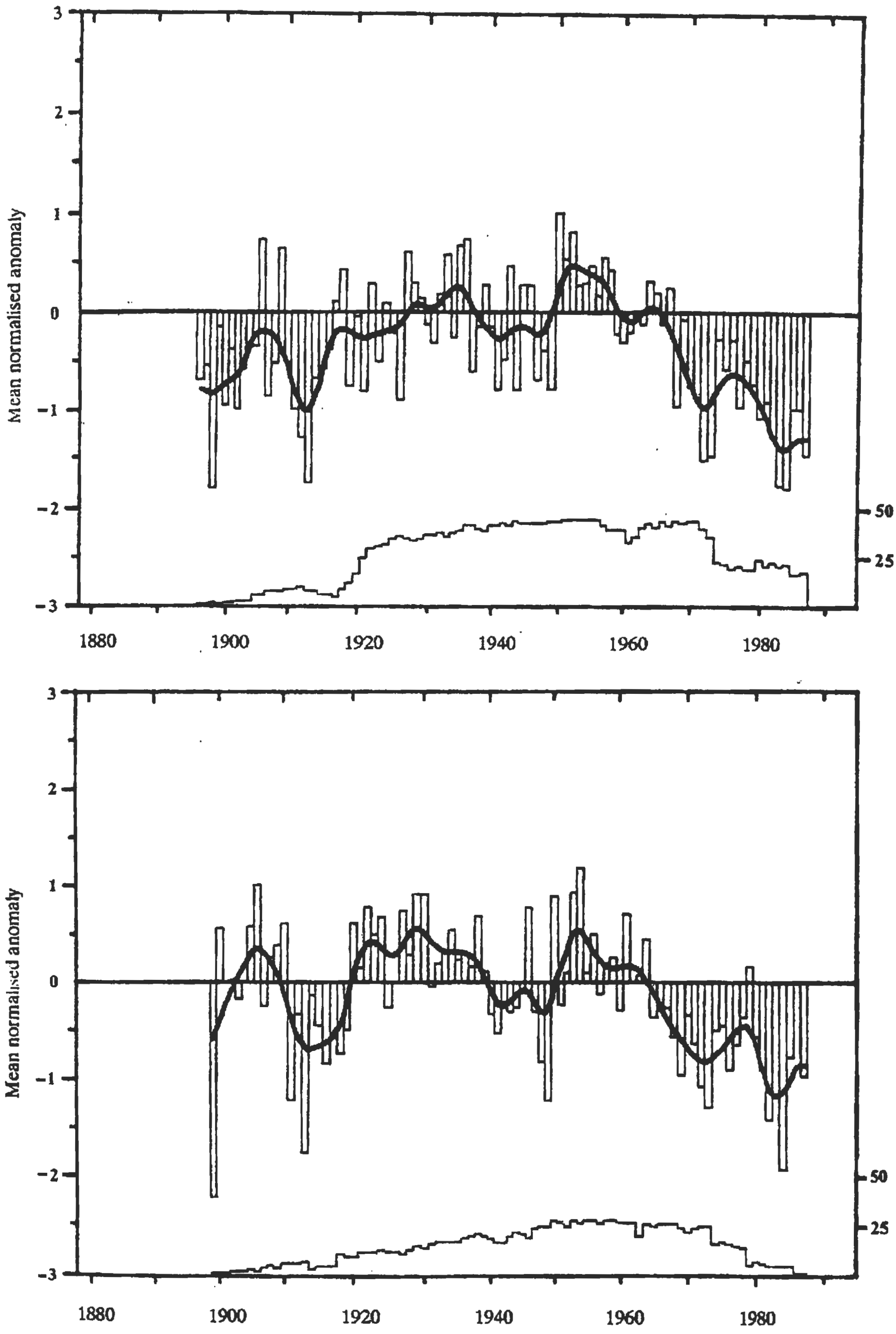
Hypothetical relationship between Drought Frequency and Severity
for CVs of 33%
Fig 16

University of East Anglia in conjunction with the Department of Meteorology, University of Reading, amongst others. By approaching these institutions it became clear that the study had not been updated with respect to Somalia, not really surprising since no reliable, long term data collection has been possible in the past ten years or so. The study therefore represents a useful leaving off point before the war.

The study was concerned with the period of instrumental rainfall measurement in the twenty years preceding 1987 evaluated in the context of variations since the late nineteenth century. Rainfall data was derived from a combination of sources, and confidence in the reliability of the data sets reached using spatial averaging to minimise errors, which were considered to be random in sign and to occur randomly in space and time (Farmer *et al* 1985).

Time series were derived from normalising data for each station with respect to the same reference period (1941 - 1970) and a spatial mean rainfall anomaly found by averaging the values of all stations. The period on which the mean and standard deviation were based was chosen as it was the most recent period with a wide geographical spread of available data. Regional time series were then derived for Western and Central Sahel (fig 17), with rainfall season runs chosen from May to October. Geographical boundaries between 10°N and 15°N for both regions, plus 20°W to 10°E for the western Sahel and 10°E to 40°E for the central Sahel were set. Those parts of Ethiopia, Somalia and Djibouti which lie east of 40°E were grouped separately due to the different timings of their rainy season and the different cause of rainfall.

An inspection of the series clearly shows the deficit years since the 1960s in both regions. Taking the western Sahel first it should be noted that the 1950s were generally wetter than the 1941-70 average and that this was also a period of increase in both human and livestock numbers. The early part of the century is also relatively dry, with only 1906 and 1909 being above normal in a 21 year period, but here the



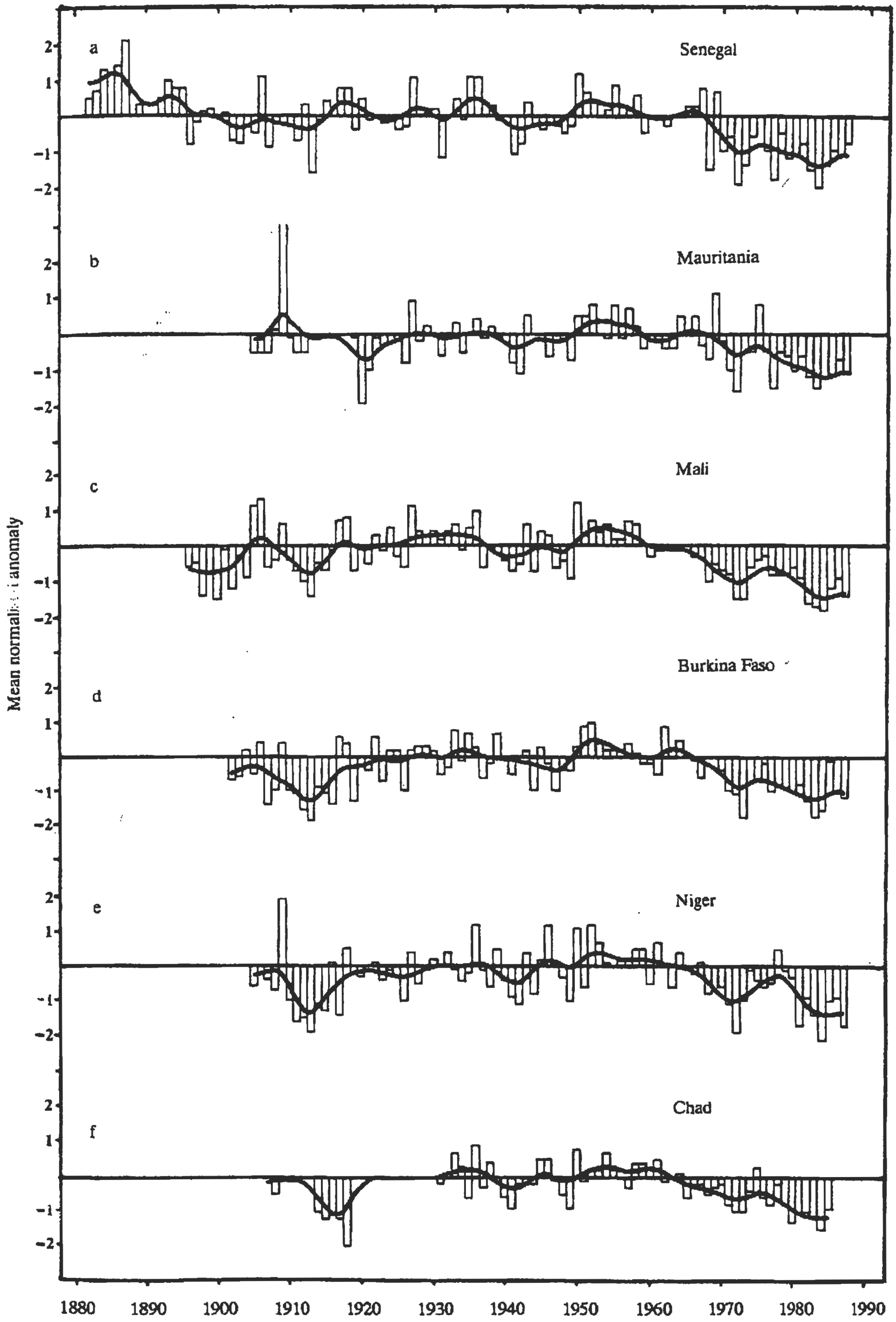
Mean normalised anomaly annual seasonal rainfall series for Western Sahel (upper) and Central Sahel (lower)
Fig 17

spatial average is based on a relatively small number of stations and must therefore be less spatially representative. The central Sahel also shows dryness in the early 20th Century, but for a much shorter period than in the Western Sahel (for a comparative study of the 1910s and 1970s drought see Bowden *et al* 1981). The late dryness in the region started earlier but is not as severe as in the Western case.

Fig 18 gives national series for the six most westerly countries of the region where the recent trend in dryness is clearly shown. In contrast Fig 19 shows rainfall series for Sudan, Djibouti and two seasonal series each for Ethiopia and Somalia. The network of stations from which the series derive have at least 20 years of data from which to form a mean and standard deviation within the period 1941-70. An inspection of the Sudan series shows much the same pattern as those countries further west. In the two series for Ethiopia the early *Belg* rains (fig 19b) are in contrast with the main season *Kirmet* rains (fig 19c). However, the correlation coefficient between the *Belg* and *Kirmet* series over the period 1881-87 is equal to -0.08, indicating no link or predictive capability from the early to the main season. For the Ethiopian data the spatial representativeness of the series is also questionable as there was known to be significant spatial variations in the drought-affected areas (Degaefu 1987).

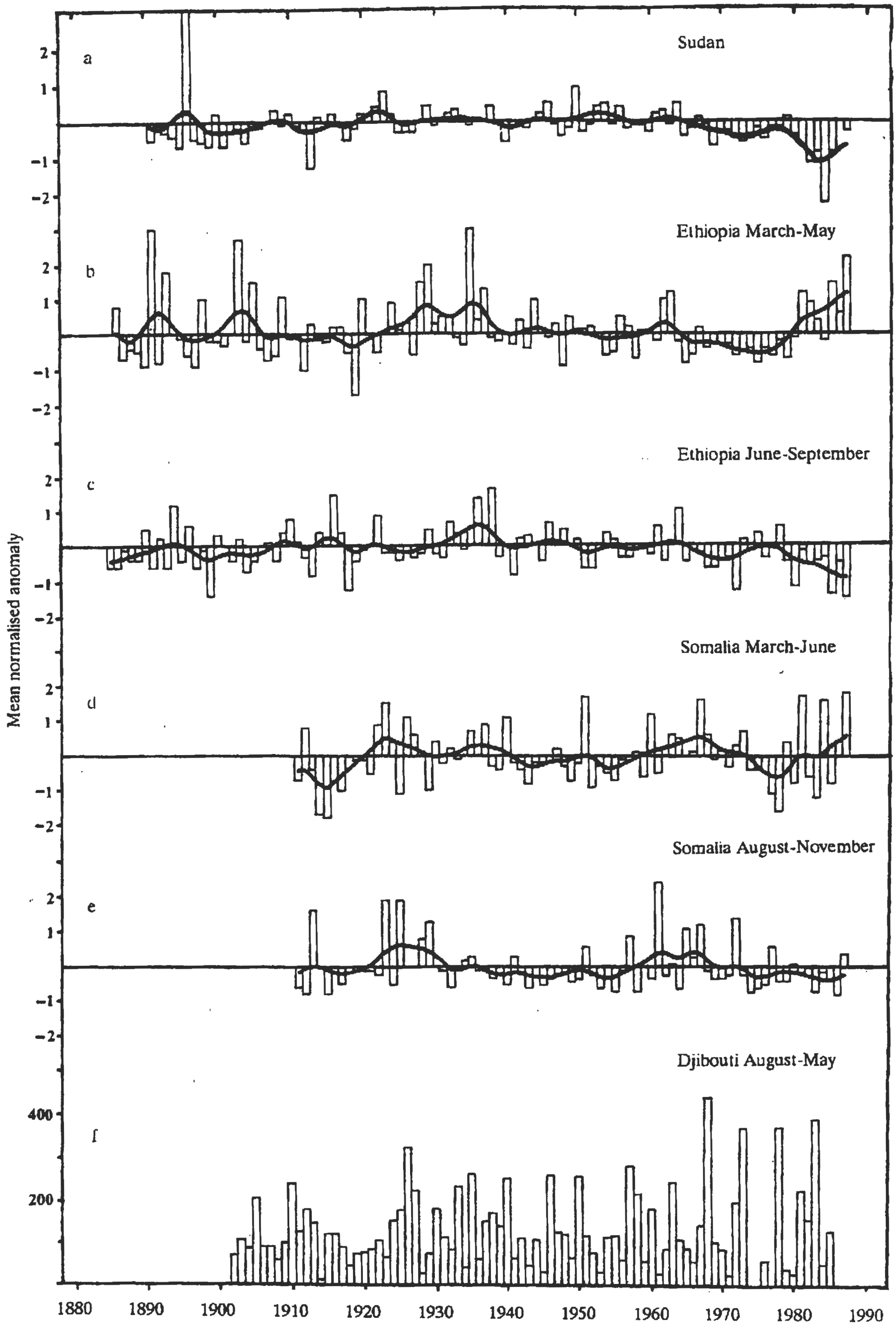
For Somalia neither of the rainfall seasons *Gu* from March to June (fig 19d) or *Deyr* from August to November (fig 19e) show the persistent deficits in the later years common further west. Flohn (1987) presents an analysis for southern Somalia for the period 1921 through 1977 and finds similar, temporally-stable rainfall series. However, the distribution of the *Deyr* rains suggests that the series is positively skewed, with few large and many small values. As can be seen there are no long prolonged periods of deficit or surplus from the long term mean.

The IUCN study of the intra-regional variations was not significant from the Somali perspective; it seems that only one Somali station was



Mean normalised anomaly, national annual seasonal rainfall series for Western and Central Sahel

Fig 18



Mean normalised anomaly, national annual seasonal rainfall series for Eastern Sahel
Fig 19

being employed in the study. In fact later IUCN Sahel Studies publications neglected Somali entirely, as the region slid deep into insecurity.

4.4.1 Correlation of Rainfall, Livestock and GVP

However, the rainfall series were later recalculated for a 1961-87 based mean period, and used in conjunction with a similar 26 year time series of an index of available soil water calculated by FAO to analyse the influence of rainfall on agricultural production. The correlation between rainfall deviations and deviations in Gross Value Product (GVP - which expresses in constant dollars the total value of all agricultural production for a given country in a given year) and livestock numbers are give in table 2 (IUCN 1989).

Region	**GVP & Rainfall**	**Livestock & Rainfall**					
	Yr0	*yr0*	*yr-1*	*yr-2*	*yr-3*	*yr-4*	*yr-5*
Western	0.51	-.05	.39	.53	.58	.43	.29
Central	0.48	-.28	-.09	.14	.45	.44	.33
Eastern	0.3	.22	.16	.15	.1	.32	.54

$\rho<0.05$ for r>=0.42

yr0, *yr1*, *yr2*, ... show correlation in the current year, last year, ..., etc.

Table 2. Correlations between normalised series for rainfall, GVP production (constant $) and livestock (millions).

The results show that correlation with GVP production are very strong in the Western Sahel, slightly less so in the Central Sahel and are barely statistically significant in the Eastern region. These correlations broadly conform with the conclusions of the climatic analyses above. The correlation between rainfall deviation and deviations in livestock numbers for the same year are completely different in that none are statistically significant. However strong lagged effects are clear in the Western and Central region, where livestock numbers are well correlated with rainfalls of three years previously. No such lagged correlation are seen in the Eastern time series, which is not surprising in view of the almost stochastic nature of the rainfall time series.

These lagged relationships between live stock numbers and rainfall are widespread throughout Africa and demonstrate the way in which livestock production systems damp out the effects of climatic perturbations. Livestock are clearly more susceptible to persistent droughts than short, sharp droughts (as was deduced in section 4.3). Crops however, always recover more quickly.

4.5 Drought Processes in Relation to the Sahel

As had been stated the essential feature of a drought is that it is tied to the idea of a deficit in the supply of moisture for some particular purpose. Abnormal low flows in rivers are generally experienced during any drought, their study being concerned with the statistical treatment and the understanding of the physical development of flows at a point along a river in the short term. By contrast the study of drought concerns the description of rainfall, river flow, soil moisture and groundwater over a season, year or several years and also of the spatial extent of the phenomenon.

4.5.1 Drought Persistence

There are processes within the hydrological cycle acting over all time scales that tend to maintain a drought once started. This is known as the persistence phenomenon. There are many who argue there is a tendency for drought conditions to persist over longer periods than can be explained by chance alone (Beran *et al* 1985) and that plausible hypotheses exist to explain both within and between year memory.

Attempts to quantify and test for persistence fall into two main groups:

The first uses sequences of annual rainfall or river flow data to compute the first order serial correlation coefficient. This is tested against the null hypothesis that the sample derives from a stochastically independent population (Yevjevich 1964, Brunet-Moret 1975). In the cases analysed by Beran and Rodier (1985) the conclusion is broadly that persistence as measured by this index is a relatively minor factor.

The second uses the statistics of runs, ie. the length of successive years of below or above average conditions. WMO (1966) and Clarke (1973) describe tests using random sequences on which to base the null hypothesis. Further studies tabulate properties of runs from Markov processes with various levels of serial correlation. A synopsis of results from Sahelian studies is presented in table 3.

Author	Data	Conclusion
Brunet-Moret (1975)	179 rainfall records in tropical North Africa	ρ_1 between 0 and 0.17
Sonuga (1977)	14 rainfall records in North Nigeria	ρ_1 not different from 0
Jenkinson (1973)	Sahel rainfall between 12° and 14° N	appeared random
Walker *et al* (1977)	Sahel rainfall in 16° to 18° N band	long runs found
Kraus (1977)	West African Sahel and India	long runs found
Chervin *et al* (1981)	Sahel/Soudano-Sahel	very long runs of 15 years

Table 3. Results of first order serial correlation coefficients (ρ_1) and runs analysis based on Sahel data sets

Beran and Rodier conclude there is more evidence of persistence in runs analysis than in serial correlation, and that the presence of long runs in data (eg. Walker *et al* 1977) is due to persistence that is manifest mainly in extreme years (thus accounting for indifferent ρ_1 values). This highly non-Normal behaviour thus invalidates conventional significance testing procedures. Katz (1978), using Kraus' data, showed that the range of values of areal rainfall in years following very dry years is considerably larger than that of rainfalls following very wet years. He concluded that persistence is of less note than intrinsic variability in developing an action plan for combating drought, and that *"rainfall records are more "noisy" than those of other geophysical variables. This applies particularly to regions which receive their water through convective storms. A few isolated perturbations can, and often do, produce transient excess precipitation locally without necessarily breaking a continuing drought. In general, the overall duration of a subtropical drought can therefore not be documented from the analysis of single station rainfall records. Streamflows are more suitable"* Kraus (1977). Beran and Rodier concur that the evidence for greater persistence in particular regions is not conclusive but that the persistence phenomenon is seen more clearly when regional rather than individual stations are employed. Thus although the causes of persistence are still speculative, there is much to support within and between year memory.

4.5.2 Drought Variability

Within all droughts there are areas that are particularly hard hit and others which are relatively spared. Space and time variations are bound to be present. For example river discharge, soil moisture and aquifer level deficiencies are not the same from point to point within the afflicted area, nor do the values of such variables remain at uniform levels during the drought.

Soil variability is a source of spatial heterogeneity. In different regions rainfall deficits on soils of the same permeability may not produce the same soil moisture deficits. Soil conductivities are also noted for their highly spatial and absolute variability (Butler pers comm). Differences in vegetation cover or the temporal or intensity variations of the rainfall will almost certainly differ from region to region. In the Western Sahel heterogeneity is thus studied along bands of constant climate and which slope relative to lines of latitude (IUCN 1989).

For active hydrologists, local events that are typical effects of spatial heterogeneity, can be gauged from their effects on small stream runoff. Beran and Rodier argue that such effects are apparent "mainly on small streams that are not commonly gauged". Where few streams are gauged it is usually more reliable to map rainfall data. Maps may portray rainfall depth or deficit in depth or proportional form, or alternatively may express the deficit in terms of probability. Rainfall deficiency analysis requires a sufficient number of good rainfall records and where the density of rainfall records is low, the contour map must be qualitatively completed by aerial observations of vegetation cover.

A contour map of runoff deficiency would differ from that of rainfall for two reasons;

1. Soil permeability influences drought severity because impervious soils can produce runoff from quite small intense rainfall events.

2. The time distribution of rainfall influences runoff, the more concentrated the rainfall the higher the proportion of runoff.

For example, in 1961 in Burkina Faso north of Ouagadougou the rainy season presented a significant global deficit, but two big storms accounted for the main part of the seasonal rainfall and thus the annual runoff on small basins was significantly above average. As a consequence on small streams the pattern of runoff deficiency contours does not in general follow those for rainfall deficiency, except where the pervious and impervious soils are randomly distributed, and the pattern of rainfall deficiencies is uniform. In runoff from large catchments, 100,000 km^2 and above, this source of heterogeneity is largely absent (Beran and Rodier 1985).

In order to quantify the spatial heterogeneity of drought the spatial correlation coefficient of monthly or annual rainfall is used, in particular the rate of decay of the correlation coefficient between the rainfall of satellite stations and a central station as the distance between the two increases. In the western Sahel Rodier (1960) showed that, although the influence of mountains is usually not so pronounced on total rainy season rainfall correlation decay rates, significant correlation may be found for distances of more than 3,000 km along lines of latitude. It was also observed that the correlations between stations in the Sahel, Tropical Dry Belt and Equatorial Zone are not statistically significant. However, between the North and South Tropical Dry Belts significant correlations are found. It was also observed that the spatial coherence is greater during dry years.

From an economic perspective the threshold of potential transhumance defines the scale at which spatial heterogeneity is beneficial; as the spatial variation generally allows some agricultural/fodder production to survive. The threshold value is scale dependent and will range under differing rainfall-vegetation regimes. It depends partly on the severity and persistence of a drought, in relation to variations in temporal and spatial vegetation production over time. It also depends partly on the coping strategy adopted by the herder during a deepening drought. A few areas with sufficient vegetation and water may allow part of the livestock herd to be saved. The recognition and understanding of sources and the extent of heterogeneity, in relation to "key resource patches" of water and vegetation, are important prerequisites of drought management and forward planning.

4.6 Managing Water Scarcity in Pastoral Environments

Of all the sources of conflict over natural resources throughout dry pastoral Africa, water - its abundance, location, and control - is perhaps the most highly emotive and politicised. Water resource developers have repeatedly ignored the socio-political significance of water and its critical influence upon pastoral decision making (Prior

1994). Often this lack of understanding has resulted in fatal conflict, destruction of pumping equipment, and intense pressure on the surrounding land. This process is well documented in Somalia (Prior 1994, ICRC 1998).

Conflict and/or co-operation over pasture, wells and surface water resources have long been part of the traditional pastoral dynamic. Where permanent water is scarce the spatial distribution of surface water resources becomes an important aspect of pastoral tracking strategies. Where rainfall is highly variable in time, space and depth, the harvesting of rainfall through surface catchments is an equally patchy subsistence strategy. Pastoralists typically exploit surface water through earth dams (*balli* in Somali - see plates 23, 24, 25) in areas of good pasture during the wet season and migrate to more water secure areas, along rivers or seasonal wadis (*tugga* - see plates 7, 8, 9, 11) during the dry season. In Somaliland, the importance of mobility and flexibility as integral to pastoral production, and the subsequent need to concentrate development on wet and dry season "key resource patches" of surface and shallow groundwater has been recognised (Print 1998). Drought proofing through improving the efficiency of key resource patches, rather than separating "normal" year development and drought relief programmes, typify this approach.

In Somaliland the seasonal pastoral migrations and the home wells of the various clans have been well documented (Hunt 1952). Where pastoralists rely on surface water harvesting, the length of time between the end of one wet season and the beginning of the next is critical. Dry season depletion rates of harvested water are related to pastoral supplies, and losses through evaporation, which are significant in arid lands. As the dry season lengthens cumulative losses increase, dams dry up and supplies have to be derived from fewer and fewer sources, until some threshold level is reached and migration is forced. Persistent droughts severely stress both wet and dry season resources.

Attempts to mitigate water scarcity in Somaliland led to the introduction of private surface water cisterns (*berka* - see plates 26, 27, 28) during the 1950s in the waterless pastoral areas of the Haud. It was mainly Somalis abroad sending remittances that paid for their construction. This led increasingly to sedentarisation when family members were left to manage them, and when seasonal trading camps became permanently established around the clusters. The result is a radius of restrictive grazing, as the berka owners remain within distance to ensure access to water. Whether this is a good thing remains an emotive issue. Before the war the National Range Agency discouraged *berka* construction in the rangeland, the rationale being that *berka*, located in low lying areas, rapidly drain water from a large area through purpose built bunds. This does not allow water time to seep into the soil to deliver nutrients to plant roots and sustain plant cover (NRA from FEWS 1996). On the other hand the comparative water scarcity of the area has greatly decreased, so the proliferation of *berka* retains the support of the majority of Somalis in the affected areas (VETAID 1997). In fact Ali concluded in a study of the Waqoyi Galbeed Haud that *"the traditional nomadic pastoralism is no longer treated as a sustainable system, at least not in the area under study. The trend is indicating a disappearing nomadic system being replaced by a new system based on sedentarisation of the once commonly owned rangeland"* (Ali for VETAID 1997). This sedentarisation process has been driven by attempts to solve the problem of water scarcity. How resilient such a system is, and how the area will respond to, and cope with, the incidence of severe and persistent drought remains to be seen.

MacFadyen (1952) saw the answer to water scarcity in Somaliland to be the supply of permanent water, through boreholes and other permanent groundwater wells. This is common to the Sahel. Well managed systems in times of peace can certainly be sustainable. However, in a climate of uncertain security seizure and control of a well by one pastoral group to the exclusion of others is not an uncommon ploy, and typically occurs when pasture is diminishing, at the end of the dry season or during a drought. It may also be used to claim not pasture as season or during a drought. It may also be used to claim not pasture as such but land. In Erigavo, Somaliland, the process of sedentarisation of nomadic communities and the consequent privatisation of formerly common rangeland resulted in opposing groups claiming the ownership of wells formerly in the public domain. The seizure allowed the controlling group to lay claim to lands within grazing distance of the wells. In times of conflict the seizure and defence of wells, even during the wet season when access to pasture is not a problem, is both an act of political will in the most traditional of manners, and a natural pragmatic response by pastoralists (Prior 1994). On the other hand, during drought permanent wells and boreholes often afford the only viable supplies and can be a focus of strong communal co-operation, and need not be viewed negatively (Farah 1996).

4.6.1 Boreholes and Land Degradation

There are probably more references in Sahelian literature to the barren areas around boreholes than there are boreholes in the Sahel. Few studies have approached the matter scientifically, to test the widely held belief that boreholes (and consequent settlement) act as a foci for desertification and degradation caused by overgrazing and the trampling of livestock (IUCN 1989). A definitive study was carried out by The Centre de Suivi Ecologique (CSE) in Senegal during the late 1980s. CSE analysed herbaceous production around 21 boreholes in 30,000 km^2 of North Ferlo, which had been used by livestock for 30 to 35 years. Each borehole was selected on the criteria of age (20 years) and distance from the nearest neighbour (25km).

For each borehole pixel values of the standing crop of herbaceous biomass at the end of the growing season were extracted along linear transects east and west of the borehole up to a maximum of 25km. The data was transformed to a percentage of the biomass at the borehole itself (0km = 100%) and averaged by distance east and west thus making all boreholes comparable. The null hypothesis that there is no detectable difference in standing crop of herbaceous biomass at the end of the growing season as a function of distance from the borehole, was tested by regression analysis of percentage biomass as a function of distance.

Here a statistically significant negative regression slope would indicate a fall in biomass production away from the borehole (thought typical of oases in very arid non-productive areas). Whereas a positive slope would indicate increasing production away from boreholes, thus lending support to the concept of the damaging impact of overgrazing in the vicinity of boreholes. In the event no regression coefficients over the study period were significantly different from zero. The analysis concluded that *"bare zones around boreholes are largely irrelevant, and to consider otherwise is likely to detract from the more serious efforts to improve land management in the Sahel"*. (IUCN 1989)

A further study was carried out by the Centre for Arid Zone Studies, University of Wales in collaboration with ACORD Mali based on well field studies in Gao, Mali between 1987 and 1989. Amongst other aims, the study assessed the relationship between distance from stock watering wells and the quantity of forage available and used by stock throughout the year. In general terms, at distances greater than two kilometres from established wells there was no clear relationship between distance and forage availability at any time of the year. The study concluded that overgrazing was evident at distances of less than 2km radius from any well due to stock movements to and from water. However, outside that radius customary patterns of livestock management took precedence over convenience of access to water, in the sense that pastoralists were well informed as to the whereabouts of good pasture and were happy to send stock long distances to take advantage of it.

The study thus also confirmed the view that bare zones around boreholes are largely irrelevant, due to the uncompromising scale, and patchiness of resources in the pastoral environment (Brown 1994). But it also suggests that a simple model of distance from well versus rangeland exploitation cannot be considered fully adequate. Certainly this makes sense where rainfall is normally variable and vegetation growth and herding patterns correspond. The heterogeneity of the system suggest that in these circumstances stochastic modelling of spatially useful rainfall, in relation to vegetation, soil characteristics, surface channel flow and pastoral movements in rangelands would probably allow for a more complete analysis.

However, both analyses are useful starting points and have been taken up by the proponents of non-equilibrium rangeland ecology, as proof of the resilience of African dryland systems. These studies are also important for the development of water resources in drylands since they confirm that boreholes and permanent water points continue to be a priority in areas where water is a limiting factor. Scoones *et al* (1994) and IUCN (1989) agree that the cost of bare "sacrifice" zones immediately surrounding each borehole is usually far outweighed by the benefits of more efficient fodder use and livestock populations.

5. Food and Water Security in Somaliland

Conditions and trends in Somaliland are similar (though not exclusively) to elsewhere in the Sahel. Urbanisation and changing land use patterns have led to environmental resource stress. For example, Hargeisa the capital has increased rapidly in size from 2,000 population in 1930 to around 280,000 in 1982 and may reach 650,000 by 2015 (Allport 1996). The water supply production of its well field at Ged Dheeble is well below Hargeisa's projected requirements, and suffers severe stress when drought conditions force temporary in-migration. There is an urgent need to conduct a water resource assessment that establishes the sustainable limits of the aquifer supply in relation to future potential demand, and that investigates other potential resources (Allport 1996). It is not inconceivable that, as elsewhere in the Sahel, the mining of groundwater resources will be adopted as the working solution to the city's water security needs, and that the root problem of water insecurity will therefore not be sustainably solved. Under these circumstances the engineer should take cognisance of the relative efficiency of deeply rooted pastoral coping mechanisms.

5.1 Livelihoods and Food Security in Somaliland

In Somaliland the nomadic population is still the majority, and was estimated to account for between 60 to 70% of the total population in 1992 (Holt *et al* 1992). Population estimates for Somaliland now vary between 1,100,000 (EC 1999) and 2,100,000 (Min of Planning 1997). Livestock is estimated as 1,400,000 camels, 375,000 cattle and 12,000,000 sheep and goats. A very rough estimate of annual pastoral stock watering demand can therefore be made (based on Elmi 1996)

People		1,000,000	5.5	M.cum
Livestock	Camel	1,400,000	2.5	M.cum
	Cattle	375,000	4.8	M.cum
	Shoats	12,000,000	7.5	M.cum
Total			**18.7**	**M.cum/pa**

Food security in Somaliland is always tenuous. Periods of turmoil have disrupted normal economic activities and trade. Somaliland's ports provide opportunities for trade with the rest of the world, but the dependence of the region's economy on the export of livestock make it vulnerable to events and decisions over which it has no control. Livestock and crop production strategies depend heavily on receiving useful rainfall at the right time, and periodic drought can create substantial hardship. The challenge for the people of Somaliland is thus to develop strategies for taking advantage of the available opportunities, while managing the risks associated with a harsh and changing environment. The challenge for development co-operation is to prioritise those areas that support economic and social development while mitigating adverse effects on the resource base.

5.1.1 Farming Systems

According to Alpman (1996) 13% of the total land area is cultivable of which approximately 10% is cultivated on a regular basis. FAO (1994) estimate the figure cultivated to be 3%. The majority of farming is opportunistic and rainfed, although more settled agricultural activity is common along the *tugga*, the groundwater used for irrigation being derived from alluvial deposits. The fertile juniper forests of the scarp at Erigavo mark Somaliland as the world's leading Frankincense producer.

In certain areas of the west and north east, which receive around 600 mm of rain per year, conditions are favourable for mixed farming systems, involving both crop production and animal raising (FAO 1994). More permanent cultivation is thus found around Borooma, Gabiley and Erigavo. The average yields for rainfed agriculture are among the lowest in Africa, attributed to poor soils and unreliable rains (Alpman 1996). Yields are highly variable in space and time, as uncertain rainfall supplements residual soil moisture. Crops fail in about 2 out of 3 years due to insufficient residual moisture. This makes estimation of the cultivated area, and definition of the growing season difficult (FEWS 1998). Sorghum and maize are the main crops, supplemented by khat and small-scale fruit and vegetable growing. The main markets are in Hargeisa and Berbera.

Elsewhere in Somaliland, in the coastal plains and the main plateau of the south and east, and along the border with Ethiopia, rainfall of 200 to 250 mm annually is insufficient for reliable crop production. It is however adequate, when well distributed, to provide pasture and water for camels, sheep, and goats.

5.1.2 Changes in Herd Management Strategies

As elsewhere in the Sahel pastoral systems have changed substantially over the past few decades. Many herders have shifted from subsistence to a market-based focus as they have been drawn further into the monetized economy. As herders sell more animals through the market, they exchange fewer of them through traditional clan-based redistribution arrangements.

Water management has also changed. Increasing investments in privately owned *berka* have allowed previously nomadic households to settle permanently, maintain herds, and even engage in limited agriculture in areas that had been too dry for these purposes. In many areas, increased availability of water has also encouraged the substitution of cattle (which are more lucrative) for camels (which are more drought tolerant) as the basis for livestock herds (Oxfam 1997).

These changes in herd composition have increased herders' income expectations, but they have also increased their susceptibility to the effects of drought. Camels can survive without water for 2 to 3 weeks and thus can take advantage of distant pastures. They also produce milk throughout the year, and their milk can last for a month before spoiling. Sheep, goats, and cattle need frequent watering and thus succumb more easily than camels when pasture and water are not easily available in the same area. At these times the trucking of water is common. The decline of the traditional mechanisms for exchanging and redistributing animals undermines a system that encouraged dispersion of grazing and provided for food security through a chain of reinforcing mutual obligations (FEWS 1998). It also undermines the rangeland condition as the patchiness of the vegetation cover is eroded.

5.1.3 The Case for Food Security Monitoring

Somaliland's movement to a market-based livestock economy has been accompanied by an increase in the consumption of purchased food, particularly cereals which are the principal source of food energy for the population, plus cooking oil, sugar and tea (Ministry of Planning 1997). In general, these exchanges work to the advantage of the herders: milk is a relatively high-value commodity, and the calorie content in cereals is about five times greater (by weight) than that in milk. Herders' increased reliance on purchased foods has, however, resulted in an increased risk related to changes in prices for the products that they buy and sell. The terms of trade between animals (and animal products) and cereals are crucial for the food security of herding families, particularly during the long dry season from December through March and during droughts (FEWS 1998).

In the face of drought risks and unstable markets, Somaliland thus needs a strong system for food security monitoring and disaster response. With the re-emergence of civil institutions in only the nascent stage after the long civil war, the government of Somaliland is under-equipped and under resourced to establish such a system. Although it has seen some marked improvement in the past few years, the Somaliland government has one of the lowest capacities of any such system in the region. Therefore, the added capacity provided by UN agencies, donors, and NGOs active in Somaliland will continue to be critical to the region's food security monitoring and preparedness effort (FSAU/FEWS 1998). Several UN agencies actively cover the region, a few NGO's have more or less permanent bases. Insecurity and the difficult environment have been known to interfere with these efforts (ACH 1999). An essential aspect of any Food Security Early Warning System is the monitoring of rainfall and vegetation, as will be shown in section 7.

5.2 Water Resource Problems in Somaliland

Water insecurity in Somaliland is a serious and consistent problem: war damage, insecurity and poor water resource management capacity exacerbate the aridity found in the environment. Since the war effectively ended in the North, the aid agencies have adopted a demand driven approach to improving the coverage, quantity and quality of water supplies. Validated statistical information on water supply is hard to come by. According to the UNICEF (1996), 62% of the urban population had access to permanent "potable" water, versus 34% of the nomadic population: 56% of the urban population had access to "safe" drinking water versus 4% of the nomadic population. Alpman (1996) reporting for the EU Somalia Unit was conclusive only in so far as he noted that "*...such figures are not easily nor accurately determined. The indigenous infrastructure and administration required to establish such data does not exist either. The frequent movement of refugees, returnees and the nomadic population further constrain any reliable estimation*".

In 1997 the Somaliland government produced its first development plan (Min of Planning 1997). In it the Ministry of Mineral and Water Resources concluded that "*The absence of rain during the dry season, from December to late March, is critical for the welfare of pastoralists and their livestock, especially for small ruminants and the women and children who tend for them. They need frequent watering and cannot graze far from the source of water. This is also true of sedentary populations in built up areas where there are no permanent natural wells nor other water retaining resources such as dams and underground concrete-lined tanks, which for the most part, in any event, don't last through a period of long drought. Deep boreholes, from which water can be pumped to the surface, provide a critical* *safety net in such strained circumstances. There were 145 deep boreholes functioning in Somaliland before the start of the civil wars in 1988. Currently 85, or 61% of these boreholes are no longer producing water either because they have been destroyed or crippled".*

This emphasis on groundwater development was again reinforced in the seminar held in Hargeisa as part of the fieldwork (see section 5.2.2 and Annex B). In it the Ministry of Mineral and Water Resources placed the emphasis on prioritising groundwater in answer to the problem of water scarcity in Somaliland, and stressed the importance of the provision of good quality water for the socio-economic development of the people of Somaliland. The Ministry of Environment and Rural Development on the other hand emphasised the importance of watersheds and surface water in the rangeland production system, where attaining the right balance in the spatial distribution of available water is of primary concern. The comparative benefits of the groundwater led, or surface water led, development paradigms in such circumstances need carefully working through.

In such instances the evaluation of historic data is useful. However three periods of turmoil, the second world war, the shift of power to Mogadishu at independence in 1960, and the recent civil war have resulted in the loss of published hydrological data and the total destruction of the indigenous archive base in Somaliland. The recent war has profoundly undermined the institutional memory of international programmes and the indigenous water based institutions. At present, no adequate description or plans of any water supply installation built in the country are available for inspection in Nairobi or Hargeisa, whereas such installations certainly exist, or have existed at Berbera, Borooma, Burao, Hargeisa, Hargeisa-Ged-Dheeble, Ainabo, Erigavo, Las Anod, Sheikh, Zeila, Gabiley, Buhoodle, etc.. This serious lack of baseline information compounds high levels of uncertainty in the planning and provision of water supplies at both the macro and micro level. In such circumstances the ideal of scientific precision is unlikely to be obtained, but the more complete the data of the past work, the better chance there is to profit in the future from both successes and failures. The need to consolidate the available published water resource studies and data for the region is now well established (UNDOS 1998).

5.2.1 Water Resource Development Co-operation in Somaliland

In terms of development co-operation Somaliland has reached a stage in the transition "from relief through rehabilitation to development" characterised as the grey area between rehabilitation and development (EC 1999). Given that the majority of water sector developments in Somalia and Somaliland are currently funded and implemented within EC programming, further analysis of the application of the guiding principles of development co-operation is warranted.

The EU priority areas for intervention are;

1. Rural Development; in particular livestock and environment.
2. Education.
3. Infrastructure that enhances the local economic base (including water supply).

We have seen that the focus of the EU development co-operation guidelines is built on demand driven needs and an adequate absorptive capacity of the host country. We have also seen that in Somaliland there is: a clear lack of data from which to plan; a clear need to reassess resources based on the uncertainty that lack of data brings to effective planning; and that the institutional structures remain comparatively weak.

In the Republic of Somaliland specifically, despite the publication of the first National Development Plan in 1997 (Ministry of Planning 1997), the absorptive capacity of the central government is not yet considered adequate to manage EC support for water resources development and management. This is partly a result of the political vagaries that surround an unrecognised nation, but also very much due to a basic lack of adaptive capacity and resources in country.

On analysis this failure of the EC to fully engage with the fledgling *defacto* government may thus appear paradoxical where needs are obviously so great. However, ignoring the problems that the political reality of extra-government support to an unrecognised state brings, dialogue is ongoing with Somaliland to determine ways to strengthen capacity as a precursor to any potential EC support. In any case development co-operation is currently negotiated and implemented under a model of Decentralised Co-operation (EC 1996). It has thus proved possible to work, successfully to a degree, within all four focus areas of programme activity (EC 1997).

Nevertheless we may conclude that the first logical programming step of a national development programme is to work towards the Focus Area "Water Resources Assessments and Planning", which should be given priority as a forerunner to other focus areas.

The activities of Water Resources Assessments and Planning as a focus area within the EU guidelines, have been devised to allow for macro-planning of water resources management (EU 1999). Recommended co-operating departments are seen to be:

- Water Resources.
- Environment.
- Planning.

Related activities that are designed to assess the availability of the natural resource, protect its quality and plan its use are seen to be

- Studies into land and water use patterns.
- Hydrological/hydrogeological studies.
- Data collection and monitoring systems.
- Drought/flood mitigation and control.

- Eco-system protection/conservation.
- Review of water laws and regulatory framework.
- Establishment of water standards.
- Conflict resolution concerning water use.

These guidelines were first introduced in the Somali context at a Strategic Planning Workshop held in Naro Moru Kenya in 1998. In Somaliland there is a unique opportunity to monitor the integration of the EU guidelines in an environment relatively free of constraints, in the sense that the recent problems provide a more or less clean slate from which to begin again the process of development co-operation. In fact a draft of the guidelines was widely circulated to the aid community in Somalia and Somaliland as early as 1997, two years before official publication.

The Naro Moru workshop in Kenya brought together 41 participants, comprising: senior officers of multilateral and bilateral donor agencies, key personnel of international and local NGOs, local and international consultants in the WES sector, a Minister and several senior officers in the Provisional Government of Somaliland. During it the development of a "Co-ordinated Strategic Framework for WES sector Development" was agreed, which has subsequently been adopted by the SACB. The emphasis is on a de-centralised community managed approach (see fig 20). The framework is intended as an integrated measure, which is being implemented through a series of 10 "major outputs" and some 53 "specific activities", to be undertaken over the five year period (EU 1999). It is not surprising that the first activity of the strategic framework *"1.1.1 Facilitate necessary water resources studies (social, hydrological, hydrogeological, etc.)"* is intended, in part, to redress the lack of data and institutional memory in the water sector in Somaliland (EU 1999). There are therefore clear signs, in the application of rhetorical commitment if not yet in terms of engineering transformation, towards a logical, systematic framework for redressing the balance of national water insecurity. Clearly this is contingent on the leading contribution and participation of the Somali people.

SUMMARY OF CO-ORDINATED STRATEGIC FRAMEWORK FOR WES SECTOR DEVELOPMENT

SUPPER GOAL

Health status, peace and dignity of Somalis are sustainably enhanced

OVERALL GOAL

Contribution of water and environmental sanitation services to promotion of health, self reliance, good governance and peace process in Somalia is increased

PURPOSES

1 Communities and households exhibit improved water, hygiene and environmental sanitation behaviour/practices (LONG TERM)

2 Water committees, Local Authorities and private sector enterprises effectively and efficiently manage water supplies and the environment in a participatory and gender sensitive manner and on a sustainable basis (LONG TERM)

3 Provisional Governments demonstrate increased capabilities to formulate policies, regulate, facilitate and coordinate water and environmental resources on sustainable basis (LONG TERM)

4 UN agencies, bilateral donor agencies, International and local NGOs demonstrate increased capabilities to facilitate Somalis to plan, implement and evaluate WES programmes/projects/ activities in an effective, efficient, co-ordinated, participatory and gender sensitive manner (INTERIM)

OUTPUTS

- **1.1** Availability of safe water at community and household level is sustainably increased in the currently under-served zones
- **1.2** Public awareness of proper hygiene and sanitation issues/ practices is enhanced
- **1.3** Availability of sanitation facilities/ structures is increased
- **2.1** Gender balanced community participation in WES projects/ activities is enhanced
- **2.2** Operation and maintenance of water systems is enhanced
- **2.3** Qualified private sector organisations and individuals are available for WES
- **3.1** Capacities of local WES institutions are strengthened
- **4.1** Co-operation and collaboration among stakeholders is increased
- **4.2** WES project cycle management is improved
- **4.3** Increased availability of funds for WES projects/ programmes is promoted

ACTIVITIES

1.1
- 1.1.1 Facilitate necessary water resources studies (social, hydrological, hydrogeological studies etc.)
- 1.1.2 Increase exploitation of underground water resources
- 1.1.3 Demonstrate economically viable rainwater harvesting technologies at household and community levels
- 1.1.4 Increase productivity and distribution efficiency of existing water systems/points
- 1.1.5 Promote improvement of safety of waterthrough: treatment, separation of human and livestock watering points, improvement of water - handling etc.
- 1.1.6 Promote protection of catchment areas/ watering points in collaboration with actors of other sectors

1.2
- 1.2.1 Identify and train teachers, women leaders and other appropriate agents e.g. CHWs, local artists etc.
- 1.2.2 Facilitate teachers to elaborate water, hygiene/sanitation curricula and support them to teach pupils and communities
- 1.2.3 Identify appropriate media/ channels and support creative, effective and efficient production, dissemination and evaluation of target group specific messages e.g. for the nomads
- 1.2.4 Reward schools, institutions, communities or even individuals for best practices

1.3
- 1.3.1 Facilitate participatory development of appropriate and target group specific sanitation technologies (including solid waste disposal)
- 1.3.2 Assist schools and other public institutions to erect new or to rehabilitate existing appropriate sanitation facilities
- 1.3.3 Demonstrate appropriate sanitation facilities/ technologies at household and community levels

2.1
- 2.1.1 Review strategy for promoting effective, efficient and gender balanced participation and contribution to WES activities
- 2.1.2 Motivate and facilitate communities to form or to strengthen water committees/ organisations according to strategy
- 2.1.3 Empower communities to identify and prioritise respective WES needs
- 2.1.4 Facilitate communities to participate in the planning, implementation and evaluation of WES projects/activities and to contribute according to strategy
- 2.1.5 Train and counsel committee members and selected members of communities in the technical, Managerial and social aspects of owned WES facilities

2.2
- 2.2.1 Review strategies for promoting increased O+M for sustainability of water systems
- 2.2.2 Involve contractors, suppliers, communities and, where applicable, employees of water systems in the preparation and adoption of standard equipment, designs and implementation guidelines
- 2.2.3 Improve quality of construction through training of contractors, selection of appropriate quality materials and increased supervision
- 2.2.4 Train managers, finance officers, operators, mechanics, maintenance staff etc. according to needs and strategy
- 2.2.5 Promote full cost recovery system
- 2.2.6 Motivate reputable traders to stock needed equipment and spare parts
- 2.2.7 Identify and train local mechanics/artisans and, where applicable, ordinary community members on maintenance and repair of installed equipment/systems

2.3
- 2.3.1 Review strategy for mobilisation and motivation of private sector to play increasing roles in WES
- 2.3.2 Identify, train and counsel reputable private sector organisations and individuals to become more effective and efficient providers of needed goods and services
- 2.3.3 Contract trained/qualified private sector organisations/ personnel to provide needed goods and services
- 2.3.4 Refrain from providing goods and services which are earmarked for private sector involvement

3.1
- 3.1.1 Identify deserving institutions and conduct participatory institutional reviews
- 3.1.2 Prepare institutions for policy formulation, regulatory, facilitation, supervisory and co-ordination roles
- 3.1.3 Assist institutions to develop appropriate technical and Management systems and to train selected staff for envisaged duties/roles
- 3.1.4 Assist institutions to formulate appropriate WES policies, by-laws, regulations etc. and advise on their respective implementation, evaluation and review
- 3.1.5 Link institutions to appropriate sources of funding, actors in other sectors and to relevant grass roots organisations e.g. village water committees
- 3.1.6 Advise institutions on appropriate revenue bases in collaboration with actors of other sectors
- 3.1.7 Support initiation of a bottom-up participatory integrated approach to planning and overall sector development

4.1
- 4.1.1 Conduct participatory reviews of technical and Management strategies/approaches and lobby for their application by all agencies
- 4.1.2 Convene co-ordination/communication fora and improve/increase co-ordination efforts
- 4.1.3 Compile a central data bank and disseminate data/information to relevant stakeholders in useable forms
- 4.1.4 Advocate for a more balanced distribution of implementing agencies (Local NGOs, International NGOs, private sector actors etc.)
- 4.1.5 Conduct joint (inter-agency) and participatory monitoring and evaluation missions and disseminate experiences and lessons learnt from all WES projects/ programmes

4.2
- 4.2.1 Intensify participatory project identification and planning according to participation strategy
- 4.2.2 Improve project preparation and design, using standardised technologies and guidelines
- 4.2.3 Introduce elements of environmental impact assessment in project designs/plans
- 4.2.4 Enhance participatory project implementation
- 4.2.5 Promote applications of appropriate technologies
- 4.2.6 Train project staff in technical and Management subjects according to needs and recruit qualified staff to fill existing gaps
- 4.2.7 Introduce improved project cycle management systems/instruments
- 4.2.8 Introduce participatory evaluation of projects/programmes
- 4.2.9 Ensure timely and effective backstopping of projects/programmes

4.3
- 4.3.1 Prepare project proposals which can attract donor funding and forward them well before deadlines
- 4.3.2 Utilise M+E data and appropriate media to:
  - a) lobby for funds from regional organisations e.g. IGAD,
  - b) lobby for increased funding of projects from within Somalia,
  - c) lobby for increased funding from abroad
- 4.3.3 Link Local Authorities to appropriate sources of funds and assist them to increase revenue bases for WES activities

Fig 20

Sustainability can only be achieved through their active participation in the rehabilitation process.

5.2.2 Report on a Seminar held in Hargeisa, Somaliland

Complimentary to this framework a seminar on "Water Resources and Natural Resource Management" was held in Hargeisa, Republic of Somaliland 21st and 22nd July as part of the dissertation fieldwork. The seminar was undertaken as part of the ongoing Somali Natural Resources Management Programme of IUCN and provided the best opportunity for Somali feedback on the study aims.

The seminar took the form of feedback from a series of short presentations on "Best Practice and Water Resource Assessment and Planning" and "Some General Aspects of Dryland Hydrology". A short group planning exercise was included. A full report is included in Annex B.

The presentation on best practice focussed on a review of documents and methodologies towards "Water Resources Assessment and Planning", in relation to the SACB - Co-ordinated strategic framework for WES sector development. The feedback was that the various related activities are relevant and useful to the Somaliland situation, but that the EU guidelines are generic and need adapting to the situation in Somaliland. Specifically the Agricultural Water Use and Management (AWUM) focus was seen as unsatisfactory because it does not take enough account of the water resource distribution within the pastoral economy that drives Somaliland (or for that matter Sahelian) drylands. Adopting the AWUM guideline to best fit an integrated and area focussed approach for the huge pastoral ranges of Somaliland was thus seen as a challenge. Specific guidelines for Somaliland will take time to develop at the institutional as well as technical level, but there is a lack of social adaptive capacity (Turton 99) within Somaliland to meet the standards implied in the EU guidelines without (paradoxically) sustained international assistance.

Through the presentation on "Some General Aspects of Dryland Hydrology" it was shown that the hydrologic system is in a state of dynamic evolution, with individual elements of the system characteristically displaying different time frames of adjustment. Surface water supply is an immediate reflex to rainfall and has supported the traditional, pastoral production system, but groundwater, which is seen as a pre-requisite for urban development and "drought proofing", is limited by geologic timeframes and very limited recharge. Conjunctive use of both resources was suggested as "best practice" and the most efficient long term solution to managing water scarcity. The hydrologic system needs to quantified so that the sustainable limits of the water resources can be worked out.

However data is the limiting factor and hydrologic data is severely limited in Somaliland. With relation to data on hydrological variables it was reported that:

i. **Rainfall**

Quantitative rainfall data is not readily available. The gauging network is being re-established but lacks co-ordination. Historical data sets are being reconstituted (FSAU/FEWS 99). Rainfall data is in any case application specific.

ii. **Evaporation**

There is very little data on evaporation, and little perceived need for it. Strong doubts by one participant, were cast on the validity of evaporation estimates in relation to *berka* water levels noted by Somali pastoralists (Farah pers. Comm. 99).

iii. **Runoff**

Runoff data is largely limited to archive material based on experimental catchments that no longer exist. Only in Boroona has a concerted effort been made to record runoff as a part of a Soil and Water Conservation project. Soil maps for the region are large in scale and little is recorded of infiltration rates outside experimental plots. However, many Somalis know well the characteristics of the soil, for example many farmers plough their field before the rainfall. There is a saying that the *"first rain is to quench the thirst of the earth"*.

iv. **Spates**

Spates in *tugga* are widely observed but have not been recorded since pre-war periods. Flood damage can be serious. Local storage conditions of the *tugga* and their wells are well known by Somalis. *Tugga* constitute an important dry season water reserve for pastoralists but concern is raised over the effects of expanding irrigated farms. A quantitative analysis would be of benefit therefore. Analysis of the *tugga* water resources was undertake before the war and should be re-evaluated in the light of current developments.

v. **Groundwater**

Groundwater development is seen as the province of the specialist, whether from the Somali or International Community. Reasonable historic data is available but monitoring of water levels is not ongoing and aquifer characteristics are not well known. Some geophysical investigation has recently been restarted and such investigation should include the practical training of Somali staff. Given the high cost of borehole rehabilitation/development and the low success rate, professional hydrological and hydrogeological investigation remains a top priority for the Ministry of Water and Mineral Resources.

vi. **Quality**

There is a good local knowledge of water quality, especially in relation to salts and solids. It is highly qualitative but is supported by limited testing by the international agencies (Caritas 1997). A thorough research was done of the regional hydrochemistry during the 1980s, which is widely available (Faillace 1986). Limited bacteriological testing is being conducted. Regional quality standards were recently developed (Caritas 1998) but are not yet "approved" or widely disseminated .

There is thus a mixture of strong qualitative observations at the local level and reasonable historic data sets that have been lost or dispersed by the war. The limited ongoing data collection is seen as valuable but problematic as it is not readily available for consultation. Qualitative estimates remain very important for Somalis (eg. they support the FEWS early warning system through a functioning field based communication system). Otherwise scientific data *per se* is seen as the province of the international community.

In summary consensus was reached in that:

- Data is fundamental to planning, monitoring and evaluating - "When you know what you have, you know what you can do".
- Data collection is not a Somali priority – not an understood concept.
- Historic physical water resource data is available but has been dispersed by the war. It should be recollected and made available at the local level.
- Some data recorded in the late 70s and 80s is anyway unreliable.
- Reliable ongoing data collection (eg. rainfall) should be reconstituted, provided that it is well co-ordinated and its benefit is apparent to Somali and International institutions.

In conclusion the seminar showed that there is a strong indigenous knowledge base of the regional hydrologic characteristics (this does not in general include groundwater), which is based on qualitative observation. It was agreed that there is a need to assess the available Water Resources accurately, if the sustainable limits of the resources are to be calculated, and that this requires a scientific approach that can be backed up by local knowledge. However, there are only a very small number of Somali professionals who have a good grounding in

Water Resource Development; they lack resources to support their skills and would benefit from retraining to bring them up to date.

5.2.3 Data Availability

Due to the scant information openly available it was recognised as useful to compile an authoritative bibliography on Water Resources in Somaliland. This could serve as a basis for further research. Also as a basic aid to the rehabilitation process when distributed through the SACB or UNDOS documentation centre in Nairobi, which is responsible for literature and data holdings in the absence of a recognised Somali government.

It is ironic that one of the difficulties in reviewing the literature on Somaliland Water Resource development arise precisely because many of the projects are undertaken with support from the international development agencies. Although project reports may be produced they are effectively inaccessible and unavailable to other agencies and individuals outside the project. In addition the objectives and results of these activities are rarely published. It seems highly unlikely that all the relevant data and reports will ever be centralised and available *en masse* to the interested party.

The bibliography is attached (see Annex A) and represents a list of known relevant documents of works undertaken in the pre-civil war period. Where known the location of at least one copy of each document is given. The bibliography has been pieced together from cross-referencing within the main documents studied during the dissertation, coupled with catalogue searches in the principle libraries and websites visited. The internet was also used to trace institutional links in search of data. The published literature in the bibliography probably represents a small part of the Water Resource Development that has been undertaken in the region. Although it covers the most important documents it cannot be considered to be exhaustive. The bibliography does not include a historical map index, which can currently be got from UNDOS GIS centre in Nairobi. Known sources of rainfall data can be found in section 6.1 below and Annex A.

The bibliography shows a distinct hydrogeological bias, partly as a result of the geo-referencing tools employed to research, and partly as a result of stringent reporting standards that are the norm in the physical development of urban and groundwater supplies. The separation of the bibliography into 48 general references including 17 area based geology/hydrogeology studies, plus 21 urban supplies are evidence of this bias. The bias of the bibliography agrees to a greater extent with the findings of the seminar.

There is also a bias to the North West region, or Western Somaliland. This is probably related to the relative strategic importance of the West in the regional economy, based on the markets of Hargeisa, the throughfare to Ethiopia and the port of Berbera. It is also due to the perceived agricultural potential of the North West based on reliable rainfall around Borooma and the abundance of *tugga*. Studies in the resources of the tugga systems are concentrated in the west (eg. Hawes 1951, SOGREAH 1983, MacDonald 1986). Although Erigavo is known as an area of equal if not greater agricultural potential no specific studies seem to have been conducted there. A large gap in coverage is therefore clearly evident in the central and eastern districts of Togdheer, Sanaag and Sool, including extensive areas of the most productive rangeland. The Halcrow studies (1980, 1982) of the Northern Rangelands are the only known systematic investigations since the protectorate period.

It is probable that further agriculturally focussed studies, which may include rainfall data, are likely to exist as an output of the Food Early Warning System project of the Ministry of Agriculture. The Ministries development co-operation with the FAO may also have yielded significant data but this requires verification, (eg. the Crop Production Systems Zone database of the IGADD sub-region does not include detailed information for Somalia, over 60% of the 500 indicators are signed "not available"). Similarly studies by WHO in the health related aspects of water resource development, by UNDP in the institutional/gender aspects and also studies specific to the Veterinary sector may exist. It is also likely that NGO operational reports, (eg. Oxfam or ActionAid) which are not referenced in the bibliography will be the most useful source of project information in relation to developing and managing community water supplies, due to the grass roots nature of their activities and their long term commitment in certain areas (eg. ActionAid in Erigavo/Sanaag). Unfortunately no management data on the operation and maintenance of urban supplies is recorded, a problem since it is from these records that lessons in the sustainability of systems can be learned and improved management systems adopted.

Significant data gaps are evident in primary data sources. Rainfall records, wadi flows and lithologic well logs would be extremely useful in contributing to our knowledge of physical and environmental conditions. In most cases this data is probably lost for good unless held outside of Somaliland in international agency project files. Secondary reporting is available in some documents however (eg. rainfall in SOGREAH 1983, lithology in Bao-sheng *et al* 1986). There are also gaps in secondary data sources. For example, information on soils is poor and no known soil map of the region has been produced, although SOGREAH (1983) did produce a 1:500,000 study in the West districts. The availability of more general data on livestock numbers, population census and movements would also be useful in correlating water resources with environmental and societal trends, in order to present an integrated model of regional development.

6. Water Resources and Resource Potential of Somaliland

It has been recognised that without good data sets and studies, the meaningful analysis of water resources and resource potential are severely limited. In the case of Somaliland (fig 21) comparatively little research has been done and data sets are either lost or dispersed. There is a need to consolidate the existing knowledge with further hydrological and hydrogeological studies.

It has been possible to trace and review a few key documents and some primary rainfall data. A review of these is presented below and, within reason, a description of the major water resource characteristics and potential thus proves possible. Although this covers the salient features it cannot be considered to be exhaustive, being limited by the extent of the information at hand.

Abbate,E., Sagri,M. and Sassi,F.P. eds (1993) **Geology and Mineral Resources of Somalia and Surrounding Regions. Part B Mineral and Water Resources** Istituto Agronomico per L'Oltremare, Firenze
Location: British Library

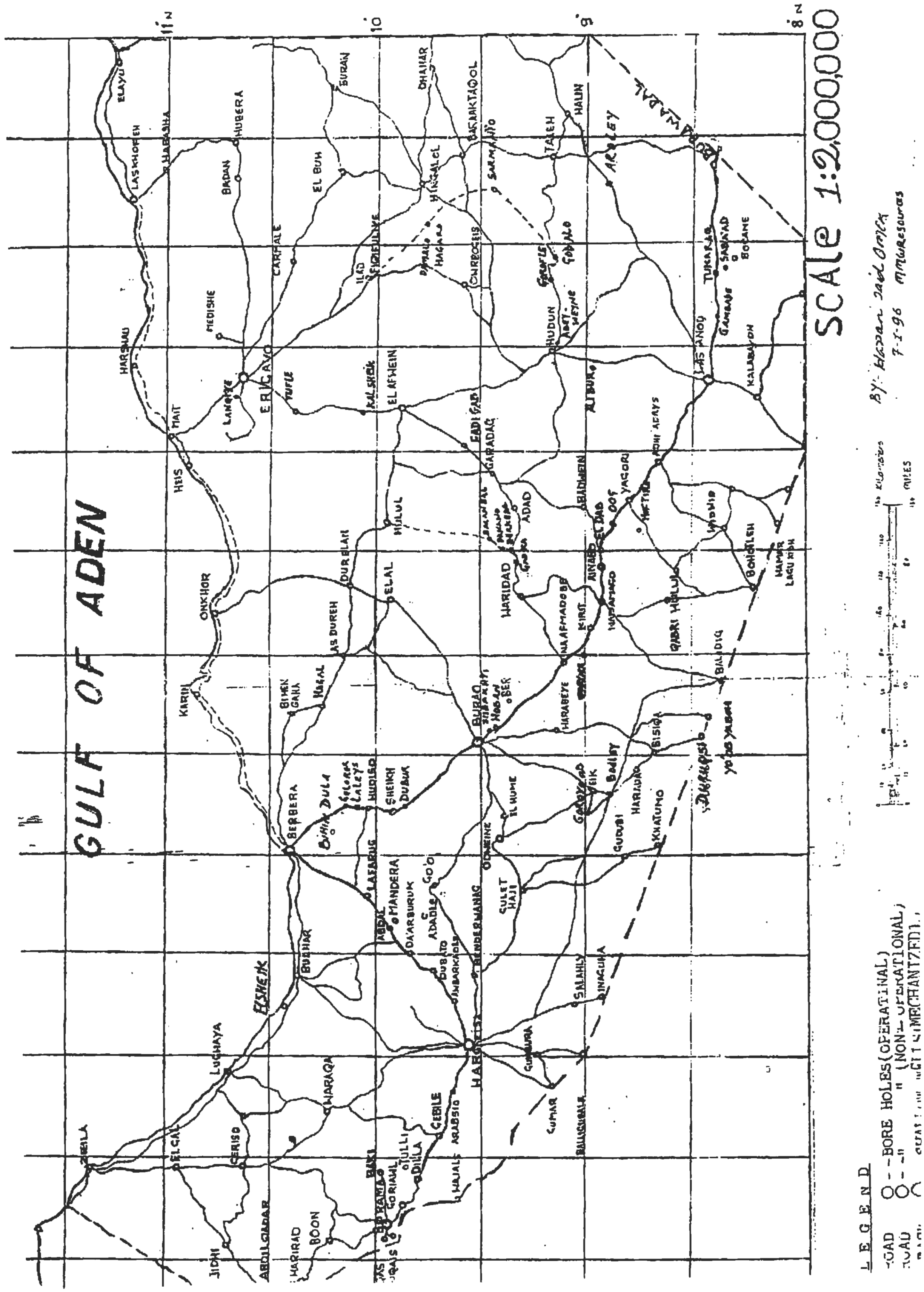
Alpman, C.G. (1996) **Technical Study for the Rehabilitation of the Water Supply and Sanitation in the Awdal, W.Galbeed, Togdheer and Sanaag Regions in Somalia** European Union Somalia Unit, Nairobi
Location: EU Somali Unit, Nairobi

Faillace and Faillace (1986) **Hydrogeology and Water Quality of Northern Somalia: Volume 1** GTZ
Location: UNDOS documentation centre, Nairobi

Hemming, C.F. (1966) **The Vegetation of the Northern Region of the Somali Republic** Proc. Linn. Soc. Lond., 177
Location: IUCN resource library

Howard Humphreys Consulting Engineers (1960) **Hargeisa Water Supply Investigation - A Report to the Crown Agents for Overseas Governments and Administrations** Colonial Development and Welfare Scheme
Location: SwissGroup Somaliland

Hunt, J.A. (1951) **A General Survey of the Somaliland Protectorate: 1944 - 1950** Crown Agents for Overseas Governments and Administrations, London
Location: British Geological Survey Archives



The Republic of Somaliland
Fig 21

Hutchinson, P. and Polishchouk, O. (1988) **The Agroclimatology of Somalia** Ministry of Agriculture/FEWS, Somali Democratic Republic (part complete)
Location: Somaliland personal loan

MacFadyen, W.A. (1950) **Water Supply and Geology of Parts of British Somaliland** Government of Somaliland Protectorate, Hargeisa
Location: British Geological Survey Archive

Mohamoud, M.M. (1990) **Sand Storage Dams in Northern Somalia (M.Sc. Dissertation)** WEDC - Loughborough University
Location: WEDC resource centre

Mott MacDonald Ltd (1986) **Water Resources of Wadis of Northern Somalia** ODA, London
Location: Mott MacDonald

SOGREAH Consulting Engineers (1983) (part only of) **Hydrogeology Report for Feasibility and Technical Assistance to the North West Agricultural Development Project** SOGREAH, Grenoble
Location: SOGREAH Grenoble

6.1 Rainfall Processes

The Horn of Africa is unique in that its coastline is the only tropical eastern coast of a major land mass not to receive reasonable amounts of rain. The "Somali Jet" explains why. Instead of the low level flow from the Indian ocean being allowed to cross into the interior of the continent, it is diverted by the highlands, and having rained over equatorial areas, it is dry as it crosses the Horn as an offshore, not onshore, wind (Hutchinson *et al* 1989).

Somaliland lies between 8°N and 12°N, entirely between the two subtropical anticyclonic belts. The movement of the Intertropical Front (ITF) and the Intertropical convergence zone (ITCZ) determine the succession of the weather seasons. In general the ITF is not as well defined as in West Africa and squall lines that are a feature of the wet seasons in the west and central Sahel are unknown in Somaliland (Griffiths 1972). Thus rain occurs not in association with synoptic or mesoscale features, but as pseudo-random showers within suitably moist air masses. The showers themselves are of relatively small dimensions, but since they originate from cumolo-nimbus development, may have distinct edges. Given that the clouds themselves are in motion with the winds, so that shower patterns on the ground are elongated, it is evident that there is a very high spatial variability on a daily basis.

Nevertheless, several mesoscale controlling features are in evidence, such as the coastline, the low level convergence caused by the Kenya-Ethiopia-Somaliland highlands, and the topography of the Somaliland highlands themselves. As a result distinct patterns are evident on a seasonal and long term basis.

The main weather pattern is controlled by the passage of the monsoon winds. The rains in Somaliland are thus bi-modal, The south-westerly monsoon brings the primary *Gu* rains in March or April. When it is not actually raining there is a strong wind which is general hot and dry. This period of the year has the most impact on both rain and wind erosion (Hemming 1966) and is followed by a lull of hot calm (*Hagaar*) and then a change in wind direction. The onset of the north-east monsoon marks the beginning of the short *Deyr* rains of August through October and the cooler long dry winter season (*Jilaal*). The length of the dry season and the start of the Gu rain is critical for pastoral movement, available water storage being adversely influenced by either a late *Gu* or a poor *Deyr* rain. Fig 48 (section 6.4.3) shows typical seasonal patterns for nine Somaliland regions.

6.1.1 Rainfall Data

In Somaliland, rainfall data has been collected since the turn of the century. The first rainfall stations were located in the coastal areas and spread slowly inland with time. The first recorded annual rainfall was in Berbera in 1905-06. Even then the extreme variability was acknowledged, the annual total was 199 mm of which not less than 122 mm fell within 24 hours of March the 22nd" (FCO Colonial Reports 1904-5). At independence in 1960 Somaliland inherited a functioning though basic network. After 1960 some of the old stations were strengthened but by the late 1980s the hydrometric network collapsed. It is only since mid-1995 that rain-gauges have returned to Somaliland.

There are not many studies dealing with Somaliland. Between 1944 and 1950 a basic meteorological study was conducted, as part of the "General Survey of the Somaliland Protectorate" (Hunt 1951). About 50 posts were set up during the course of the study, of which 20 were maintained for the whole seven years. The available data is reproduced in Annex C. The average rainfall maps are too reduced to be of use. The study was useful as it integrated earlier data sets (ie. 1906-1939 from MacFadyen 1951) and set the national averages and spatial set that became the basis of most mapping from that time on. Humphreys (1960) studied annual and monthly rainfall based on observations from 1944 to 1958 at Hargeisa airport and from an experimental plot at Dagahkureh approximately 30km away. Hemming (1966) interpreted the Humphreys data and produced a rainfall map based on Hunt (1951). Griffiths (1972) used Hemming figures to produce a variation on this map for the World Survey of Climatology. Unfortunately all primary sources of data (ie daily records) from this historical period are reported missing, except for daily series for Hargeisa (1943-1960) and Berbera (1908-1950) that are available from the Met Office and are analysed here (see Annex C).

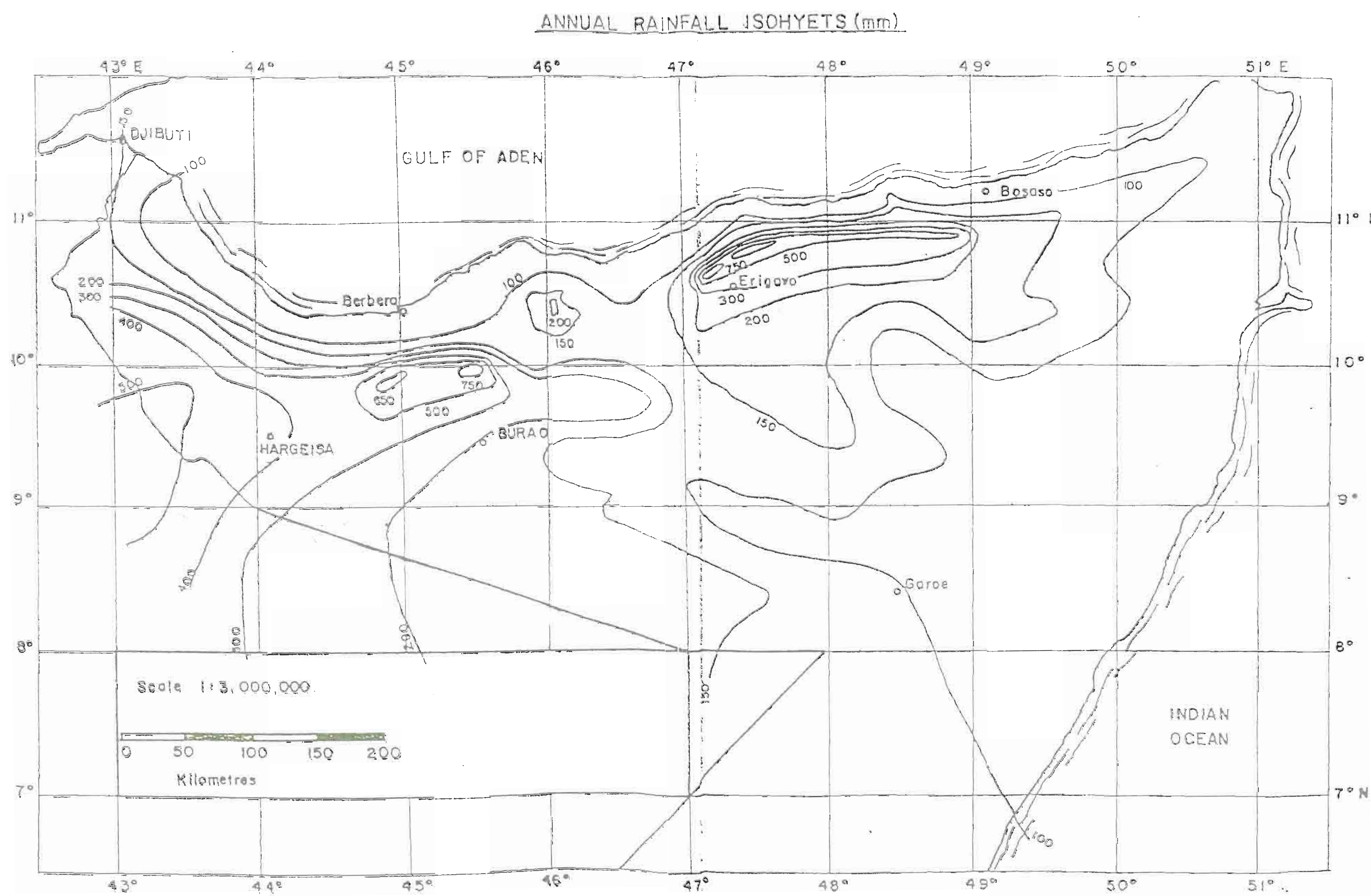
Rainfall was recorded across Somaliland from the 1960 until the late 1980s but the data is difficult to trace and the sources difficult to verify because so many different agencies were involved. It is known that the Somali Department of Civil Aviation, the Somali Rangelands Schools and the Ministry of Agriculture Food Early Warning System recorded rainfall. The Climate Research Centre of the University of East Anglia (CRC UEA) and FAO both hold databases of monthly rainfall extending to 1988 but it is not known from which primary source the data is derived. With no known central co-ordinating agency in Somalia at that time, there is thus a problem of validating these "approved" databases with the actual primary sources. This is certainly the case where separate agencies have run stations in the same locations in name (Halcrow 1980).

SOGREAH (1981) examined the available data in Mogadishu, and themselves installed about 14 gauges in western Somaliland. They produced a climatology for the North West including all available records. In 1988 the Somali Ministry of Agriculture Food Early Warning System published "The Agroclimatology of Somalia" (Hutchinson *et al* 1988). According to the text meteorological records were to be published separately; it cannot be verified if they ever were. For Somaliland Hutchinson *et al* (1988) drew on Hunt (1951) and integrated (unknown) data from the post independence period. Statistics on average conditions, and the inherent variability were produced.

6.1.2 Analysis of Available Information

Isohyets of mean annual rainfall have been compiled by Hemming (1966) based on Hunt (1951). Halcrow combined Hemming with Doorenbos (1977) to produce fig 22. Faillace (1986) has adapted Resource Management and Range (RMR - unknown data) to produce fig 23. Significant differences in the figures should be noted. Faillace (1986) indicates that the zone north of Erigavo to be the wettest, with 1100mm of annual rainfall. However, records at Daloh (2050m) just north of Erigavo for 1945-1950 (Hunt 1951) show the lowest value to be 45mm in 1945 and the highest to be 1276mm in 1949. The six year average is 751mm/year which accords with fig 22. The higher values given by Faillace-RMR (1986) thus seem too high if based if Hunt (1951) alone.

In both cases annual rainfall increases with altitude. Thus there is a ridge of high rainfall lying parallel to the coast, which is not continuous, being dependant on the topography of the scarp. Based on Hunt (1951), Hutchinson (1988) produced a relationship between rainfall and altitude; rainfall increasing with altitude at a rate varying from 7mm/100m, to about 40mm/100m at higher levels. Faillace (1986) summarised the available data sets up to 1982, which indicates the overestimation of RMR, and seemingly invalidates his own findings.



Annual Rainfall Isohyets (source Halcrow 1980)
Fig 22

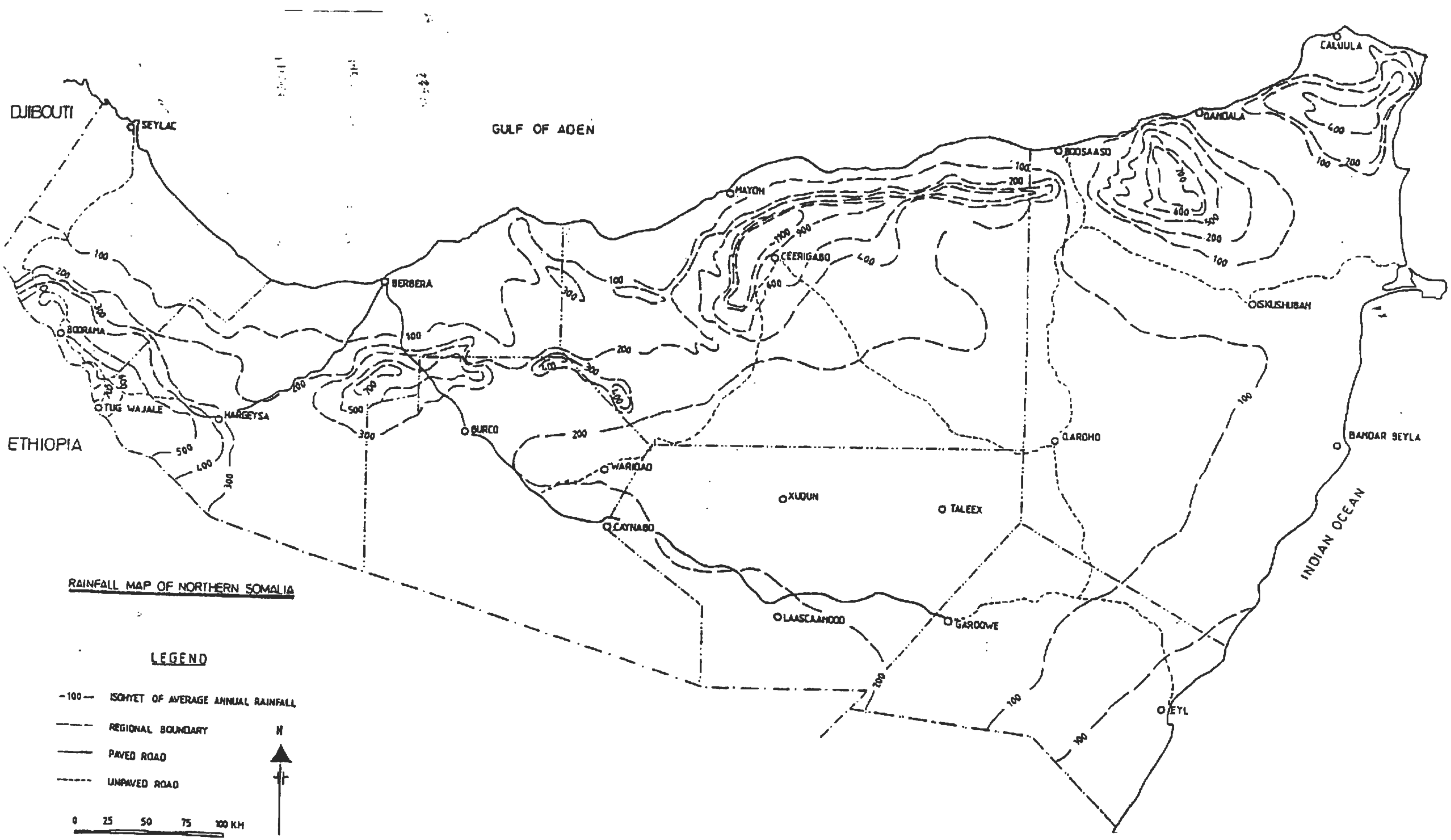


Fig 23
Annual Rainfall Isohyets (source RMR)

The mean annual averages of stations with over 10 years of record are shown in table 4.

Station	Elev.(m)	Years Record	Mean Annual Rainfall (mm)	CV(%)
Zeila	1	24	93	81
Berbera	8	44	57	86
Silil	70	14	129	76
Las Anod	700	18	163	71
Burao	1040	31	186	68
Hargeisa	1370	50	429	35
Sheikh	1430	34	523	22
Borooma	1450	38	508	25
Erigavo	1740	27	314	51

Table 4. Rainfall Records for Somaliland up to 1982

Hutchinson (1988) derived a relationship between the inter-annual coefficient of variation based on the mean rainfall - R:

$$CV = 0.94 - 0.00136 \times R$$

CVs have been calculated for Faillace's (1986) data. The figures accord well with the map of the coefficient of variation for Somalia presented by Hutchinson (1988) in fig 24. He observed that stations in the North West (ie. west Somaliland) have lower variability compared to other areas in Somalia with similar rainfall regimes. However, compared to other tropical areas with similar rainfall regimes the range of coefficients found in Somalia is high. Elsewhere in the Sahel CVs are around 20% and approach 30% only when rainfall is less than about 250mm annually. Gommes *et al* (1994) agree that the national CV averages for Somalia are among the highest in Africa and conclude that it is the high variability, rather than the low absolute rainfall amounts, that introduces high elements of risk to land use activities.

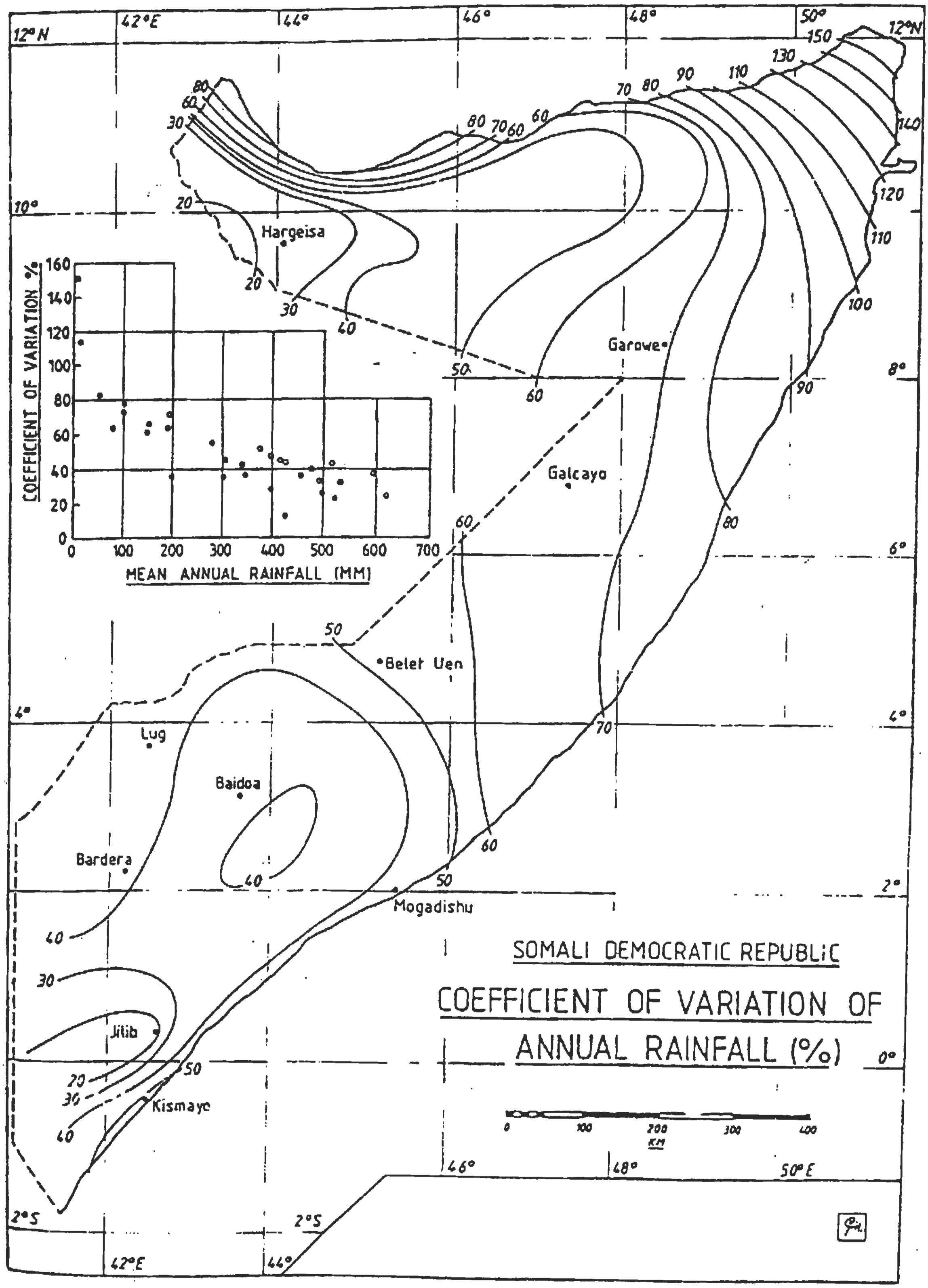

SOMALI DEMOCRATIC REPUBLIC
COEFFICIENT OF VARIATION OF ANNUAL RAINFALL (%)
COEFFICIENT OF VARIATION %
MEAN ANNUAL RAINFALL (MM)
Hargeisa
Garowe
Galcayo
Belet Uen
Lug
Baidoa
Bardera
Mogadishu
Jilib
Kismayo
KM

Fig 24

Analysis of the CRC UEA Hargeisa data (Annex C) shows monthly variability at a point source. Monthly CVs vary between 53% for September and 336% for January and reflect seasonal rainfall patterns. The average CV over the annual series is 31%, similar to Faillace (1986) and more or less at the threshold of the non-equilibrium state.

A full analysis of the spatial variability of within year rainfall in Somaliland would be useful, but lack of data presently inhibits it. High spatial variability has been recorded within a short distance in Hargeisa. For example, SOGREAH (1981) report that in 1980 the two Hargeisa gauges, in the town and at the airport, although less than 5km apart, gave very different results (322 mm against 193 mm), which cannot be attributed to reading errors since the same discrepancy is found for daily rainfall figures. Hunt (1951) set three gauges in Hargeisa as part of the General Survey which recorded 542mm, 400mm and 447 mm in 1947, 397mm, 305mm and 284mm in 1948 and 280mm, 281mm and 285mm in 1949. Within year spatial variability ranges significantly, in accord with the cloud-precipitation process.

The extent of the spatial variability is useful to know when trying to validate spot gauge rainfall series. For example annual and monthly data for Hargeisa are available from SOGREAH (1980), Hunt (1951), the ex-Somali government (British library abstracts) and the CRC UEA amongst others (Annex C). Between the two major series (SOGREAH and CRC UAE) there are discrepancies clearly shown in 1950, 1951, 1952, 1953, 1958, 1966, 1968, 1969, 1970, 1973, 1974, 1975, 1977, 1978 and 1980, but agreement on all other years from 1921 to 1980. It is highly probable that in some years the rainfall is recorded from the same gauge (eg 1921 through1938) and other years not (eg. CRC record 207mm for 1980 vs. 322mm and 193mm of SOGREAH). This does not invalidate any statistical approach towards design rainfall from any of these data series but does limit confidence as errors are bound to compound. It also limits the usefulness of trying to rehabilitate historical data series. These limits support the subsequent development of spatially integrated and temporally averaged estimates that have been the products of remote sensing applications, by way of smoothing out the data (see section 7).

Inter-annual variation series have been plotted for Berbera (fig 25) and Hargeisa (fig 26). From the annual series for Berbera the CV has been calculated as 76%, which is 10% lower than that derived from the Faillace data. The plots show the magnitude and severity of droughts. In Berbera the distribution shows that the series is positively skewed with few large and many small values. Below average conditions persists from the mid 1910s to 1920s, and from the mid 1930s to 1940s. A very wet year is recorded for 1908, derived from significant 24hr rainfall of 132mm/24hr, a return period of more than 1:60 years In Hargeisa the distribution appears more normal, extremes are more or less equally evident both above and below mean conditions. Persistent deficits are evident in the early 1950s and in the early 1970s, which is known also from Hunt (1951) and Andrzejewski (1975).

Fig 27 and 28 for Hargeisa shows *Gu* and *Deyr* rain series normalised over the period 1941-1970, in an identical way as the IUCN Sahel studies series shown in figs 17, 18 and 19. Although based on a single gauge, and therefore not regionally representative, a direct comparison of the two seasons in relation to the IUCN series is possible. In both Hargeisa series the distribution suggests that the series is positively skewed with few large and many small values. This is more pronounced in the *Gu* series although extreme wetness is more common in the later years. In the *Deyr* series the deficit in the 1970s is clear, corresponding to an inter-annual extended dry season and the persistent inter-annual drought "*Dabadheer*" that struck Somaliland at that time.

Daily time series for the primary Hargeisa and Berbera data (ie. Met-Office records) are presented in fig 29. The statistical properties of the daily rainfall are presented in Table 4 and 5, derived from the Onof (1997) program. This is simply to get some sense of the shape of rainfall events on a reduced temporal scale. First and second order

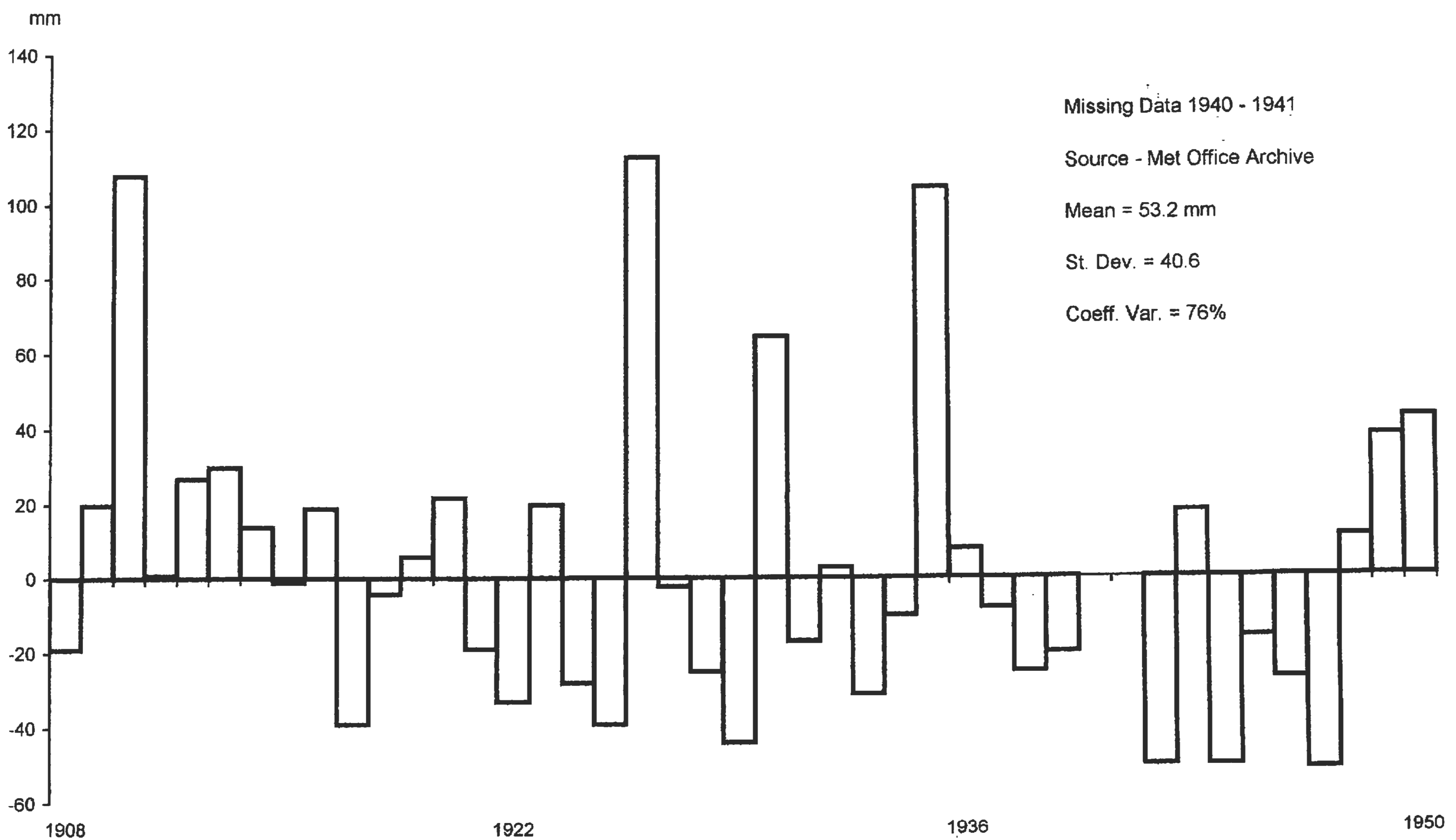


Fig 25. Rainfall Inter-annual Variation - Berbera 1908 - 1950

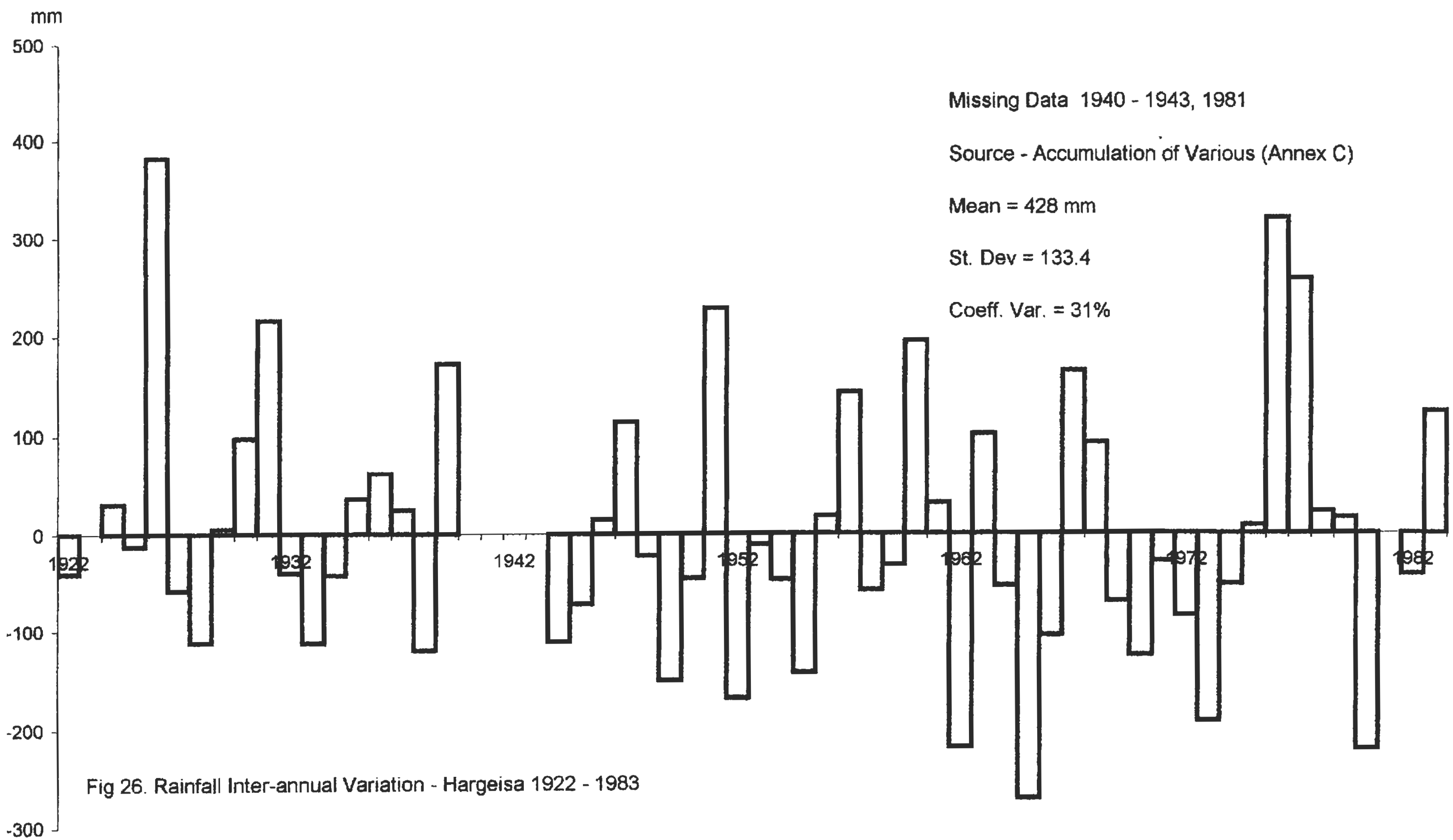


Fig 26. Rainfall Inter-annual Variation - Hargeisa 1922 - 1983

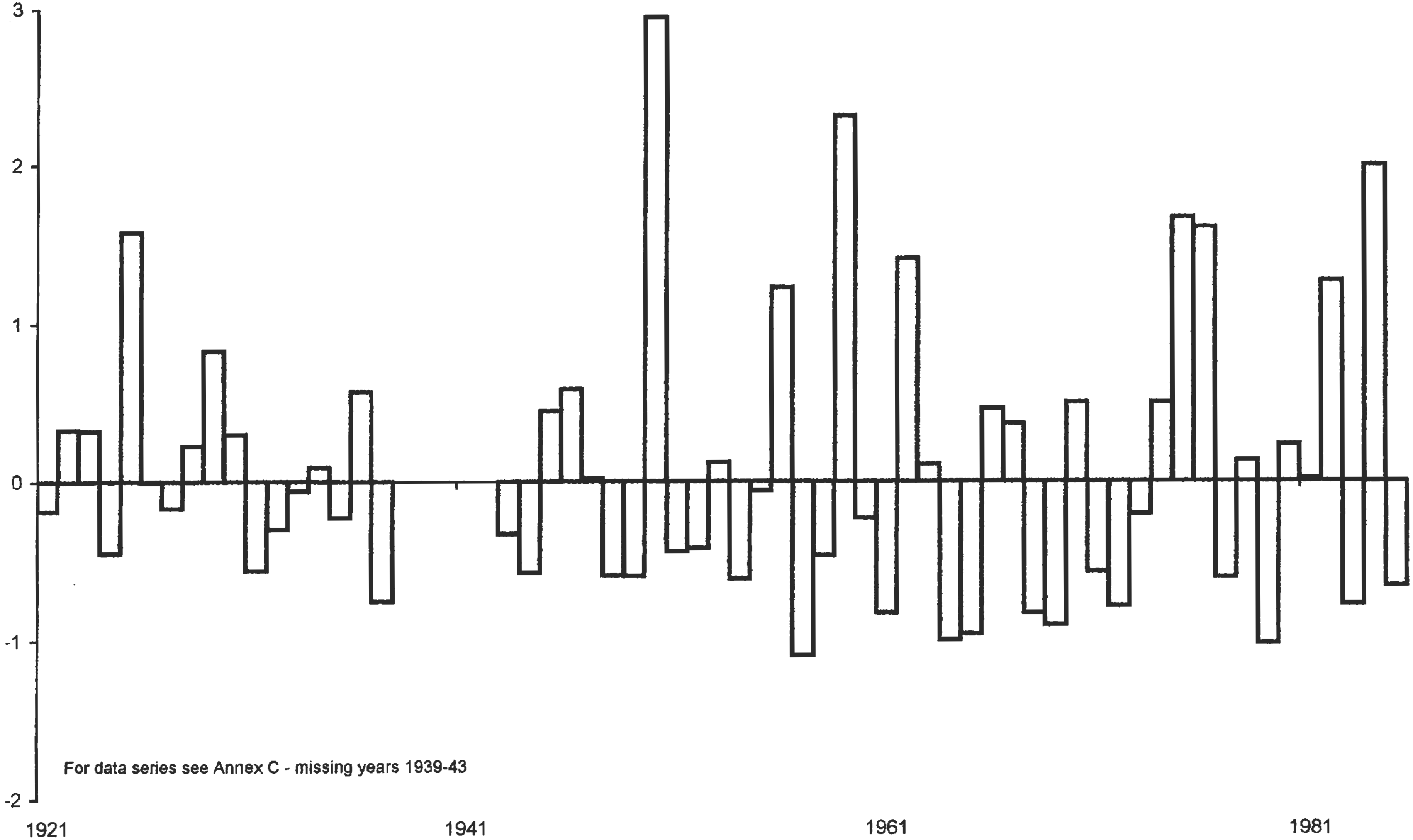


Fig 27. Normalised Anomoly - Gu season rainfall for Hargeisa 1921 - 85

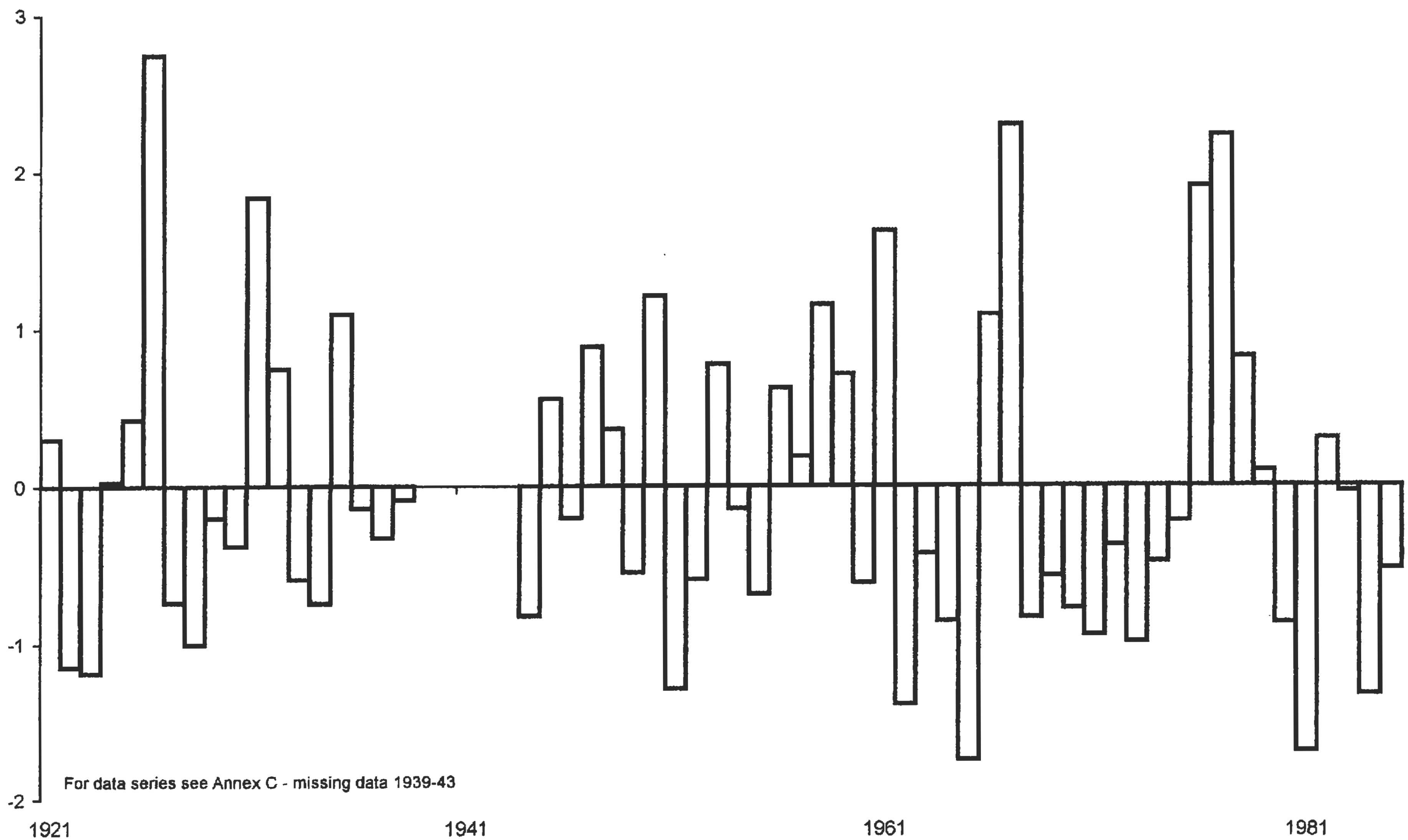


Fig 28. Normalised Anomoly - Deyr season rainfall for Hargeisa 1921 - 85

Table 5 a. Statistical Properties of BERBERA Daily Rainfall

M = mean intensity, S = standard deviation, A = serial correlation coefficient, CM = conditional mean, SKW = skewness, PDRY = proportion dry period, M/S-DRY/WET = mean/standard deviation dry/wet period, NEPM = No of events per month

Berbera Daily TIME-SCALE h= 24 hrs Intensity > 0.00

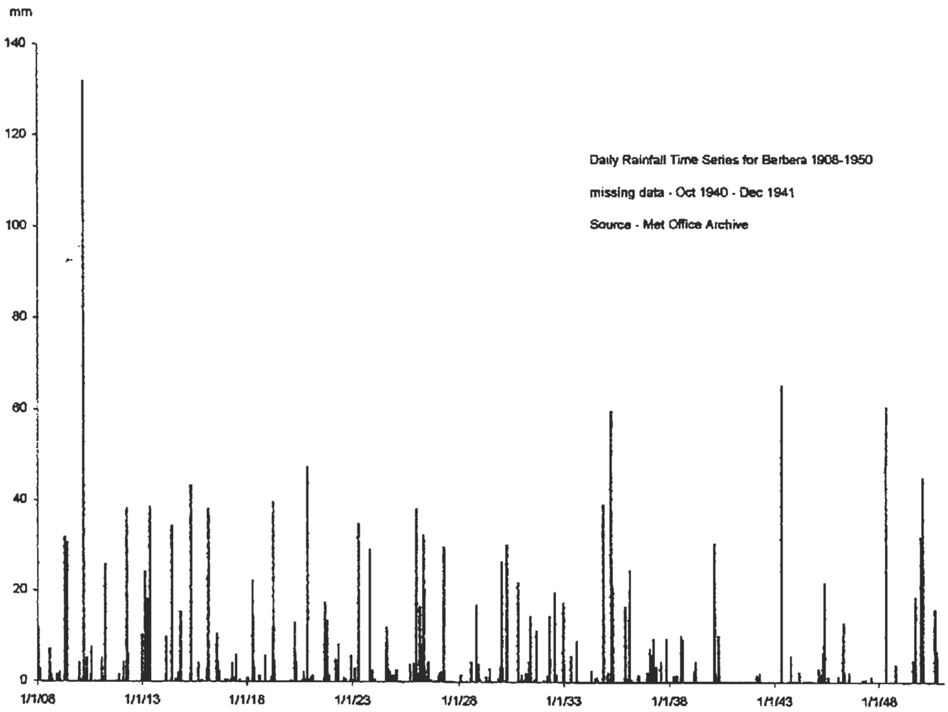
Month	M(h) [mm]	S(h) [mm]	A(1,h)	A(2,h)	A(3,h)	CM(h) [mm]	SKW(h)	PDRY(h)	MDRY(h) [hr]	SDRY(h) [hr]	MWET(h) [hr]	SWET(h) [hr]	NEPM(h)
Year	0.1336	1.7899	0.0408	0.0481	0.0209	6.2205	20.537	0.9785	*******	*******	30.375	16.043	0.51
Jan	0.1294	1.4714	0.1951	0.1899	0.1001	3.6327	19.413	0.9644	150.857	151.037	35.200	25.782	0.73
Feb	0.1655	1.8209	0.0818	0.1544	0.0451	4.6723	15.127	0.9646	160.800	153.070	34.154	18.181	0.62
Mar	0.1873	1.8930	0.0786	0.0918	0.0997	5.2959	14.283	0.9646	169.600	197.590	33.000	14.618	0.76
Apr	0.3733	3.6043	0.0032	0.0357	-.0069	12.0520	12.166	0.9690	114.857	148.895	28.364	9.400	0.79
May	0.2854	2.8594	0.0219	0.0150	0.0052	10.0355	14.927	0.9716	188.000	182.411	27.692	8.831	0.62
Jun	0.0262	0.6467	-.0017	-.0018	-.0018	10.9914	31.388	0.9976	nan	nan	24.000	0.000	0.10
Jul	0.0581	0.7644	0.0195	0.0188	0.0436	5.8186	18.192	0.9900	102.000	76.837	26.182	7.236	0.26
Aug	0.0460	0.4860	-.0090	0.0062	0.0180	2.2168	14.347	0.9792	123.000	84.549	24.923	4.707	0.62
Sept	0.0641	0.8545	-.0058	0.0097	-.0063	5.6311	17.592	0.9886	84.000	49.960	24.000	0.000	0.34
Oct	0.0735	1.1854	0.0394	0.0063	-.0042	8.4843	19.401	0.9913	252.000	288.500	36.000	18.142	0.20
Nov	0.1036	1.8457	-.0033	-.0034	-.0033	9.0926	22.165	0.9886	248.000	204.118	24.000	0.000	0.34
Dec	0.0896	1.1544	0.1812	0.0061	-.0067	4.7421	18.987	0.9811	414.000	81.682	32.471	14.552	0.41

Table 5 b. Statistical Properties of HARGEISA Daily Rainfall

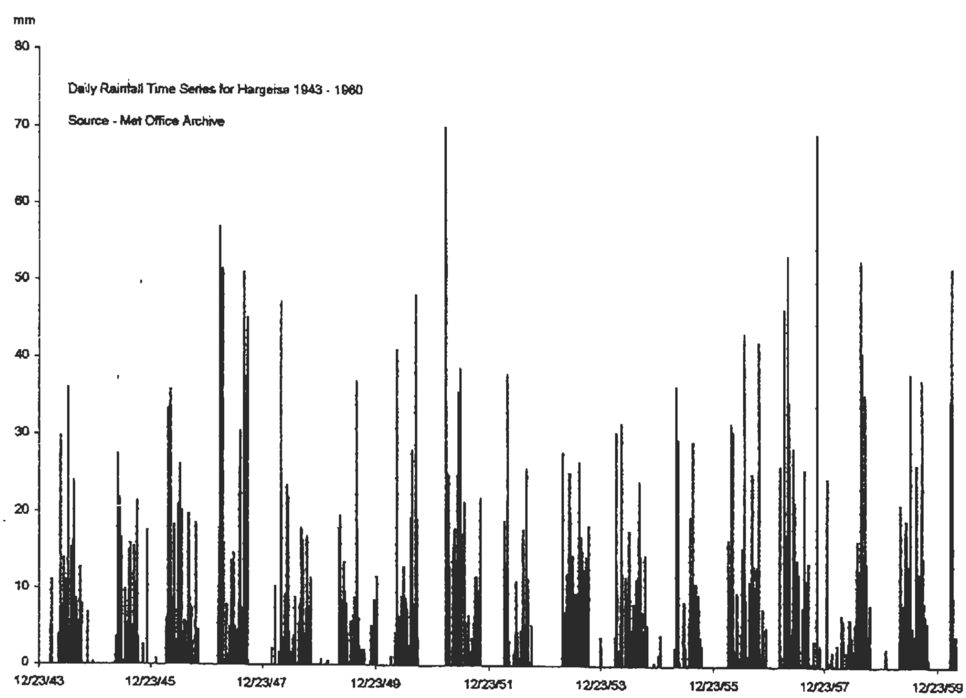
M = mean intensity, S = standard deviation, A = serial correlation coefficient, CM = conditional mean, SKW = skewness, PDRY = proportion dry period, M/S-DRY/WET = mean/standard deviation dry/wet period, NEPM = No of events per month

Hargeisa Daily TIME-SCALE h= 24 hrs Intensity > 0.00

Month	M(h) [mm]	S(h) [mm]	A(1,h)	A(2,h)	A(3,h)	CM(h) [mm]	SKW(h)	PDRY(h)	MDRY(h) [hr]	SDRY(h) [hr]	MWET(h) [hr]	SWET(h) [hr]	NEPM(h)
Year	0.9368	4.1111	0.1132	0.0969	0.0740	5.7567	7.342	0.8373	135.022	225.692	41.362	27.195	2.61
Jan	0.0611	1.0755	0.0091	0.0369	-.0025	3.5710	22.291	0.9829	90.000	116.550	26.667	8.000	0.53
Feb	0.0715	1.2007	0.1101	-.0003	-.0040	3.4329	21.203	0.9792	88.000	73.321	32.000	19.596	0.35
Mar	0.9818	5.7680	0.2087	0.1698	0.0713	11.7368	8.159	0.9163	101.333	139.313	63.429	44.759	0.82
Apr	1.6618	6.5476	0.1154	0.0928	-.0197	8.7200	5.098	0.8094	103.200	113.475	52.200	30.205	2.35
May	1.3655	4.4246	0.0042	0.0117	0.1812	5.6801	4.391	0.7596	96.393	87.140	38.328	24.382	4.19
Jun	1.6325	4.7144	0.1040	-.0142	0.0783	5.3195	4.307	0.6931	76.000	56.638	37.333	21.466	5.06
Jul	0.9617	3.3025	0.1116	-.0488	-.0151	4.0002	6.583	0.7596	87.238	71.000	37.000	18.431	4.50
Aug	2.2008	5.6520	-.0328	-.0007	-.0530	6.6427	4.304	0.6687	70.871	57.360	39.273	26.286	5.50
Sept	1.6535	5.0639	-.0107	0.0506	0.0972	4.5260	5.539	0.6347	68.400	74.547	44.414	35.396	5.44
Oct	0.5071	2.2658	0.2630	0.0572	0.0569	4.4034	5.867	0.8848	109.091	102.555	38.400	19.528	1.88
Nov	0.1279	1.0589	0.0094	-.0137	-.0120	4.7132	11.818	0.9729	278.400	217.726	26.182	7.236	0.69
Dec	0.0572	0.6697	0.0768	0.0458	-.0081	4.1204	14.492	0.9861	168.000	203.647	33.600	21.466	0.29



a. Berbera 1908 - 1950



b. Hargeisa 1943 - 1960

Fig 29. Daily Rainfall Time Series for Hargeisa and Berbera (source Met Office Archive) properties of depth duration are estimated, plus the proportion dry periods and statistics of distribution of wet and dry periods.

Accepting a significance threshold of 0.2 it is evident there is no significant lagged correlation in the Berbera series. Structural patterns are more evident at the onset of the *Gu* with the conditional mean 12mm/24hrs per rainfall event. In June there is never more than one rainfall event, proportion dry periods range from 96 to 99%, the temporal distribution of rainfall events showing high variability expected in such arid conditions. The high skewness support this as a process driven by significant convective events.

In Hargeisa skewness is significant in November through February, probably as a result of isolated, convective rainfall events in *Jilaal*. The high conditional mean in March (11.7 mm), more than twice that of any other month mark the definite onset of the *Gu*. But rainfall events, albeit of reduced intensity, are more common in the *Deyr*. Dry periods range from 75% in *Hagaar* (due to many less intense events) to 98% in *Jilaal*. As with Berbera there is no significant correlation evident, the strongest being the first order lag in October when seasonal rains end.

The comparison of properties for Hargeisa and Berbera confirm the higher variability of the coastal plain at a daily temporal scale; there is less rainfall in total but rainfall in any event is likely to be as intense as in Hargeisa. In fact annual conditional mean rainfall is higher in Berbera than Hargeisa by almost 0.5mm.

6.2 Topography, Geomorphology and Geology

According to Faillace (1986) Somaliland consists of three distinct physiographic provinces:

1. A low lying coastal belt and sloping plain bordering the Gulf of Aden:

2. An uplifted mountainous zone, forming the main watershed rising from west to east.

3. An uplifted lifted plateau of greater extent lying to the South.

These three features have been recognised as the main features in regional water resource studies (Faillace 1986, Bao-Sheng *et al* 1985), although Hemming (1966) earlier proposed only two provinces; the mountainous zone and plateau being subdivisions of a single major geomorphic unit.

The basic structure of Somaliland is due to normal faulting, some of the faults have very great throws (MacFadyen 1933). There have been two major series of faults: those of the Gulf of Aden trend running East to West (or ENE to WSW) which date from the upper Eocene to Oligocene. And those of the Red Sea trend running North West to South East (or WNW to ESE) which date from the early Miocene.

Faulting of the Gulf of Aden trend was responsible for the uplift of the plateau. The uplifted northern edge comprises the *Golis* mountains which are incised by the numerous *tugga*. The main fault scarp runs across the country and reaches 2408 north west of Erigavo (1740m) but only 1400m near Hargeisa (1370m). It is largely hidden in the central areas by broken hilly country. The line of the escarpment crosses the underlying stratigraphy and passes through the crystalline rocks of the basement complex in Western Somaliland and to the east of Sheikh, while in the east it cuts through and creates sheer cliffs of lower Eocene limestone of the Auradu Series (Hemming 1966). The basement complex outcrops extensively in the Western scarp, and is represented by metamorphic and igneous rocks of the Pre-Cambrian and Palaeozoic age (Faillace 1986).

The plateau, which lies to the South of the main faults of the Gulf of Aden trend, dips to the South East and extends well into the Ogaden region. The plateau consists of a number of distinct sub-regional plateau including the large undulating Haud, Sool and Taleex; as well as a number of well defined valleys and smaller plains, such as the Haded south of Erigavo, the Karman south of Ceel Afweyn, and the Gubato to the north-east of Burao. Las Anod (700m) and Burao (1040m) are major settlements. The Red Sea trend was responsible for establishing much of the drainage pattern of the plateau, notably the Nugaal valley and the Tug Der (Somaliland Oil 1954). The plateau is generally flat and is composed of limestone of lower Eocene (Auradu Series) and middle-upper Eocene (Karkar Series) with extensive deposits of anhydrite of lower middle Eocene in the south east. Much of the superficial anhydrite has been altered to gypsum. The main gypsum exposures are to be found in the Nugaal valley but there is also an extensive area of secondary gypsum in the Heman basin to the north. The main surface of the plateau is thought to be comparable with the end-Tertiary land surface common in more southern parts of Africa (Pallister 1963).

The Coastal plain (plates 1,2) varies in width from 60k the west to less than 1km in the east and is covered with a mantle of stony or sandy alluvium and raised beach deposits. The *tugga* that flow onto the plain have, in previous pluvial periods, spread enormous fans of ill-sorted materials which merge with the underlying marine deposits. The land surface is of quaternary age with most of the shore line consisting of raised beaches except for the wide western plain which is a basin of subsidence. About 65km east of Berbera (8m) there are extensive high dunes of loose sand that are the most desert like environment to be found in the country. These sands are derived from Cretaceous sandstone, locally up to 1700m thick (Abbate *et al* 1993).

The topography (fig 30) is thus generally related to the underlying rock types, and rainfall correlates reasonably with topography so an appreciation of elevation can be gained from average annual rainfall isohyets (fig 22). Faillace (1986) has presented a regional geological history and stratigraphy of Northern Somalia (fig 31).

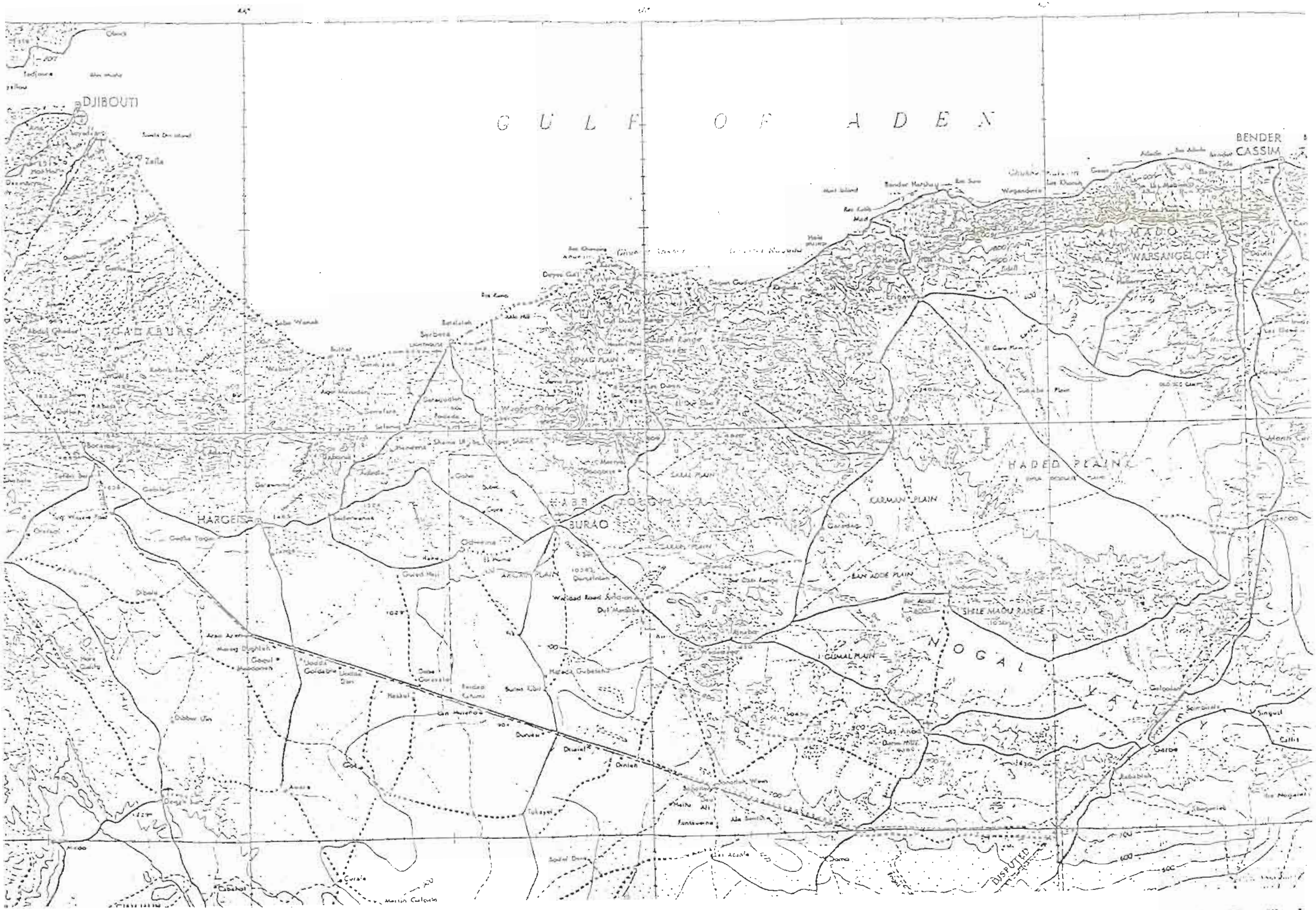
6.3 Hydrogeology

Within the three major physiographic provinces Faillace (1986) has proposed several hydrogeological provinces (fig32) having, to a certain extent, similar hydrogeological characteristics.

Physiographic Province		Hydrogeological Province
I.	Coastal Belt	a. Gulf of Aden Coast b. Sloping Plains
II.	Mountainous Zone	a. Mountainous Zone
III.	Plateau and Valleys	a. Darror Depression b. Haud plateau c. Taleex Plateau & Nugaal valley d. Sool Haud & Sool plateau

The limits between some provinces are not always well defined, as is the case between the 1st and 2nd (Ia and Ib) and between the 5th, 6th and 7th (IIIb, IIIc and IIId). In fact the geological formations of the Haud, Sool Haud and Sool plateau belong to the Eocene and are widely exposed in these areas. At the regional scale the movement and discharge of groundwater is better defined within the sub-division of the area according to the three major physiographic provinces than within the seven hydrogeological provinces.

The delimitation of hydrological provinces is a convenient regional descriptor based on the poor knowledge of local aquifer properties and geometry. The extent and response of deep aquifers have not been closely studied in Somaliland, which is evidenced by the low number of recorded boreholes (157 in pre war environment Min of Planning) and the low success rate of groundwater development programmes, in terms of yields (MacFadyen 1951, Alpman 1997). The extent of shallow aquifers associated with alluvial deposits in tugga can be more easily

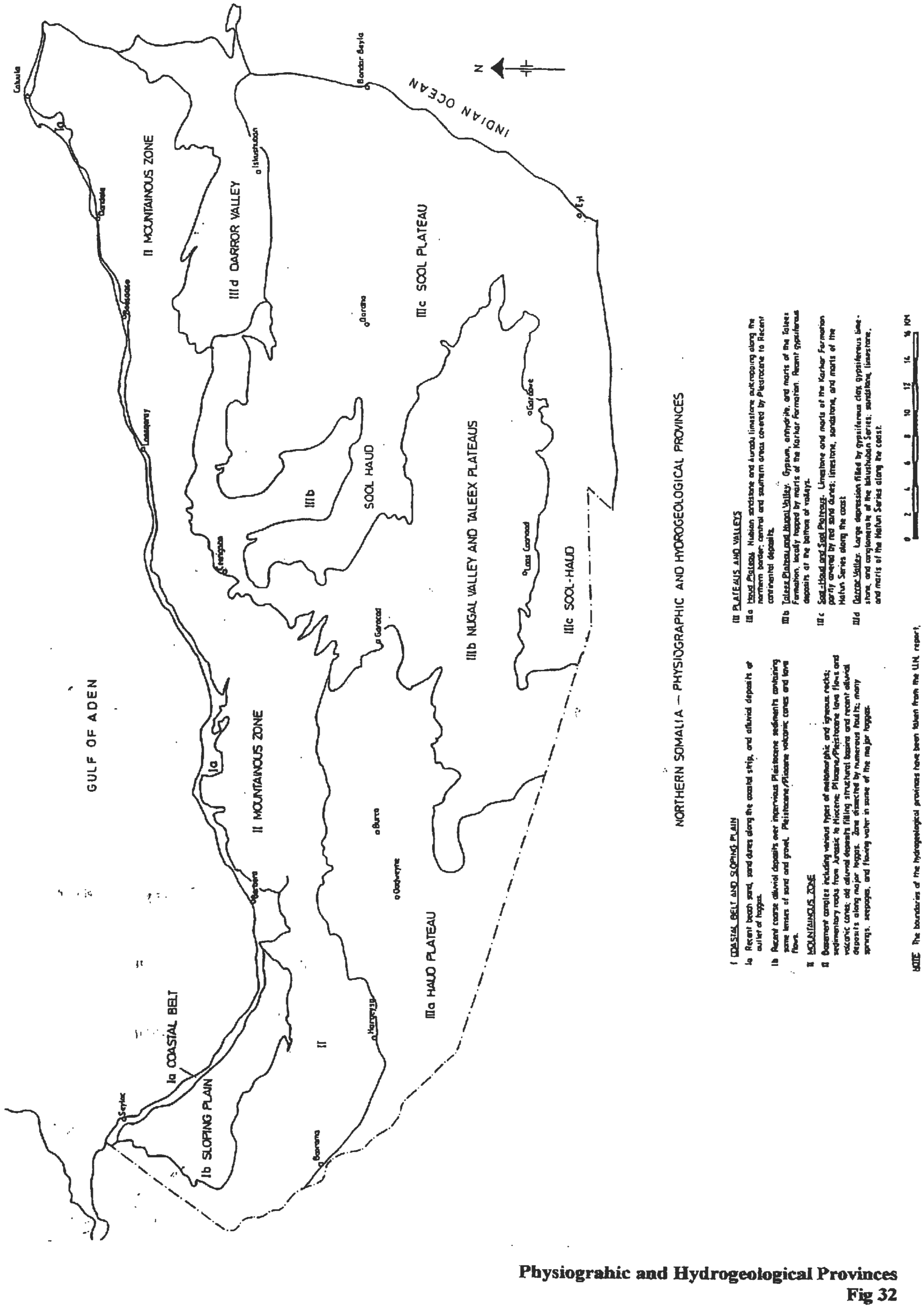


Topography of Somaliland
Fig 30

STRATIGRAPHY OF NORTHERN SOMALIA

ERA	PERIOD	EPOCH	SERIES OR SUITES	SYMBOL ON MAP	THICKNESS (M)	LITHOLOGICAL CHARACTERISTICS	DISTRIBUTION
CENOZOIC	NEOGENE	Recent - Pleistocene	Surface cover	not mapped	0 - 20	Talus, breccia, alluvium of small streams, caliche, and laterite.	In mountainous areas, pediments, and small valleys.
			Stream alluvium	Qga	1 - 20	Gypsiferous alluvial deposits covering gypsum and limestone.	Depressions and riparian belt in the Sool and Nugal regions.
			Stream and estuarian deposits	Qa	2 - 200	Sand, sandy clay, gravel layers, conglomerate deposited by streams along riparian belts, in structural basins and pediments.	Mountainous zone from Awdal to Bari (recent alluvium), N.W. Galbeed (structural basins and pediments).
			Alluvial/Eluvial deposits	Qs	5 - 80	Red silty clay and red sand covering sandy clay layers with intercalations of gravel and coarse sand.	Large areas of the Haud and Sool plateaus.
			Coastal deposits	Qsd	20 - 150?	Beach sand, coral limestone, coastal and inland sand dunes, mixed beach sand and alluvial materials.	Coastal belt bordering the northern regions.
		Pleistocene - Pliocene	Aden Volcanic Series	?	50 - 60	Basalt, tuff.	Large areas of Awdal and N.W. Galbeed. Small areas along the Gulf of Aden coastal belt.
	PALEOGENE	Miocene - Oligocene	Upper Daban Series	M - c	120	Conglomerate, limestone.	Gulf of Aden coast, Bari and Sanaag regions.
			Iskushuban Formation (Middle Daban Series)	M - i	150 - 200	Gypsiferous clay, marls, gypsiferous limestone, sandstone.	Darror Valley.
			Hafun and Dubar Series	M - d	50 - 500	Biogenetic limestone, marls, sandstone, and conglomerate.	Indian Ocean coast north of Hordyo (Hafun) and Gulf of Aden coast. (Dubar).
		Oligocene	Hafun Series (marine facies)	O	20 - 220	Biogenetic limestone and marls grading to coarse sandstone, marls, and sandy limestone toward the bottom.	Indian Ocean coast from Hordyo to Eyl.
			Middle Daban Series	M - d	800 - 2400	Green sand and silts, sandstone, gypsiferous sandstone, conglomerate, shales, and sandy limestone.	Southwest of Berbera.
CENOZOIC	PALEOGENE	Eocene	Lower Daban Series	not mapped	465	Sandstone, shales, clay, sandy limestone, conglomerate.	South of Berbera.
			Karkar Formation	E - kr	260	Limestone, marly limestone, cherty limestone, marls, and siltstone.	Eastern mountainous zone, south of Ceerigabo Plateau, Sool Plateau.
			Taleex Formation	E - tx	250 - 300	Massive anhydrite, gypsum, marls, conglomerates, and sand.	Central and eastern mountainous zone, Nugal Valley, Sool and Haud plateaus.
			Auradu Formation	E - a	380	White massive limestone, cherty limestone, marls, and dolomite.	Central and eastern mountainous zone, Haud Plateau.
MESOZOIC	CRETACEOUS	Cretaceous	Nubian sandstone	Cr - ns	200 - 1700	Sand, sandstone, siltstone, and gravel.	Central mountainous zone and the area south of Hargeysa.
			Cretaceous limestone	Cr - l	500 - 700	Sandy limestone and sandstone grading eastward into fossiliferous neritic limestone.	Northeastern mountainous zone of the Sanaag and Bari regions.
	JURASSIC	Upper and Middle Jurassic (undifferen.)	Bixinduule Suite	Jl	1000	Grey and brown limestone, marls, calcarenites, shales, and fossiliferous limestone.	Central and western mountainous zones.
		Lower Jurassic	Basal sandstone (Adigrat sandstone)		220	Arenaceous limestone, cross-bedded sandstone, and conglomerate.	Western mountainous zone.
PROTEROZOIC	PRE-CAMBRIAN	Pre-Cambrian (undifferentiated)	Basement complex	B		Four basement complexes (Qabri Baxar, Abdul Kadir, Mora, Inda Ad) including low and high grade metamorphic rocks and intrusive rocks (sandstone, shales, crystalline shists, limestone, ortogneiss, quartzites, marble, diorite, gabbro, and granite).	Northwestern and central mountainous zone.

Stratigraphy
Fig 31



Physiograhic and Hydrogeological Provinces
Fig 32

deduced. From the underlying geology it is, however, possible to draw broad conclusions on the recharge, movement and discharge of groundwater.

6.3.1 Recharge

Recharge occurs where rainfall events are favourable, mainly from run-off water originating from the watershed range. From the mountains, run-off water reaches the coastal plain and infiltrates into the large alluvial fans formed by numerous *tugga* in the upper part of the sloping plain. The streams flowing towards the Haud and Sool plateaux and the Nugaal and Daror valleys, which generally have a NW to SE direction such as Tog Der, carry a large amount of run-off water which is spread out in floodable areas and lost by evaporation and infiltration. Shallow groundwater aquifers along the temporary water courses and in the terminal, floodable areas of the internal basin are lense-like and have a thickness of a few metres (Faillace 1986).

Infiltration in rocks of the basement complex is very low and in most cases occurs through fissures that close rapidly at shallow depths. Furthermore the steep slopes that characterise the areas covered by the basement complex facilitate a fast run-off towards the lowlands (Bao-Sheng *et al* 1985).

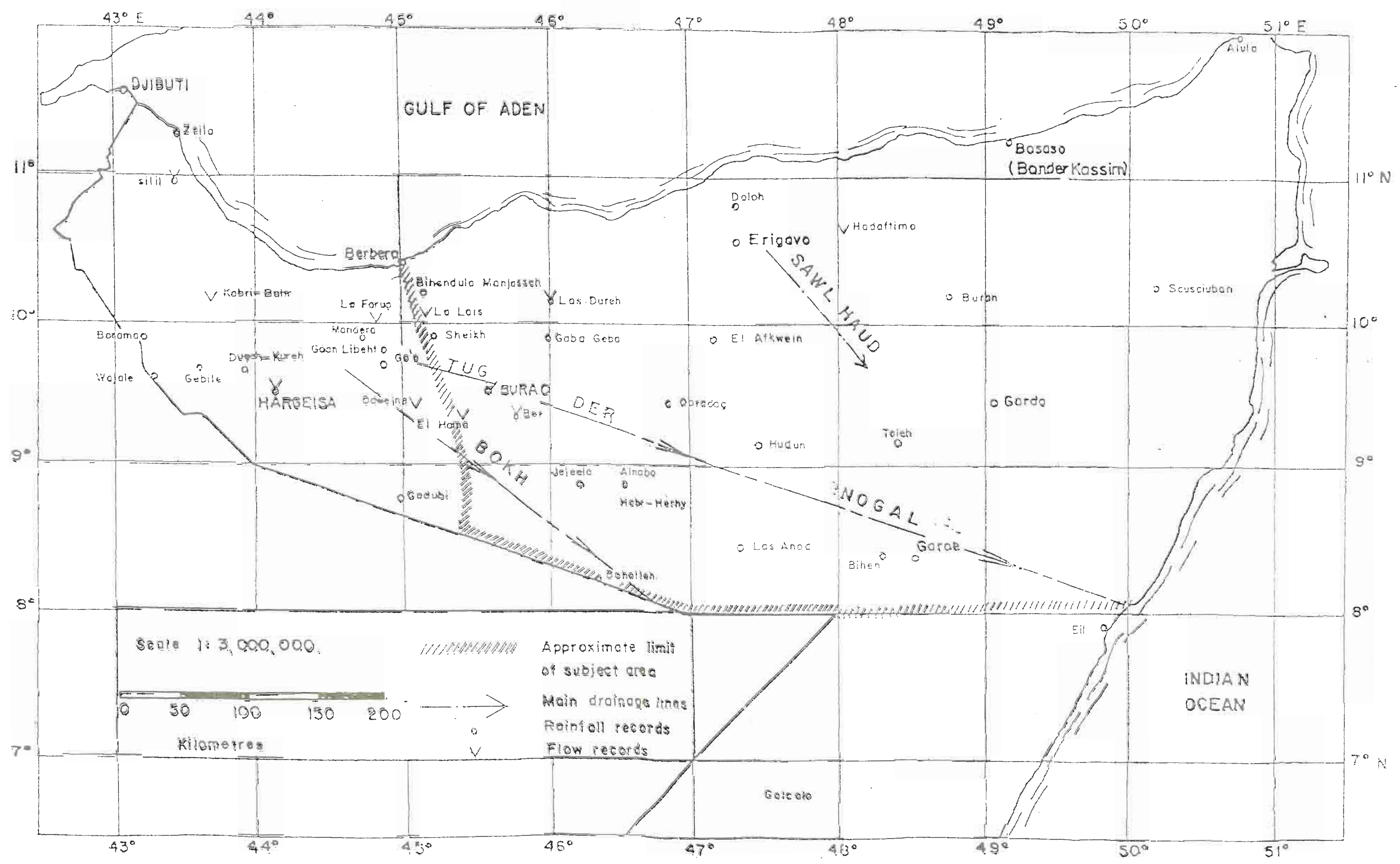
The Jurassic limestone outcropping in large areas, mainly in the western Regions, is highly karstified, and water rapidly infiltrates in depressions and sinkholes. The cretaceous Nubian sandstone, which is gently sloping over large areas and is characteristic of the Haud south of Hargeisa, is covered by sandy-clayey soils of low permeability and thus direct recharge is minimal. Recharge of the Auradu, Taleex and Karkar formations, occurs through fissure, joints and karstic depressions. In these formations the major intake is along the edge of the scarp. Here rainfall is relatively high, and rocks are generally stripped of soils and dissected by faults and joints through which water infiltrates and flows along structural isoclines (Abbate *et al* 1993).

6.3.2 Movement and Discharge

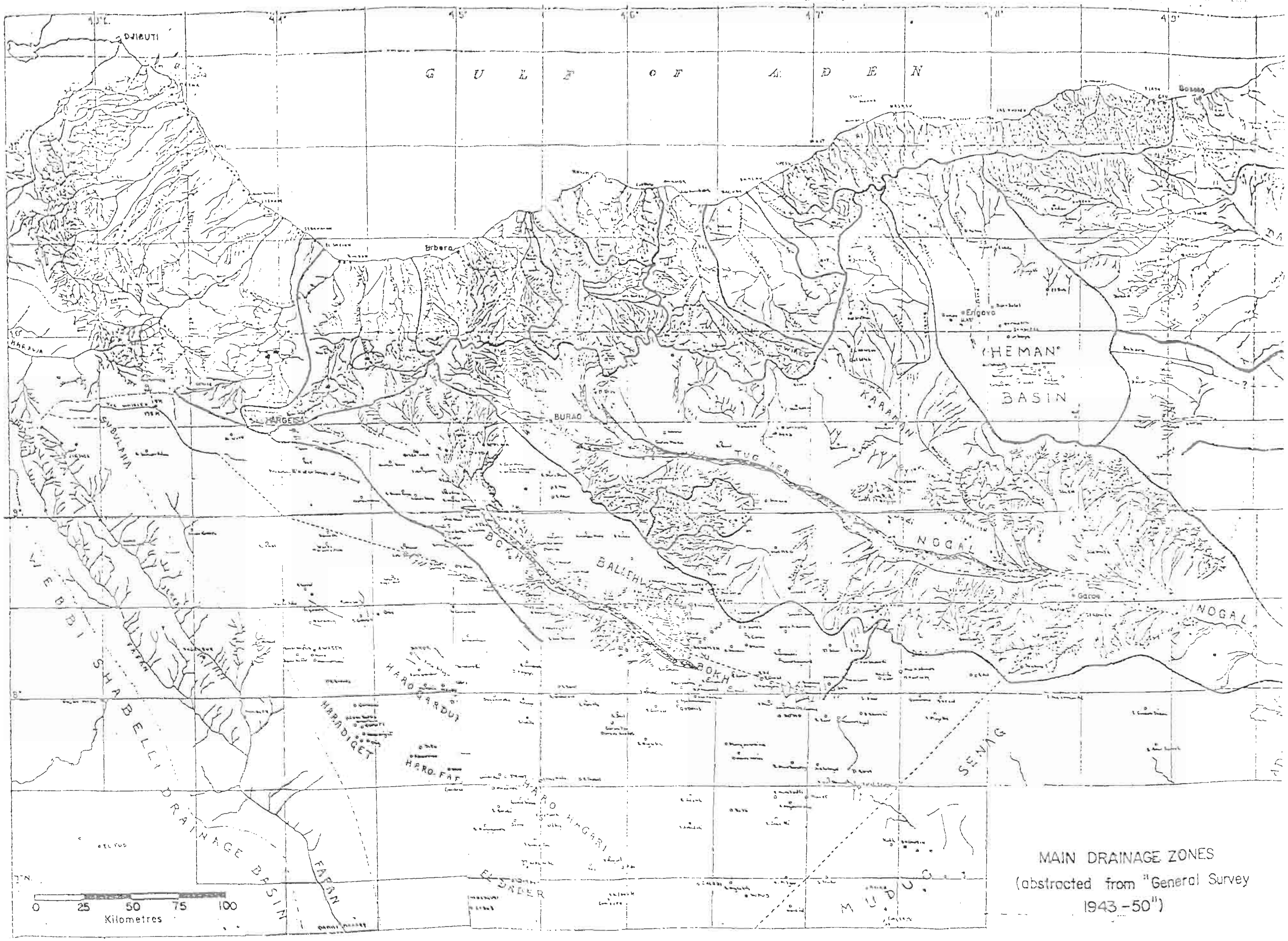
Groundwater movement starts in the mountain area and continues in two major directions: south to north towards the coastal plain coinciding approximately with the surface drainage, and north to south towards the Haud and Sool plateau. The hydrological divide thus coincides to a degree with the hydrological divide (Faillace 1986). Movement occurs under phreatic conditions in alluvial deposits along the *tugga* flowing from the watershed range to the coastal belt and plain. Water infiltrates in deep permeable layers of the coastal plain and is generally under semi-confined conditions. Movement from the watershed range towards the Haud and Sool plateau occurs mainly in the Auradu limestone and the Taleex formation, which are interlain with clay and marls. Thus groundwater movement may be under semi-confined conditions and is likely to follow the general dip of the formations that are karstified to different degrees at different depths. Perched shallow water from karstified gypsum is generally under phreatic conditions. Alluvial areas along all the major *tugga* have permanent underground flow, the groundwater movement in these areas, as well as along *tugga* channels, is related to the occurrence of spates (Mott MacDonald 1986).

Due to the major drop in elevation from the mountain to the sloping plain, groundwater flows quickly towards lowland fissures and faults and is discharged at various elevations through numerous springs (*durdur*) in the basement complex and the Mesozoic and tertiary formations. Spring water generally flows in stream channels and infiltrates rapidly in after short distances. The water is mostly of good quality because of the relatively short time between infiltration and discharge, low rock solubility, and the rather shallow water circulation. The numerous thermal springs are connected with deep faults; water generally flows out from the base of the mountain areas and faulted outcrops along the coast. In the Taleex formation, some springs discharge from the contact between permeable gypsiferous layers and marls (plate 21). The area of Taleex and Xalin on the Taleex plateau is

SKETCH MAP OF NORTHERN PART OF THE SOMALI REPUBLIC



Main Drainage Lines, Flow and Rainfall Records
Fig 33



Main Drainage Zones
Fig 34

SURFACE DRAINAGE AND CLASSIFICATION OF THE CATCHMENTS

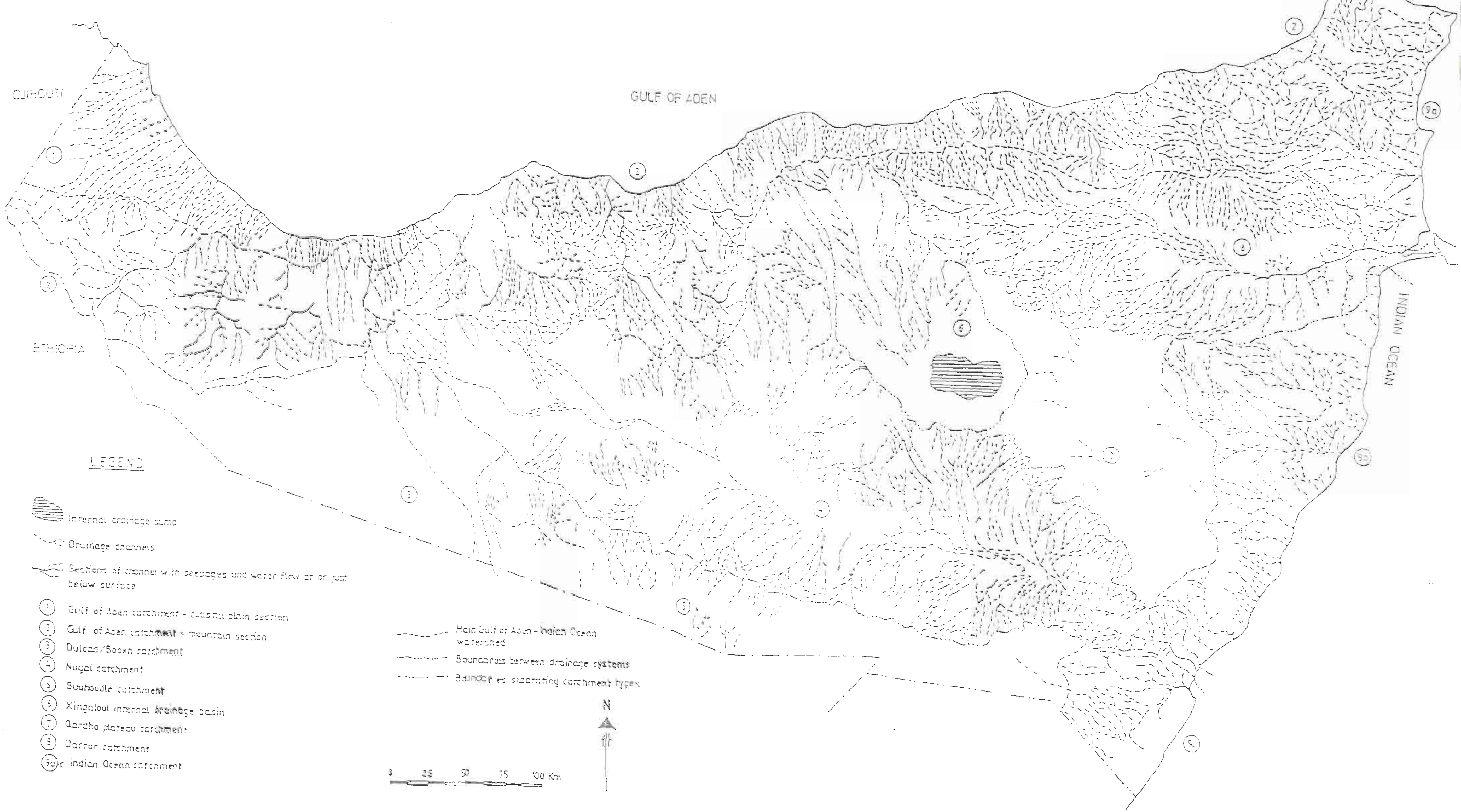


Fig 35

one of the major discharge zones of this gypsiferous formation (Faillace 1986).

6.4 Hydrology

The hydrology of Somaliland has been briefly documented by Hunt (1951), MacFadyen (1950) and Humphreys (1960). During the 1980s renewed vigour led to investigations by SOGREAH in the west and Halcrow in the rangelands of the central and eastern plateau. The extent of these later studies is not known, but some key characteristics can be inferred from cross-referencing of the documents at hand, notably Faillace (1986), Mohamoud (1990) Hemming (1966) and MacDonald (1986). Fig (33) show the extent of major drainage lines, rainfall and flow records known to Halcrow (1980).

6.4.1 Drainage and Major Catchments

Hunt (1951) mapped the main drainage basins of the region (fig 34). Resource Management and Range (RMR) adapted this to classify the major catchments of Northern Somalia (from Faillace 1986) (fig 35). The reasons for the extent of the disagreement between the two maps cannot be deduced from the documents at hand; so a definitive drainage map is not possible without further research.

It is clear that numerous short *tugga* dissect the escarpment facing the Gulf of Aden. Large *tugga* are located in western Somaliland and drain the mountain areas of Borooma, Hargeisa, and from Sheikh to Erigavo; which discharge their water towards the coastal plain. All other *tugga* draining the Nugaal, the Bokh and other minor valleys, discharge their water into the Indian Ocean or into endoric basins. Much of the surface water is ephemeral, surface water is known only from seasonal ponds (*balleh*)and springs (*durdur*). Streams which flow permanently generally lie on impervious rock of the highlands, coastal area and anhydrite series. Streams also occur in *tugga* as spates which transport large amounts of sediments. Erosion and deposition of sediment can cause streams to migrate (plate 10, and 19).

In the western area there are four major basins, and in the central area three major *tugga* that drain into the coastal plain. The *tugga* Nugaal has a massive catchment and drains parts of Togdheer and Sool regions.

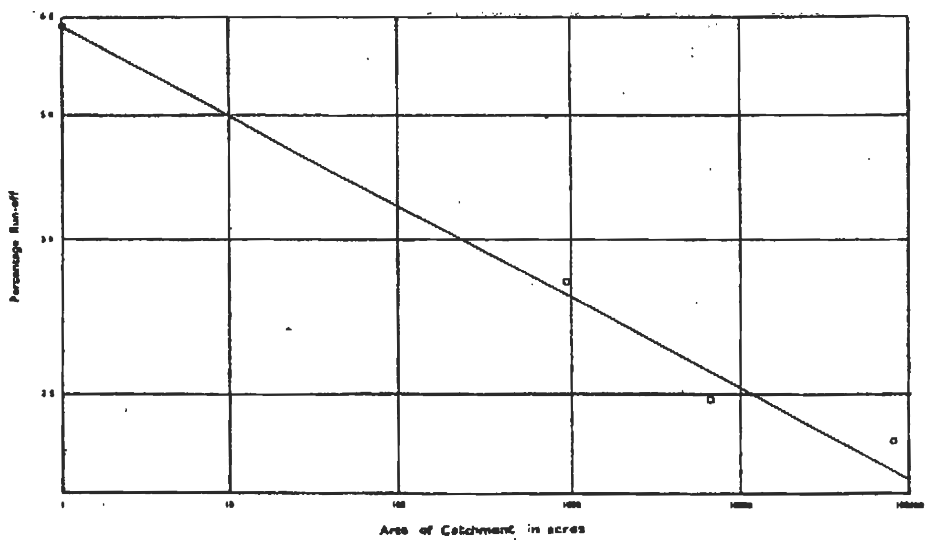
Tugga	Location	Catchment Area	Source
Western Area		***km²***	
Waheen		3000	c,d
DurDur		3850	c,d
	Kabri Bahar	3500	e
	Kabri Bahar	3040	b
Biji		3560	c, b, d
Silil		1930	c,d
		5250	e
	Silil well	4200	a
	Silil well	3850	b
Wajaale	Well 2	500	a
Central and Eastern Area			
Der	Burao	1500	a
	Burao	2240	e
	Ber	1810	a
	Ber	3050	e
	Waridad	3380	a
Jangarra		3700	c
Hodmo		3800	c
Belgeabili		4800	c
Nugaal		70,000	c

Table 6. Catchment Areas of Tugs (km2)
Source. a. MacFadyen (1950), b. Morgan from Mott MacDonald (1986), c. Faillace (1986), d. SOGREAH (1981), e. Halcrow (1980)

Table 6 shows that estimates of catchment areas vary within and between the documents available. Without recourse to primary sources it is not possible to explain these discrepancies. The discrepancies highlight the need for further study to consolidate the available data. The table also highlights the bias of reporting to the western areas, where most development activity has taken place, which is also evidenced in the flow records of fig 33.

6.4.2 Characteristics of Runoff

As part of the Hargeisa Water Supply Investigation (Humphreys 1960) gauged the runoff from five catchments ranging from one to 83,500 acres over a two year period. The primary data is now lost but fig 36 shows that runoff expressed as a percentage of rainfall decreases inversely with the size of the catchment.



Relationship between run-off and catchment area (Humphreys 1960) Fig 36

Humphreys (1960) observed that "*rainfall of less than 6mm per day will seldom produce run-off from catchments of bare rock*". During Humphreys investigation a one acre experimental catchment was established at Dagahkureh. The runoff data has been published by Hemming (1966) and is reproduced in Annex C. Hemming concluded that "*runoff is proportional to rainfall intensity and that no significant runoff occurred when the rainfall intensity was less than 25mm/hr unless the duration of the shower was very long*". It is apparent from the records that most rainfall events produce little or no runoff. Table 7 lists the equivalent depths of runoff over the whole area and the percentage runoffs of the seven greatest run-off producing storms. Over the study year the runoff was 6% of which two major storms accounted for 90%. Only three storms in the year produced depths of more than 1mm and only the two major storms had runoff in excess of 5%. It thus seems clear that annual runoff depends mainly on the number of major storms and here further regression analysis between the runoff and rainfall depth and intensity would be useful. Antecedent soil moisture conditions also require further study.

Halcrow (1982) experimented in much larger catchments and concluded that in much of Somaliland, rainfall of about 18 to 23 mm/day, if preceded by a few rainy days of lesser intensity can also produce floods. SOGREAH (1981) observed that on the plateau for unit drainage areas of less than 100 km^2, a run-off threshold of 24mm applies with a corresponding runoff coefficient of 65%.

6.4.3 Tugga Spates

Tugga flows have been derived from available spate data collected in Burao, Ber, Hargeisa and Odweina between 1946 and 1958. Data was collected by Somaliland Protectorate Department of Agriculture and Veterinary Services and are supplemented by MacFadyen (1951). Spates were recorded as number of days per year without an indication of magnitude (table 8). A record of flood peaks at eight stations also exists for 1956 (table 9), readings being taken at hourly intervals during spate flows.

Date	Runoff	Runoff	Equivalent Depth	Rainfall Depth	Rainfall Intensity	Storm Duration
	m3	*%*	*mm*	*mm*	*mm/h*	*mins*
9.08.58	1.74	3	0.43	14	13	64
17.08.58	0.15	0.2	0.04	18	32	33
20.08.58	0.15	0.5	0.04	7	21	20
29.08.58	4.47	4.6	1.11	24	26	54
3.09.58	1.5	1.9	0.37	20	11	109
27.04.58	49.7	39.7	12.29	31	81	23
29.04.58	23.7	13.3	5.85	44	13	206

Table 7. RunOff at Dagahkhureh experimental catchment (data source Hemming 1966)

Station	Altitude	Tugga	Area	Length	Slope	MAF	MAF	Rainfall	Rainfall	Rainfall	QP1956	CVAF	RunOff
	m		*km2*	*km*	*%*	*m10-3*	*10(6)m3*	*1956*	*ann. avg*	*catchment*	*cumecs*		*%*
Burao	1052	Der	2240	75	1.3	5.71	12.8	248	200	420	112.04	0.56	1.36
Ber	930	Der	3050	104	1	2.46	7.5	155	120	355	60.69	1.2	0.69
Odweina	1067	Der	340	39	1.3	4.74	1.61	215	240	360	57.34	0.81	1.32
Hargeisa	1250	Waheen	340	31	0.65	21.1	7.18	375	300	410	466.27	0.66	5.15
Kabri-Bahr	604		3500	80	1.5	9.8	34.23	187	300	550	266.78	0.9	1.78
Silil	168	Silil	5250	123	1.2	0.735	3.86	112	170	320	26.05	0.85	0.23
La Farug	747	Waheen	320	24	3.9	28.1	9			440	44.8	0.81	6.39
Las Dureh	534		570	34	2.1	2.47	1.41			290		1.35	0.85
Hadaftimo	1320		400	32.5	1.9	33.5	13.41			330		1.18	10.16

Table 10. Characteristics of some major Somaliland catchments (Halcrow 1980)

Year	Burao	Ber	Hargeisa	Odweina
1946	23	?	?	?
1947	29	14	?	11+
1948	35	?	11+	13+
1949	43	9+	8+	8+
1950	?	?	29	?
1954	?	44	?	?
1955	24	24	35	12
1956	36	32	35	22
1958	?	20	?	?

Table 8. Number of Spates per Year for Burao, Ber, Hargeisa and Odweina 1946 - 1958 (source MacDonald 1986)

Station	Annual Flood Peaks (cumecs)					
Year	*1953*	*1954*	*1955*	*1956*	*1957*	*1958*
Burao				112.1		
Ber	45.8	119	133	60.7	-	77.9
Odweina				57.5		
Hargeisa				466.4		
Kabri-Bahr				266.9		
Silil				26.1		
La Farug				44.9		

Table 9. Annual Flood Peaks 1953-1958 (source MacDonald 1986)

The paucity of flow data suggests that flow statistics can only be predicted from equations correlating spates with known rainfall.

Halcrow (1980) presented characteristics for some major catchments (see table 10). Flow variables Mean Annual Flow (MAF), Mean Annual Flow per unit Area (MAF/AREA) and the Coefficient of Variation of Mean Annual Flow (CVAF) have been related to morphological catchment characteristics. A relationship for the Mean Annual Flow per unit Area was calculated as

$$\textbf{MAF/AREA}\ (m3/km2) = \mathbf{4.580 \times 10^{-6}\ X\ Length^{-1.266}}\ (km)\ \mathbf{X\ Rainfall^{2.042}}\ (mm)$$

Correlation is generally low, the coefficient quoted as 0.81.

Flood peaks for 1956 were also related to catchment slope and rainfall to yield

$$\mathbf{QP1956\ (cumecs) = 1.409 \times 10^{-9}\ X\ Slope^{-1.42}\ X\ Rainfall^{4.385}}\ (mm)$$

For which the correlation coefficient is quoted as 0.87

The use of Slope rather than Area in the calculation and the high powers to which the independent variables are raised would appear to limit the utility of the equation. Clearly the validity would be enhanced if it were known that the flood peaks of 1956 at all stations were of a similar return period. Without more flow data, the probability of the peaks can only be suggested by an analysis of the annual rainfall. The rainfall for 1956 is shown in table 10 along with the average annual rainfall for the areas in which the flow readings were taken. The return period of the rainfall clearly varies across the region. If the 1956 peak flows show a similar variation in return period, the above equation could prove to be too low an estimate of the mean annual flood. The difficulty associated with the flood peak measurement and the uncertainty of the return period combine to limit confidence.

SOGREAH (1981) studied the four major western *tugga* and concluded that for the western region in an average year there can be expected to be 3 large floods. Such figures are in marked contrast to those of table 8 and in fact Hunt (1951) suggests that minor spates are more frequent in the tugs. The threshold between major and minor spates is not evidenced from the documents available. Halcrow (1982) suggest that "only about once in every 15 years will there be less than 3 such floods recorded, and only once in 40 years will the aquifer receive no useable replenishment at all". Flood events are clearly dependent on rainfall. Fig (37) shows the relationship between annual rainfall and the frequency of flow generating storms for Hargeisa.

6.4.4 A Simple Water Balance

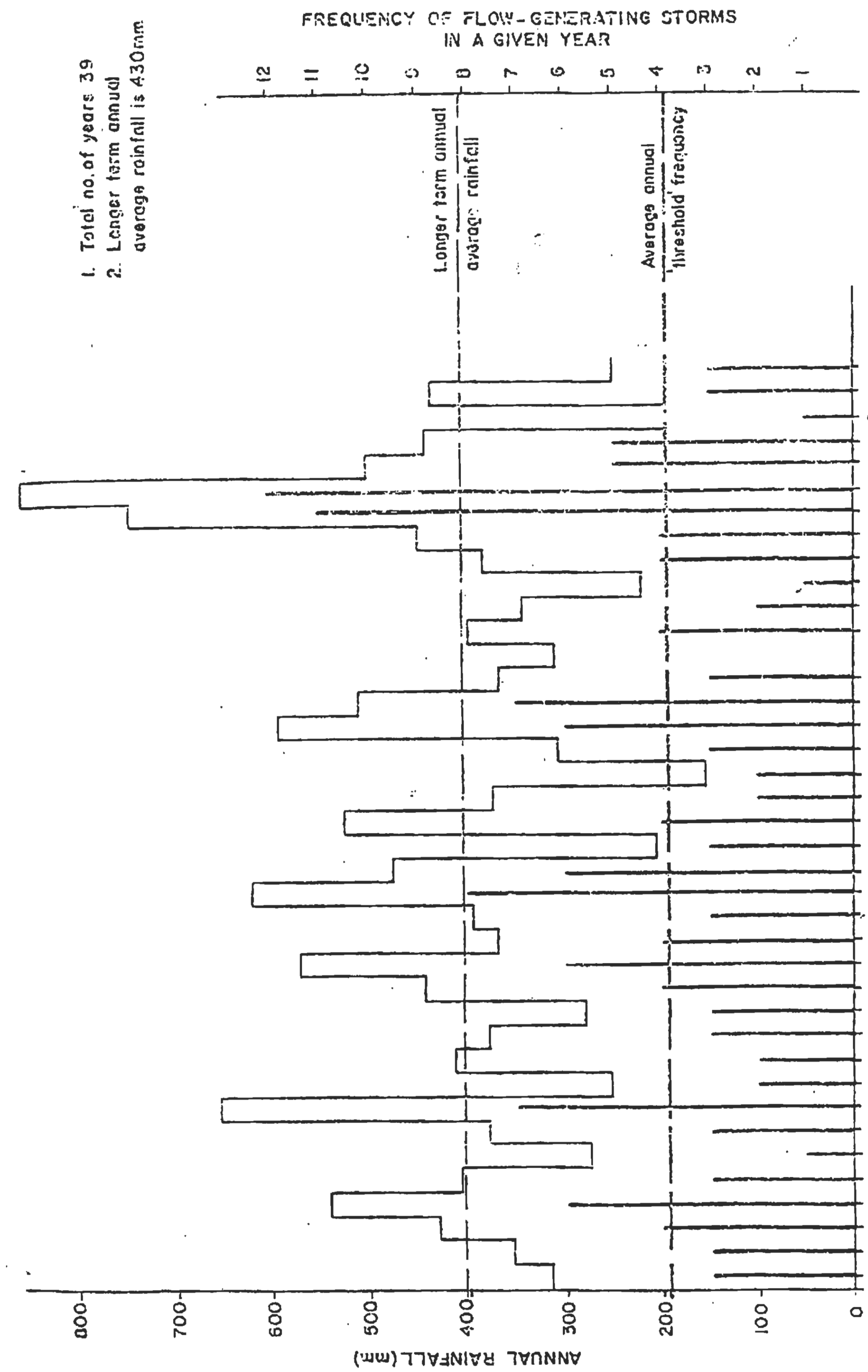
Further interpolation of the IGAD-FAO database has focused on the production of a simple water balance. A monthly series of average condition rainfall, potential evapotranspiration (PET), and NDVI based on map units for Somaliland are shown in (figs 38- 47). For each map unit in each month the water deficit has been calculated using values of half-potential evapotranspiration (FAO 1977). The balance is intended to show average conditions at the reconnaissance level and therefore is of limited use. It represents a static, not dynamic approach. The variability in the rainfall pattern, and hence the opportunities for production in wetter years, are not reflected. There is therefore more usefulness in looking at the inter-annual variation in the length and timing (particularly the start) of the seasons.

The results of the interpolation indicate the agro-ecological zones (FAO 1977) that predominate, being either;

Dry: when rainfall is less than half PET for the entire year, (which is over 90% the case in Somaliland), or

Intermediate: when rainfall exceeds half PET for some of the year, (for example in Erigavo or Borooma).

Accepting that the growing period occurs when rainfall exceeds half PET (ie. the country is essentially dry), from table 11 the limits of non-irrigated agricultural potential are evident. Fig 48 shows plots from table 11 of monthly rainfall averages against half PET values for various administrative units in Somaliland, from which the limited potential *Gu* and *Deyr* growing periods Erigavo (Ceerigabo) and



Relationship between Annual Rainfall and the Frequency of Flow-Generating Storms for Hargeisa
Fig 37

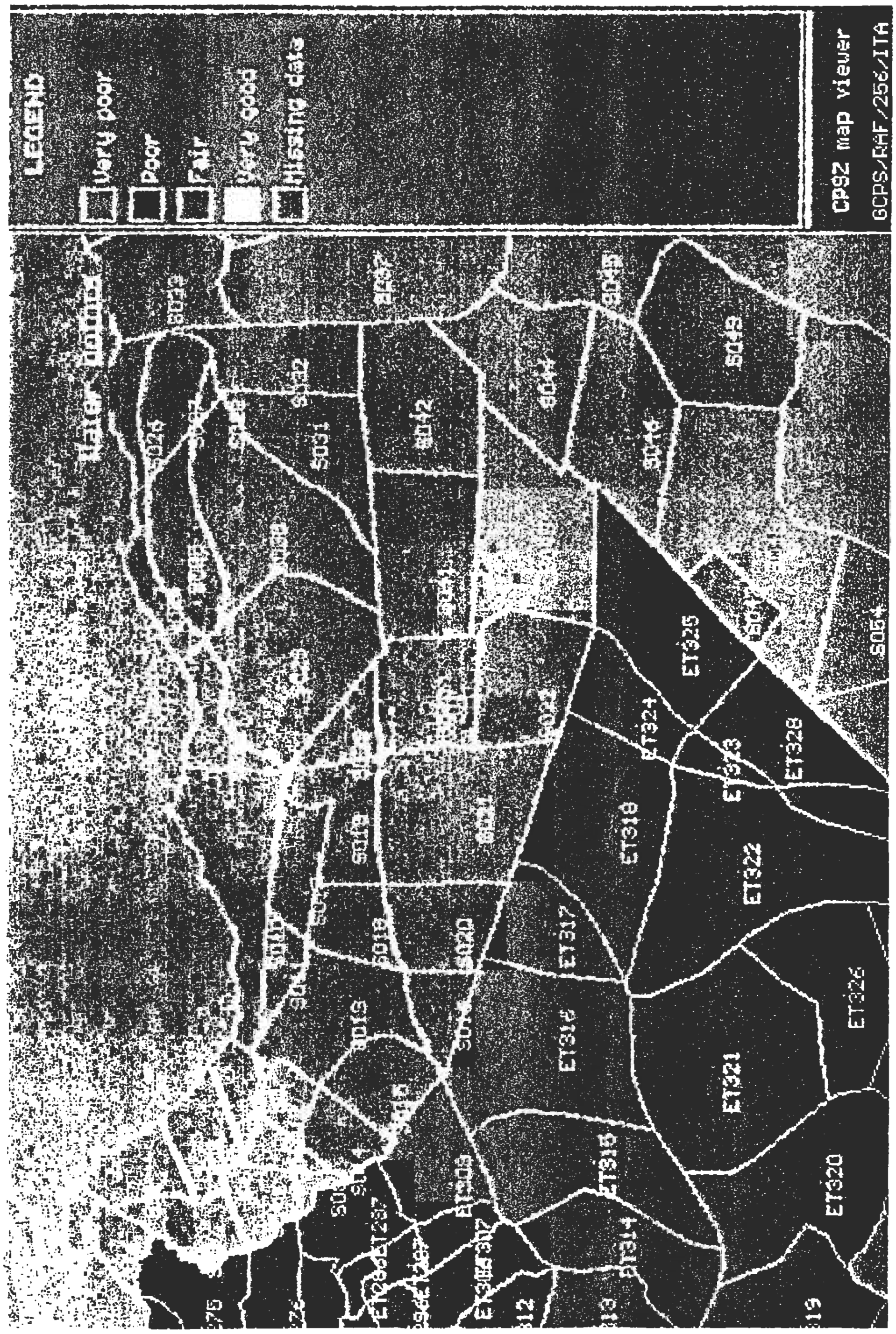


Fig 38
Map Units covering Somaliland

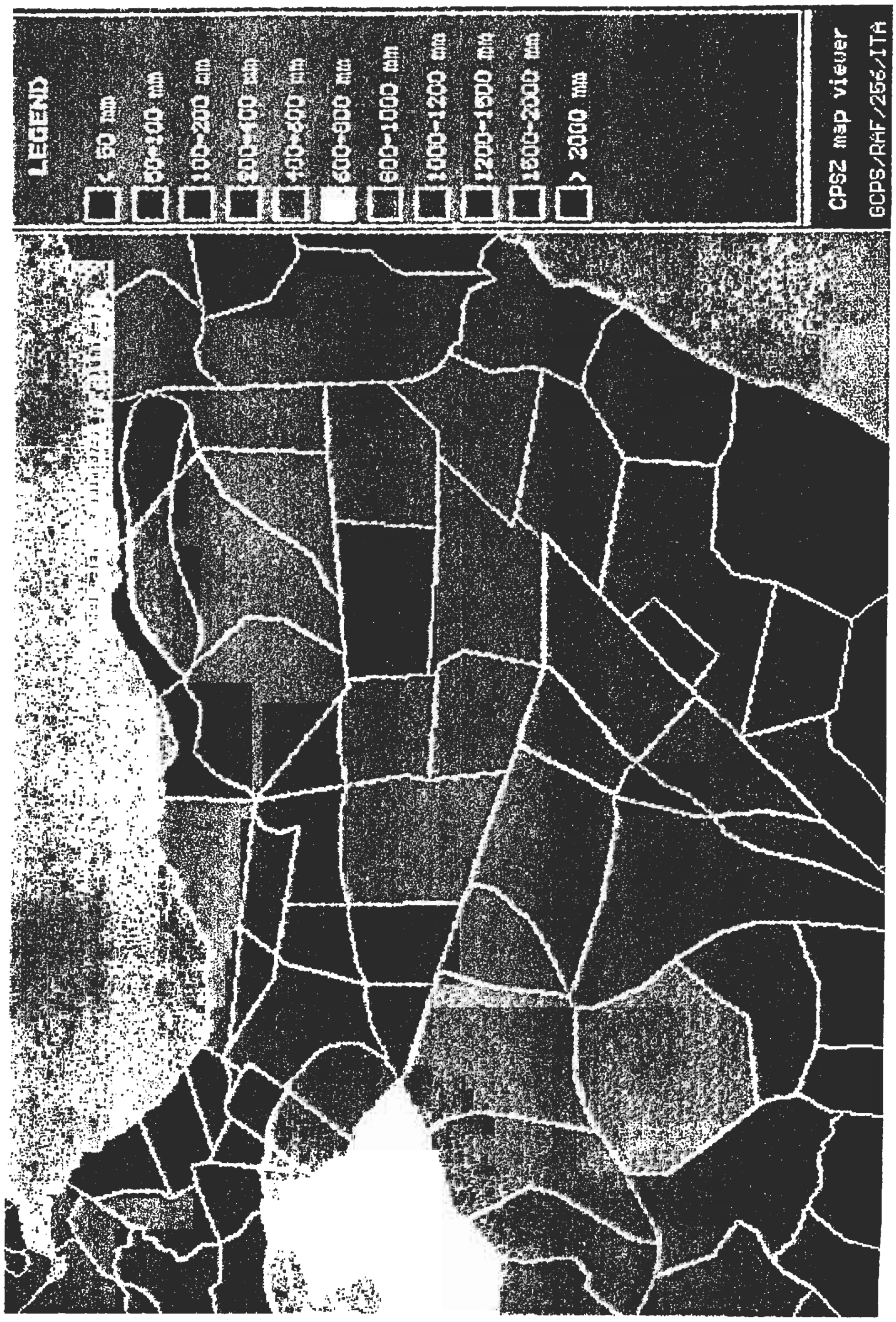


Fig 39
Average Annual Rainfall

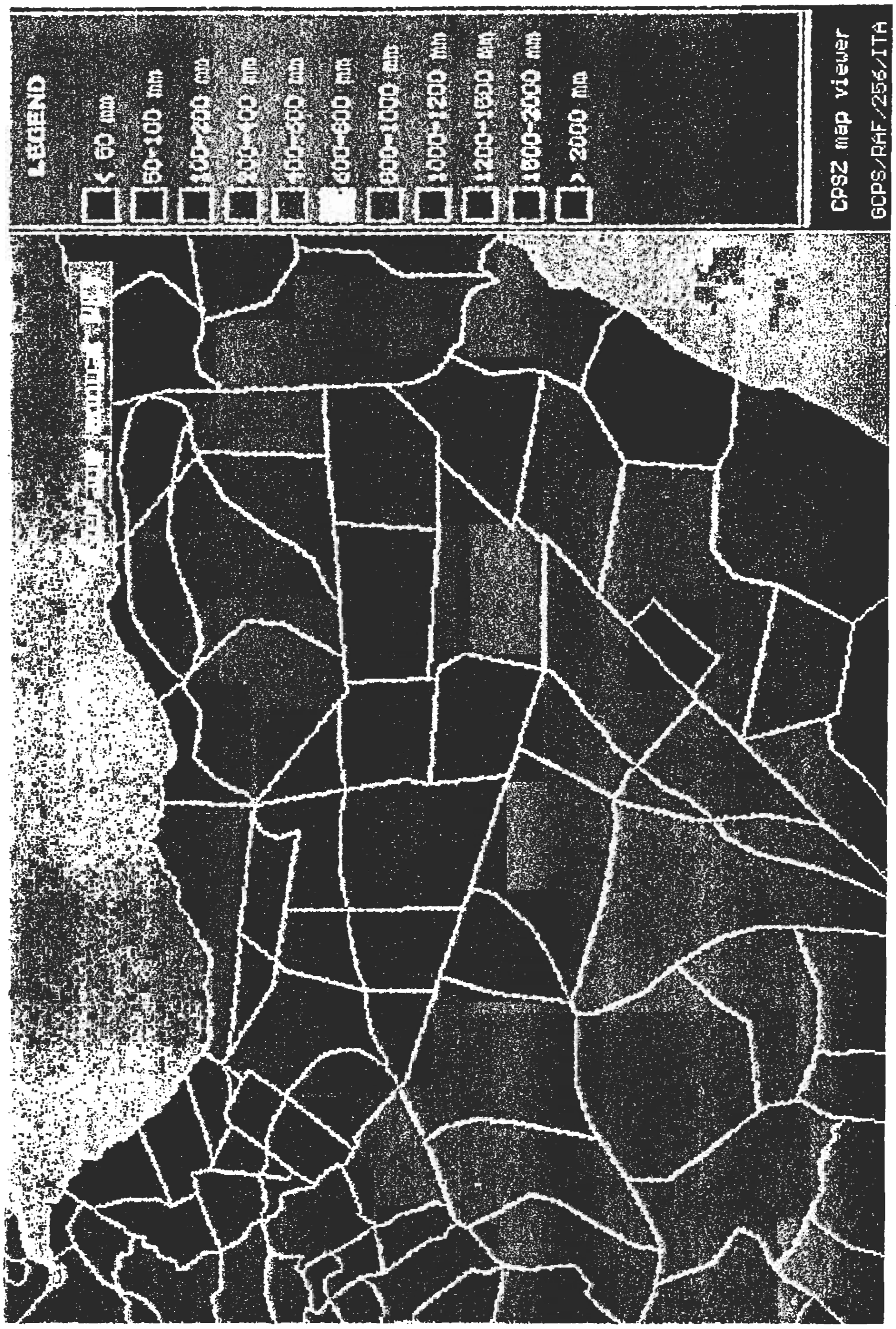


Fig 40
Average Annual Potential Evapotranspiration

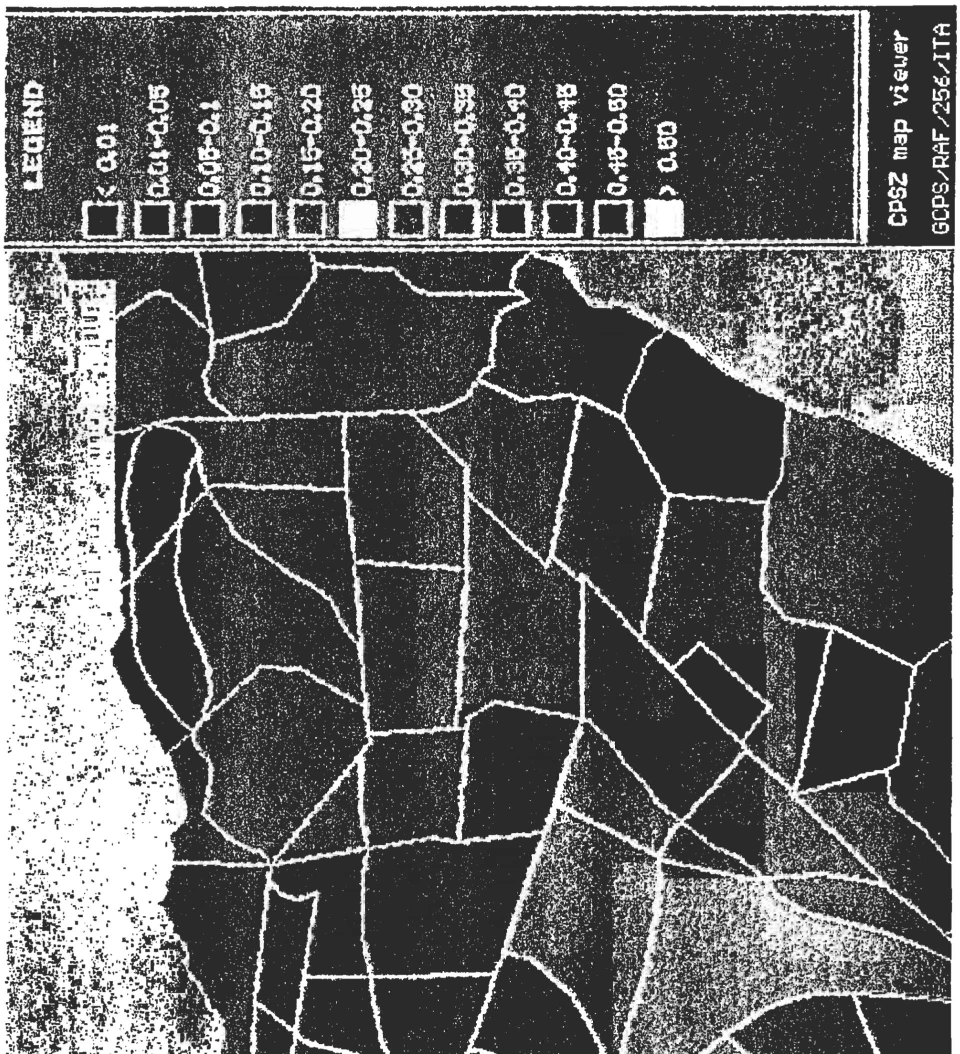
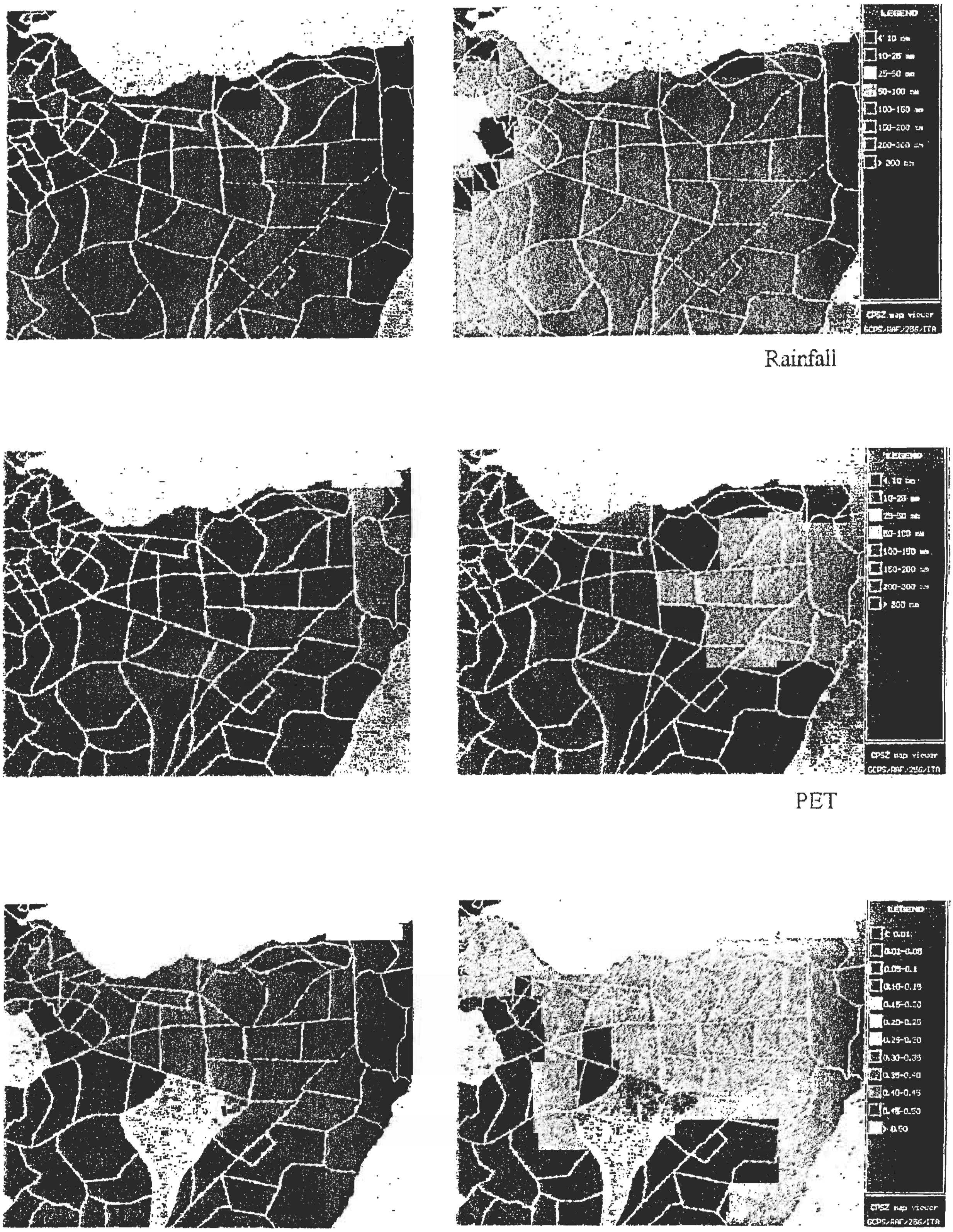


Fig 41
Average Annual Normalised Difference Vegetation Index

Fig 42



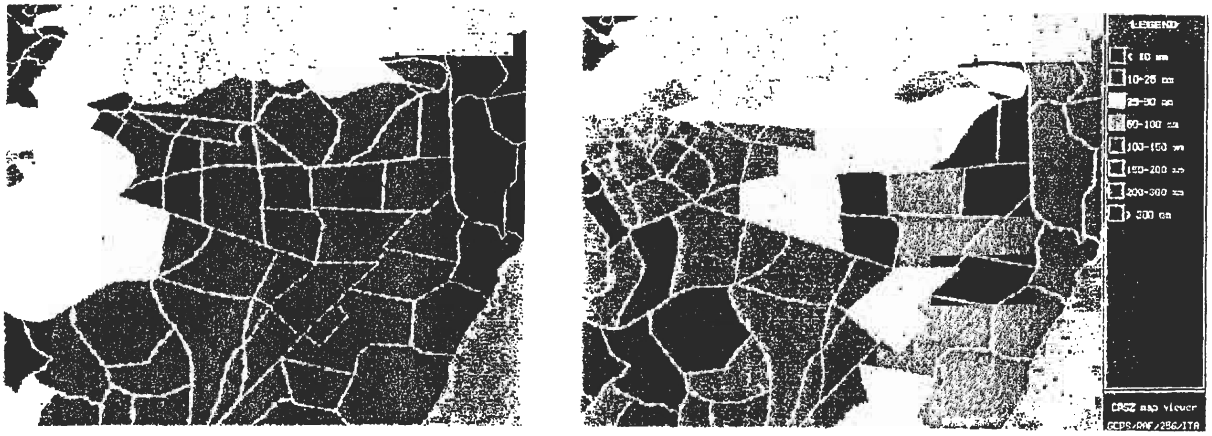
Rainfall

PET

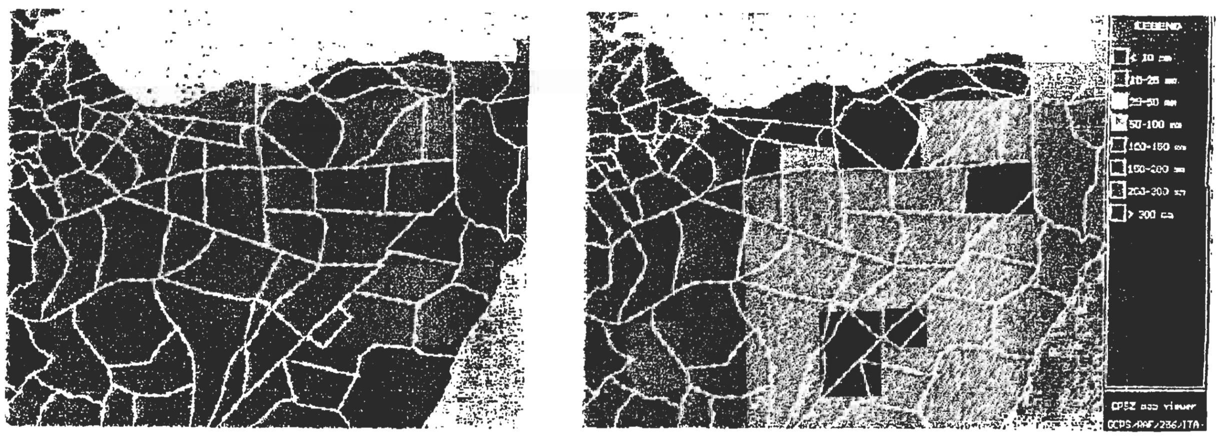
NDVI

JANUARY FEBRUARY

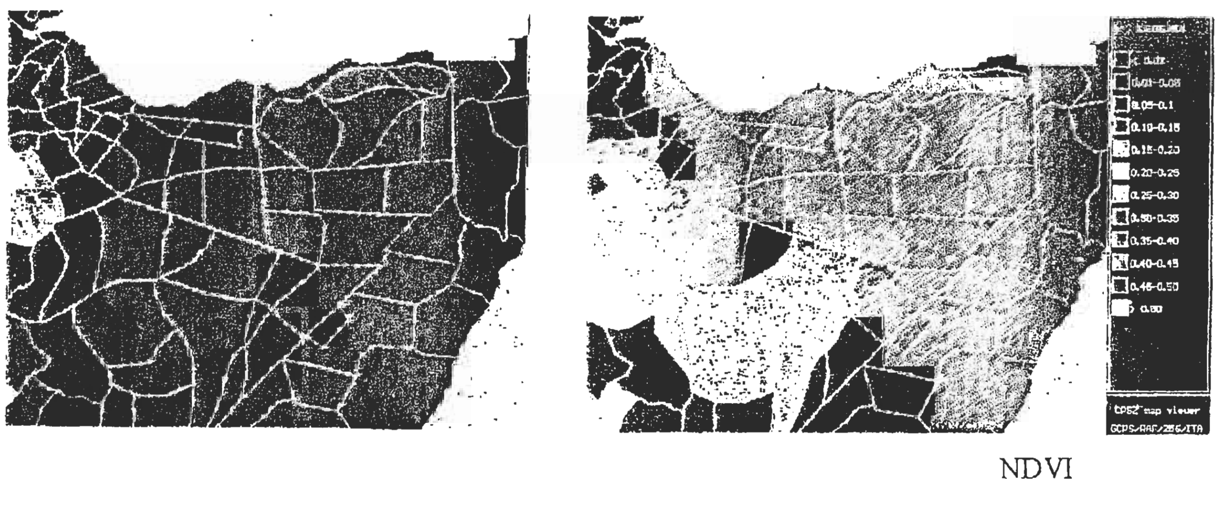
Fig 43



Rainfall



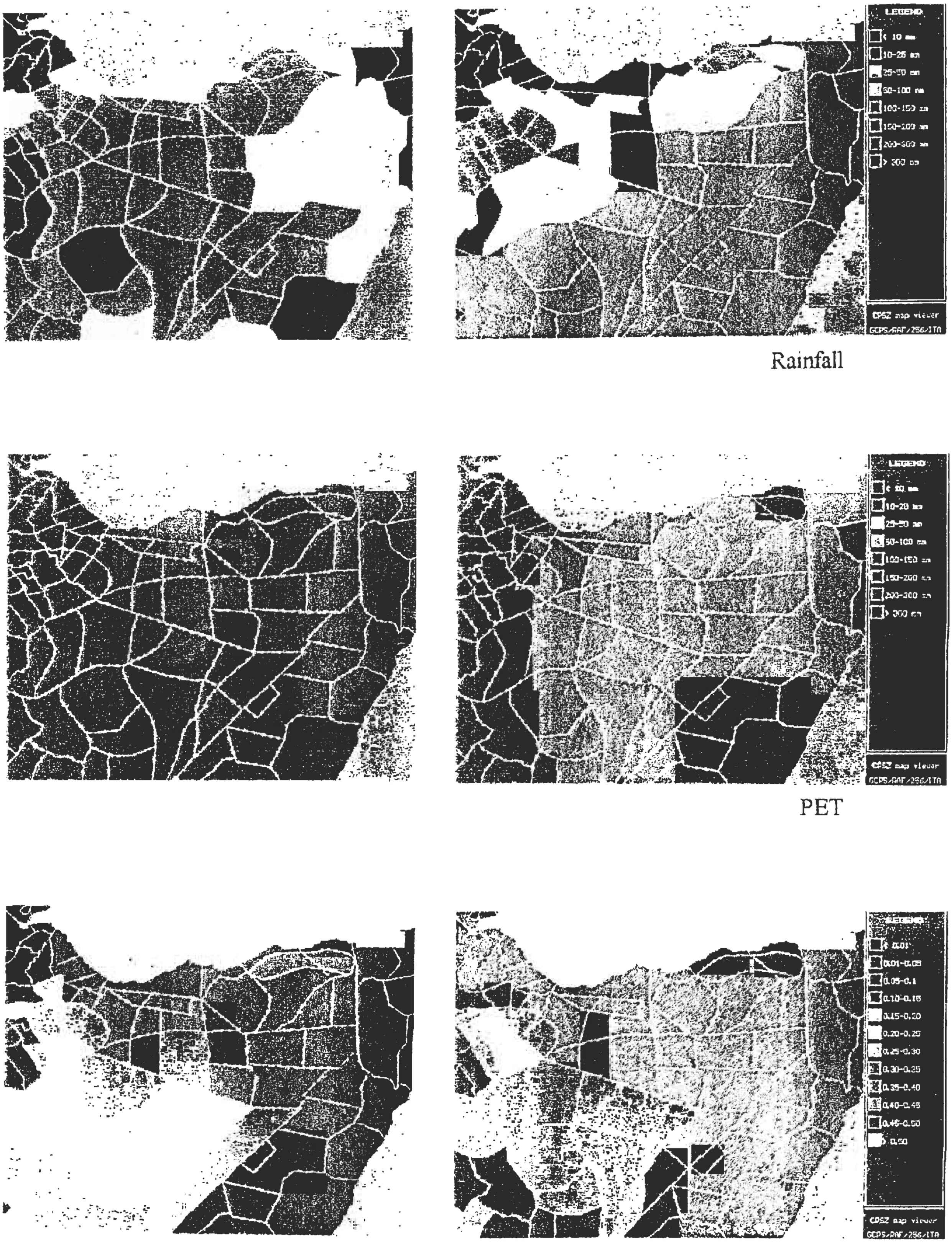
PET



NDVI

MARCH APRIL

Fig 44



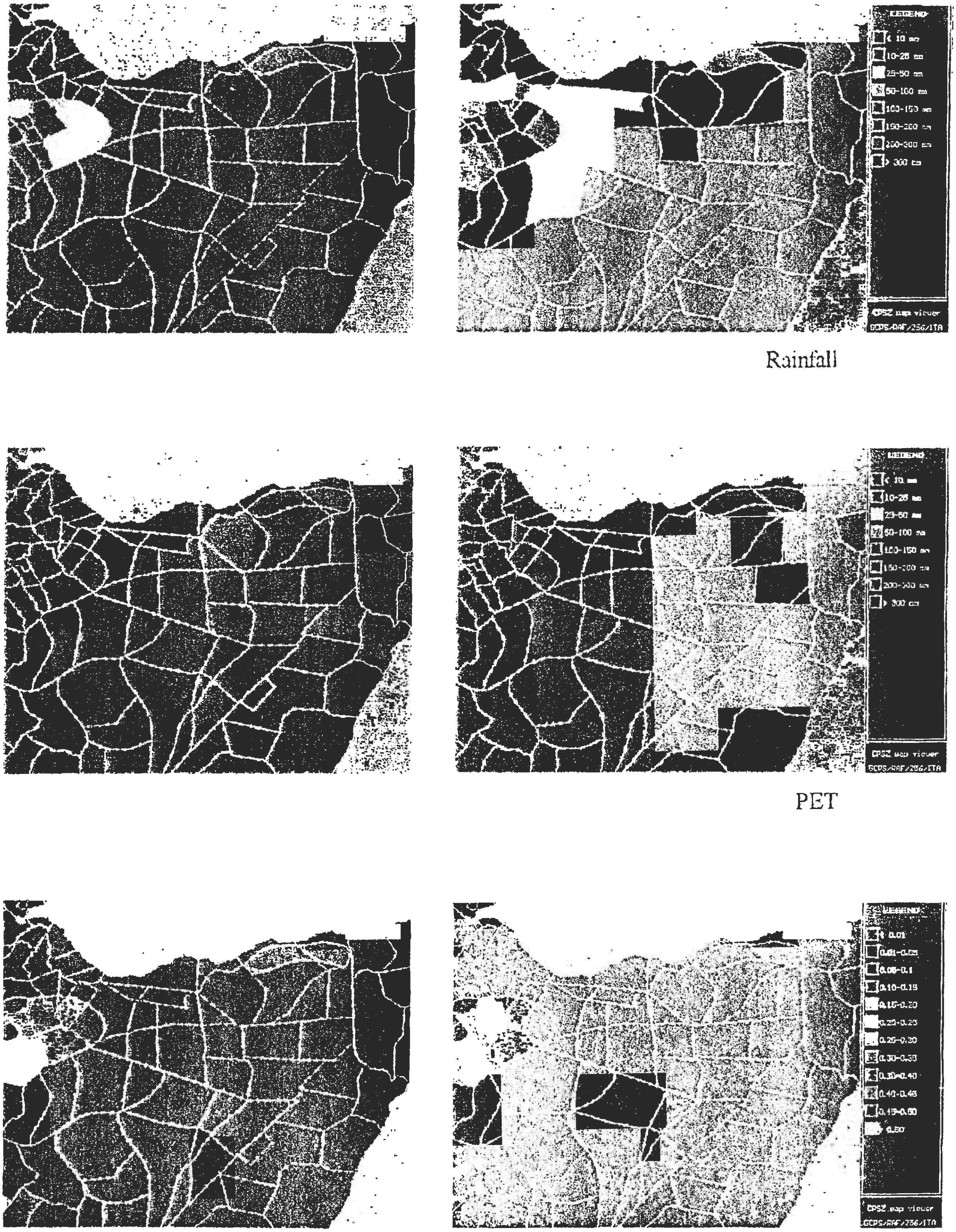
Rainfall

PET

NDVI

MAY JUNE

Fig 45



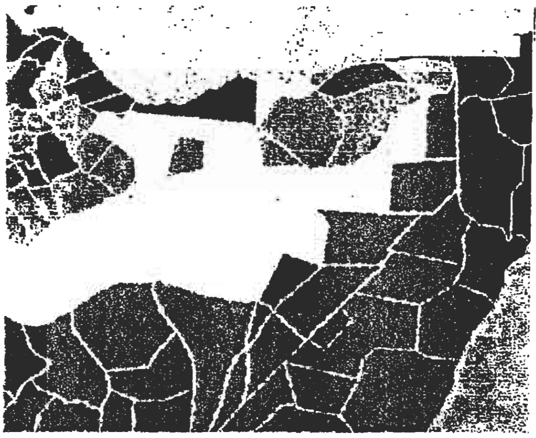
Rainfall

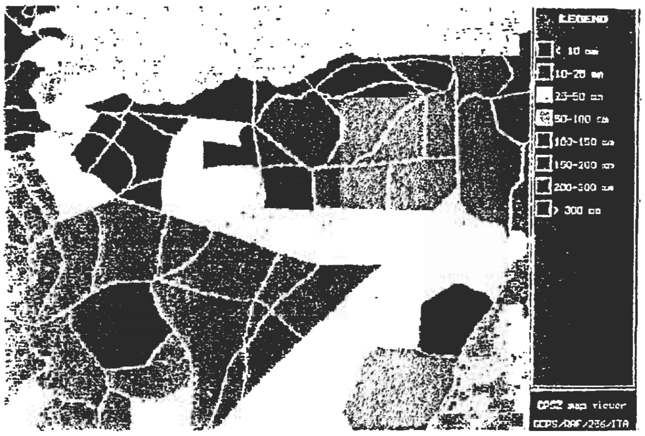
PET

NDVI

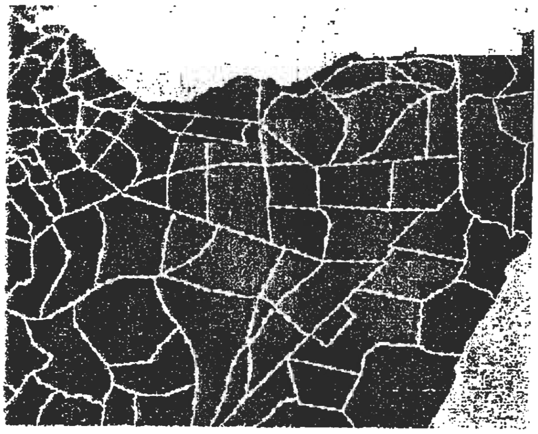
JULY AUGUST

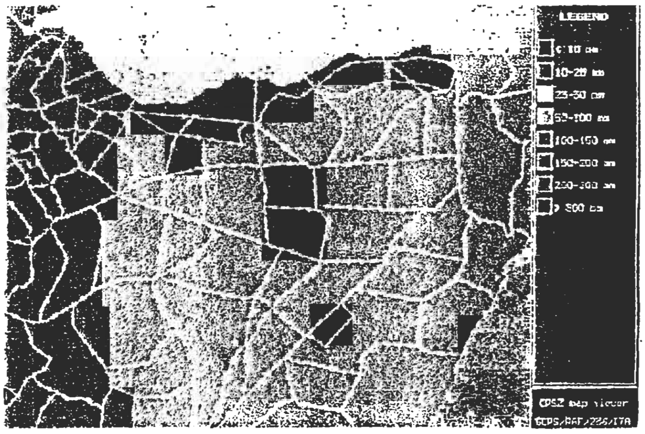
Fig 46



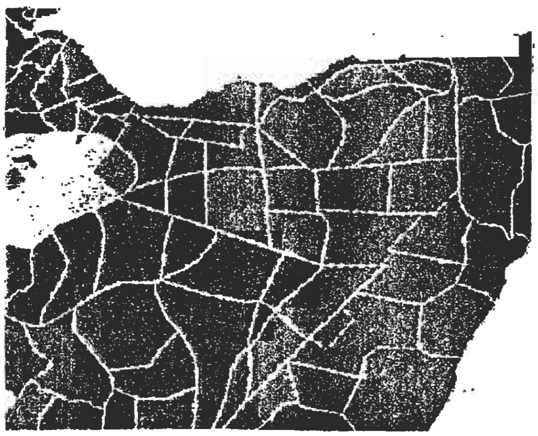


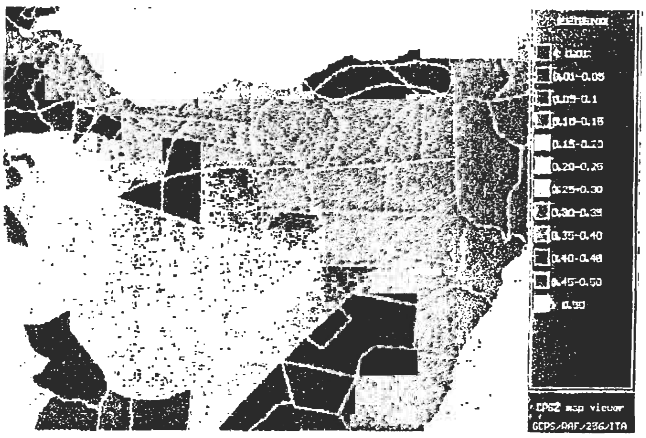
Rainfall





PET



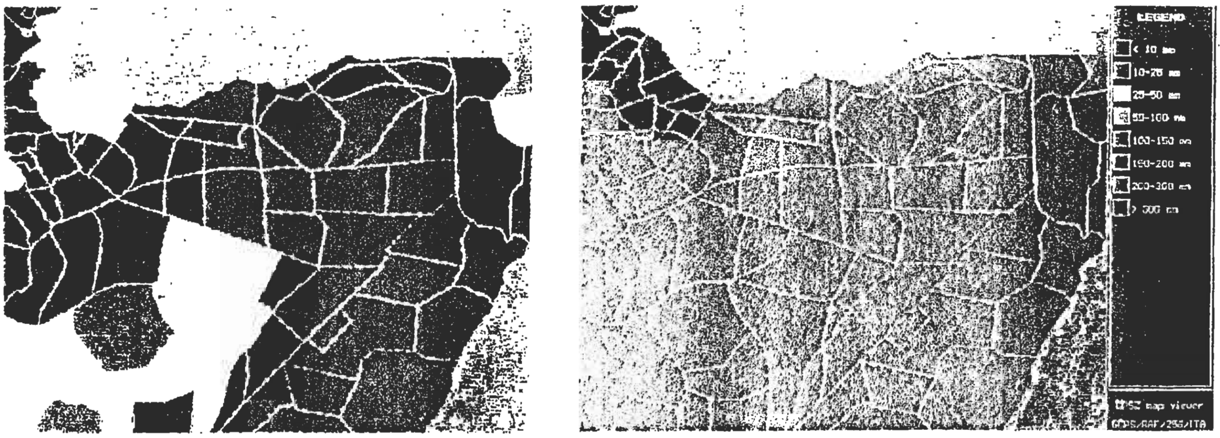


NDVI

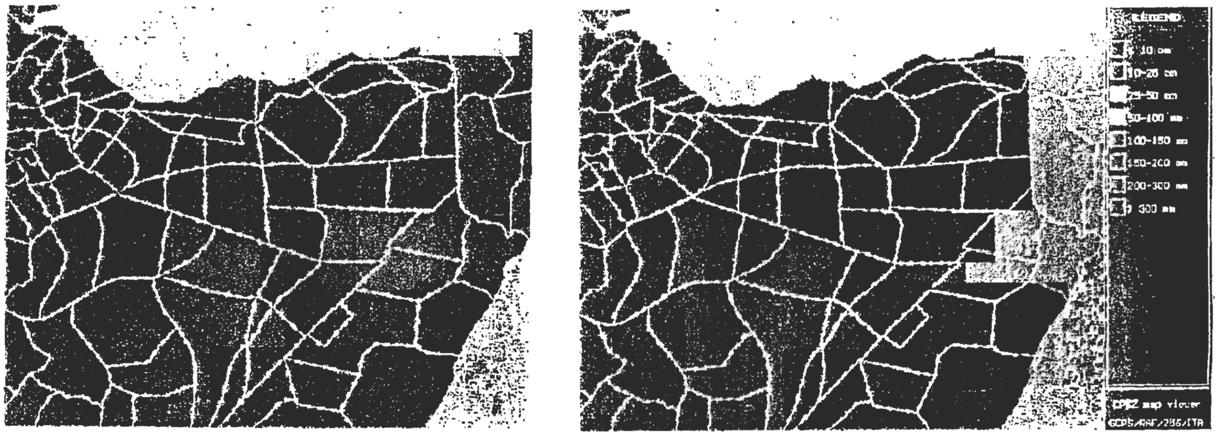
SEPTEMBER

OCTOBER

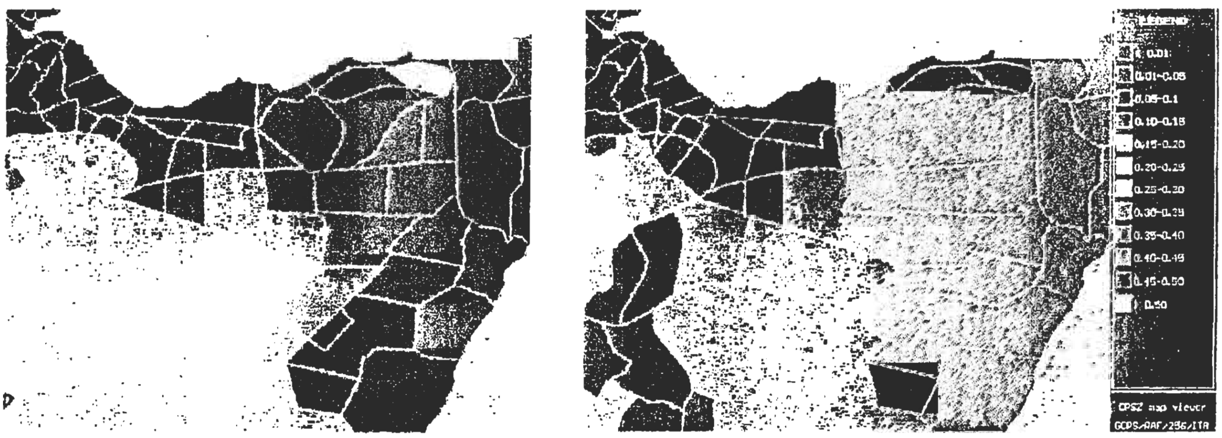
Fig 47



Rainfall



PET



NDVI

NOVEMBER DECEMBER

Table 11. Water Balance for Somaliland Regions

	Map Unit		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Avg p/a
SO1	E-Saylac	Rainfall	2	4	30	34	16	2	4	2	18	54	54	22	242
		PET	142	146	178	188	208	234	246	254	214	190	160	138	2298
		Deficit	-69	-69	-59	-60	-88	-115	-119	-125	-89	-41	-26	-47	
SO2	W-Saylac	Rainfall	4	8	34	46	22	6	0	0	98	54	42	16	330
		PET	138	140	174	182	200	218	222	226	198	182	154	134	2168
		Deficit	-65	-62	-53	-45	-78	-103	-111	-113	-1	-37	-35	-51	
SO3	Laghaya	Rainfall	0	0	38	54	26	8	0	6	20	46	44	22	262
		PET	160	184	202	206	226	282	286	294	244	210	176	152	2602
		Deficit	-80	-82	-65	-49	-87	-133	-143	-141	-102	-59	-44	-54	
SO4	N-Boorama	Rainfall	12	12	30	60	50	26	4	32	90	34	32	12	394
		PET	138	142	176	178	192	222	220	222	196	176	152	134	2148
		Deficit	-57	-59	-58	-29	-46	-85	-106	-79	-8	-54	-44	-55	
SO5	C-Baki	Rainfall	6	4	32	62	52	28	2	50	50	28	40	14	368
		PET	158	162	200	200	214	266	266	270	232	200	172	148	2488
		Deficit	-73	-77	-68	-38	-55	-105	-131	-85	-66	-72	-46	-60	
SO6	N-Baki	Rainfall	0	0	24	46	28	10	0	14	16	18	30	16	202
		PET	174	178	220	220	242	324	326	334	272	224	188	160	2862
		Deficit	-87	-89	-86	-64	-93	-152	-163	-153	-120	-94	-64	-64	
SO7	E-Baki	Rainfall	2	0	24	54	42	18	0	14	20	16	32	14	236
		PET	180	184	228	226	246	338	338	348	280	230	192	164	2952
		Deficit	-88	-92	-90	-59	-81	-151	-169	-159	-120	-99	-64	-68	
SO8	S-Boorame	Rainfall	12	24	34	88	56	38	46	114	94	50	18	6	580
		PET	136	140	172	172	180	212	208	210	188	168	148	132	2066
		Deficit	-56	-46	-52	2	-34	-68	-58	9	0	-34	-56	-60	
SO9	S-Baki	Rainfall	12	20	32	92	56	34	40	104	86	44	14	8	542
		PET	142	146	182	180	188	228	226	228	200	178	154	136	2188
		Deficit	-59	-53	-59	2	-38	-80	-73	-10	-14	-45	-63	-60	
SO10	N-Berbera	Rainfall	6	2	12	34	26	8	2	10	12	10	12	8	142
		PET	160	150	188	188	224	352	348	376	268	194	156	142	2746
		Deficit	-74	-73	-82	-60	-86	-168	-172	-178	-122	-87	-66	-63	
SO11	S-Berbera	Rainfall	10	6	22	76	52	22	10	30	26	24	22	12	312
		PET	172	168	210	208	236	360	356	374	280	214	178	152	2906
		Deficit	-76	-79	-83	-28	-66	-158	-168	-157	-114	-83	-66	-64	
SO12	N-Gabiley	Rainfall	10	6	24	62	50	26	2	32	40	18	30	10	310
		PET	172	178	220	218	232	308	306	312	282	220	186	158	2772
		Deficit	-78	-83	-86	-47	-66	-128	-151	-124	-81	-92	-63	-69	
SO13	N-Hargeysa	Rainfall	6	8	24	60	50	34	20	46	42	20	16	6	332
		PET	172	178	220	212	228	326	322	330	270	218	182	154	2812
		Deficit	-80	-81	-86	-46	-64	-129	-141	-119	-93	-89	-75	-71	
SO14	S-Gabiley	Rainfall	10	16	32	80	78	58	48	112	84	22	16	4	560
		PET	150	156	192	186	194	246	242	242	214	186	160	140	2308
		Deficit	-65	-62	-64	-13	-19	-65	-73	-9	-23	-71	-64	-68	
SO15	SW-Hargeysa	Rainfall	4	10	30	70	66	62	40	92	62	22	16	2	476
		PET	166	176	216	206	212	284	280	280	246	208	178	152	2604
		Deficit	-79	-78	-78	-33	-40	-80	-100	-48	-61	-82	-73	-74	
SO16	SE-Hargeysa	Rainfall	4	4	22	54	56	56	20	36	46	22	10	2	332
		PET	166	172	212	198	206	282	278	284	244	200	172	152	2566
		Deficit	-79	-82	-84	-45	-47	-85	-119	-106	-76	-78	-76	-74	
SO17	Sheekh	Rainfall	12	10	24	84	72	28	18	34	42	40	22	14	398
		PET	152	144	180	176	206	324	320	342	250	182	148	134	2558
		Deficit	-64	-62	-66	-4	-31	-134	-144	-137	-83	-51	-52	-53	
SO18	N-Oodweyne	Rainfall	4	8	24	52	56	30	22	42	50	34	16	8	346
		PET	148	146	182	178	194	294	290	304	234	180	150	132	2430
		Deficit	-70	-65	-67	-36	-41	-117	-123	-110	-67	-56	-59	-58	
SO19	N-Burco	Rainfall	6	4	14	44	60	22	12	20	38	24	14	6	264
		PET	150	142	178	172	196	296	288	308	236	174	142	132	2414
		Deficit	-69	-67	-75	-42	-38	-126	-132	-134	-80	-63	-57	-60	
SO20	S-Oodweyne	Rainfall	0	4	20	46	62	30	20	32	46	36	16	2	314
		PET	164	164	204	190	204	290	286	296	242	190	164	148	2542
		Deficit	-82	-78	-82	-49	-40	-115	-123	-116	-75	-59	-66	-72	
SO21	S-Burco	Rainfall	2	0	8	34	76	22	12	16	36	34	16	2	258
		PET	158	152	190	178	196	272	268	282	230	174	148	144	2390
		Deficit	-77	-76	-87	-55	-22	-114	-121	-125	-79	-53	-58	-70	
SO22	Buuhoodle	Rainfall	0	0	2	24	88	10	4	8	28	40	14	2	198
		PET	158	146	184	170	186	240	228	246	212	180	138	144	2212
		Deficit	-79	-73	-90	-61	-25	-110	-110	-117	-78	-40	-55	-70	
SO23	N-Ceel Afweyn	Rainfall	12	6	16	38	42	22	4	16	36	8	10	6	216
		PET	152	140	178	178	208	316	318	338	250	178	138	134	2526
		Deficit	-64	-64	-73	-51	-62	-136	-154	-153	-89	-91	-59	-61	

	Map Unit		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Avg p/a
SO24	N-Ceerigaabo	Rainfall	16	10	26	36	80	52	8	26	76	6	14	4	354
		PET	152	140	180	180	208	298	306	318	246	174	130	132	2464
		Deficit	-60	-60	-64	-54	-24	-97	-145	-133	-47	-81	-51	-62	
SO25	C-Ceerigaabo	Rainfall	20	14	36	50	98	70	12	50	140	12	18	6	526
		PET	126	116	148	146	170	236	242	250	200	140	106	108	1988
		Deficit	-43	-44	-38	-23	13	-48	-109	-75	40	-58	-35	-48	
SO26	N-Badhan	Rainfall	6	4	12	12	26	14	2	8	22	4	10	4	124
		PET	142	136	174	176	202	268	290	286	234	160	116	124	2308
		Deficit	-65	-64	-75	-76	-75	-120	-143	-135	-95	-76	-48	-58	
SO27	CN-Badhan	Rainfall	8	6	18	26	48	28	8	24	54	10	12	6	246
		PET	132	122	158	156	182	238	248	250	210	144	106	114	2060
		Deficit	-58	-55	-61	-52	-43	-91	-118	-101	-51	-62	-41	-51	
SO28	CS-Badhan	Rainfall	4	4	10	16	24	14	2	12	28	8	8	4	132
		PET	134	120	154	152	178	230	232	240	206	144	106	114	2010
		Deficit	-63	-56	-67	-60	-65	-101	-114	-108	-75	-66	-45	-53	
SO29	S-Ceel Afweyn	Rainfall	12	8	18	36	60	34	6	24	58	12	12	4	284
		PET	144	132	166	162	186	268	264	282	222	160	126	126	2238
		Deficit	-60	-58	-65	-45	-33	-100	-126	-117	-53	-68	-51	-59	
SO30	SW-Ceerigaabo	Rainfall	10	8	22	28	60	36	6	24	62	10	10	4	280
		PET	136	120	154	150	172	234	228	242	204	144	112	116	2012
		Deficit	-58	-52	-55	-47	-26	-81	-108	-97	-40	-62	-46	-54	
SO31	SE-Ceerigaabo	Rainfall	6	4	14	24	48	20	4	16	40	12	8	4	200
		PET	150	126	164	158	182	236	218	240	214	152	118	126	2084
		Deficit	-69	-59	-68	-55	-43	-98	-105	-104	-67	-64	-51	-59	
SO32	S-Badhan	Rainfall	2	2	8	18	32	10	2	10	18	10	6	4	122
		PET	154	130	168	164	196	244	226	246	226	160	120	130	2164
		Deficit	-75	-63	-76	-64	-66	-112	-111	-113	-95	-70	-54	-61	
SO39	N-Caynabo	Rainfall	10	6	16	44	62	26	6	16	50	20	14	6	278
		PET	142	132	166	160	184	268	262	282	218	160	128	126	2228
		Deficit	-61	-60	-67	-36	-30	-108	-125	-123	-59	-60	-50	-57	
SO40	S-Caynabo	Rainfall	4	2	8	24	54	18	4	10	36	20	10	2	192
		PET	156	144	180	170	190	262	254	272	224	166	138	138	2294
		Deficit	-74	-70	-82	-61	-41	-113	-123	-126	-76	-63	-59	-67	
SO41	Xudun	Rainfall	4	2	8	20	44	16	2	10	34	16	6	2	164
		PET	166	144	182	172	194	252	234	258	226	166	134	144	2272
		Deficit	-79	-70	-83	-66	-53	-110	-115	-119	-79	-67	-61	-70	
SO42	Taleex	Rainfall	2	2	6	20	40	8	2	8	16	20	4	4	132
		PET	172	140	184	174	202	248	214	246	232	170	134	146	2262
		Deficit	-84	-68	-86	-67	-61	-116	-105	-115	-100	-65	-63	-69	
SO43	Laascaanood	Rainfall	0	0	2	16	40	4	0	2	16	28	8	2	118
		PET	168	146	186	174	194	238	218	240	218	162	138	148	2230
		Deficit	-84	-73	-91	-71	-57	-115	-109	-118	-93	-53	-61	-72	

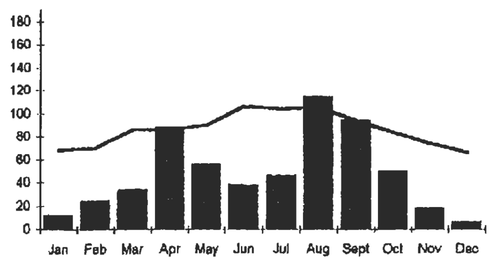
All dimensions in mm

Deficit based on Rainfall minus PET/2 (FAO 1977)

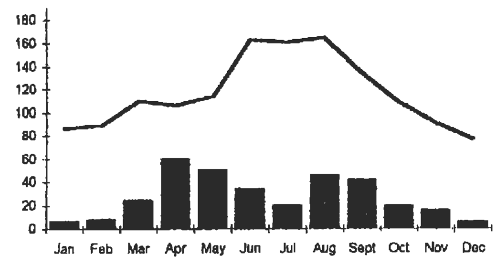
For corresponding map units refer to fig. 38

Source: Crop Production System Zones of the IGADD Sub-Region

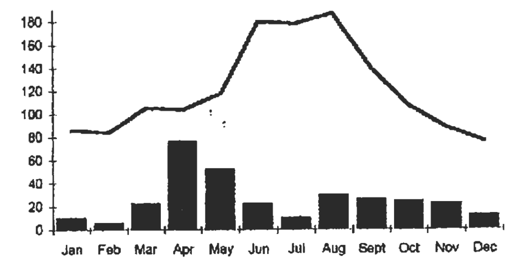
Table 11. Water Balance



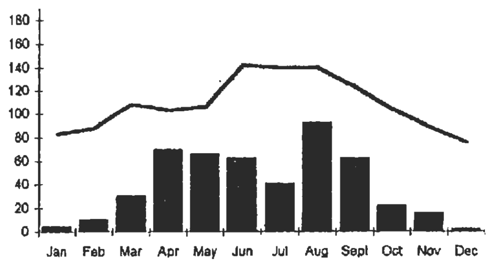
SO8 - South Boorame



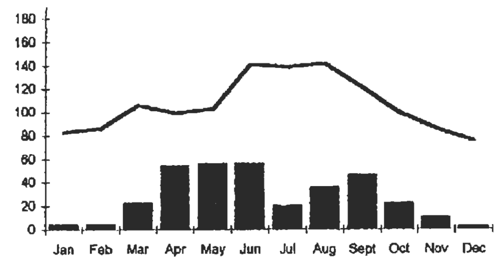
SO13 - North Hargeisa



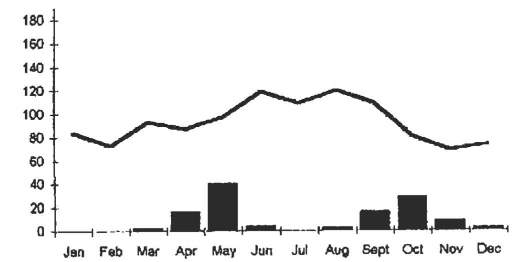
SO11 - South Berbera



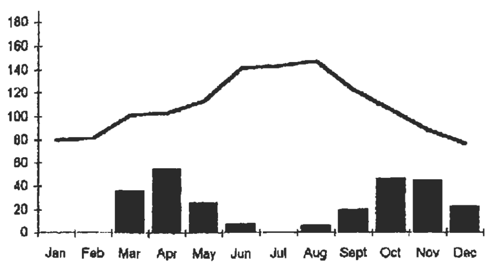
SO15 - SE Hargeisa



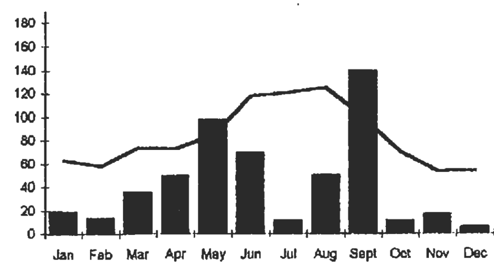
SO16 - SW Hargeisa



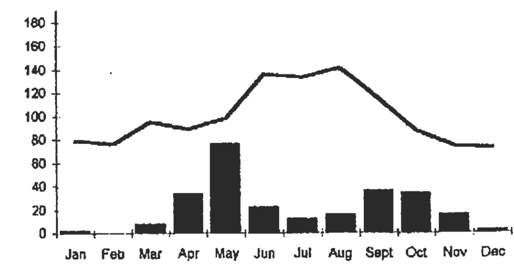
SO43 - Las Anod



SO3 - Lughaya



SO25 - Central Ceerigabo



SO21 - South Burao

Fig 48. Plot of Rainfall (mm) and PET/2 (mm) vs Time for Selected MapUnits

Borooma can be inferred. This does illustrate why water conservation and concentration techniques, such as planting in *tugga* and water retention bunds are practised throughout the country.

It is also interesting to note that the FAO model of growing period (FAO 1977) suggest that by August the developing crops are past their most sensitive stages and rainfall is often surplus to requirements. In a normal year, losses in *Deyr* rainfall may therefore have the minimum possible effect on any crop production, but the reverse effect for pastoral production. Hutchinson (1986) derived a calculation method for annual dry matter production in Somalia

$$Y_{dm} = \sum_{1}^{12} 0.54(15.3 + 10.6\tfrac{n}{N})Ra\tfrac{P}{PET}$$

Ydm = annual dry matter production in t/ha
P = monthly rainfall
PET = monthly potential evapotranspiration
n = actual sunshine hours
N = maximum possible sunshine hours
Ra = extra-terrestrial radiation

The equation is clearly most affected by the ratio P/PET. As can be seen from values in table 10 and fig 48, although variation in PET has some effect, it is the temporal and spatial variation in rainfall that has the greatest effect on variations in Ydm.

Despite the limitations of the water balance approach, and the statistical algorithms that underpin it, the development process of spatially and temporally averaged mapping is an important step towards the subsequent development of dynamic regional monitoring tools. Shifting the maps into real time monitoring of rainfall and vegetation at the regional scale, (ie. remote sensing applications) has removed the emphasis from spot recording (ie. gauge rainfall) and the inherent difficulties in extrapolating from spot to areal values, to a more useful spatially and temporally integrated approach. A combination of both techniques is shown to be the basis for powerful real-time monitoring of rainfall in Section 7.

6.5 Development Potential of Water Resources

Based on the three physiographic provinces and the review of hydrological and hydrogeological studies, general recommendations can be made on the development potential of water resources. However, in the absence of detailed data, the recommendations should not be taken as authoritative. The over-riding need for development activities related to Water Resource Assessment and Planning have already been made clear, as a precursor to the implementation of large scale water resource development projects. But in general, in a year of normal rainfall, and hence adequate recharge of surface and shallow groundwater, the resources are ample. The stock watering requirement alone 18.7 Mm3/pa (section 5.1) being appreciably less than just the infiltration on the coastal plain of one major *tugga* (eg. Waheen 40 Mm3/pa - SOGREAH 1981). This is especially the case considering the low man/land ratio and the suitability of pastoralism to the exploitation of a patchy rainfall-driven ecological regime.

6.5.1 Coastal Belt and Sloping Plain

Along the coastal belt there is a continuous shallow aquifer which is recharged by the underflow of the numerous *tugga* draining the mountainous zone, by ground water flowing in alluvial deposits and other sediments of the sloping plain, and by the runoff water of *tugga*. In places close to the shore the water table is within 2-3m, getting deeper inland. Shallow wells along the coast already supply water of good to marginal quality used by villages, nomads, and for the irrigation of date palms and these activities could be strengthened. Date palm could be cultivated nearly every where along the coast. Potential areas for resource development include those close to, or covered by, inland deltas of *tugga* with large catchments in the mountainous zone.

The runoff water of the four major *tugga* in the west reaching the coastal plain amounts to 130Mm3/pa (SOGREAH 1981) and the water is of excellent quality (Faillace 1986). Groundwater in *tugga* and alluvial cones is suitable for most purposes and could be exploited by hand dug wells and shallow boreholes with high expected yields.

6.5.2 Mountainous Zone

In the west and central areas from Borooma to Hulul there are deep valleys, steep slopes and mountain ranges reaching about 1,800m in elevation. Due to the large variety of rocks, the accentuated drainage network, and the high rainfall in the mountain range, the surface and groundwater conditions of the area are good. Several types of projects could be implemented for village water supplies, livestock water supply and limited agriculture. Conditions favour the construction of sub-surface, surface and sand-storage dams in several places across major *tugga* and their tributaries. Infiltration galleries along major *tugga* would increase present exploitation through shallow wells. There are numerous springs issuing from the geological formations at various elevations; little used because water usually disappears after short distances into gravel and sand streams. Spring water is generally of good quality and could be used for most purposes.

In the East along the Erigavo-Ahl Mado escarpment, development is limited due to the steep rocky slopes covered by evergreen vegetation. Some 30-40 springs have been recorded, generally yielding less than 1l/s of water but of good quality (Faillace 1986). Spring water development and small scale gravity systems would therefore be viable in many locations.

All along the *Golis* range water quality from alluvial deposits and springs is good: the first step for the development of these resources is to carry out a complete inventory of the springs and to investigate the groundwater potential of the alluvial deposits of major *tugga*.

6.5.3 Plateau and Valleys

Haud Plateau has the best grazing potential in Somaliland but the area is most badly affected by droughts. The potential is difficult to realise due to the excessive depth of the water table (from 200 to 400m), the low yield of boreholes, and the drilling difficulties in fine, unstable sands. The groundwater conditions across the plateau are not well known. The water table gets increasingly deeper from North to South and from West to East. Across the Haud and Sool impounding run-off appears a more appropriate solution (MacDonald 1986). There is good potential in areas of calcareous red limestone soils or red alluvial soils for surface water harvesting and runoff irrigation/fodder production (Halcow 1980). Deep boreholes should only be drilled in areas with large grazing potential, for large villages, and to supply areas affected by recurrent droughts.

An investigation aimed at assessing the groundwater conditions of the Bokh valley and the Horufadhi-Buuhoodle area is recommended with boreholes drilled to depths of between 350 and 420m selected on the basis of hydrogeological conditions and grazing potential (Faillace 1986). The shallow aquifers of the Togdheer and the *tugga* located in the upper catchment of the Bokh valley require an hydrogeological investigation, including shallow drilling. The study should assess the aquifer potential and define the type of water works most appropriate for each area. The selection and investigation of the most promising sites for impounding reservoirs should also be included based on the assessment of soils and surface channel flows (Halcrow 1980).

The area, covering the inland side of the escarpment along a continuos east-west belt extending from Erigavo to Hadaaftimo and Huberra further East, has the greatest reported agricultural potential of Somaliland due to good climatic conditions and large areas covered by brown calcareous soils. Prospects for agricultural development are good. Soil conditions, surface and groundwater resources, human resources, and grazing potential need to be properly evaluated.

6.5.4 The Case for Simple and Appropriate Technology

In most areas of Somaliland there is potential to develop the available resources. But in Somaliland, where the population is scattered and where distances are great, this requires a large financial investment beyond the means of the productive capacity of the state. Taking care of thousands of village water supply systems would require an organisational and financial commitment that Somaliland cannot afford. Considering the low income of the rural families and the limits of funding from the government and donors, low cost projects using simple technologies or improving indigenous technologies have a better chance of success. Experience elsewhere in Africa has shown that local community participation in the planning and implementation of affordable small scale water supplies, backed up by local management in their operation and maintenance, provide every chance of such supplies being sustainable. In Somaliland the types of simple and appropriate water structures are likely to be:

- Hand dug wells - and infiltration galleries
- Sub-surface dams - and sand storage dams
- Rainwater harvesting - by *berka*, *balleh*, and roofs

Boreholes will continue to play a crucial role in Somaliland. The drilling of deep wells in the past 40 years or so has solved the water problems in certain areas, mainly for settled populations. But in the rural sector, due to the high cost of drilling, operation and maintenance and also of fuel and spare parts, deep drilling should be restricted to those areas with favourable hydrogeological conditions and where simple and low cost technologies cannot be implemented. In the many large areas with saline or brackish groundwater, solutions appropriate to local conditions need to be considered.

A selection of the simple appropriate technologies are shown in plates 23 to 35. In particular consensus is agreed on the high potential for sub-surface and sand dams in the numerous *tugga* (Hunt 1951, MacFadyen 1950, Faillace 1986, Mohamoud 1990, MacDonald 1986). Although there is no accurate information on aquifer characteristics, guideline aquifer units sufficiently representative of Somaliland *tugga* can be assumed. A typical aquifer thickness of 2m occurs in the tugga composed of medium grained sand.

Porosity	25%
Specific Yield	10%
Aquifer thickness	2m
Vertical permeability co-efficient	2m/day
Horizontal permeability	50m day
Aquifer transmissivity	
Initial 90 days from start dry season	$60m^3$day
Remainder of dry season	36 m^3day
Hydraulic gradient	1:300

For a 1 hectare site aquifer storage will be $5,000m^3$ under optimum conditions, of which roughly $2,000m^3$ is available. Print and Farah (1997) have shown that with a typical yearly shallow aquifer replenishment of 3 spates, 160 m^3/day can be sustainably extracted from a typical 12 ha section of *tugga* using these figures. MacFadyen (1951) reported that 3,000 camels, 12,750 sheep and 4,200 goats were watered daily during the one dry season month of March at Hargeisa tug, over a 1km section. This equates to a supply rate of some $250m^3$ per day and there is a thus a good sense of agreement on figures here.

7. Remote Sensing and Early Warning Systems in the Sahel and Somaliland

The need for an effective Famine Early Warning System in Somaliland and the importance of comprehensive environmental data have been highlighted in Chapter 5. In both cases, due to scale of the region and the remoteness and difficulties of detailed ground studies, the use of remote sensing tools can be of great assistance. The implications of the developments in remote sensing are of fundamental concern to the engineer working on a regional scale in the Sahel or East Africa, and an analysis of the role of remote sensing and its applications in early warning systems is therefore warranted.

7.1 The Role of Remote Sensing

One of the main impediments to improved environmental management is the lack of reliable and up to date information. Development in all Sahelian countries is closely dependent on their natural resources and regular monitoring should be an integral part of national resource management and planning. In addition, long term monitoring can be used to assess the sustainability of development (Falconer *et al* 1988).

At present satellite remote sensing is the only way of obtaining systematic regional observations and to undertake spatially comprehensive monitoring of the Sahelian environment. In many cases, the full potential of remote sensing to Sahelian issues is unknown, the role is likely to be unique and cannot simply be transferred from elsewhere (Prince *et al* 1990). In spite of the need for improved resource management in the Sahel there are currently few operational programmes using remotely sensed data. This appears to be based on the lack of long term-commitment to the development and integration of such programmes rather than the suitability of available techniques.

This might be explained by:

1. The relatively high cost of the operations and data that inhibits its use for Sahelian applications. This is particularly true for high spatial resolution data, and with the commercialisation of space data.

2. The need for regionally synthesised planning and management frameworks to handle national resource databases. This basic administration capacity is not evident in many Sahelian countries on a national nor regional scale.

3. The somewhat negative attitude of some donors towards projects based on complex technical systems. This is a legacy of past failures in high-tech approaches to development, there being an often expressed view that African solutions must be low-tech (Luscombe *et al* 1988).

In fact experience with high technology activities such as image processing and geographical information systems in the Sahel need not be discouraging (eg. CSE in Senegal) in that, given adequate training and incentives to learn and stay with the programme, there is no shortage of able staff. This must be borne in mind in the case of remote sensing since the potential for the technology to dominate the project is so evident. Successful development projects are motivated by the needs of genuine users of the products of the activity. The technology that is implemented must therefore not become isolated from those needs as understood at any point in time, nor should the process of co-operation development stop with the creation of remote sensing products (Bonifacio *et al* 1998).

Building on the success of LANDSAT during the mid-and-late 1980s, the use of satellite data became more firmly established through the efforts of the FAO and its ARTEMIS programme (African Real-Time Monitoring and Information System) and USAID/FEWS (Famine Early Warning System) amongst others. These projects tended to rely on products provided by external agencies rather than derived locally. For example ARTEMIS produced dekadal values of rainfall and vegetation status that were derived in Rome and disseminated to regional centres.

Recent shifts in technology transfer policies, in part based on the falling cost of microcomputers and satellite receivers, have allowed African meteorological institutions to produce their own information for dissemination to users while providing major improvements in human and technical capacity building (Bonifacio *et al* 1998).

Many satellite applications are now in various stages of development and testing. The general procedure is that once a technique has been developed and tested at the local and regional scale, a further stage of research and development is needed to integrate the technique into operational procedures and resource management frameworks (Prince *et al* 1990). The process of technology transfer from purely research into an operational environment is one that ideally involves multidisciplinary investigations by a team of users as well as scientists; an appropriate development framework therefore needs to be worked out. Prince *et al* (1990) and Bonifacio *et al* (1998) provide examples of functioning projects and recommendations for co-operation development frameworks in remote sensing applications in Sahelian Africa.

The development of applications is currently rapid. Applications of interest to the field of water and environmental management, and that are currently near or fully operational include:

- Rainfall Estimation.
- Rangeland production monitoring.
- Food security and early warning systems.
- Groundwater surveying.

Whereas applications that are in the transition to fully operational status, or require further research and testing at the local and regional level include:

- Crop production monitoring and modelling.
- Evapotranspiration estimation.
- Hydrological catchment modelling.

- Erosion monitoring and prediction.

For a description of the technologies, providers and a review of the techniques, accuracy and relative benefits of these applications see Curran (1985), Hutchinson (1991) or Prince *et al* (1990).

7.2 Early Warning Systems

The use of remote sensing in Somaliland is mainly in the context of food security and early warning systems. Specific applications include rainfall monitoring. Working within the SACB, the Food Security Assessment Unit (FSAU) is a project funded by the EC, supported by FAO, USAID(FEWS) and WFP. The project has been ongoing since 1995 but is only now being more concretely established. The project is a typical early warning system that relies on a chain of data collection, data analysis, communication of early warning, and response and mitigation. The approach is based on the research and surveillance of a set of inter-related indicators;

- Food economy
- Markets
- Meteorology
- Agricultural production
- Nutrition
- Livestock
- Population movements

that are analysed, ideally in real time, for early indications of food insecurity (FSAU 1999).

FEWS collaborates with the FSAU to improve early warning and vulnerability analysis methodologies. Remotely sensed and ground-based early warning data are collected, analysed, and disseminated on an ongoing basis. A FEWS/IGAD training presentation is reproduced in Annex D, and shows the mechanics of the operational system in relation to the two remotely sensed indicators: Rainfall and NDVI (Normalised Difference Vegetation Index). As we have seen previously the behaviour of vegetation and the driving role of rainfall play an essential part in regional production systems, and the monitoring of vegetation and rainfall therefore play a significant part in early warning systems.

Haile (1999) recommends that a rainfall monitoring system for early warning and food security functions should integrate:

- Seasonal forecasts if they exist.
- Rainfall from station data.
- Rainfall estimates using remote sensing (satellite data).
- Qualitative information on rainfall (reported by field monitors).

The need for merging of the first three parameters is apparent and improvements in scientific precision are warranted. However the importance of qualitative estimates is interesting since it agrees with the statements recorded in the seminar held in Hargeisa (section 5.3.2) and Haile (pers comm) who, from experience throws doubt on the reliability of raingauge recording per se, and from Steffen and Shirwa (FEWS 1996). On the other hand it can be argued that an obvious problem with qualitative observations is that the institutional memory is limited, and is probably biased towards extreme events. Qualitative observations can also be abused through opportunities for subjective reporting.

The importance of qualitative monitoring of vegetation in Sahelian early warning systems has also been supported. (Prince *et al* 1990) conclude that the results of programmes such as AgRISTARS (Agricultural and Resources Inventory Surveys Through Aerospace Remote Sensing) show remote sensing techniques add little to conventional yield estimates. This apparent paradox may be explained by the differences in type and precision of conventional yield estimates in Africa and the developed world. Also, low capital investment into most African semi-arid agriculture means that the landscape contains extensive areas of uncultivated, semi-natural vegetation. Here the vegetation dynamics detected by remote sensing may provide strong clues to the prevailing growing conditions of crops, even though they may be grown in a small proportion of the total area.

7.2.1 Rainfall Estimation Techniques

Due to the less than optimal density of the rain gauge network over Sahelian Africa, precipitation is not adequately measured, necessitating the use of statistical algorithms for precipitation estimation. The method used has in the past augmented the available surface data with remotely sensed data in order to produce estimates of accumulated precipitation. But in Africa the number of meteorological observing stations has been declining for the past thirty years, and the collected data is seldom relayed to processing centres in anything like real time (Grimes *et al* 1998). Remote sensing instrumentation on the other hand, has evolved rapidly.

Rainfall can be directly measured from raingauges, or indirectly from radar and satellites. Measurement by ground based radar give measurements that are valid for a much wider area than a raingauge, but have not been widely used in the Sahel due to high operational cost. Raingauge data are only valid for a small area in proximity to the gauge and can be considered as observation at a point. On the other hand satellite data are integrated values for the entire surface covered by the instantaneous field of view of the sensor (eg 5km for METEOSAT) (Flitcroft *et al* 1989). As a result satellite data will give a better spatial representation of rainfall events but will be less accurate for determination of point rainfall. The EPSAT Niger research programme solved the problem of incompatibility in the spatial representation of the data by independently measuring spatially integrated rainfall through a network of ground based radar (Lebel *et al* 1997). A more economic method is the use of geo-statistical techniques such as block kriging (Journel and Huijbregts 1978) to merge satellite and raingauge data.

Remotely sensed estimation techniques include use of visible, infrared or microwave spectral regions to measure cloud characteristics. From visible or infrared imagery cloud indices, such as cold cloud duration (CCD) are derived, which are then related to the amount of rainfall. Methods using the visible part of the electromagnetic spectrum determine cloud type and brightness of a cloud, the latter being related to cloud thickness, which in turn is related to rainfall amount. Techniques based on the microwave region of the electromagnetic spectrum can be divided into those that derive data from active and passive instruments. Radar are an active method well documented for the measurement of rainfall (Collier 1998) whereas the majority of satellite microwave sensors are passive instruments which determine the amount of predictable water in the atmosphere by means of radiation that is naturally emitted by water molecules.

Geostationary satellites (eg. European Space Agency (ESA) METEOSAT series) and polar orbiting satellites (eg. the NOAA series) provide frequent data at a resolution suitable for rainfall event monitoring. Geostationary satellite thermal infrared (TIR) imagery has been used to produce real time, quantitative, areal rainfall estimates for more than a decade. In fact most Sahelian applications use visible or infrared techniques or a combination of these. Techniques have been developed at the University of Bristol for use with the NOAA AVHRR data, such as ADMIT, PERMIT and BIAS methods (Barret 1986). With these methods raindays are identified from which precipitation is determined using climatological data on rainfall amount per rain day. An adjustment is applied for topography of the area in order to correct for orographic rainfall effects, and for seasonal deviations from the long-term mean. The TAMSAT method (Tropical Agricultural Meteorology using SATellite) (Milford *et al* 1990) uses an algorithm that was specifically developed to provide rainfall estimates for drought and famine warning in Africa. The precision of these different techniques have been tested by Snijders (1991), who found no significant differences between techniques when compared to raingauge data, and Carn *et al* (1989) who concluded that the TAMSAT method was the most accurate. TAMSAT has subsequently become operationally dominant.

The TAMSAT method uses cloud top temperatures calculated from METEOSAT TIR radiances, and is based on the following assumptions:

1. Rainfall is predominantly convective in origin. Rain clouds can be identifies as those above a certain height and with cloud-top temperatures below a threshold temperature.

2. The number of hours for which a pixel is colder than the threshold (ie. CCD) is linearly related to the rainfall over the same time period.

3. Calibration zones can be identified within which calibration parameters have stable values for a given month of the year.

TAMSAT subsequently undertook statistical analysis of Sahelian data, which permitted the calibration of cold cloud duration against observed rainfall over periods of 10days and 30 days, and which resulted in the broad calibration zones covering the Sahel that have subsequently been adopted by the FAO ARTEMIS system. The calibration zones are shown in fig 49. Zonal boundaries are drawn to reflect the predominantly latitudinal variation in climate of the region while taking account of mesoscale topographic effects such as coasts and the orography of the Ethiopian highlands. It is clear therefore that for regions where rainfall is predominantly associated with the passage of the ITCZ, assumptions 1 and 2 of the TAMSAT approach are reasonable, whereas assumption 3 seems more dubious. This is particularly clear where there is significant inter-annual variability in the calibration, which can lead to under or overestimation of rainfall.

Calibration is a problem common to all TIR based methods of rainfall estimation in that cloud top temperatures only relate indirectly to

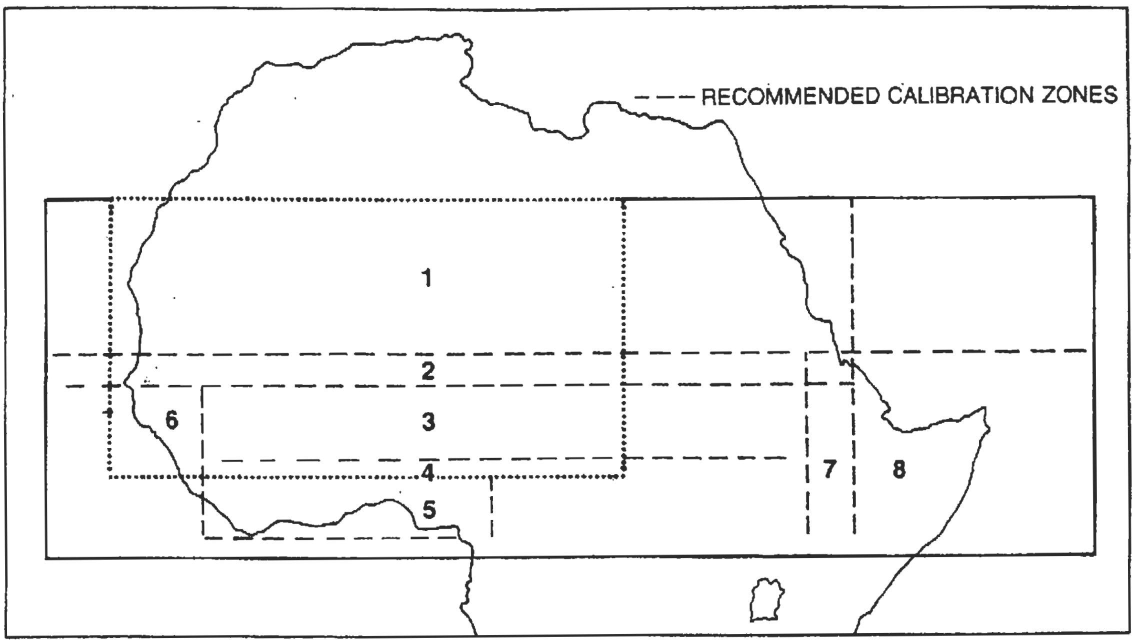


Fig 49 Calibration Zones of the Sahel

rainfall, there being no information on the detailed variation in rainfall pattern below the cloud. Therefore for rainfall estimates to be meaningful a significant amount of averaging must take place. Averaging can be spatial, temporal or both, assuming climatic conditions are consistent. Grimes *et al* (1998) recommend caution for estimates averaged over a threshold of less than 5,000 km^2 days. Bonifacio *et al* (1998) suggest that daily estimates are feasible if made over areas greater than 10,000 km^2. The setting of the threshold is, in effect, a way of smoothing out the uncertainty of the rainfall given the limits of detail available.

7.2.2 Merging of Satellite and Raingauge Data

Most estimation methods rely on empirical calibration against ground data. Specific drawbacks are in assuring the spatial and temporal stability of the calibration coefficients. Furthermore, although rainfall amounts averaged over large time periods or areas may be adequately estimated, localised intensity variations are not well represented; in particular, heavy rainfalls are often underestimated (Bonifacio *et al* 1990). Errors associated with these problems may be reduced by modulating the satellite estimates with available real-time raingauge data. The calculation of pixel average rainfall estimates can be carried out using block kriging (Journel *et al* 1978) and a single estimate can be combined where gauge based and satellite based rainfall estimates have the same spatial support (ie. the satellite pixel or $5km^2$ for METEOSAT). Optimal merging of data sets requires the calculation of pixel average values, with each contribution weighted according to the inverse of its associated error. The variance is thus a simple addition of the independent mean square errors associated with the satellite and gauge estimate for any given pixel. Given that the total variance and kriging error increase with rainfall, the optimum pixel estimate and its associated error can then be calculated from modelling a given mean rainfall per unit pixel area, ie.

Areal Rainfall Estimation from Raingauge Data

The mean rainfall $\boldsymbol{P}_i$ over the *i*th satellite pixel with centre at position $\mathbf{x}_i$ and with area $\boldsymbol{B}(\mathbf{x}_i)$ is the variable of interest:

$$P_i = \frac{1}{B(x_i)} \int_{B(x_i)} P(x)dx \tag{1}$$

The value of $\boldsymbol{P}_i$ is estimated by block kriging as a linear combination of the point observations at the rain gauges:

$$P_{gi} = \sum_{j=1}^{n} \lambda_j P(x_j) \tag{2}$$

where $\boldsymbol{P}_{gi}$ is the estimate of $\boldsymbol{P}$ and $\boldsymbol{P}(\mathbf{x}_j)$ is the observed rainfall for gauge j at position $\mathbf{x}_j$. ${e_{gi}}^2$ is an estimate of the mean square error associated with $\boldsymbol{P}_{gi}$.. The weights λ_j are optimal in the sense that they provide unbiased estimates and they minimise the estimation variance. The weights are obtained as solution to the block kriging system:

$$\sum_{j=1}^{n} \lambda_j \gamma_p(x_k, x_j) + \mu = \gamma_p(x_k, B(x_i))$$

with k = 1,...,n (3)

$$\sum_{j=1}^{n} \lambda_j = 1$$

and the estimation variance is given by

$$e^2{}_{gi} = \sum_{j=1}^{n} \lambda_i \gamma'_p(x_k, B(x_i)) + \mu \tag{4}$$

where μ is a Lagrange multiplier, $\gamma_p(\mathbf{x}_j, \mathbf{x}_k)$ is the rainfall variogram function between points $\mathbf{x}_j$ and $\mathbf{x}_k$, and $\gamma'_p(\mathbf{x}_j, \boldsymbol{B}(\mathbf{x}_i))$ is the mean rainfall variogram function between point $\mathbf{x}_j$ and pixel i with area $\boldsymbol{B}(\mathbf{x}_i)$).

The variogram $\gamma(\mathbf{x}_j, \mathbf{x}_k)$ describes the variation of the correlation of the rainfall field with distance, defined as

$$\gamma(x_j, x_k) = \gamma(h) = \frac{1}{2n(h)} \sum_{i=1}^{n(h)} (P(x_i) - P(x_k))^2 \tag{5}$$

where $\boldsymbol{h}$ is the vector separating $\mathbf{x}_j$ and $\mathbf{x}_k$ and $n(\boldsymbol{h})$ is the number of gauge pairs with separation vector $\boldsymbol{h}$.

Thus where gauges are sufficiently close that their observed rainfalls are well correlated, γ will have a small value. Where the gauges are further apart, γ is larger and will eventually reach a limiting value equal to the spatial variance of the field. The inclusion of γ in equations (3) and (4) mean that both the rainfall estimate and their associated errors take account of the distribution of the gauges relative to the spatial structure of the rainfall.

Satellite Gauge Merging

As previously stated optimal merging of data sets requires the calculation of pixel average values, with each contribution weighted according to the inverse of its associated error. Thus for any pixel i, the optimum estimate P_{oi} is given by

$$P_{oi} = \frac{e^2{}_{si} P_{gi} + e^2{}_{gi} P_{si}}{e^2{}_{si} + e^2{}_{gi}} \qquad (6)$$

and the associated error is given by

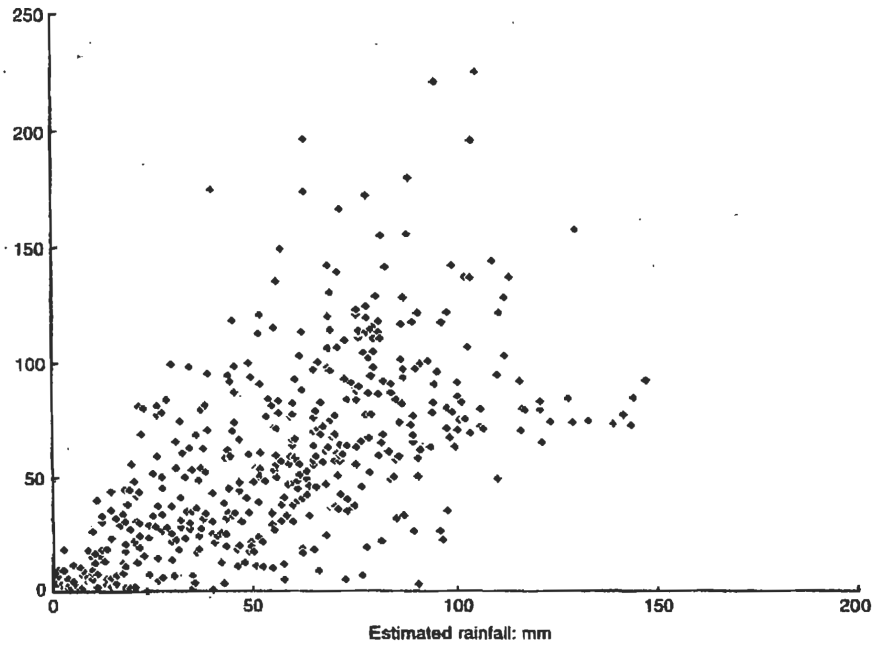
$$e_{oi} = \frac{e_{si} e_{gi}}{\sqrt{e_{si}{}^2 + e_{gi}{}^2}} \qquad (7)$$

where $e_{si}{}^2$ and $e_{gi}{}^2$ are the mean square error associated with the satellite estimate and the gauge estimate for the pixel. e_{gi} is obtained from equation (4). To evaluate e_{si} a scatter plot of pixel rainfall derived from CCD is required (eg fig 50). It can be assumed that a similar degree of scatter would occur for the same amount of data from an individual pixel as can be expected from any number of pixels. The scatter of points is due to both e_{si} and e_{gi}. As these are independent the total variance is simply:

$$e^2{}_i = e^2{}_{si} + e^2{}_{gi} \qquad (8)$$

Fig 50 clearly shows $e_i{}^2$ and the kriging error both increase with rainfall. Therefore these relationships can be modelled so that for a given P_i; $e_i{}^2$ and $e_{gi}{}^2$ can be calculated, leaving e_{si} to be obtained from equation (8). P_{oi} and e_{oi} can thus be calculated by equations (6) and (7).

The technique is important since it has subsequently been shown that the satellite-gauge merging process gives very promising results (Grimes *et al* 1998). The merging process automatically gives the gauge data an appropriate weighting dependant on gauge density, and will produce estimates that are better than other methods such as satellite estimates, or kriging with external drift (Hudson *et al* 1994). It logically follows that where, as in the case of Somaliland, raingauges are limited in number, money is tight, and where a gauging system is needed to provide input to an early warning system, the emphasis may be better directed to a dense small area "calibrating network", rather than a regional spread of independent gauges for which real time reporting is problematic.



Scatter plot of kriged pixel average gauge rainfall against estimated rainfall derived from CCD (this example CCD at -30°C: Zambia Oct 1995 - Apr 1996) **Fig 50.**

7.3 Rainfall Estimation in Somaliland

In Somaliland and Somalia, by virtue of being operational, it is the FEWS METEOSAT derived images that are the defacto early warning system output. Operational since June 1995, dekadal estimates of accumulated precipitation for the portion of the African continent south of 20°N are prepared at the Climate Prediction Centre (CPC) of the National Oceanographic and Atmospheric Administration (NOAA) for the United States Agency for International Development (USAID) FEWS project.

Specifically the dekadal estimates are designed to help estimate or monitor changing vegetation conditions across the African continent, and to assist in drought monitoring efforts for the sub-Saharan portion of the African continent. The rainfall estimates are used in conjunction with Normalised Difference Vegetation Index (NDVI) to provide insight into the possibility of rainfall/crop-related food shortages.

Satellite data, surface observations and model analyses are utilised in the computation of the dekadal rainfall estimates. The algorithm for processing these data is primarily based upon CCD, derived from METEOSAT 5. METEOSAT acquires a thermal infra-red image every 30 minutes at a spatial resolution of 5 km, a graphical interpretation of temperature and the spatial extent of the cumulonimbus or thunderstorm cloud tops is first obtained. A preliminary estimate of accumulated precipitation is made based on the GOES Precipitation Index (GPI) algorithm (Arkin *et al* 1987). The GPI assumes a linear relationship between precipitation and cold cloud duration (with cold defined to be 235K or lower) and assumes that 3 mm of precipitation occurs for each hour that cloud top temperatures are measured to be less than the 235K threshold.

Surface observations of precipitation obtained from the Global Telecommunication System (GTS) are the secondary data type used in the scheme. The GPI estimate is corrected using a bias field that is calculated by incorporating the GTS observational data and fitting the biases to a grid using optimal interpolation (ie. reduction of cost functions) producing an estimate of convective rainfall. This estimate is finally augmented with an estimate of the orographic precipitation, derived from clouds (mainly stratiform) that are relatively warm, with temperatures ranging from 235-275K. The estimated precipitation is computed using the local terrain features and numerical model analyses of relative humidity and winds from the Global Data Assimilation System (GDAS).

The combined technique thus incorporates rainfall from both the convective and stratiform cloud types producing a final estimate of total accumulated precipitation, with a new rainfall estimate generated every 10 days (Kousky *et al*, 1997). Typical dissemination output is shown in figs 51 and 52.

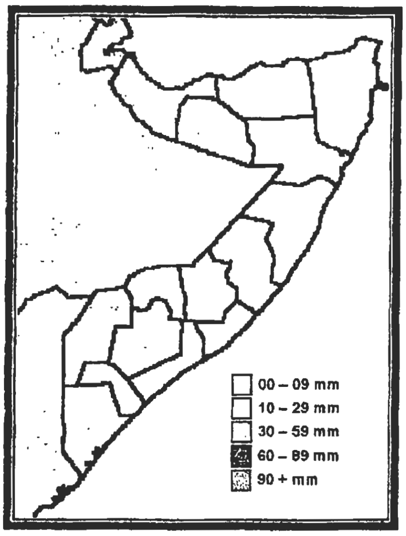
7.3.1 Observations from East Africa

Fieldwork undertaken in western Somaliland allowed for a first hand inspection of the raingauge network. The inspection was undertaken to assess the viability of the rainfall estimation system, in relation to the integration of rainfall estimates from satellite data, gauge measurements and qualitative information on rainfall reported by field monitors.

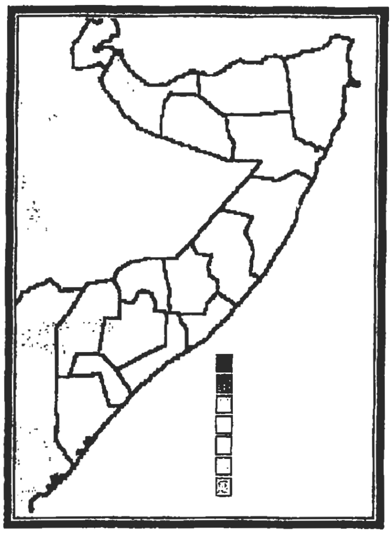
Observations show that the systems are still at an early stage of integration, with respect to the collection of basic raingauge data. Although it is encouraging that the return to normalcy has meant the rehabilitation, to some extent, of the gauge network, there are problems in the organisation, reliability and transmission of readings that need to be addressed. Optimising the gauge network will mean tightening up on procedures which has been widely accepted (Shirwa pers comm.).

The location of gauges is shown in fig 53. Of the 11 gauges shown as operational, only four in Berbera, Hargeisa, Gebiley and Borooma are in the same location as historical stations, and these four stations are run by four different agencies. In fact eleven stations are run by ten different agencies, ranging through the police (!), two separate ministries and the civil aviation authority to five separate international organisations (FSAU/FEWS 1999). Moreover there are more than two gauges in at least two locations Borooma (three known gauges) and Hargeisa (two gauges) and each gauge is run by a separate agency, to the extent that the term "same as historical" is in doubt. This wide diversity of agencies might be explained by the fact that the gauges have not been set up specifically for the early warning system and each

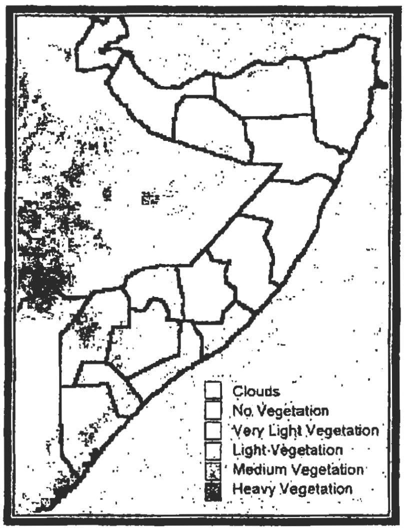
Actual Rainfall, Meteosat
21-31 March 1999



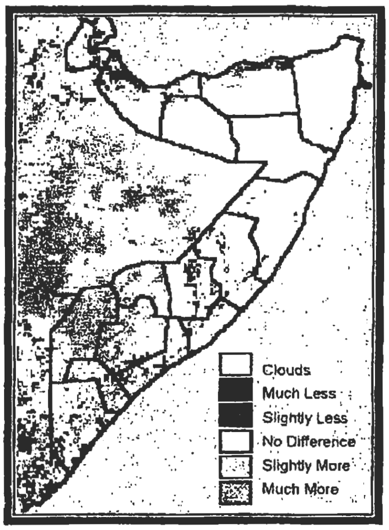
Difference Between Normal and
Actual Rainfall, 21-31 March



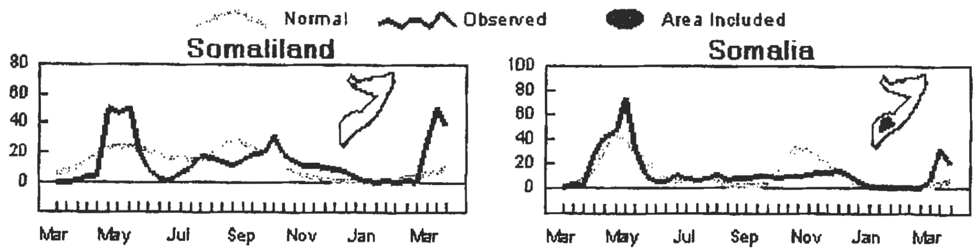
Actual Vegetation, NDVI
21-31 March 1999



Difference Between Normal and
Actual Vegetation, 21-31 March

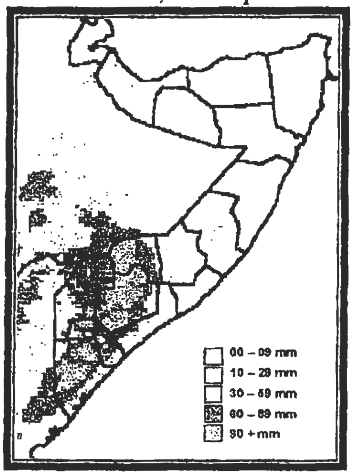


Rainfall from 1 March 1998 to 31 March 1999

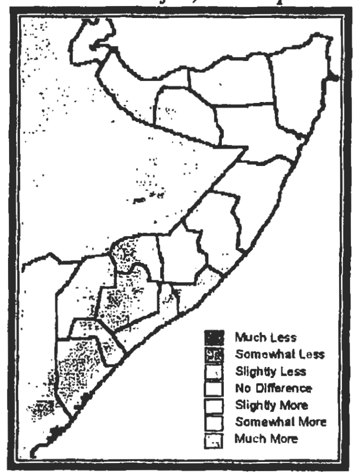


FEWS/FSAU Somalia dekadal rainfall and vegetation analysis
Fig 51

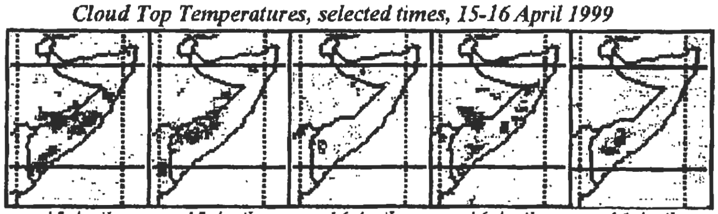
Actual Rainfall, Meteosat Estimate, 11-20 April



Difference Between Normal and Actual Rainfall, 11-20 April

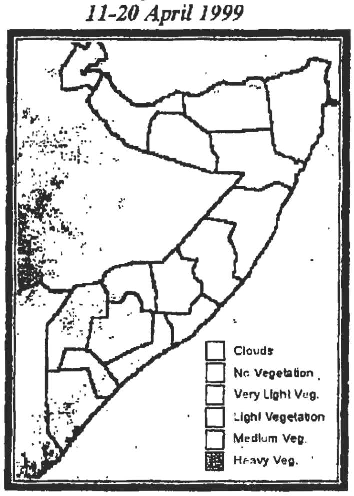


Cloud Top Temperatures, selected times, 15-16 April 1999

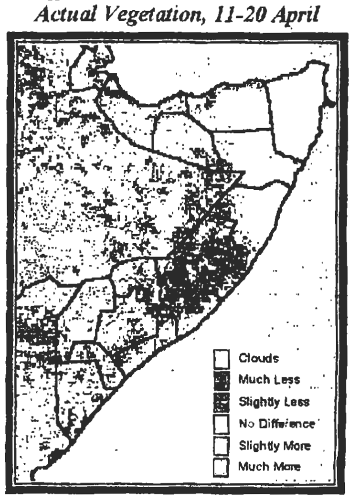


15 April 14.00 | *15 April 20.00* | *16 April 01.00* | *16 April 15.00* | *16 April 21.00*

Actual Vegetation, NDVI 11-20 April 1999



Difference between Normal and Actual Vegetation, 11-20 April



FEWS/FSAU Somalia dekadal rainfall and vegetation analysis

Fig 52

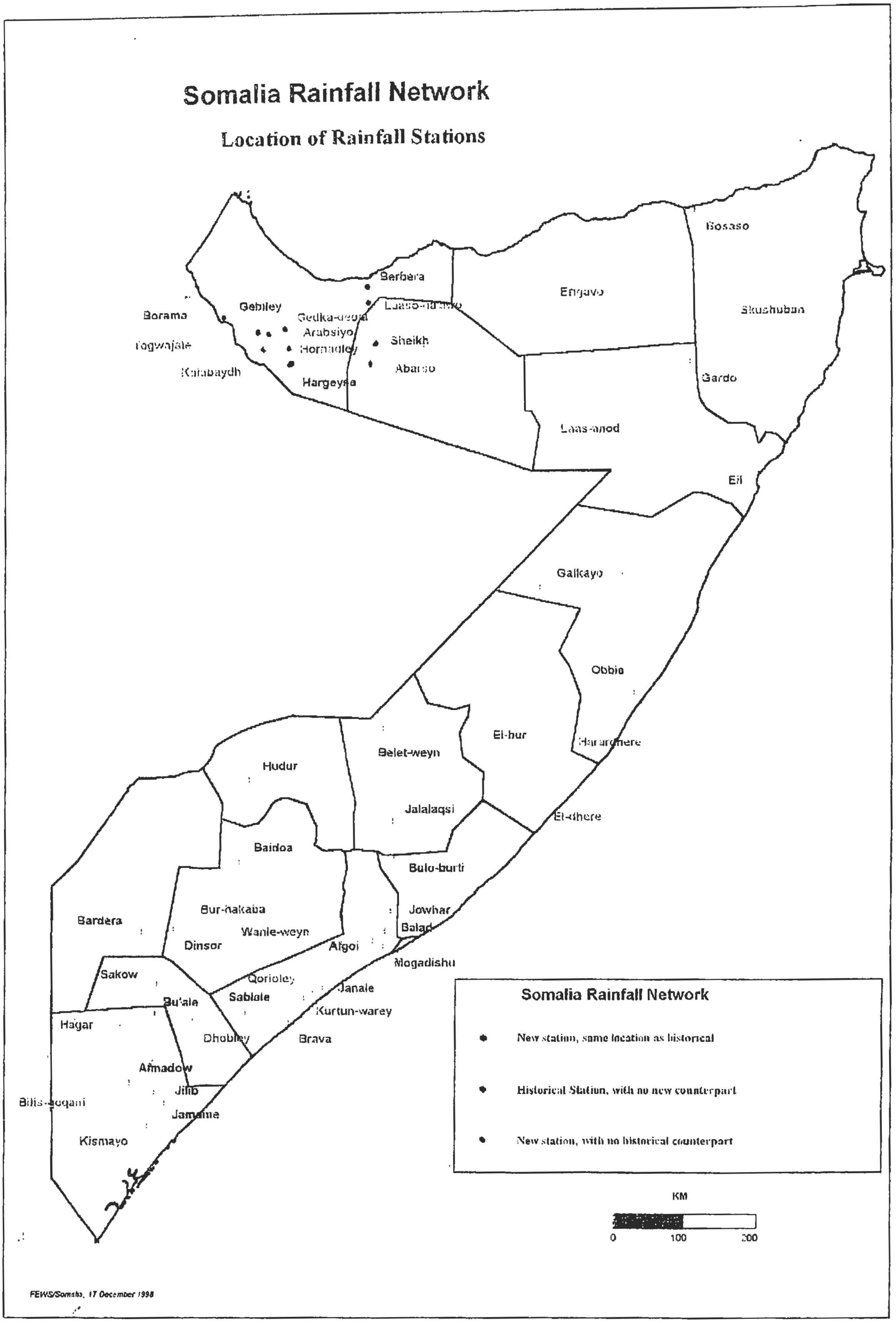


Fig 53
Location of Somali Rain Gauges as of December 1998

gauge is therefore specific to the context of its location, application and agency. Rather attempts have only recently been made to integrate the network within the early warning system and it will thus take some time to develop an efficient administration. This problem, with many agencies involved and working in a highly fragmented way has been recognised (Shirwa pers comm, Odowa pers comm).

Three operational gauges were visited; in Hargeisa at the Ministry of Water and Mineral Resources (Plate A) and at the airport (Plate B), and in Borooma in the compound of COOPI NGO (Plate C). Gauge readings are daily at these sites and, even if data is somewhat crudely presented, the gauge attendants are well motivated and conscientious. A reasonable degree of confidence can therefore be placed in the accuracy of the data. Plate D however, which is from another gauge, shows that there is some way to go to ensuring the reliability of the readings from standing gauges at many locations. It is also clear that gauge readings arrive in Nairobi (if at all) after the FSAU/FEWS bulletin (available since March 1998) is released so they are clearly not used to calibrate the satellite images in real time. Gauge reports could however be used to verify the images through retrospective calculation. However, the gauge at Hargeisa airport is currently being linked into the Global Telecommunication System again, after a series absence since 1989, so that real time reporting from a spot gauge will be possible again from a site with a reasonable historical record. This gauge is included in the monthly time series plot shown in Annex C.

Discussions with Dr. Menghistab Haile of IGAD and Shirwa of FEWS in Nairobi affirm that the early warning system will continue to rely more on qualitative analysis of rainfall and vegetation cover from field monitors based in Somalia, than quantitative analysis of ground variables for the foreseeable future. This is partly due the problem of co-ordinating the raingauge network. It is also partly because the system is operational and appears to be working reasonably well, within the existing and obvious constraints. From experience in Somalia this qualitative success is not suprising (eg. the strong oral tradition and

Plate A

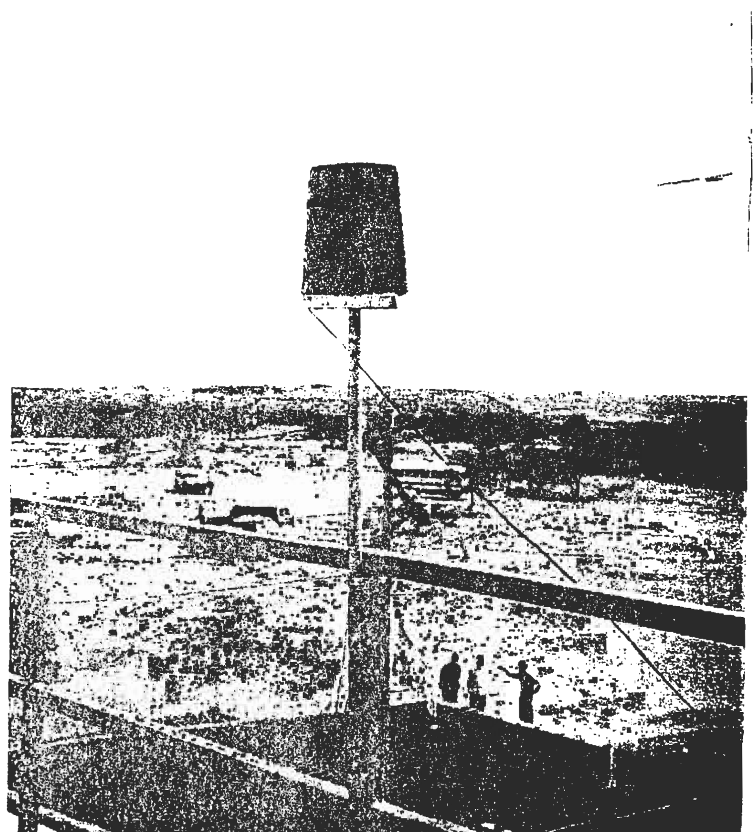


Plate B

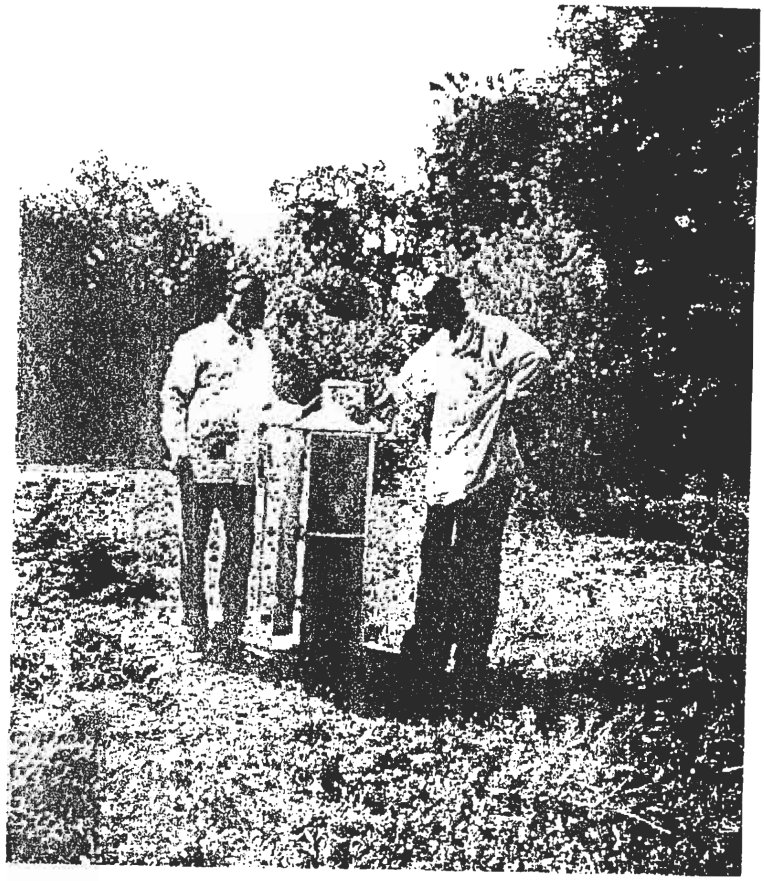


Plate C

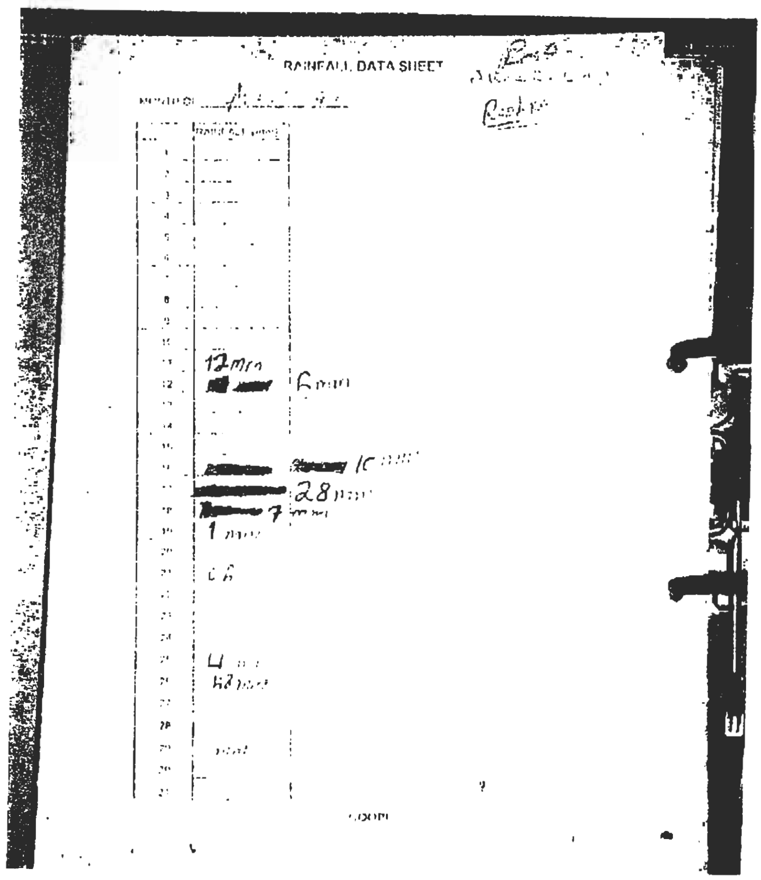


Plate D

radio networking already support the ready transfer of information) and the system has been proven to work effectively in this way (Steffen and Shirwa 1997). For example in the slow onset of drought conditions of 1996 in the North, FEWS were challenged by Somaliland officials for their interpretation of vegetation conditions in the eastern regions. FEWS stood by their algorithm but concluded that anomalies can occur when the environmental conditions are assessed only with satellite data, and that it is necessary to complement remote analysis with on-the-ground inspections of variable usefulness. Haile (per comm.) concurs that close qualitative analysis of selected ground sites for deviations in rainfall and vegetation from the norm, based on site memory, although not ideal, is sufficient for the system to work effectively in most of the Somali territories. In any event the dissemination of the analysis through real time bulletins remains qualitatively biased. It was however observed by Sacco (pers comm.) and Shirwa (pers comm.) that the satellite estimates overestimated the actual rainfall.

A further aim of the fieldwork was to determine how normal rainfall conditions in Somaliland (fig 51) are defined. It is useful to know if the FSAU/FEWS definition of the normal is correlated with historic records in Somaliland or is simply the variance produced from the onset of the remote sensing project (ie. the first year - 1995 - is the first average year). If the first case were true this would imply that a definitive archive for Somaliland does exist, which would be useful in the rebuilding of a data series for Somaliland. This aim was addressed directly in East Africa and also in the US through correspondence with NOAA CPC. Unfortunately the result is not conclusive.

According to NOAA it is probable, but not verified, that NOAA and FEWS would have a different definition of normal. Whereas NOAA definition of normal according to their rainfall estimate statistics would be from the onset of the project (ie.1995), at the FEWS/USAID office, the definition of normal is derived from the Australian National University database, which has records from 1922-1980, but is otherwise comprised of data from unknown sources. Grimes (pers comm) and Haile (pers comm) have advised that the FEWS definition of normal does *not* take account of historical correlation, which is one of the failings of the calibration technique. A visual interpretation of the normal sequence versus gauge readings for Hargeisa is similarly not conclusive.

8. Discussion and Conclusions

Nin talo ma yaqaane gun baa talo taqaan
(A lone man knows no solution; a council knows it.)

We have seen that there are serious problems experienced in a regional setting that can result in food insecurity and outright famine. The overarching problems of poverty, famine and war in the Horn of Africa and the Sahel are well documented. In the Sahel the processes that lead to these conditions are not well understood, which might explain why attempts to ameliorate and mitigate them have so far failed. The processes that result in such widespread loss of life are related to the social and physical environment, which are of concern at the global, regional, national and household level.

A scientific understanding of the Sahelian environment, and the underlying physical processes, may provide a firm foundation from which solutions to the problems of food insecurity and famine may in time be engineered. So while acknowledging many policy analysts conclusions that the problems are related to inequity rather than technology, and with distribution and politics rather than production; we may also conclude that **the positive potential role of science and the application of appropriate technology in enhancing the productive capacity of the region must be recognised, and strengthened, at every opportunity.**

We have seen that pastoral social and ecosystems predominate across Sahelian Africa, and have recognised that pastoralists of the Horn of Africa neither created states of their own, or imposed themselves on states created by others. Low investment politics produced organisational flexibility in pastoral societies which were (and still are) appropriate to the highly dynamic, poorly predictable external situations. This served the nomads poorly when the external situation was transformed by the changes of by the 20th century. The collapse of the Somali state thus marks the close of a historical period and acts as a warning against attempts to resuscitate the past. If Somalis are to avoid further debility they must clearly understand were they have come from and the dynamics of the present. **In particular, an understanding of the role of international aid must be re-examined in the light of past experience, and mutual concepts for development co-operation established between Somalis and the International Community**. Somalis must recognise their leading role in maintaining the integrity of aid funding, and through active participation at every stage of the development process. The International community must maintain its integrity, through the development and application of appropriate paradigms and operational tools for the Somali context.

Pastoral people of the Sahel and Somaliland who derive livelihoods from drylands have always suffered recurring droughts and times of food shortage. The pastoral system is traditionally adapted to the arid climate through tracking strategies based on a high degree of mobility and recognition of the uncertainty of rainfall, which drives the whole process. Pastoralists will increase stock levels until an upper threshold is reached; traditionally the occurrence of droughts is the limiting factor. Experiences from Somaliland and elsewhere in the Sahel lead to the conclusion that: **"Drought proofing" in water development programmes in arid dry countries, with an emphasis on improving the efficient use of the limited water resources and the appropriate development of permanent supplies, can mitigate, but not solve the cycle of growth and then drought driven decline.**

It has been shown that in drylands the nature of rainfall is a major constraint. Rainfall is characterised by low precipitation amounts, by high spatial and temporal variability, and by persistent drought. The seasonal and annual variability of rainfall and the corresponding mobility of the animal and human population produce substantial spatial and temporal variability of the factors affecting the environment. Somaliland is no exception. In conclusion it is **the high variability, rather than the low absolute rainfall amounts, that introduces high elements of risk to the land use activities, and it the economic, social and environmental cost of accommodating periodic drought**

that determines the long term viability of land use. The irregular cycles of drought and recovery, together with the slow but continuing process of economic development within the region, point to the need for a long-term and spatially comprehensive programme of environmental monitoring.

Partly based on observations of the pastoral rangelands of the Sahel, new thinking on the ecosystems of the Sahel has led to the non-equilibrium theory. Ecologists and rangeland scientists have proposed that in non-equilibrium environments resilience is rainfall driven and man and animals are basically "along for the ride". **The controlling variable is the co-efficient of inter-annual variation of rainfall. A CV of 33% is proposed as the threshold limit between equilibrium and non-equilibrium states, and where drought driven domains of uncertainty may exist.** This is a reasonable hypothesis but seems simplistic and not yet fully convincing from the climatological evidence offered by the non-equilibrium ecelogists. Predicting the likelihood that non-equilibrium dynamics will occur in a particular ecosystem is a formidable analytical task. It requires a detailed analysis of drought patterns and the responses of principle plants and herbivores to drought. We may conclude that **the significance of the hypothesis has yet to be tested, or verified, by the hydrological scientific community. There is considerable scope for basic research in this area but empirical assessment of non-equilibrium dynamics is challenging, and requires long term data collection.**

The drylands of Africa are said to be some of the most finely balanced hydrological systems in the world, where the scarcity and vulnerability of water resources make water resource planning of primary importance. However water resource studies, particularly at the regional and countrywide scales, are severely limited by the paucity of quantitative data. It seems that in most instances the ability to model the overriding phenomena is well in advance of the data necessary to validate the models. Regionalisation techniques are generally poorly developed in the arid and semi-arid regions of Africa compared with temperate regions. Remote Sensing is beginning to make a significant contribution to our understanding of hydrological processes in remote arid areas, but remotely sensed techniques lack validity without calibration by ground truthing of data.

Long period records of weather conditions, flood and wadi base flows and groundwater levels are clearly valuable aids in the analysis of water resources. **Provided that records are accurate, the longer the record the more accurately defined are the annual and monthly means and variations about the mean.** Long term trends and cycles may thus be detected. Unfortunately long term records are not available in many areas. However **where data is limited it is possible to derive the design parameters, based on statistical analysis and the recognition of uncertainty.** For example in Somaliland a quantitative water balance has been derived. But this approach is not really satisfactory, as it does not address the complexity of the situation at any less than reconnaissance level.

Some basic analysis of the data for Somaliland has been undertaken, and some key documents reviewed. There are few specialist texts on Somali affairs, and less than a handful published specifically on the water resources. Data is exceedingly limited and disjoint; primary data almost non-existent, secondary information mostly derived from consultants reports which differ over basic issues like rainfall data and catchment mapping. This is disappointing. Given the fact that available studies are so thin on the ground for Somaliland, it was hoped that this study would result in some definitive statements on the water resources and resource potential. Instead **the results seem to support the principle that when information available is limited, with respect to quantity and quality, it may pay not to try to describe the complexities that are really present in the situation.** Nevertheless from the information at hand a **basic regional review of Somaliland is possible. In particular the hydrogeology is well known through the landmark studies of Faillace and there is reasonable data from SOGREAH studies in the west of Somaliland. But there is a clear**

need for further hydrological and hydrogeological study to consolidate the information at hand, and to extend our knowledge of the region. An understanding of the regional processes, and the quantification of the resources is both a priority and a challenge. As in other water scarce developing countries lack of data and trained personnel in Somaliland hinder water resource development. Few Somalis have experience of the profession but many more exhibit a strong qualitative understanding of the processes within their hydrological regime. Their appreciation of the variations in environmental condition is adapted from the suitability of the land for pastoral production.

What is clear is that in Somaliland the long term rainfall trends do not follow the proven recent deficits in the West and Central Sahel. In fact **there appears to be no discernible trend in Eastern Sahelian annual rainfall series, other than a fairly stochastic one. In Somaliland rainfall is more variable in both space and time than most of Africa; and it is the temporal and spatial variation in the rainfall that has the greatest effect on the major facets of pastoral production.**

Development Co-operation in Water Resource Development has largely neglected the pastoral production system, either because of the large rate of project failures in the past, or because the emphasis has been placed on development models that (unwittingly) undermine the relative success of pastoral systems. Typical of this has been the preoccupation with agricultural development in the wet season "key resource patches" of rangelands. **In relation to the incidence of famine in dryland Africa, it is clear why agricultural development is promoted, but in certain instances agricultural development may seriously undermine the resilience of pastoral ecological system, leading to greater, and not lesser, food insecurity.** The balance between conflicting land use needs to be worked out. Water intensive development is anyway a high risk enterprise in drought persistent lands, where surface water is scarce, evaporation rates are high, recharge is severely limited and where the limits of groundwater resources are unknown. However, in non-equilibrium environments **permanent water supplies continue to be a priority in areas where water is a limiting factor, the scientific case for their contribution to land degradation on rangelands being as yet unproven.** In addition, measuring the effects of watering points, and thus the effects brought on by changing herd and water scarcity management strategies on rangeland systems, is difficult. Variation in production from year to year due to availability of water to plants, is liable to be greater than the variability of water available to livestock.

Paradigms in development co-operation that can address the issues in water scare developing countries are slowly being developed, based on the experiences of the past and a set of guiding principles developed at the global level during the 1980s. Guiding principles are valid for macro and micro level programmes, but the continuum "between sectors" and "within sectors" needs to be carefully worked out. A good example is the perceived conflict of interest between the Agriculture Water Use and Management (AWUM) programme line, and the pastoral production system in Somaliland that was pointed out during the seminar in Hargeisa. In any case, in an ideal environment, **planning should logically be integrated and area focussed, as opposed to sectoral and site focussed.** This is to suggest **that investment in water supplies should be complemented with investments, not only in other services, but also in the improvement of the natural resources base to offset the deterioration that usually accompanies the provision of water.** In Somaliland pasture improvements, re-aforestation measures, soil conservation and agricultural improvements should not be neglected in favour of meeting demand. These are all difficult development activities compared to point water supply installation from an organisational as well as technical point of view.

On a wider scale we have seen that there is evidence of growing global consensus on the critical importance of water, but differences between regions - and within them - concerning the priority issues. Globally this is reflected in a broad dichotomy of view between North and South about priorities to be addressed. In particular reservations towards blanket prescriptions about resource management are being expressed by professionals in developing countries, in relation to the current pre-occupation of the industrialised world with environmental issues. The expression of these concerns has appeared to demand the imposition of constraints on the exploitation of the natural environment to which the developed countries were not subjected during their own industrialisation process. These reservations need to be taken into account, and underscore **the challenge of matching an international consensus on principles to the realities of local situations. This implies the recognition that problems must be identified according to the local context and solutions developed which take local particularities into account.**

There are also significant technical and resource constraints affecting the means whereby, and degree to which, the consensus emerging at the international level can be made operational. Factors such as climate, hydrology, terrain, human settlement patterns, infrastructural capacity, investment requirements and sources, economic considerations, and socio-cultural setting all have to be taken into account. These factors help to explain why **there is so far a much stronger rhetorical commitment to the Dublin and Rio principles than there is evidence of their practical realisation on the ground. This also help to explain why Water Resource Assessment and Planning as an operational programming step in Somaliland remains an ideal, yet to realised on the ground.**

In Somaliland the commitment to developing water resources is currently in relation to meeting basic Food and Water Security needs. Uncertainty in environmental and social conditions dictate a clear and established need for the Famine Early Warning System, which should be strengthened at every opportunity. **Remote sensing plays a critical role in the early warning system: given the driving nature of the rainfall and the strong relation between water and food security, its accurate measurement is of fundamental importance.** In fact the remote sensing technique is also useful for what is now approaching real-time monitoring of rainfall and vegetation at the regional scale. The technique has removed the emphasis from spot recording (ie. gauge rainfall) and the inherent difficulties in extrapolating from spot to areal values, to a more useful spatially and temporally integrated approach. In time therefore **remote sensing may also play a significant part in terms of identifying regional or sub-regional trends in land use, including degradation, in relation to the spatial and temporal distribution of water.**

However **remote sensing is not a panacea for resource development and management problems, although it can provide the data which are the basic tools for sound resource inventorying, monitoring and management. Consultation with the communities it is intended to assist is always required. Satellite derived data also needs to be backed up with quantitative and qualitative ground truthing.** For now the priorities in Somaliland are on remote sensing for Famine Early Warning Systems which are backed up effectively by qualitative observations of rainfall and vegetation. The gauging network in Somaliland is slowly being rehabilitated, signs are encouraging and deserve the support of the international community. However, **calibration remains a major problem, and it is strongly suggested that a dense gauge network plot of between ten and twenty gauges could be installed at a single site to allow for merging of gauge and satellite data in relation to establishing regional calibration parameters. A single site would be more efficiently managed than the diverse array of rainfall recording stations now in operation.**

The results of the observations from East Africa confirm that there are challenges to overcome with respect to the basic administrative capacity for handling remotely sensed data in the national and regional context. A major obstacle disturbing the economy of Somaliland is also the absence of technological capabilities to offset drought, most especially in terms of the regional coverage of proofing wells and other water structures. We have clearly seen the significance attached to drought by the Somali people, and the need for new drought proofing strategies to reinforce traditional coping mechanisms. We have also clearly seen that Somaliland has undergone changes on many levels that present both opportunities and challenges for food security. The population has adapted its settlements, production systems, consumption patterns, and livelihoods in response to market influences, and has found a new form of flexibility to meet basic food and water security needs. Virtual water imports are thus increasing along with rapid urbanisation. But while these adaptations offer the prospect of increased returns, they bring added risks. **In conclusion the age old risk of drought and water scarcity has not been settled, and signs are that water resource development will not keep pace with population increase. Thus water stress, driven by a rainfall process of unusually high inter-annual variability, will continue to dominate the agenda for the Somalis of Somaliland. Water stress has been central to the psyche of Somalis for generations past. Without doubt, it will be well into the future.**

9. Recommendations

The investigation and analysis of this thesis, and the conclusions that have been drawn, support recommendations in three broad focus areas. At this stage, the recommendations are made in the form of general statements, and it is recognised that further work is required to develop these proposals fully.

In the first instance a thesis peer review with practitioners in the Somali aid programme is advised; to introduce the information now at hand to a wider audience, and to serve as a "best practise" catalyst within the wider debate on Somali water resource issues.

9.1 Water Resource Development (ASAL/Somaliland)

1. Due to future predictions of acute water stress in the world's poor drylands, guiding principles in development co-operation for these regions needs urgent and sustained support. Given the poor international political influence that such regions have, ensuring that ASAL issues are on the agenda needs great effort by all concerned. In the international setting there is a need for wide dissemination of the results of existing programmes in Arid and Semi-Arid Lands, in order that a holistic, scientific analysis can be achieved. This implies meaningful events to bring planners and practitioners together. The Second World Water Conference at the Hague in 2000 presents an opportunity to promote the issue at the highest level.

Also (and from a natural science perspective), it is recommended that guiding principles for water resource development within typical eastern Sahelian environments must clearly recognise;

i. The primary role of rainfall (and drought) as ecological prime movers, in an environment characterised by high levels of uncertainty,

ii. The positive and potential role of pastoral production systems and the extensive rangeland resources within social organisation,

iii. The potential future role of "virtual water" in mitigating the effects of both highly variable inter-annual rainfall, and social change.

It is also recommended that in operational terms, paradigms and guiding principles must be adapted to the physical and social conditions of the regional, sub-regional and local environments at hand.

2. In Somaliland a more coherent policy on water resource development, and with strong co-ordination between the principle actors and stakeholders, needs to be further developed. The strategic framework that has been worked out is a firm foundation on which to start developing policy and its practical translation. But it must be understood that good policy can only be based on a sound understanding of the scientific, technical, economic, institutional and social mechanisms that influence the Somaliland condition; and must ultimately be driven by the Somalis themselves.

The need for hydrological studies has been recognised, and this thesis is clearly a contribution to that initiative. The conclusions drawn underline the need for a comprehensive assessment of regional water resources, before effective development can be planned. As a first step it is therefore logical, and strongly recommended, that the major actors work towards activities within the Water Resource Assessment and Planning paradigm advocated by the EC guidelines. While it is not possible to implement a full scale WRAP project at this time, the issues can be effectively primed by exposing the major stakeholders to the range of activities and commitments that a Somaliland WRAP would be likely to contain. In such a way, the level of institutional and social responsibility implied by a coherent WRAP, is more likely to be understood by the major stakeholders at an early stage of the development process.

Practically, it is recommended that the causal links between rainfall, environment and water resource development as outlined in this thesis, are first reviewed with planners and practitioners in Somali water resources. It is further recommended that a water resource assessment desk study be commissioned (by the EC Somali Unit?) in order to;

i. consolidate the various studies and data outlined in this thesis,

ii. improve on the existing knowledge of the water resources of Somaliland and,

iii. bring that improved knowledge to the attention of a wider professional audience, and to the public at large.

The recommended desk study must aim to identify the existing gaps in the regional water resource knowledge, and should include some activities to start bridging the gaps. It would therefore be part research and part practical project. Selective field assessment in collaboration with Somali counterparts would be included, and the available applications of remote sensing tested and evaluated.

The desk study recommended is therefore the first step of a long-term aim, which is for a full on strategic WRAP project in Somaliland. Such a project would need to be designed, developed and implemented by stages. It must be a mutual process between Somaliland and the international community, and must be based on balancing the development of water policy, available economic resources, and partnership volition in the service of improving the poor water conditions of the country.

3. At the existing project level in Somaliland, it is recommended that "drought proofing strategies" within normal year programmes should be routine. An emphasis on conserving and optimising available water is the first priority. How to integrate "drought proofing" needs to be engineered with practitioners in the field within field based projects.

It is also recommended that the routine monitoring of hydrological and hydrogeological variables, such as spates, flows, groundwater levels and water quality are made normal within existing projects. This requires a certain level of expertise within specialist staff from both the international and local communities. The training of adequate numbers of professional water staff thus assumes a high priority, and is strongly recommended.

9.2 Rainfall Monitoring in Somaliland

Continued improvement to the rainfall monitoring system within the early warning system is recommended (which is recognised by the major concerned parties). The system needs strong co-ordination, which must be based on a "mutual development paradigm" endorsed by the Somalis and FEWS/FSAU, and where the role of the Somaliland authorities is clearly defined.

The emphasis must be placed on a cost efficient, robust and "least complex" system of gauging on the ground in Somaliland, which maximises the potential of the existing satellite system. Administration on the ground can be strengthened by the training of staff in basic hydrometry, and through the co-ordination of data collection into a central database for which a single Somali institution should assume responsibility. Ideally more stations with historical records (eg. Borooma, Erigavo, Burao, Berbera) will, in time, be linked into the GTS system, for real time reporting. However, of higher priority, it is strongly recommended that a dense gauge network plot of between ten and twenty gauges is engineered at one "representative" site (eg. Hargeisa or Gabiley?), which is then linked directly into the GTS system. This will allow for real time merging of gauge and satellite data and, through establishing a regional calibration, much improve the accuracy of the FEWS/FSAU monitoring system.

9.3 Further Research

In Somaliland it is recommended that the data collected from the routine monitoring of hydrological and hydrogeological variables form an archive (this is already partly in place through UNDOS). The work of this thesis, through collating and reviewing relevant sources of information, can also be further continued and added to the archive.

In addition, selective applied research of the surface and ground water characteristics is warranted at selected sites. Two such projects may be;

i The re-evaluation of Dagakureh experimental catchment 40 years on, based on the collection of a new data set, contrasting it with the previous data findings, and subsequently developing a regional small catchment model.

ii The use of remote sensing (eg. NOAA AVHRR night time TIR or radar based imagery in combination with other techniques) to investigate the hydro-geology of the water scarce Haud region.

In principle any applied hydrological research would be useful, so long as it serves the practical purpose of improving water security in the country. This is especially true for research that leads to the development of hydrological models and water balances at varying representative catchment scales, and which thus serves to bridge the initial gap between pure, analytical science, and water resource assessment and planning needs.

Finally, more research into the hydrological validity of the non-equilibrium ecological hypothesis is strongly recommended. Data sets from known studies should be re-examined, backed up by data collected from the field. There is no reason why this should not include Somaliland, where the proposed non-equilibrium threshold of rainfall inter-annual variability is clearly evident, and where environmental conditions and pastoral livelihood conditions so clearly correspond.

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Plates

1. Narrow section of the Coastal Plain showing alluvial fan.

2. View into hinterland across the escarpment.

3. Awrboogeys water hole in Sool Haud during 1996 drought.

4. Nomadic village.

5. and 6. Spring discharge in the Nugaal valley tugga, Puntland.

7. Tugga Maroodhi Jeh on the marginal border of range and agricultural land.

8. Tugga Maroodhi Jeh downstream of Hargeisa showing impact of fluvial (spate) erosion, and the surface run-off tugga recharge zone.

9. and 10. Tugga Maroodhi Jeh, shows migration and spate level.

11. Tugga Maroodhi Jeh just upstream of Hargeisa, crusting from surface flow evident.

12. and 13. Small scale irrigation typical of tugga exploitation.

14. Rainfed agriculture between Borooma and Gabiley.

15. and 16. Severe land degradation (desiccation process).

17. Aerial view adjacent to Borooma showing foothills, *balli* and rain-fed agriculture.

18. Typical settlement/land pattern of Western Somaliland.

19. Large scale alluvial fans in the sloping plain.

20. Aerial view across the Haud plateau

21. and 22. Nomadic spring well in Sool. Conditions less than sanitary and showing damage.

23. and 24. Typical *balli*

25. Impounding dam intake in Somalia.

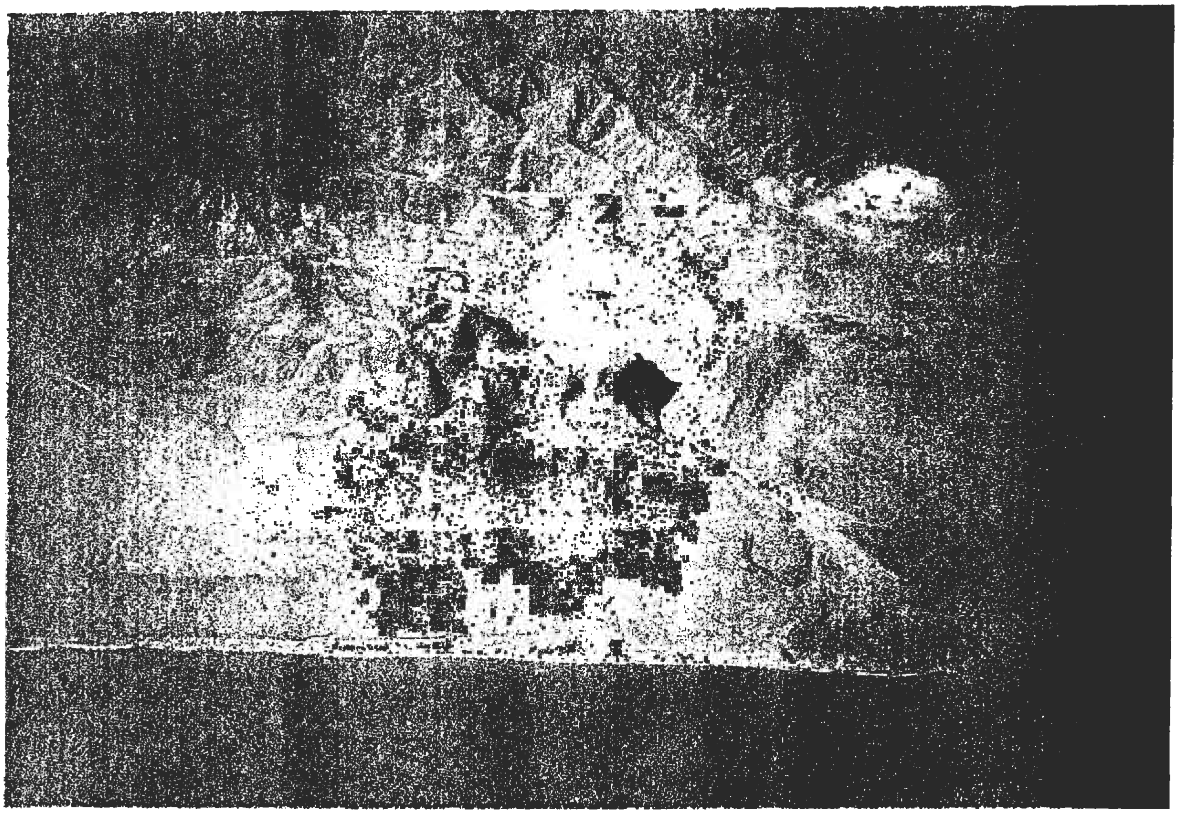
26., 27. and 28. Rehabilitation of berka in the Haud plateau

29. Sub-surface dam construction.

30. Roof catchment in urban area.

31. - 36. Typical shallow wells adjacent to tugga. Note traditional well at right of picture in 35.

37. Groundwater irrigation near Garowe in neighbouring Puntland.



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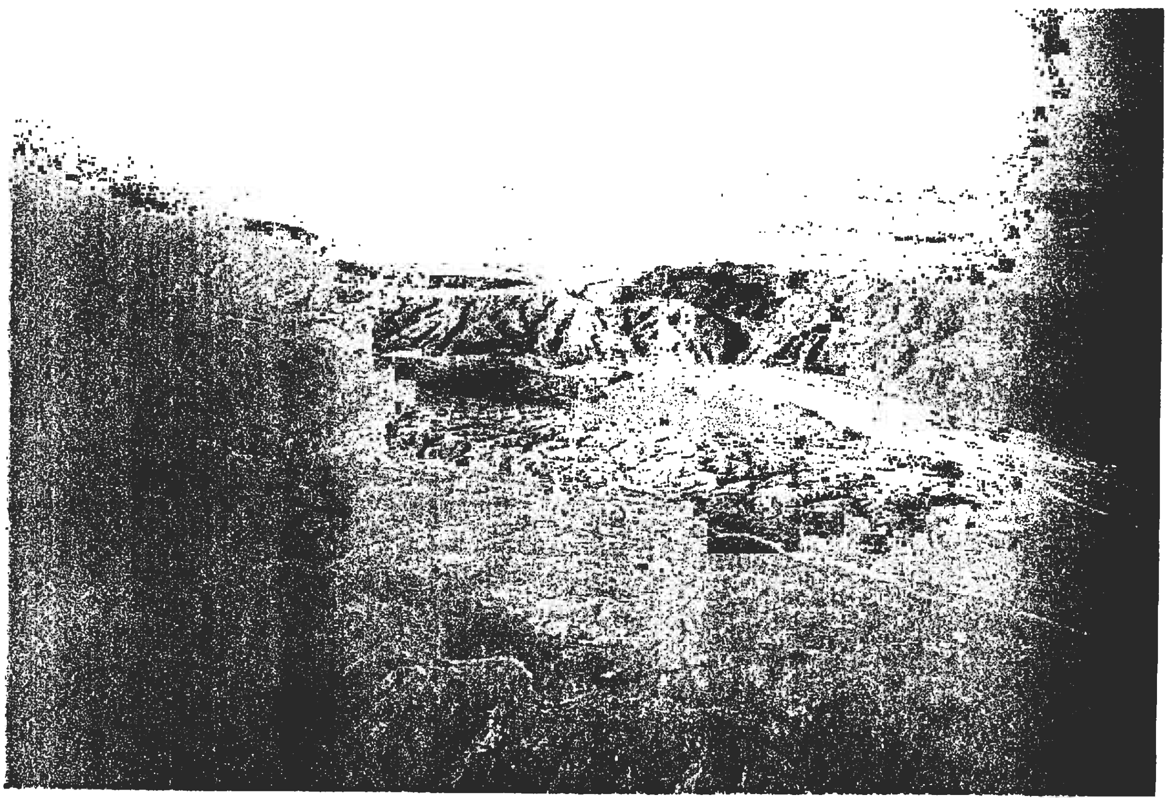

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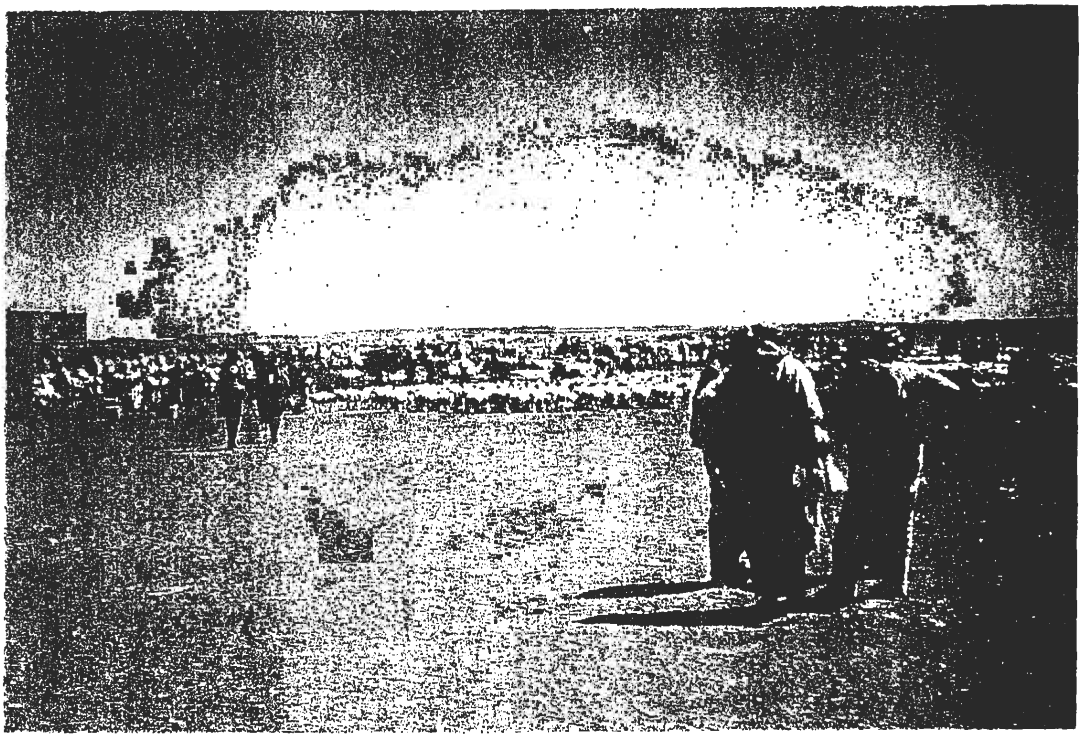

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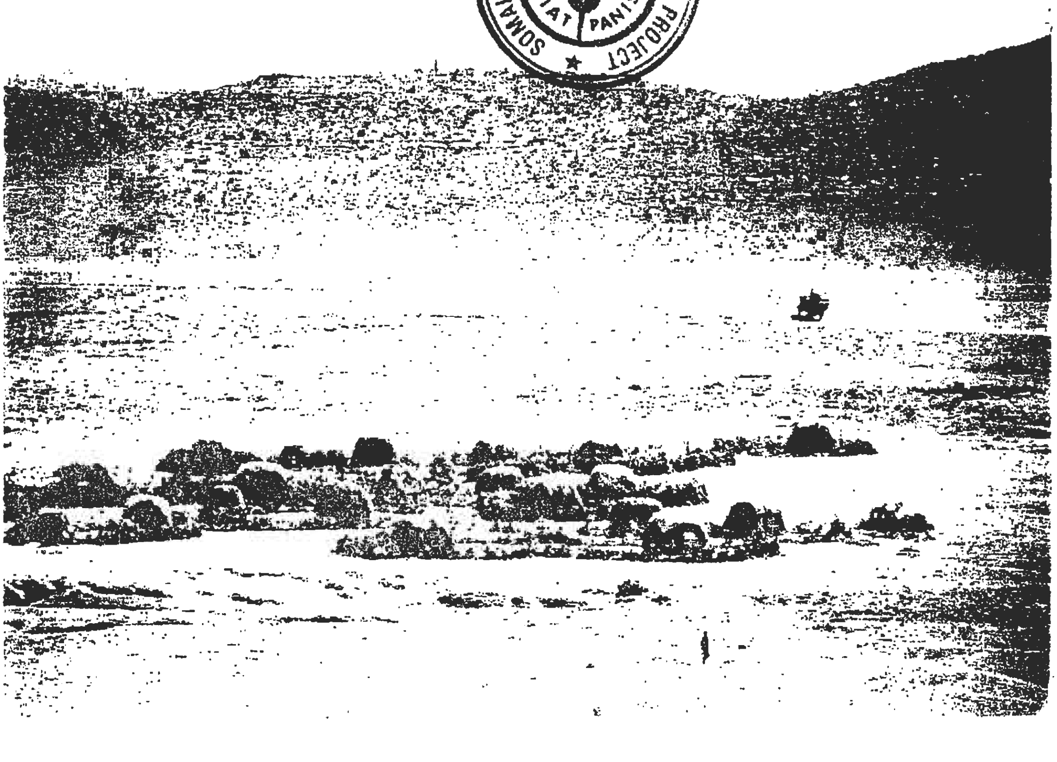
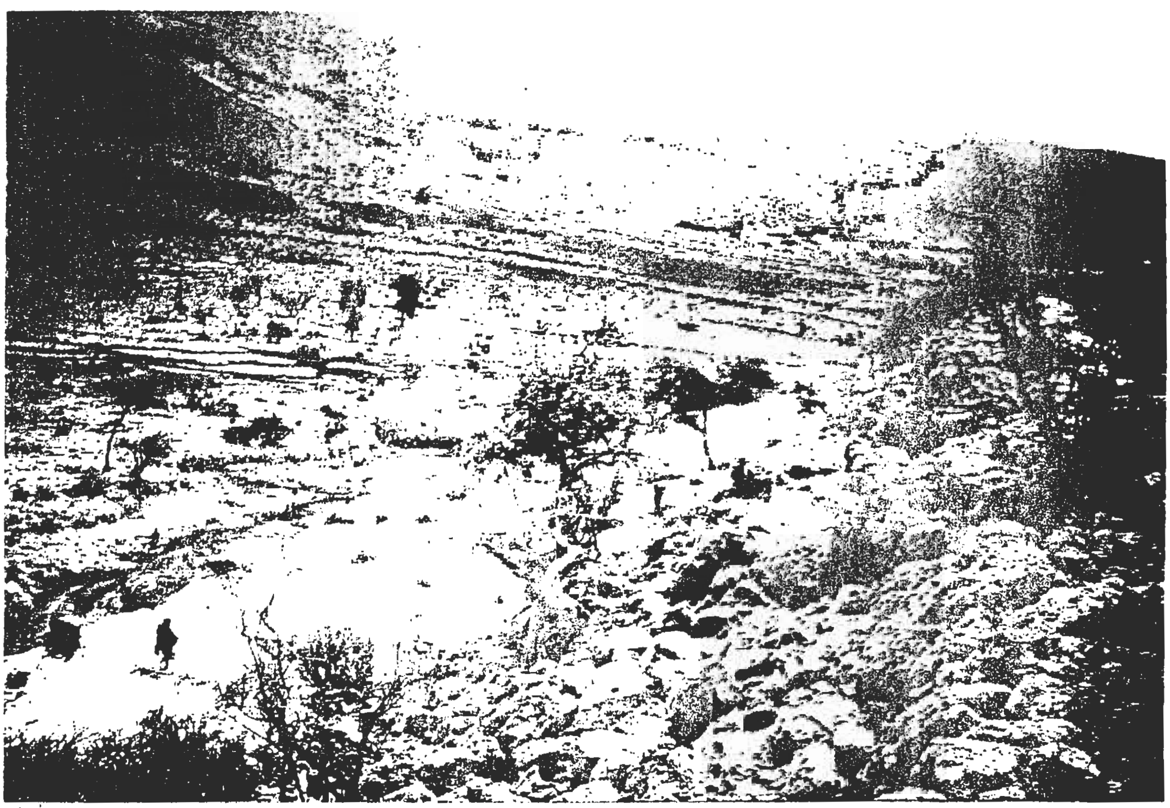


Plate 4

Plate 5



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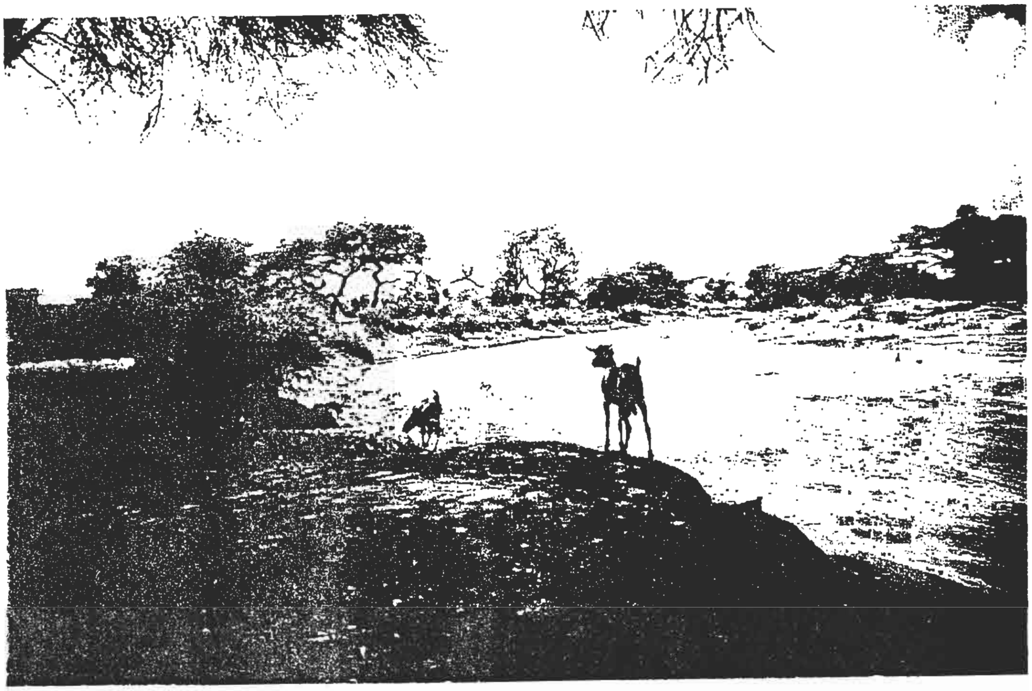


Plate 7

Plate 8

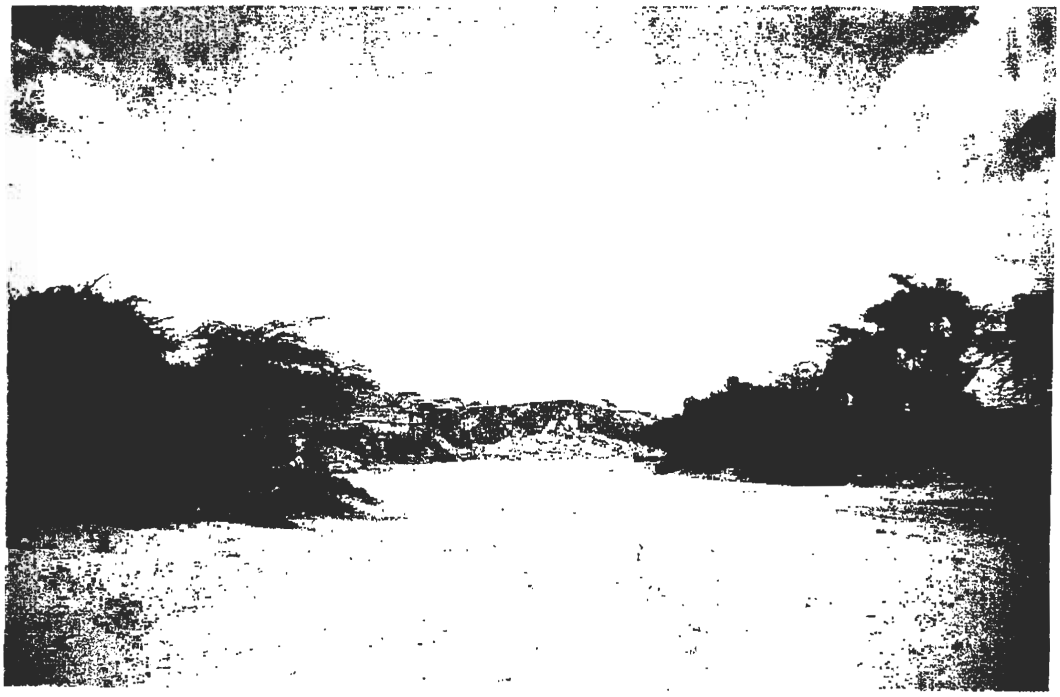


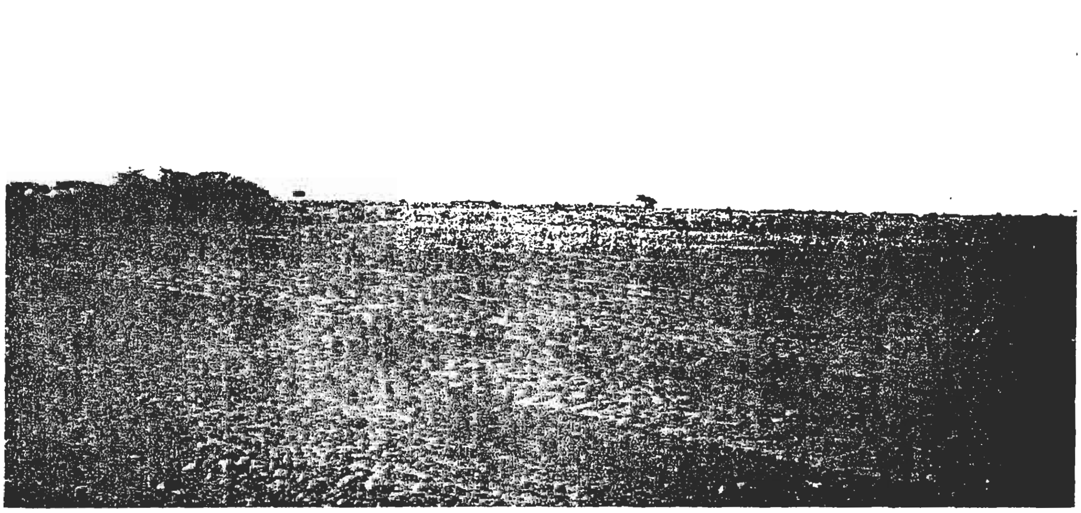
Plate 9

Plate 10

Plate 11

Plate 12

Plate 13



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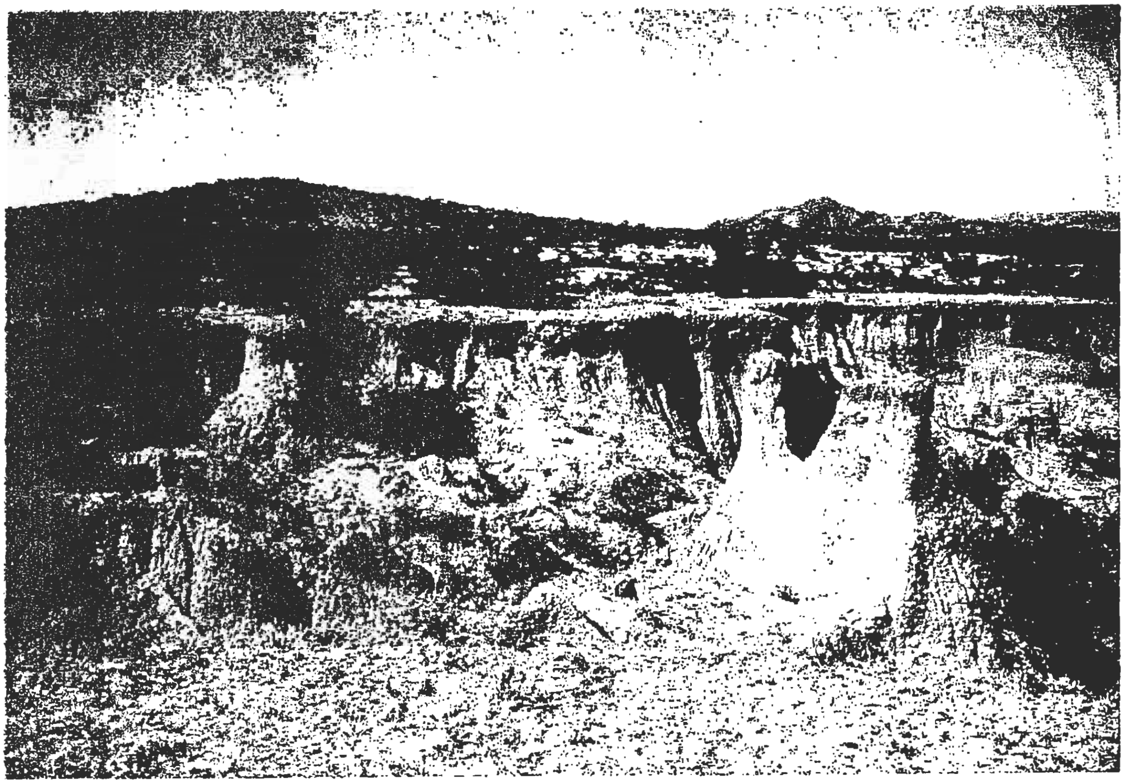
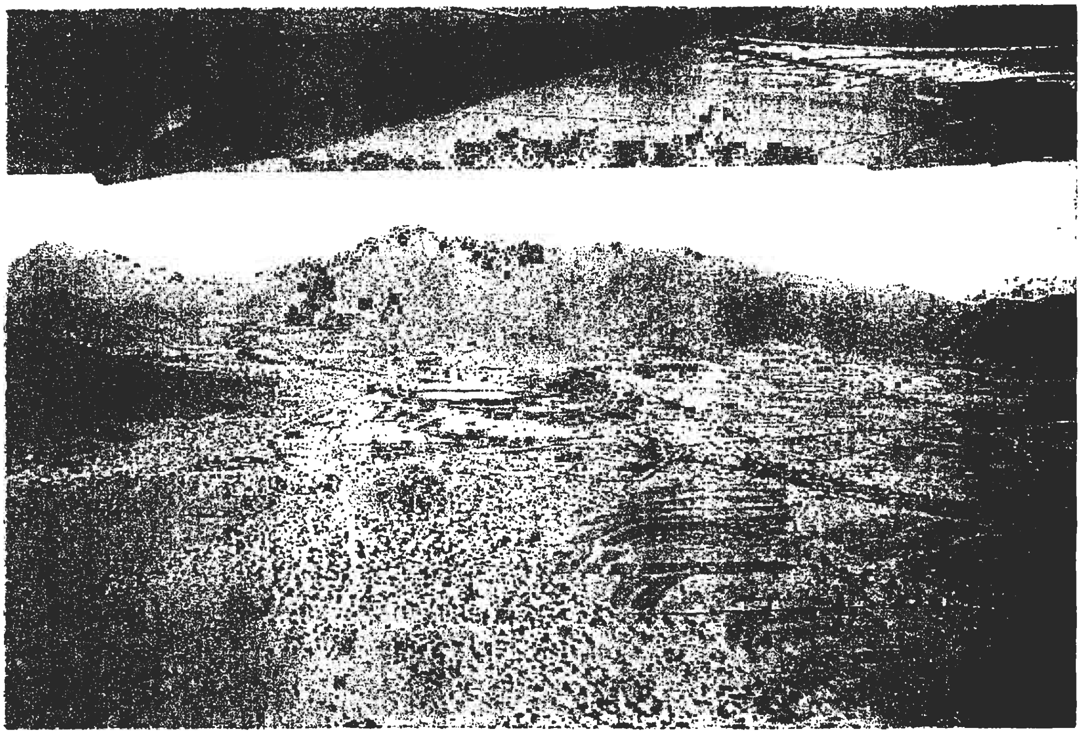


Plate 15

Plate 16



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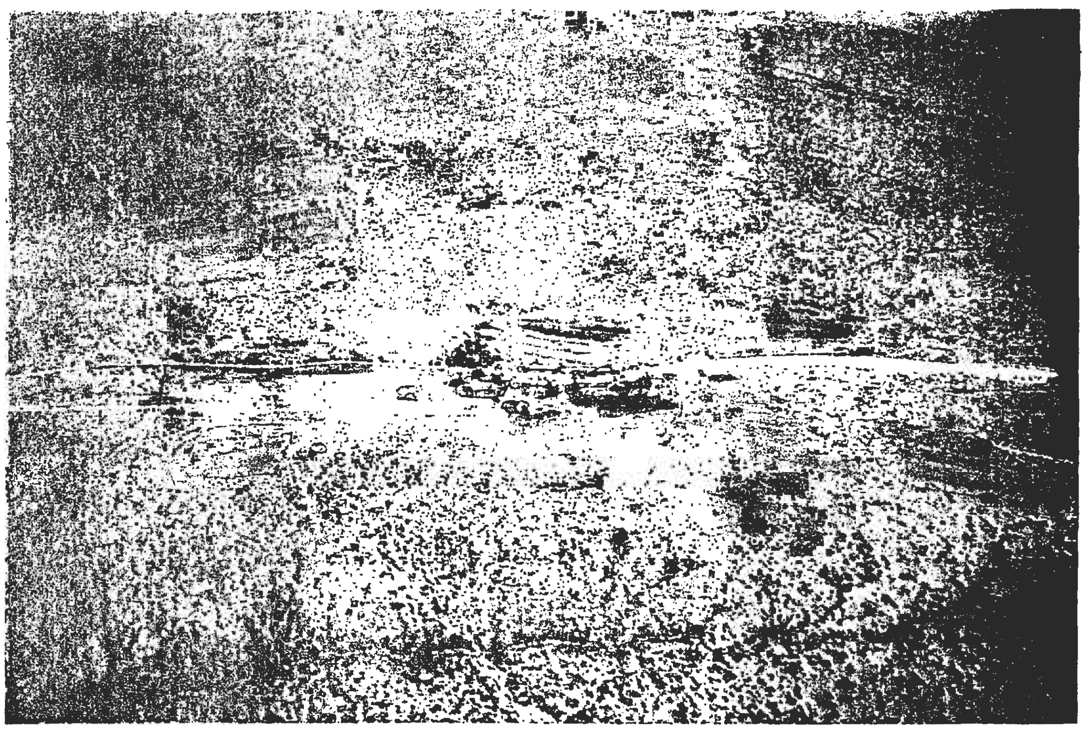

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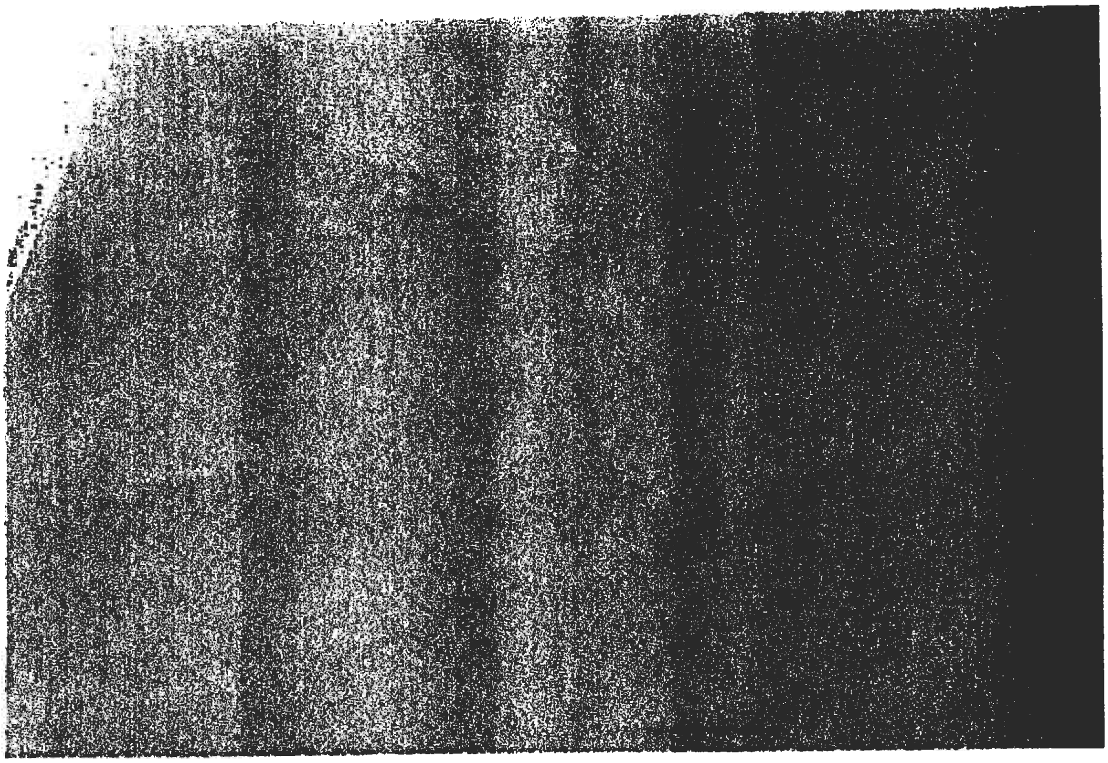

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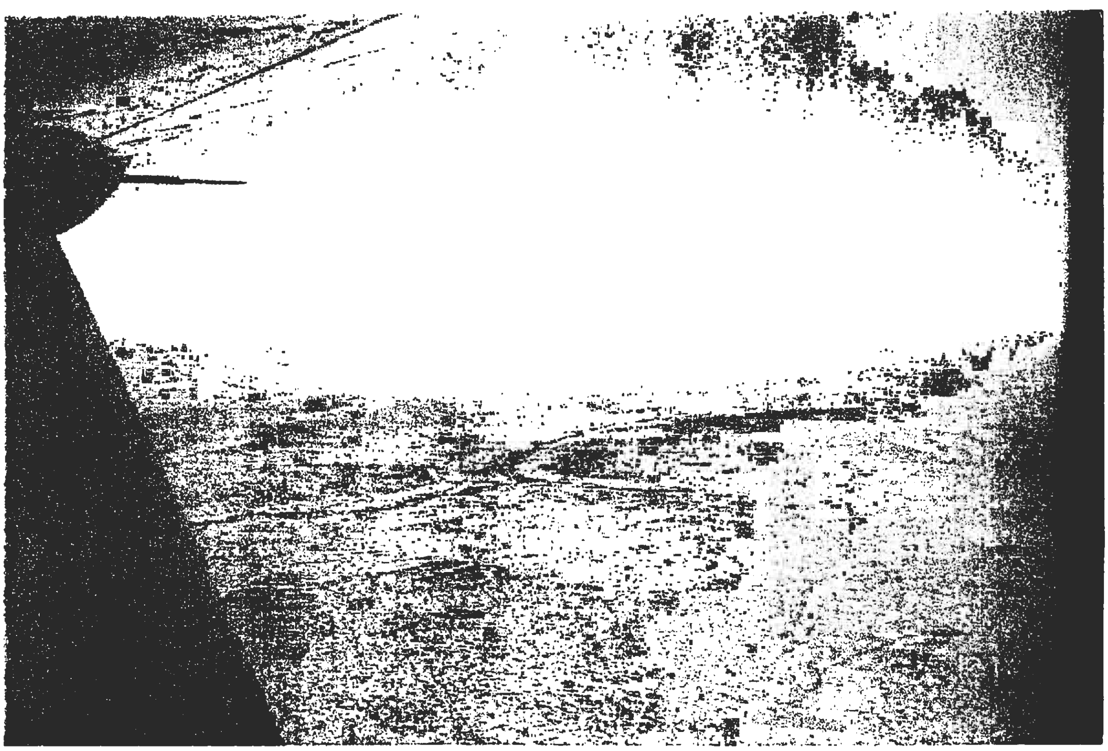

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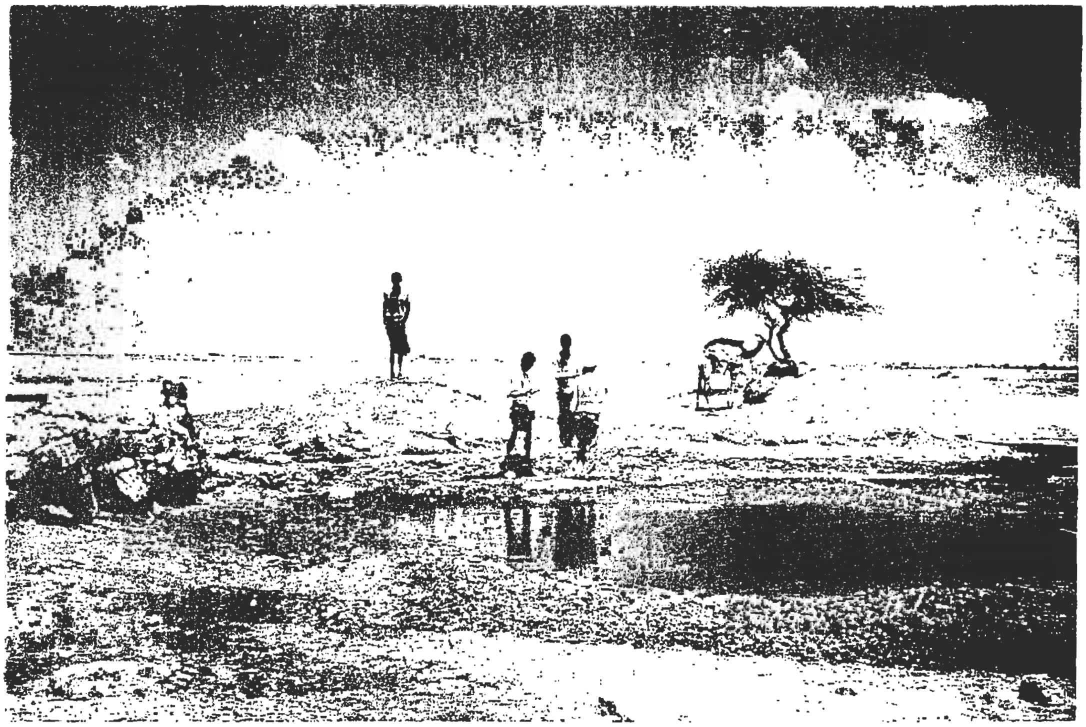

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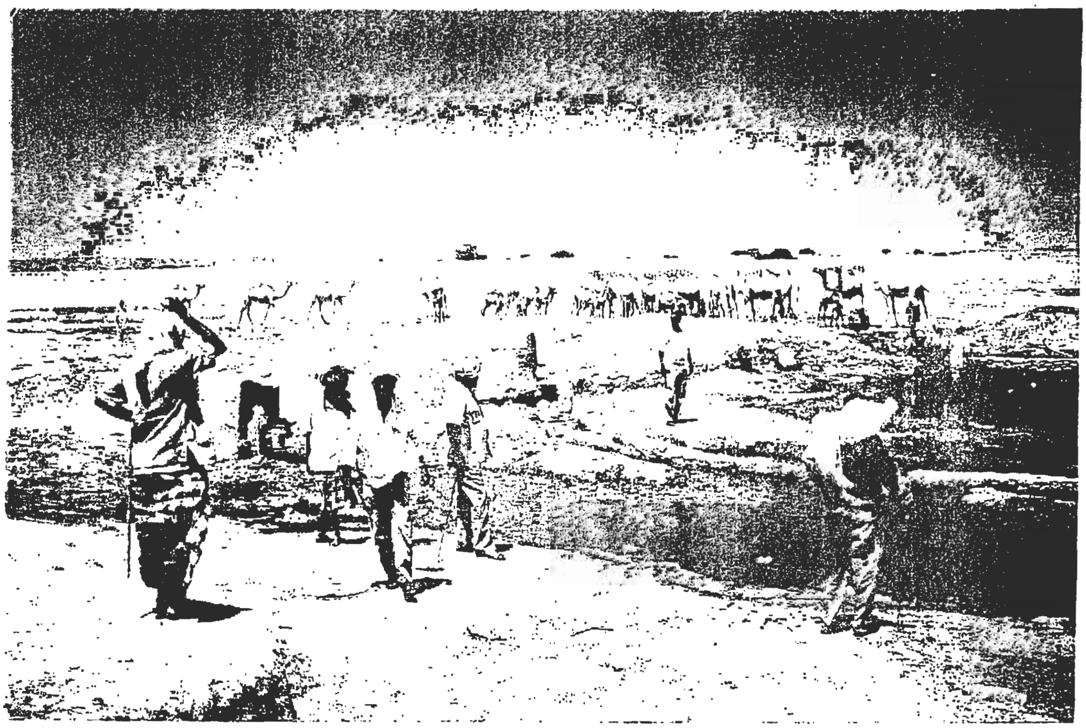

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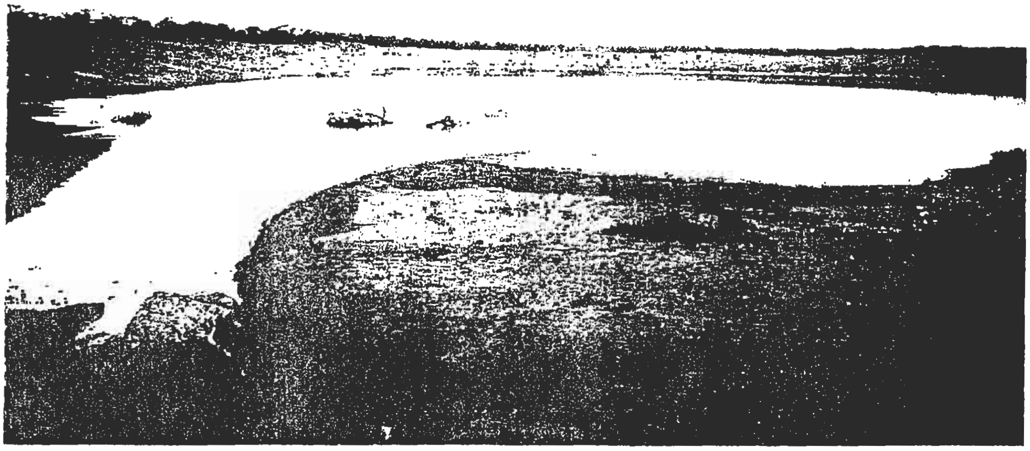


Plate 23

Plate 24

Plate 25

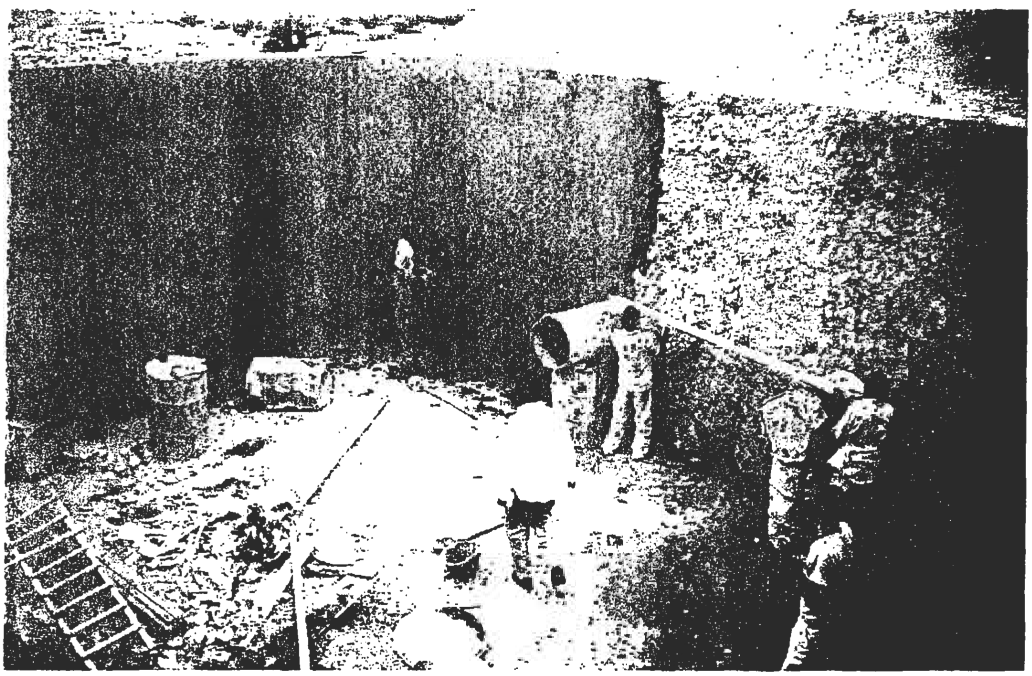


Plate 26

Plate 27

Plate 28

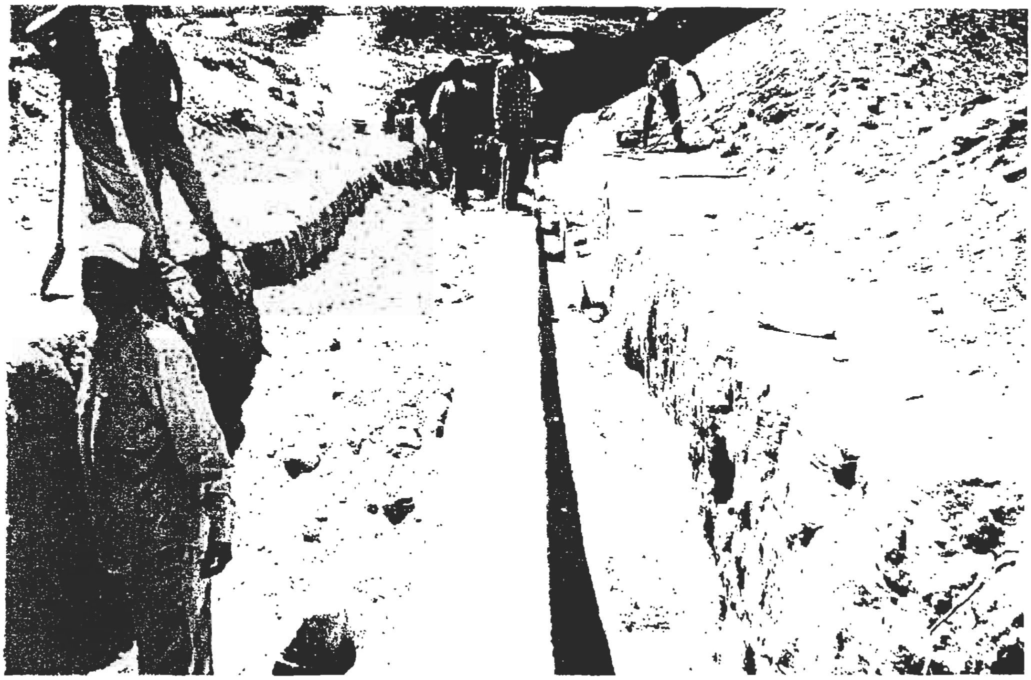
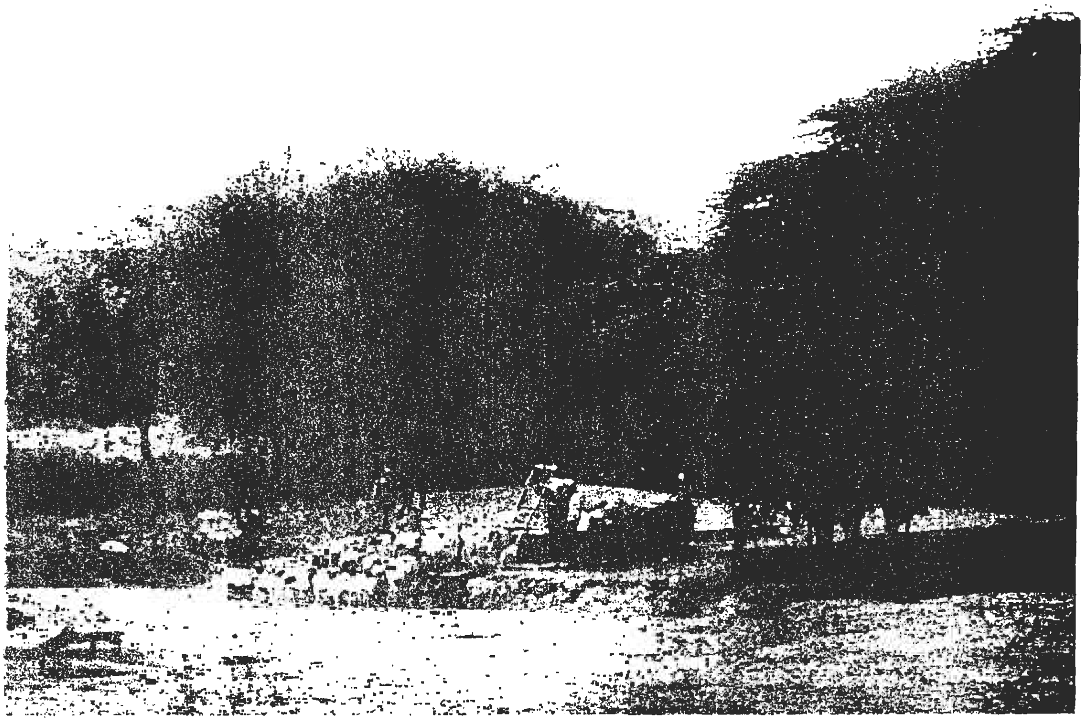


Plate 29

Plate 30



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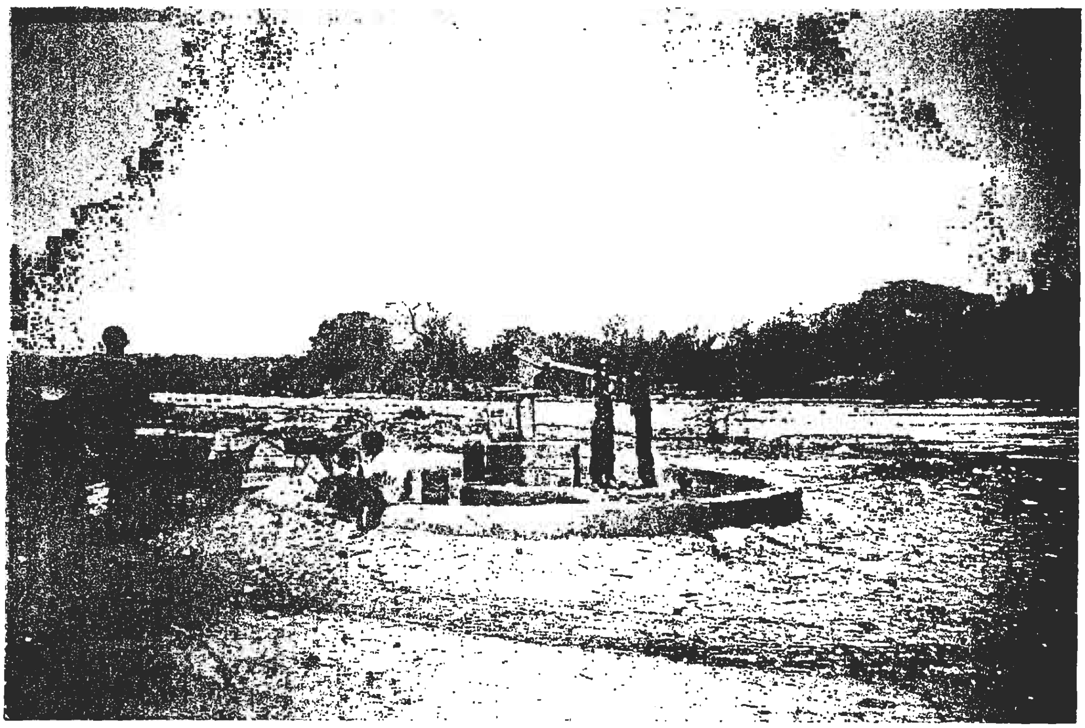

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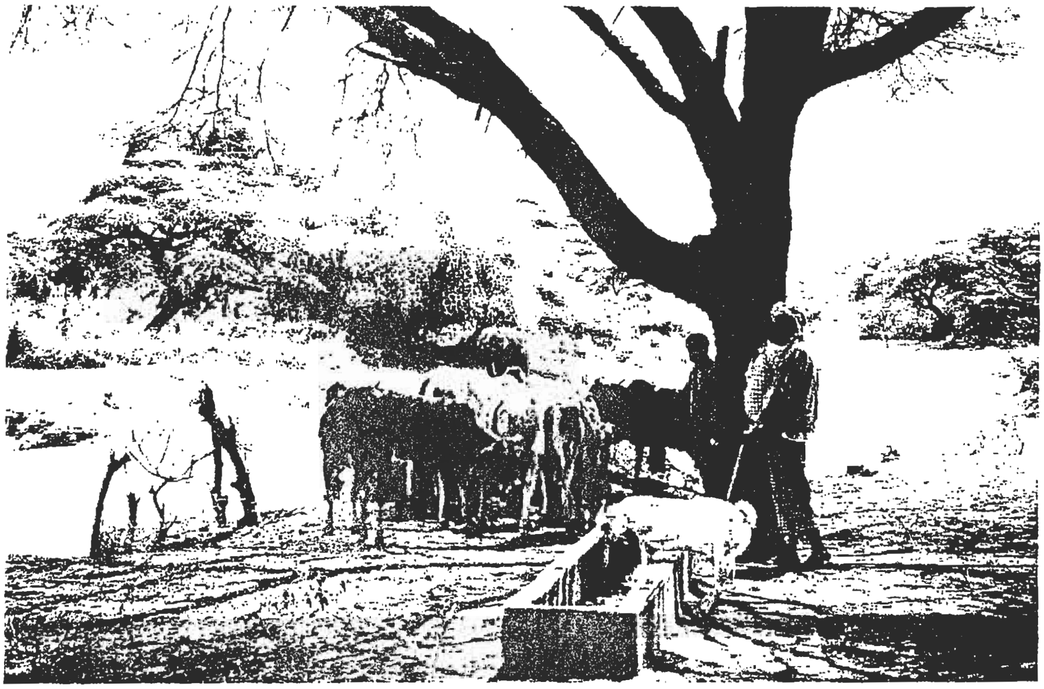
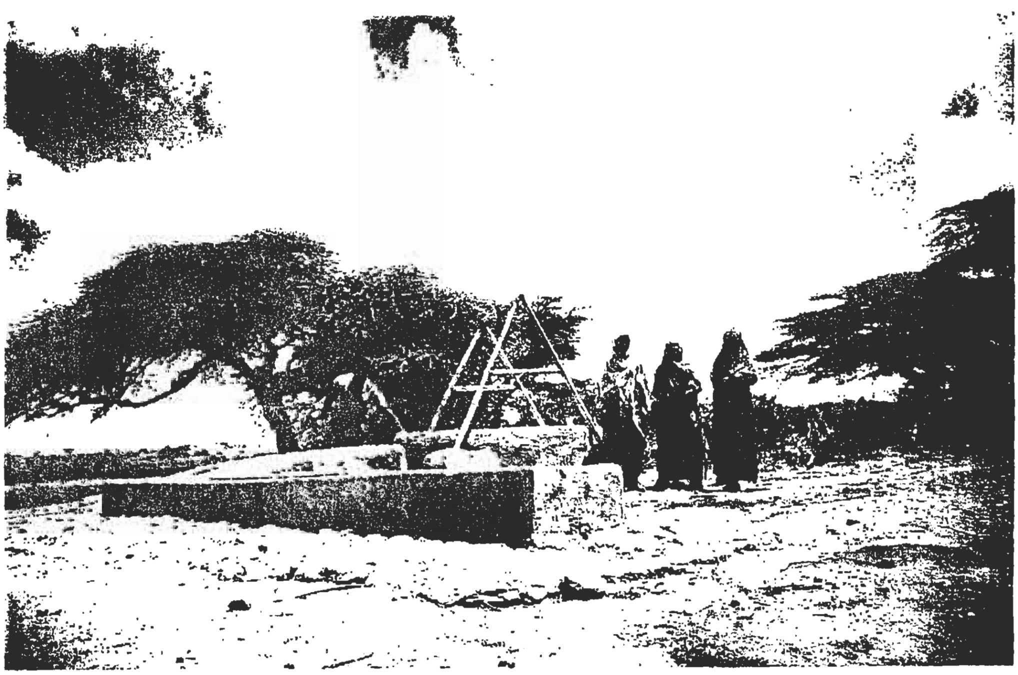


Plate 33

Plate 34

Plate 35



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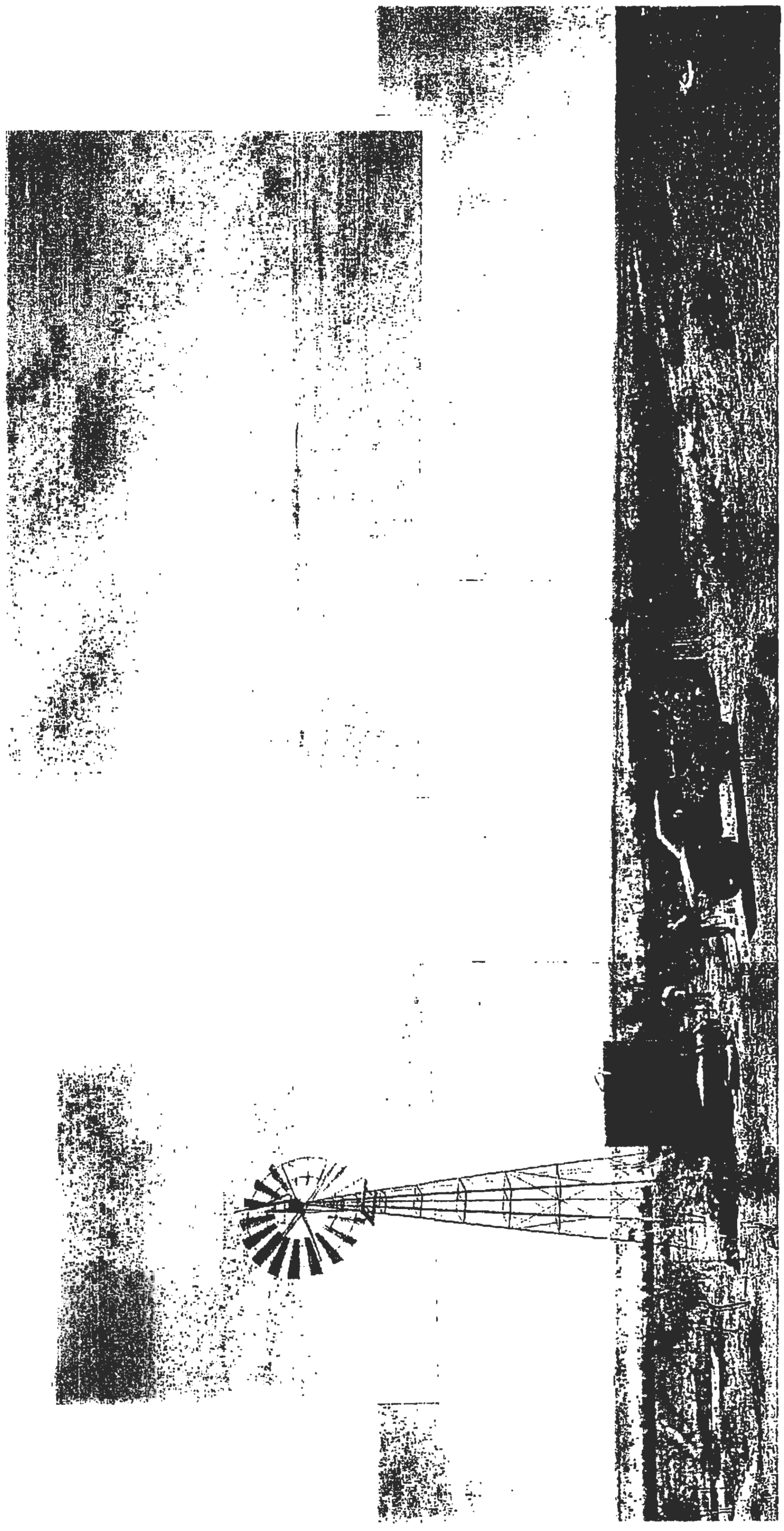

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ANNEX A

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List of known documents and known location of the pre-civil war period in chronological order

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Contains: monthly series

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Contains: daily series

ANNEX B

REPORT on a SEMINAR held in HARGEISA - SOMALILAND

Somali Natural Resources Management Programme

WATER RESOURCES
and
NATURAL RESOURCE MANAGEMENT

REPORT on a SEMINAR held in HARGEISA, SOMALILAND 21-22 July 1999

By

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Project No. 6/SO – 82/95 + 6/SO – 83/04

WATER RESOURCES SEMINAR

Mansoor Hotel, Hargeisa, Republic of Somaliland. 21st – 22nd July 1999

Opening

The Seminar was opened with a short welcome speech from the Minister of Mineral and Water Resources. He emphasised the centrality of water to life, the problem of its apparent scarcity in Somaliland, and the importance of the provision of good quality water for the socio-economic development of the people of Somaliland. The Minister of Environment and Rural Development then emphasised the importance of watersheds and surface water in the rangeland production system, where attaining the right balance in the spatial distribution of available water is of primary concern for effective environmental management.

1.1 Introduction

The seminar was aimed at Somali Water Engineers, Scientists, Planners, and Environment and Natural Resources Specialists. The seminar was attended by Somaliland Government staff from the Ministry of Water and Mineral Resources and the Ministry of Environment and Rural Development. It was also attended by Somali members of the principal international organisations (UN and NGOS) working in water and environment in the region. The presence of the Ministers, and the continued involvement of the Minister of Environment and Rural Development throughout were especially welcomed.

The seminar timetable and participants list are as annexed. The seminar took the form of informal discussions based around a one and a half-day timetable of short presentations. The idea was collate the participants' feedback from the various concepts introduced in the presentations, and then to evaluate the Somali perspective of the various issues surrounding water resource development. In addition a group working exercise based on typical "Water Resource Assessment" scenarios was undertaken.

1.2 Constraints

It is readily acknowledged that water is central to the Somali psyche. Also that Water Resources are central to the livelihoods, production systems and subsequently the development of Somaliland. It is a wide ranging subject that should ideally be addressed systematically over long time frames. Given the time available, the emphasis of the seminar was on "action research". However, given the calibre of the participants present, it was felt that a synoptic analysis of the situation in Somaliland would result.

1.3 Objectives

The stated objectives were towards:

- A common understanding of some key concepts of water resources.
- An appreciation of some "best practice" approaches in developing water resources.
- Feedback from Somali professionals with respect to "Water Resource Assessment and Planning".
- Identifying some basic data needs, gaps and gathering techniques with respect to "Water Resource Assessment and Planning".

From IUCN there was also a specific need to

- Gather feedback from the participants on the IUCN EIA guidelines and ideas on current practice.

IUCN's interest was stated in general terms to be in indigenous production systems and the natural resources on which they are based. More specifically to provide technical support to the EU rehabilitation programme in sustainable resource use, and to promote the planning of activities that improve the environmental conditions in Somaliland.

2.1 Presentation on "Best Practice"
The presentation focussed on a review of documents and methodologies towards "Water Resources Assessment and Planning". Key documents were introduced and discussed.

- *SACB - Co-ordinated strategic framework for WES sector development*

This document has been adopted by the SACB and results from a workshop in 1998 which the Minister of Water attended. The emphasis is on a de-centralised, community managed approach. Particular reference was drawn to sections;

1.1.1 Facilitate necessary water resource studies *and*
1.1.6 Promote protection of catchment areas/watering points in collaboration with actors of other sectors

- *EU - "Guidelines for Water Resources Development Co-operation" a strategic approach towards sustainable water resources management*

The so called "Blue Book" which has recently been developed by the EU as a methodology for water resources development co-operation in the global context. Six interrelated and inter-linked guiding principles: Institutional And Management Principles, Social Principles, Economic And Finance Principles, Environmental Principles, Information, Education And Communications Principles and Technological Principles

support four focus areas of programme activity

- Water Resources Assessment And Planning (WRAP)
- Basic Water Supply And Sanitation Services (BWSS)
- Municipal Water And Waste Water Services (MWWS)
- Agricultural Water Use And Management (AWUM)

- *IUCN – "Strategic Framework for Sustainable Natural Resources Management"*

Outline of the IUCN philosophy with regard to sustainable natural resource management at policy, planning and implementation levels of Somalia's rehabilitation and development.

and

- *"Environmental Impact Assessment Manual and Guidelines for the Somali Water Sector"*

An approach by IUCN to institutionalising EIA processes within the Somali water sector rehabilitation projects, which is considered "best practice" by the EU.

Feedback on the comparative benefits of the EIA guidelines was sought after a brief presentation of the actual procedure.

Shared elements of all the documents were shown to be the issue of sustainability, wise use of natural resources and the interdependence of water resources and the environment. It was agreed that water is a fundamental issue in the development of Somaliland, since it is integral to basic survival, health, food, livelihoods and production systems

2.2 Water Resources Assessments and Planning

Particular focus was placed on Water Resources Assessments and Planning as a focus area within the EU guidelines, which has been devised to allow for macro-planning of water resources management. Recommended co-operating departments are Water Resources, Planning and Environment. Related activities that are designed to assess the availability of the natural resource, protect its quality and plan its use are seen to be

- Studies into land and water use patterns
- Hydrological/hydrogeological studies
- Data collection and monitoring systems
- Drought/flood mitigation and control
- Eco-system protection/conservation
- Review of water laws and regulatory framework
- Establishment of water standards
- Conflict resolution concerning water use

2.3 Feedback/Discussion on "Best Practice"

Regarding the EIA procedure it was commented that a simplified version could be produced for decision makers whereas the version for specialists could be more quantitative in approach. Otherwise no particular technical problems were raised. It is not clear to what extent the guidelines are used in Somaliland.

Water resource development is central to livelihoods and the supporting production systems so should not be limited to drinking water alone. Water is a natural resource. Sustainability requires careful definition in the Somali context. There is no direct translation of sustainable from English into Somali, only that one of the names of the oneness of God is "Sustaining".

A particular case of a previously protected nature reserve acting as part of the catchment for the well field of Hargeisa was presented. Concern was raised over environmental degradation in the catchment (mainly tree cutting) since the war.

There is a huge amount of paperwork generated in the development of guidelines and "best practice" approaches to developing and managing water resources. The guidelines are usually generic and need adapting to the situation in Somaliland. For example the EU guidelines with respect to Agricultural Water Use and Management do not cover the pastoral production system situation in Somaliland adequately (i.e. the pastoral production system is more closely linked to Basic Water Supply). The development of appropriate guidelines therefore requires partnership and understanding between the relevant Somaliland and International community institutions. A first step would be to identify the relevant stakeholders and develop a co-ordinated framework for co-operation. Then agree basic definitions and a conceptual framework. The approach should be geared towards practical outputs from which Somalis can realise benefits.

All the related activities of "Water Resources Assessments and Planning" are relevant and useful to the Somaliland situation. The activities need to be co-ordinated by professional staff from the International and Somali institutions. A practical approach should be taken that is of value to the Somaliland community. The role of the institutions needs to be defined in each case, for example water standards require government action whereas land and water use pattern studies my be devolved to the community level and then "assembled" through regional co-ordination. Assessing and Planning are seen as fundamental steps in coherent development, "When you know what you have, you know what you can do".

3.1 Presentation on "Some General Aspects of Dryland Hydrology" and relation to Somaliland Environmental Conditions

The water cycle was briefly presented. It was shown that the hydrologic system is in a state of dynamic evolution, with individual elements of the system characteristically displaying different time frames of adjustment. "Some General Aspects of Dryland Hydrology" was presented as annexed. It was intended to be a generic background to ASAL lands and was discussed in terms of the application and data needs within the Somaliland context.

3.2 Feedback/Discussion on "Some General Aspects..."

A basic definition of common Somaliland resources and sources was discussed.

Sources	***Resources***
Balley	*Rainfall*
Berka	*Land - Soil*
Well	*- Tugga*
Borehole	*Aquifer*
(Spring)	*(Spring)*

It was agreed that sources and resources are conceptually similar, since both can be viewed as dynamic storage. Surface water storage was agreed to be a function of catchment area, rainfall, evaporation, runoff and soil characteristics. Similarly shallow groundwater tugga storage was shown to be dependent on catchment size, topography, rainfall, evaporation, runoff and soil/sand characteristics plus the geology of the sub-surface environment. Water quality is an additional factor.

It was shown that a systems approach could be adopted to assess water resources quantitatively, and the system in Somaliland is driven by the apparent water scarcity. In general runoff is related to vegetation cover and soils. Man-made erosion can result where the environment is inappropriately managed. Natural erosion is possible where surface flows converge. Groundwater is also not an unlimited supply and the storage capacity is related to geologic geometry and timeframes.

There was much discussion about the virtues of "surface water" versus "ground water" with each having distinct advantages

Surface water	*Good for*	*Pastoral Production System* *Traditional (eg. balli)* *"Apparent Quality"*
Groundwater	*Good for*	*Urban development* *Drought mitigation*

Conjunctive use of both resources was introduced as a "best practice" operating elsewhere in the world. It was agreed that there is much further investigation needed on this issue and that "appropriate" water resource development is a matter of great concern.

3.3 Feedback/Discussion on Data

- *Data is fundamental to planning, monitoring and evaluating.*
- *Data collection is not a Somali priority – not an understood concept.*
- *Historic physical water resource data is available but has been dispersed by the war. It should be recollected and made available at the local level.*
- *Some data recorded in the late 70s and 80s is anyway unreliable.*
- *Reliable ongoing data collection (eg. rainfall) should be reconstituted, provided that it is well co-ordinated and its benefit is apparent to Somali and International institutions.*

4.1 The importance of data - scenarios and group work
Three planning scenarios were introduced which are typical of the ongoing development in Western Somaliland. However the scenarios were considered static, in that nomadic movements were not pervasive.

1. Small town water supply
2. Irrigated farms along a tugga
3. Soil erosion related to rainfed farms

Simple maps were offered as shown in figs 1 and 2.

The objectives were set as

KEY CONCEPT – WATER RESOURCE ASSESSMENT

"For the scenario you have been given:

a. Produce an action plan detailing the steps necessary to collect all the relevant data

b. Prepare a presentation of the plan including priorities."

4.2 Feedback/Discussion on Scenarios
Three groups prepared action plans detailing the steps necessary to collect all the relevant data, in terms of a water resource assessment. The presentations are annexed. In paraphrase the responses showed different approaches to integrating data that can help in the planning process.

1.Group 1 divided the data into Social Data (eg. population and demography, community plan), Environmental Data (eg. climate, hydrogeology, catchment) and Other Factors (eg. existing water sources, sanitation).

The response showed that a broad range of data is needed for holistic development planning, including information on policy, community need and environment as well as physical data of the available resource within the catchment.

2. Group 2 divided the data into a "Survey of Water Quantity and Quality that can be Supplied" (eg. catchment geometry, rainfall, runoff and flow) versus an "Assessment of Water Demand" (eg. area irrigated, upstream consumption and crop water requirement). Exogenous factors (eg. livestock numbers) were considered and an "Assessment of the Managed Project" proposed to monitor irrigation practice and the water table response.

The response was hydrologically sound; it focussed on the physical assessment of the water resources in terms of a supply and demand balance within the catchment, plus taking account of quality considerations. This requires a scientific approach based on practical fieldwork.

3. Group 3 assumed a qualitative approach to identifying manmade (eg. too much livestock/overgrazing, too much tree-cutting/charcoal and firewood, lack of legislation and land tenure policy) and natural (eg. heavy rainfall on bare lands) erosion. Measures for remediation were offered in terms of preserving the resource area, the farming area and addressing the corresponding social needs.

The response was not therefore data driven, but was useful as it integrated physical and social measures in a setting of community based environmental management and planning.

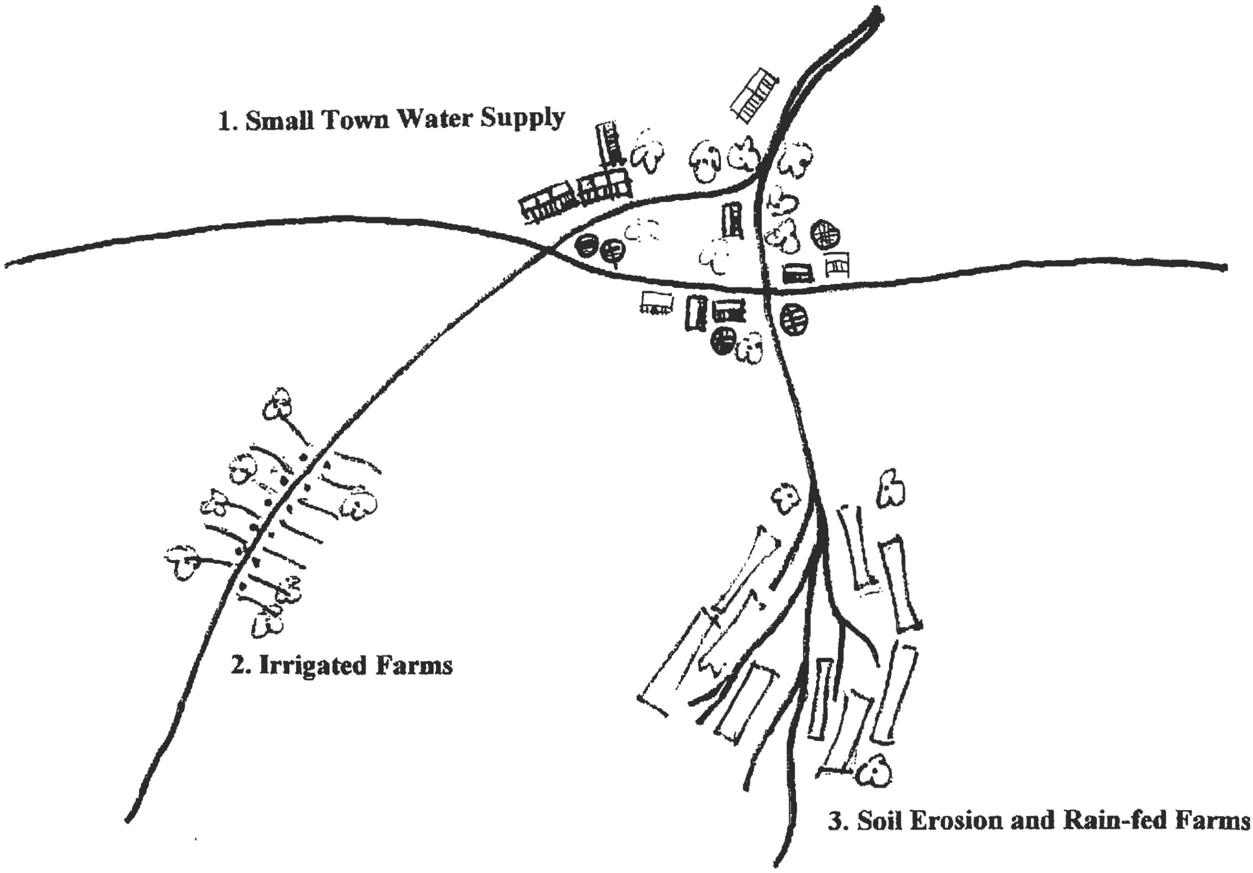


Fig 1. Development Scenario - Map at local level (Not to scale)

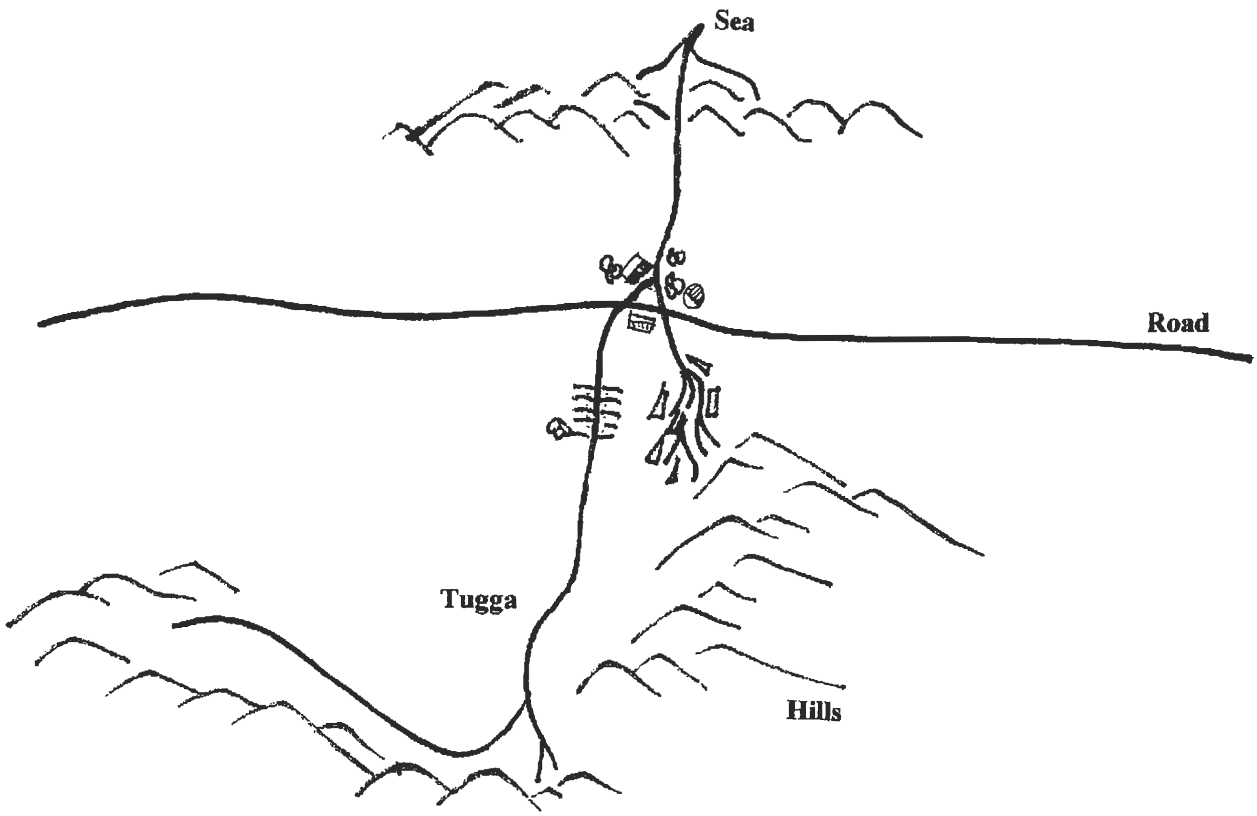


Fig 2. Development Scenario – Map at district level (Not to scale)

In general the responses show that water resources are strongly linked to the environment (eg. vegetation cover, soils, topography), and that at micro level the catchment is the appropriate planning area. Also that a broad range of data is needed for development planning but that an empirical approach is required to assess resources effectively.

5.0 Data availability and Data gaps in Somaliland with respect to Assessing Water Resources

The session started with a brief re-cap of the scenarios and the implications of "Best Practise" approaches to assessing water resources in Somaliland. Broad consensus was reached on the feedback/discussion documents, which are reproduced in section above.

Two matrices were introduced, which were filled in by the group, in order to assess the availability and quality of data within Somaliland. The first matrix concentrates on typical hydrologic data – a measure of the availability of the supply, whereas the second concentrates on typical social "demands". The matrices are produced as annexed and the feedback on the hydrologic variables paraphrased here.

5.1 Feedback/Discussion on Available Hydrologic Data

In general hydrologic data is severely limited in Somaliland. There is a mixture of strong qualitative observations at the local level and reasonable historic data sets that have been lost or dispersed by the war. The limited ongoing data collection is seen as valuable but is not readily available for consultation. Qualitative estimates are very important for Somalis (eg. they support the Food Security Assessment Unit through a functioning field based communication system). Otherwise scientific data per se is seen as the province of the international community, an attitude that might change if there are more trained Somali staff or more educated Somalis returning from abroad.

Quantitative rainfall data is not readily available. The gauging network is being re-established but lacks co-ordination. Historical data sets are being reconstituted. Rainfall data is in any case application specific.

There is very little data on evaporation, and little perceived need for it. Strong doubts by one participant, were cast on the validity of evaporation estimates in relation to berka water levels noted by Somali pastoralists.

Runoff data is largely limited to archive material based on experimental catchments that no longer exist. Only in Boroma has a concerted effort been made to record runoff as a part of a Soil and Water Conservation project. Soil maps for the region are large in scale and little is recorded of infiltration rates outside experimental plots. However, many Somalis know well the characteristics of the soil, for example many farmers plough their field <u>before</u> the rainfall. There is a saying that the "first rain is to quench the thirst of the earth".

Spates in tugga are widely observed but have not been recorded since pre-war periods. Flood damage can be serious. Local storage conditions of the tugga and their wells are well known by Somalis. Tugga constitute an important dry season water reserve for pastoralists but concern is raised over the effects of expanding irrigated farms. A quantitative analysis would be of benefit therefore. Analysis of the tugga water resources was undertake before the war and should be re-evaluated in the light of current developments.

Groundwater development is seen as the province of the specialist, whether from the Somali or International Community. Reasonable historic data is available but monitoring of water levels is not ongoing and aquifer characteristics are not well known. Some geophysical investigation has recently been restarted and such investigation should include the practical training of Somali staff. Given the high cost of borehole rehabilitation/development and the low success *rate, professional hydrological and hydrogeological investigation remains a top priority for the Ministry of Water and Mineral Resources.*

There is a good local knowledge of water quality, especially in relation to salts and solids. It is highly qualitative but is supported by limited testing by the international agencies. A thorough research was done of the regional hydrochemistry during the 1980s, which is widely available. Limited bacteriological testing is being conducted. Regional quality standards were recently developed but are not yet "approved" or widely disseminated.

6.0 Feedback on EIA guidelines and recommendations for future needs
Due to time constraints feedback was limited to the collection of a comment sheet. IUCN gave a commitment to follow up the EIA guidelines with each organisation individually.

7.0 Conclusions
The seminar provided a useful synopsis of the current situation in Somaliland vis-à-vis an understanding of Water Resources and Natural Resource Management. The seminar was a success in that all the seminar objectives were (to some extent) met.

It can be surmised finally that

- **Water is central to life, livelihoods and production systems. There is a strong indigenous knowledge base of the regional hydrologic characteristics (this does not in general include groundwater), which is based on qualitative observation.**

- **Water is a Natural Resource. Water Resources are intrinsic to Environmental conditions. Water Resources are scarce in the Somaliland environment. They require sensitive and appropriate management.**

- **Monitoring of Water Resources within the cycle is integral to managing the resource. Data is fundamental to good planning, monitoring and evaluation of available resources. Data is severely limited in the current climate.**

- **There is a need to assess the available Water Resources accurately, if the sustainable limits of the resources are to be calculated. This requires a scientific approach that can be backed up by local knowledge. Effective planning is best based on knowing "what we can do with what we have got".**

- **There are a small number of Somali professionals who understand well the key issues regarding Water Resource Development, but they lack resources to support their skills. Retraining of staff and a practical approach to assessing resources are advised.**

Eur Ing C Print, Nairobi, 30th July 1999

The author acknowledges the kind support of the Natural Environment Research Council *for this study.*

ANNEX A

LIST OF PARTICIPANTS

TIMETABLE

Seminar Participants

Name	**Organisation**
Eng. Ahmed Mohamed Behi	Minister of Water and Mineral Resources
Mohamed Muse Awale	Minister of Environment and Rural Development
Abdirahman Abdisalam Sh. Ali	Ministry of Water and Mineral Resources
Hassan Saeed Omer	Ministry of Water and Mineral Resources
Mahmuud Ali Ismail	Ministry of Environment and Rural Development
Abdikarim Aden Omar	Ministry of Environment and Rural Development
Lillian Midi	UNICEF – consultant
Safia Jibril Abdi	UNICEF - WES officer
Hassan Jama Deria	UNDP/SRP - Technical co-ordinator
Abdullahi Ali Obsie	WHO
Khaddar Hussein Mohamed	Oxfam – Community Development Officer
Mohamed Hamoud Adam	IUCN - Wood Fuel Field Officer
Safiya Jibril Younnis	IUCN
Uffe Leinum	Danish Refugee Council - Programme Manager
Rashid I Guleed	Danish Refugee Council - Engineer
Abdikarim Hassan Nur	CARE - Senior Programme Officer
Ir. Kees Kempenaar	SwissGroup - Delegate
Osman Abdullahi Ali	SwissGroup - Consultant
Abdulkader Hashi Elmi	Mansoor Hotel
22nd July only	
Abdi Jama Abdi	Oxfam - Programme Officer
Abdirashid Omar Osman	RADA – COOPI
Abdirahman Ibrahim Abdilahi	RADA - COOPI
Abdulqadir Isse Abdulrahman	RADA - COOPI

Facilitators

Tony Potterton	Programme Co-ordinator – IUCN
Chris Print	Researcher - IUCN/Imperial College

TIMETABLE

DAY 1 – WEDNESDAY 21st JULY

- **OPENING**
- **INTRODUCTION**

PRESENTATION ON "BEST PRACTICE"

TEA/COFFEE

- **PRESENTATION ON ARID ZONE WATER RESOURCES AND RELATION TO THE SOMALILAND NATURAL ENVIRONMENT**
- **FEEDBACK ON PRESENTATION**

LUNCH

- **THE IMPORTANCE OF DATA - SCENARIOS AND GROUP WORK**
- **PRESENTATIONS BY WORKING GROUPS**
- **FEEDBACK ON PRESENTATIONS**

DAY 2 – THURSDAY 22nd JULY

- **RE-CAP OF SCENARIOS and APPLICATIONS OF BEST PRACTICE for "WATER RESOURCES AND NATURAL RESOURCE MANAGEMENT"**
- **FEEDBACK ON EIA GUIDELINES and RECOMMENDATIONS FOR FUTURE NEEDS**

TEA/COFFEE

- **VIDEO "THE ARID CHOICE"**

ANNEX B

KEY DOCUMENTS

SACB -
CO-ORDINATED STRATEGIC FRAMEWORK for WES SECTOR DEVELOPMENT

EU -
"GUIDELINES FOR WATER RESOURCES DEVELOPMENT CO-OPERATION"
A STRATEGIC APPROACH TOWARDS SUSTAINABLE WATER RESOURCES MANAGEMENT

IUCN -

STRATEGIC FRAMEWORK FOR SUSTANABLE NATURAL RESOURCES MANAGEMENT

ENVIRONMENTAL IMPACT ASSESSMENT MANUAL and GUIDELINES FOR THE SOMALI WATER SECTOR

SUMMARY OF CO-ORDINATED STRATEGIC FRAMEWORK FOR WES SECTOR DEVELOPMENT

SUPPER GOAL

Health status, peace and dignity of Somalis are sustainably enhanced

OVERALL GOAL

Contribution of water and environmental sanitation services to promotion of health, self reliance, good governance and peace process in Somalia is increased

PURPOSES

1 (LONG TERM): Communities and households exhibit improved water, hygiene and environmental sanitation behaviour/practices

2 (LONG TERM): Water committees, Local Authorities and private sector enterprises effectively and efficiently manage water supplies and the environment in a participatory and gender sensitive manner and on a sustainable basis

3 (LONG TERM): Provisional Governments demonstrate increased capabilities to formulate policies, regulate, facilitate and coordinate water and environmental resources on sustainable basis

4 (INTERIM): UN agencies, bilateral donor agencies, International and local NGOs demonstrate increased capabilities to facilitate Somalis to plan, implement and evaluate WES programmes/projects/ activities in an effective, efficient, co-ordinated, participatory and gender sensitive manner

OUTPUTS AND ACTIVITIES

1.1 Availability of safe water at community and household level is sustainably increased in the currently under-served zones

- 1.1.1 Facilitate necessary water resources studies (social, hydrological, hydrogeological studies etc.)
- 1.1.2 Increase exploitation of underground water resources
- 1.1.3 Demonstrate economically viable rainwater harvesting technologies at household and community levels
- 1.1.4 Increase productivity and distribution efficiency of existing water systems/points
- 1.1.5 Promote improvement of safety of water through: treatment, separation of human and livestock watering points, improvement of water handling etc.
- 1.1.6 Promote protection of catchment areas/ watering points in collaboration with actors of other sectors

1.2 Public awareness of proper hygiene and sanitation issues/ practices is enhanced

- 1.2.1 Identify and train teachers, women leaders and other appropriate agents e.g. CHWs, local artists etc.
- 1.2.2 Facilitate teachers to elaborate water, hygiene/sanitation curricula and support them to teach pupils and communities
- 1.2.3 Identify appropriate media/ channels and support creative, effective and efficient production, dissemination and evaluation of target group specific messages e.g for the nomads
- 1.2.4 Reward schools, institutions, communities or even individuals for best practices

1.3 Availability of sanitation facilities/ structures is increased

- 1.3.1 Facilitate participatory development of appropriate and target group specific sanitation technologies (including solid waste disposal)
- 1.3.2 Assist schools and other public institutions to erect new or to rehabilitate existing appropriate sanitation facilities
- 1.3.3 Demonstrate appropriate sanitation facilities/ technologies at household and community levels

2.1 Gender balanced community participation in WES projects/ activities is enhanced

- 2.1.1 Review strategy for promoting effective, efficient and gender balanced participation and contribution to WES activities
- 2.1.2 Motivate and facilitate communities to form or to strengthen water committees/ organisations according to strategy
- 2.1.3 Empower communities to identify and prioritise respective WES needs
- 2.1.4 Facilitate communities to participate in the planning, implementation and evaluation of WES projects/activities and to contribute according to strategy
- 2.1.5 Train and counsel committee members and selected members of communities in the technical, Managerial and social aspects of owned WES facilities

2.2 Operation and maintenance of water systems is enhanced

- 2.2.1 Review strategies for promoting increased O+M for sustainability of water systems
- 2.2.2 Involve contractors, suppliers, communities and, where applicable, employees of water systems in the preparation and adoption of standard equipment, designs and implementation guidelines
- 2.2.3 Improve quality of construction through training of contractors, selection of appropriate quality materials and increased supervision
- 2.2.4 Train managers, finance officers, operators, mechanics, maintenance staff etc according to needs and strategy
- 2.2.5 Promote full cost recovery system
- 2.2.6 Motivate reputable traders to stock needed equipment and spare parts
- 2.2.7 Identify and train local mechanics/artisans and, where applicable, ordinary community members on maintenance and repair of installed equipment/systems

2.3 Qualified private sector organisations and individuals are available for WES

- 2.3.1 Review strategy for mobilisation and motivation of private sector to play increasing roles in WES
- 2.3.2 Identify, train and counsel reputable private sector organisations and individuals to become more effective and efficient providers of needed goods and services
- 2.3.3 Contract trained/qualified private sector organisations/ personnel to provide needed goods and services
- 2.3.4 Refrain from providing goods and services which are earmarked for private sector involvement

3.1 Capacities of local WES institutions are strengthened

- 3.1.1 Identify deserving institutions and conduct participatory institutional reviews
- 3.1.2 Prepare institutions for policy formulation, regulatory, facilitation, supervisory and co-ordination roles
- 3.1.3 Assist institutions to develop appropriate technical and Management systems and to train selected staff for envisaged duties/roles
- 3.1.4 Assist institutions to formulate appropriate WES policies, by-laws, regulations etc. and advise on their respective implementation, evaluation and review
- 3.1.5 Link institutions to appropriate sources of funding, actors in other sectors and to relevant grass roots organisations e.g. village water committees
- 3.1.6 Advise institutions on appropriate revenue bases in collaboration with actors of other sectors
- 3.1.7 Support initiation of a bottom-up participatory integrated approach to planning and overall sector development

4.1 Co-operation and collaboration among stakeholders is increased

- 4.1.1 Conduct participatory reviews of technical and Management strategies/approaches and lobby for their application by all agencies
- 4.1.2 Convene co-ordination/communication fora and improve/increase co-ordination efforts
- 4.1.3 Compile a central data bank and disseminate data/information to relevant stakeholders in useable forms
- 4.1.4 Advocate for a more balanced distribution of implementing agencies (Local NGOs, International NGOs, private sector actors etc.)
- 4.1.5 Conduct joint (inter-agency) and participatory monitoring and evaluation missions and disseminate experiences and lessons learnt from all WES projects/ programmes

4.2 WES project cycle management is improved

- 4.2.1 Intensify participatory project identification and planning according to participation strategy
- 4.2.2 Improve project preparation and design, using standardised technologies and guidelines
- 4.2.3 Introduce elements of environmental impact assessment in project designs/plans
- 4.2.4 Enhance participatory project implementation
- 4.2.5 Promote applications of appropriate technologies
- 4.2.6 Train project staff in technical and Management subjects according to needs and recruit qualified staff to fill existing gaps
- 4.2.7 Introduce improved project cycle management systems/instruments
- 4.2.8 Introduce participatory evaluation of projects/programmes
- 4.2.9 Ensure timely and effective backstopping of projects/programmes

4.3 Increased availability of funds for WES projects/ programmes is promoted

- 4.3.1 Prepare project proposals which can attract donor funding and forward them well before deadlines
- 4.3.2 Utilise M+E data and appropriate media to:
  - a) lobby for funds from regional organisations e.g. IGAD,
  - b) lobby for increased funding of projects from within Somalia,
  - c) lobby for increased funding from abroad
- 4.3.3 Link Local Authorities to appropriate sources of funds and assist them to increase revenue bases for WES activities

EUROPEAN COMMISSION
DG VIII DIRECTORATE-GENERAL FOR DEVELOPMENT
DG IB DIRECTORATE-GENERAL FOR EXTERNAL RELATIONS

The management and development of water resources: A strategic approach

Guidelines for Water Resources Development Co-operation

November 1997

Draft

HR Wallingford

in association with

Office International de l'Eau

IUCN Eastern Africa Programme

Somali Natural Resources
Management Programme

Strategic Framework for Sustainable Natural Resources Management in Somalia

November 1997

IUCN
The World Conservation Union

IUCN Eastern Africa Programme

Somali Natural Resources
Management Programme

Environmental Impact Assessment Manual and Guidelines for the Somali Water Sector

December 1997

ANNEX C

SOME GENERAL ASPECTS of DRYLAND HYDROLOGY

SOME GENERAL ASPECTS OF DRYLAND HYDROLOGY

Arid and semi-arid lands (ASAL) are characterised by low annual rainfall averages, highly irregular in both space and time. Rainfall is the primary hydrological input driving an environment where life has adapted a strong resilience to the harsh climatic conditions. Droughts and ironically, floods, are typical problems associated with ASAL environments.

The industrial developments of the 19th and 20th centuries have forced the pace of change in Africa's ASAL environments. In particular groundwater development has been instrumental in supporting increasing populations and rapid urbanisation. But there are often problems associated with the groundwater quality, and, like the surface water environment, the limited extent of the resource. Abstractions from surface and groundwater for supply purposes are limited by both quantity and quality considerations.

Rainfall is highly variable in both space and time. In ASAL zones it is especially so. In ASAL areas the direct recharge of groundwater from rainfall is likely to be insignificant because of several factors.

1. For most of the year, rainfall is relatively small compared with potential evaporation.

2. Storm intensity frequently exceeds the infiltration capacity of the ground surface resulting in overland flow.

3. The unsaturated zone tends to dry out and may therefore absorb a significant volume of infiltrating water.

4. Semi-permeable crusts may form in the unsaturated zone comprising fine sediments that impede infiltration.

During the relatively few days that rainfall exceeds evaporation in ASAL zones, the storm intensity is frequently sufficient to induce surface runoff. This effectively removes the potential recharge water to a location downstream. Transmission losses are generally high. Any water that does infiltrate tends initially to reduce the soil moisture deficiency, then evaporate rather than recharge groundwater. Where rainfall becomes more infrequent and irregular, (ie. more arid) direct recharge from precipitation is likely to be even less frequent.

On the other hand the replenishment of groundwater by wadis in flood is frequently the major source of recharge. Temporary rivers are formed in the wadis, following intense storms on the surrounding slopes which are sufficiently severe to generate surface runoff. These temporary rivers may terminate either in spreading zones where the flood infiltrates to the aquifer below, or in low lying areas where temporary lakes are formed. Water that accumulates in these depressions evaporates leaving behind it's salt content. In both cases the aquifers can be recharged in the foothill areas where the surface runoff is concentrated and where topographical conditions and soil permeability tend to be more favourable for infiltration to the saturated zone.

Several factors combine to enable recharge to take place in the foothill zones.

1. In such areas there is a thickness of permeable detritus comprising sand and gravel.

2. The beds of the wadis are higher than the groundwater table and recharge is from the wadi flow to the deeper aquifer.

3. Water may flow horizontally through the banks.

4. The surface water spreads out over the ground thus accelerating the process of infiltration and subsoil saturation.

5. The finer sediments that could impede infiltration are carried to the downstream periphery of the recharge zone creating alluvial fans.

Groundwater recharge from temporary rivers is highly irregular in both space and time, just like the storms that produce it. In contrast to direct recharge from rainfall it is relatively localised. After each flood there is a period during which the aquifer is recharged causing a rise in the water table in that area. Generally speaking, any rise in groundwater levels is related to the size of the flood. But there is a delay in the response of the water table due to two factors. Firstly, there is a delay due to the thickness, permeability and porosity of the unsaturated zone. Secondly, the horizontal propogation of the flood wave in the saturated zone is related to the diffusivity of the aquifer.

Groundwater recharge from wadis also occurs where geological conditions are favourable, especially where there are Karstic systems. Groundwater is generally of good quality. However, geologic factors including the structure of the aquifer and the mineral composition of the soil and the bedrock also influence water quality. Aquifers can also be contaminated by the upward flow of fossil brines where these occur at depth below freshwater. Saline intrusion is likely to occur if the water table is lowered by groundwater abstraction at sites adjacent to the ocean or other salt water environments.

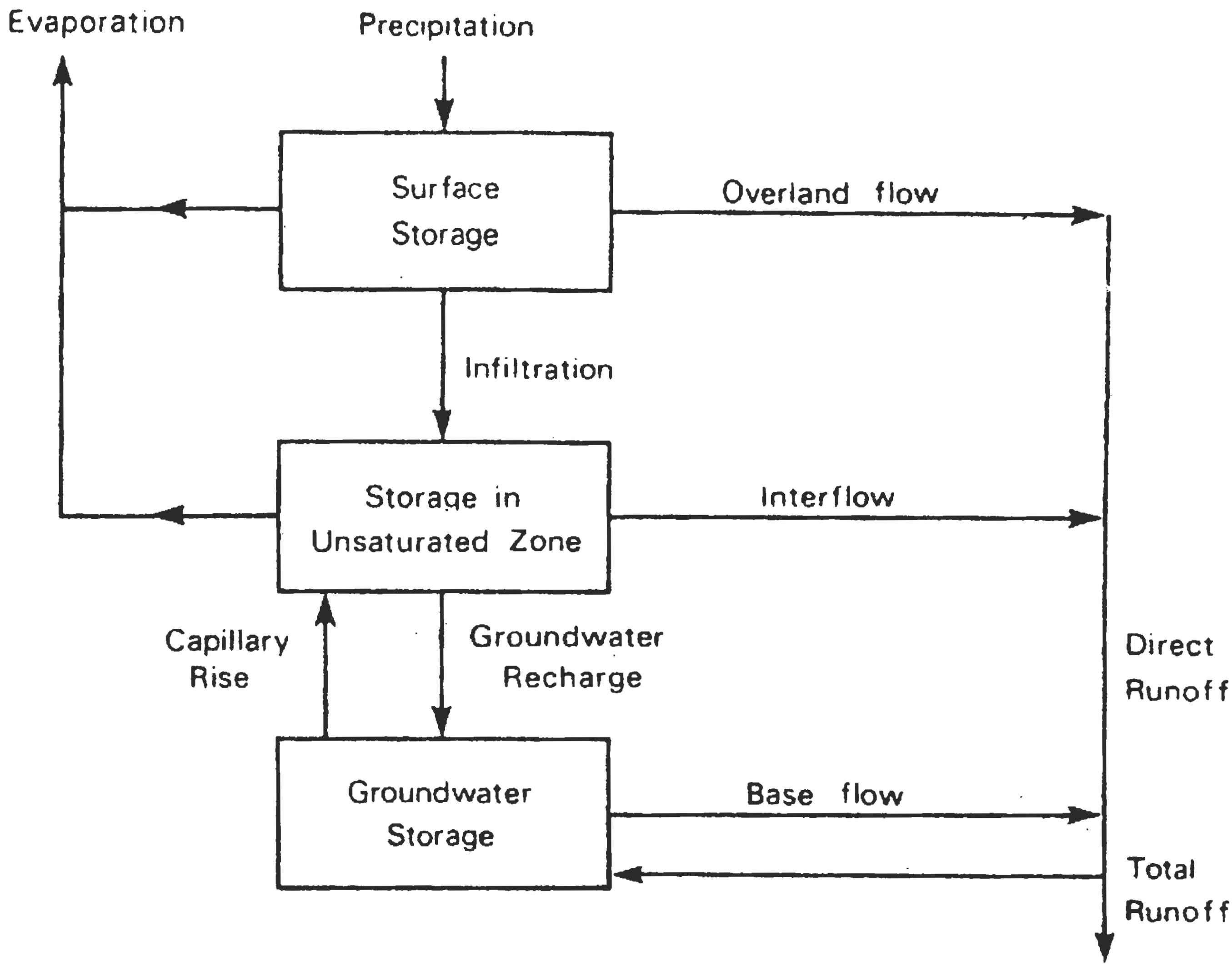
Whenever there is flow of water between the surface and aquifers, in either direction, there is a relationship between the quality of water in the two systems. Groundwater can pollute surface water and surface water can pollute groundwater. Alternatively there may be improvements in quality.

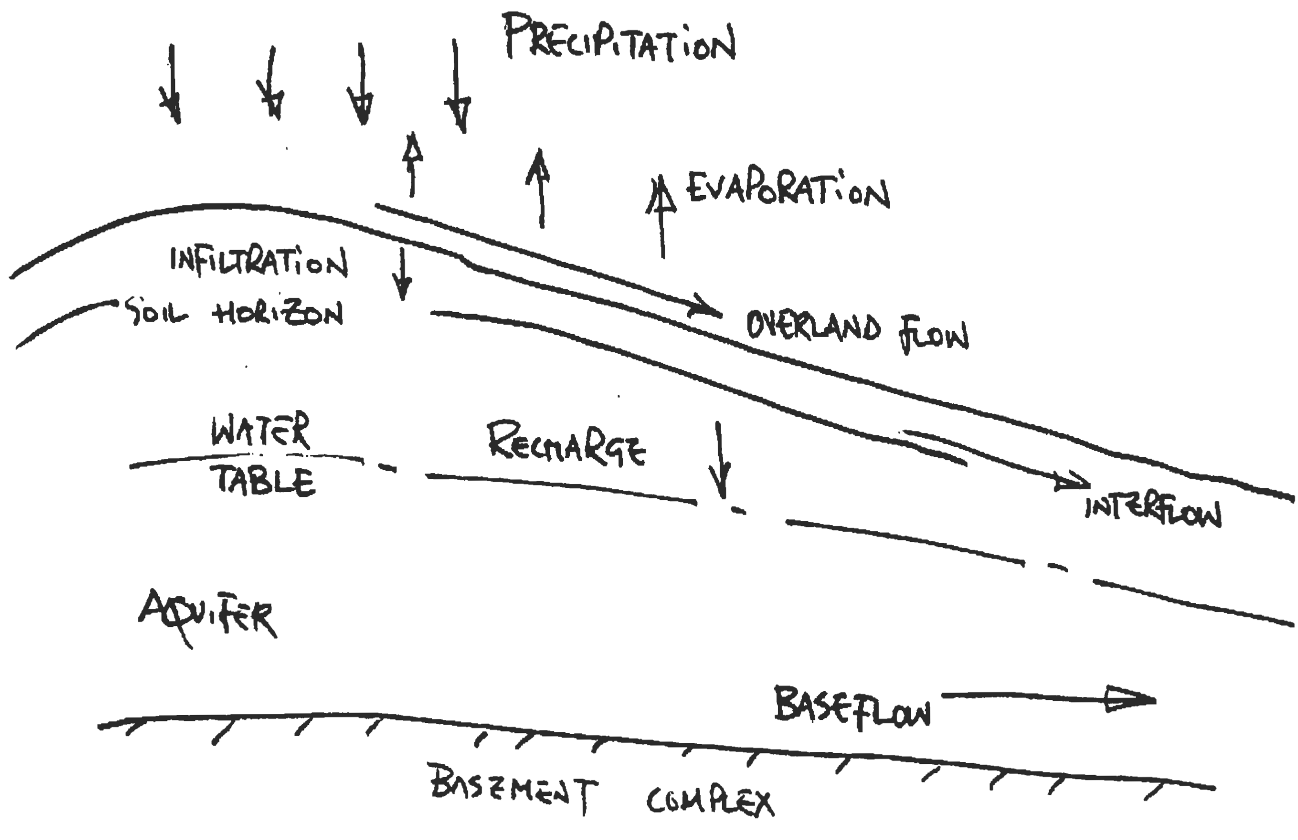
In many ASAL regions, salinity increases have been observed in both groundwater and surface water due to the effects of irrigation practices. In these areas the concentration of dissolved solids tends to increase and may reach a level intolerable to many crops. This effect can be so pronounced that the quality of water rather than the amount available restricts water use. Irrigation requires careful management in such cases.

In ASAL regions the available water, because of it's scarcity, may be used several times for varying purposes. The reuse of water can cause quality problems that may be associated with the cycling of water from the surface to groundwater and then back to the surface. Excess water applied for irrigation may infiltrate to the water table, reach the surface water channels as base flow then be abstracted and used again for irrigation. Also, quantity and quality changes may occur in surface water as a result of changes in land use, such as changes to or from arable, forest or urban environments. The run-off itself may drive severe erosion processes with a reduction in vegetation cover. In ASAL environments a significant increase in salinity may occur in surface run-off after natural vegetation has been removed for agriculture or other purposes.

Long period records of weather conditions, flood and wadi base flows and groundwater levels are valuable aids in the analysis of water resources. Provided that the records are accurate the longer the record the more accurately defined are the annual and monthly means and the variation about the mean. Also long term trends and cycles may be detected. Hydrochemical data is useful in assessing quality. Unfortunately long term records are not available in many areas. Where data is limited it is still possible to derive the design parameters, based on statistical analysis and the recognition of uncertainty. A systems approach can be applied to derive the storage and fluxes within the resource. A quantitative water balance can thus be achieved.

with reference to various material from UNSECO/IHP documentation
C Print, Hargeisa, Somaliland, July 1999


Evaporation
Precipitation
Surface Storage
Overland flow
Infiltration
Storage in Unsaturated Zone
Interflow
Capillary Rise
Groundwater Recharge
Direct Runoff
Groundwater Storage
Base flow
Total Runoff


PRECIPITATION
EVAPORATION
INFILTRATION
SOIL HORIZON
OVERLAND FLOW
WATER TABLE
RECHARGE
INTERFLOW
AQUIFER
BASEFLOW
BASEMENT COMPLEX

ANNEX D

GROUP PRESENTATION MATERIAL

The importance of Data - Scenarios and Group Work

Presentations by Working Groups

1. Small Town Water Supply

Social Data
Population and Demography
Information from the Community
Town Plan
Industries

Environmental Data
Water Quantity and Quality
Climate
Hydrogeology
Catchment size
Geo-physical data
Vegetation

Other Factors
Resource Availability
Rural Water Needs
Existing Water Sources (Other sources)
Sanitation

2. Irrigated farms along a tugga

Data - Survey of Water Quantity and Quality that can be Supplied
Size of catchment area
Rainfall data
Evaporation
Infiltration (Soil characteristics)
Runoff and flow
Water quality and salinity

Data - Assessment of Water Demand
Number of farms present and future
Type of crops cultivated present and future
Area irrigated present and future
Upstream consumption present and future
Crop Water Requirement

Exogenous factors
Animal population
Human Population

Data - Assessment of the Managed Project
Type of Irrigation (pumps, buckets, canalisation)
Traditional wells
Water table
Well depth
Discharge of the well (yield)

3. Soil erosion related to Rainfed farms

Identification of causes

Manmade

- overuse of the land

    too much livestock/overgrazing
    too much tree-cutting/charcoal and firewood
    too intensive agriculture
    demographic pressure

- lack of policy

lack of appropriate institutions
legislation and land tenure

Natural

Heavy rainfall on bare lands
Winds/temperature

Measures for remediation

- preserve the resources area

proper grazing/forestry management
community participation in all levels

Farming area
Physical measures
Bunding, terraces, dams
Agro-forestry (interaction and relation of different crops)
Planting the right type of trees

Social Measures

Capacity building/training, awareness raising of all stakeholders

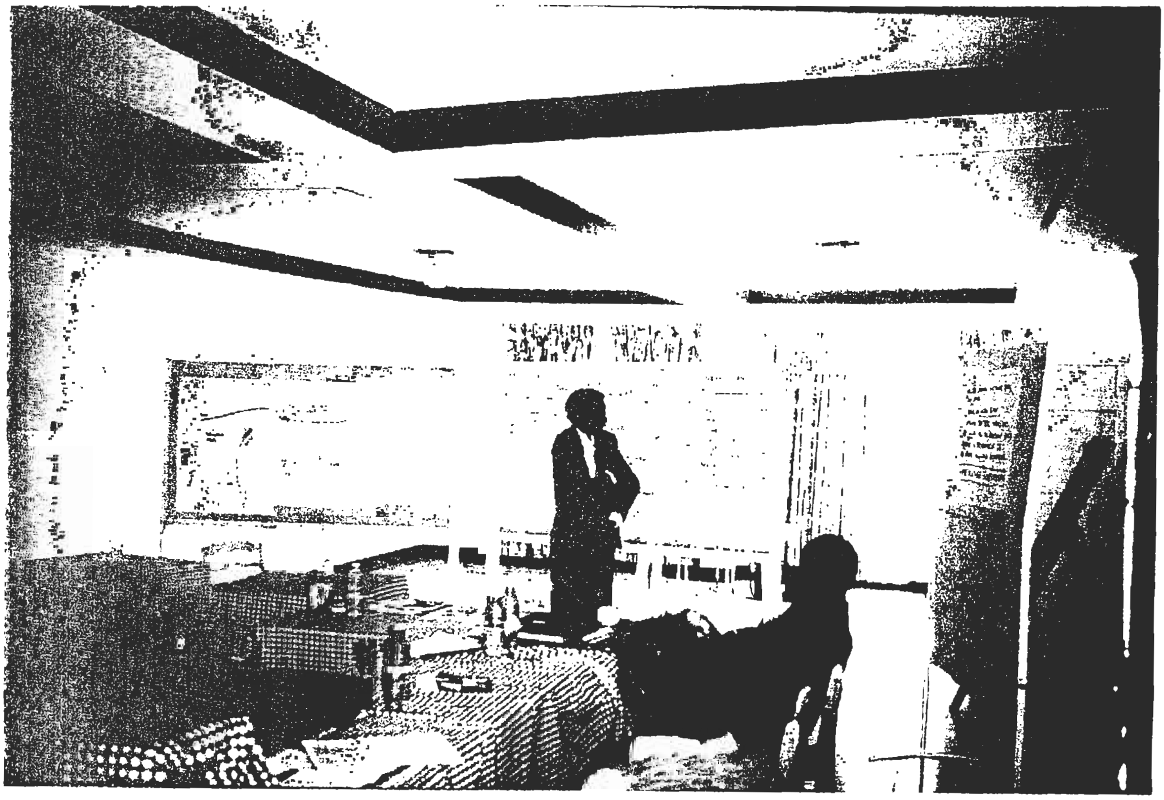
Available Data: "Resource - Supply Side"

	Ongoing		**Local Community**	**Historic Data**	**International**
	Observation	**Measurement**	**Resource Users**	**Desk Study**	**Community**
Rainfall	Traditional	Limited Eg. COOPI Boroma	Good General Data Localised	Good Historic data from 1977 not reliable Data dispersed	FEWS, Rain gauges
Evaporation	no	none	no	Very limited data Greater than rainfall Data dispersed	Required ? Irrigation only
Run-off	Spates	Limited Eg. COOPI	Local knowledge Good Indication	Limited Data Project specific Data dispersed	Water Soil Conservation oriented Training Learning
Infiltration	Localised Eg. ploughing	none	Localised	Some historic data	training Improvement – Info.
Storage/Yield (Shallow groundwater)	traditional	2001 drums berka-shallow wells	good local knowledge	Urban data available spatial distribution	
Groundwater	Existing sources	Ministry of Water Limited Eg. COOPI geophysics	Local memory no experience	Good Historic data Eg. British, Chinese	Technical Assistance Training and Eqt.
Quality ***Bacteriological***	qualitative	Oxfam, SwissGroup	Min of Water Good local network Malan, Salts, Solids	GTZ	Standards Eqt. UNICEF
Chemical	qualitative				
Catchment Characteristics	Data is limited is necessary Based on Practical Approach Strong Local Observation		Different Groups know different sides Foresters, etc	Some Work Done Historic Individually available Practical Approach	ongoing

Available Data: "Resource - Demand Side"

	Ongoing		Local Community	Historic Data	International
	Observation	**Measurement**	**Resource Users**	**Desk Study**	**Community**
Demography	Yes	Not Macro UNDOS	There is something Chiefs know their clan	Last time 1975 UNDOS 1997 for 2 regions	Not requested Has to be requested
Land-Use	Universal	1998 Gabiley Farms FSAU, veterinary	Local knowledge Good indications	Many studies in past	Technical Assistance Financial Resources
Health	Rural – little Urban – yes	Rural – little Urban – yes	Community level	Much historic data MoH, WHO, UNICEF	Finance required Training
Regulation	Law exists but difficult to enforce		Local regulation And tradition exists	Desk study required to re-evaluate	Technical Assistance Water policy
Plans – Development	Yes	Ministry of Planning 2 year plan	Yes, there is demand Communities have their aspirations	Many plans in past Ministry of Planning UNDOS	Technical assistance required

Presentation of Water Resource Assessment and Planning Groupwork



Seminar Participants

ANNEX C

DATA

Hargeisa Annual Rainfall for 1921 - 1986
Source - Various

Year Source =	1	2	3	4	5	6	7	8	9	10
1921	396	396								
1922	388	388				388			388	388
1923	428	428				428			428	428
1924	459	459				459			459	459
1925	416	416				416			416	416
1926	810	811				811			810	810
1927	370	370				370			370	370
1928	316	316				316			316	316
1929	434	434				434			434	434
1930	525	525				525			525	525
1931	644	644				644			644	644
1932	388	388				388			388	388
1933	316	315				315			316	316
1934	386	386				386			386	386
1935	464	464				464			464	464
1936	489	489				489			489	489
1937	453	453				453			453	453
1938	308					308			308	308
1939	600					600				600
1940										
1941										
1942										
1943										
1944	310		316					317		317
1945	356		368					356	356	356
1946	433		433					443	443	443
1947	541		542	400	447			541	540	541
1948	406	397	397	305	284			406	406	406
1949	277	279	280	281	285			277	277	277
1950	382	408	408					382	407	382
1951	657	661						657	675	657
1952	259	336						259	280	259
1953	417	343						417	407	417
1954	381							381	382	381
1955	285							285	285	285
1956	446							446	447	446
1957	572							571	571	571
1958	370							370	366	370
1959	396							396	396	396
1960	623								623	623
1961	459								459	459
1962	209								209	209
1963	529								529	529
1964	374								374	374
1965	156								157	157
1966	308								322	322
1967	593								593	593
1968	509								521	521
1969	366								359	359
1970	312								302	302
1971	399						399		399	399
1972	343								343	343
1973	222								236	236
1974	385								375	375
1975	449								436	436
1976	745						710		749	749
1977	809								687	687
1978	498						24		450	450
1979	444						406			444
1980	193								207	207
1981										
1982									386	386
1983									551	551
1984										
1985										680
1986										

Sources and Notes
1 Sogreah (1983)
2 FCO Archives
3 JA Hunt (1952) for RAF at 4500 ft except for 19
4 JA Hunt (1952) for SAO
5 JA Hunt (1952) for DC
6 MacFadyen (1950)
7 Office of Statistics, Somali Democratic Republic
8 Met Office Archive
9 Climate Research Centre, University of East Anglia

Hargeisa Monthly Rainfall for 1921 - 1986
Source - University of East Anglia: Climate Research Centre

WMO Cod	lat	lon	Alt	Name	Country	Record length	local codes	
631700	*9.5*	*44.1*	*1372*	*HARGEISA*	*SOMALILAND*	*1921-1986*	*1413*	*9403*

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	*Total*
1921	n	n	n	22	57	75	52	89	78	14	0	9	n
1922	0	0	22	17	110	24	121	27	60	7	0	0	368
1923	0	38	10	172	11	42	58	42	41	1	8	6	428
1924	0	14	5	40	82	107	48	96	52	17	0	0	459
1925	0	0	7	20	49	64	88	98	47	16	27	0	416
1926	9	38	45	189	115	38	51	128	66	59	72	0	810
1927	0	0	0	65	109	20	57	62	48	6	3	0	370
1928	0	0	0	46	79	50	37	36	17	4	46	2	316
1929	0	0	0	91	67	65	59	56	74	17	4	2	434
1930	69	2	91	116	48	40	15	52	56	32	0	5	525
1931	4	17	36	55	106	34	121	180	57	34	0	0	644
1932	1	0	63	13	34	17	36	140	41	26	0	19	388
1933	7	0	0	10	56	92	23	58	60	9	0	0	316
1934	1	1	21	10	49	108	79	59	58	1	0	0	386
1935	0	0	0	54	104	48	18	78	125	2	22	14	464
1936	0	118	19	31	74	43	50	68	86	0	0	0	489
1937	11	0	86	37	66	74	34	75	49	6	13	0	453
1938	1	0	0	5	53	45	46	80	40	37	0	1	308
1939	n	n	n	n	n	n	n	n	n	n	n	n	n
1940	n	n	n	n	n	n	n	n	n	n	n	n	n
1941	n	n	n	n	n	n	n	n	n	n	n	n	n
1942	n	n	n	n	n	n	n	n	n	n	n	n	n
1943	n	n	n	n	n	n	n	n	n	n	n	n	n
1944	0	0	17	4	61	72	41	80	35	0		0	n
1945	0	0	0	0	71	54	36	93	82	0	20	0	356
1946	1	0	0	129	40	80	43	78	21	46	5	0	443
1947	0	0	91	96	15	64	60	115	100	0	0	0	540
1948	0	2	10	91	33	63	23	31	85	65	4	0	406
1949	1	1	0	0	83	39	11	98	20	4	8	12	277
1950	0	0	0	1	58	63	51	98	136	0	0	0	407
1951	0	0	187	55	121	189	37	14	28	44	0	0	675
1952	0	0	0	106	4	32	11	84	38	5	0	0	280
1953	0	0	0	42	51	50	51	118	57	34	0	4	407
1954	0	0	8	65	61	76	17	72	55	27	0	1	382
1955	4	0	0	56	47	18	39	67	51	4	0	0	285
1956	0	0	17	118	22	31	60	67	61	57	14	0	447
1957	0	29	55	153	78	57	25	77	21	4	72	0	571
1958	22	3	3	15	13	30	50	125	97	8	0	0	366
1959	4	0	0	35	40	63	50	71	116	17	0	0	396
1960	0	0	230	8	225	11	15	55	64	7	0	8	623
1961	0	0	10	17	108	32	34	80	129	21	28	0	459
1962	6	0	0	73	18	3	30	35	31	14	0	0	209
1963	0	0	0	245	72	49	26	64	51	7	15	0	529
1964	0	0	0	123	38	47	55	36	68	8	0	0	374
1965	0	0	0	53	10	11	25	5	35	20	0	0	157
1966	0	13	0	38	27	13	6	143	28	56	0	0	322
1967	0	0	48	79	99	24	44	89	94	28	88	0	593
1968	0	123	0	105	72	62	42	34	71	0	8	4	521
1969	0	62	40	17	34	3	75	53	29	3	43	0	359
1970	7	7	45	27	12	1	87	59	49	9	0	0	302
1971	0	0	17	60	97	81	38	62	30	3	11	0	399
1972	0	0	0	89	5	31	78	39	84	18	0	0	343
1973	0	0	0	46	39	13	26	47	55	2	0	8	236
1974	0	0	102	1	50	16	72	62	72	0	0	0	375
1975	0	0	0	166	42	47	32	64	85	0	0	0	436
1976	0	0	2	114	200	81	76	38	175	59	3	0	749
1977	2	0	0	176	187	27	0	129	47	119	0	0	687
1978	0	101	1	34	63	23	18	128	22	62	0	0	450
1979	31	0	60	9	56	86	26	18	44	106	0	n	n
1980	0	0	0	13	41	16	26	6	72	31	2	0	207
1981	0	0	192	0	26	5	25	n	61	2	0	0	n
1982	0	0	7	48	109	32	9	37	6	132	6	0	386
1983	0	0	0	258	53	38	43	116	44	0	0	0	551
1984	n	0	n	6	71	23	0	1	83	0	0	12	n
1985	0	0	116	26	252	43	112	63	48	20	0	n	n
1986	0	0	6	103	5	0	0	6	n	n	n	n	n
Sum	180	567	1668	3889	4070	2783	2617	4179	3633	1330	521	107	23098
mean	*3.0*	*9.5*	*28.3*	*64.4*	*66.9*	*45.1*	*42.7*	*69.3*	*60.3*	*22.3*	*9.0*	*1.7*	*427.7*
st.dev	10.2	26.7	50.5	61.2	51.1	32.5	27.8	38.0	32.1	29.4	19.1	4.0	134.2
coef. Var	336	282	179	95	76	72	65	55	53	132	212	233	31

Hargeisa Monthly Rainfall for 1921 - 1999
Source - Various as indicated

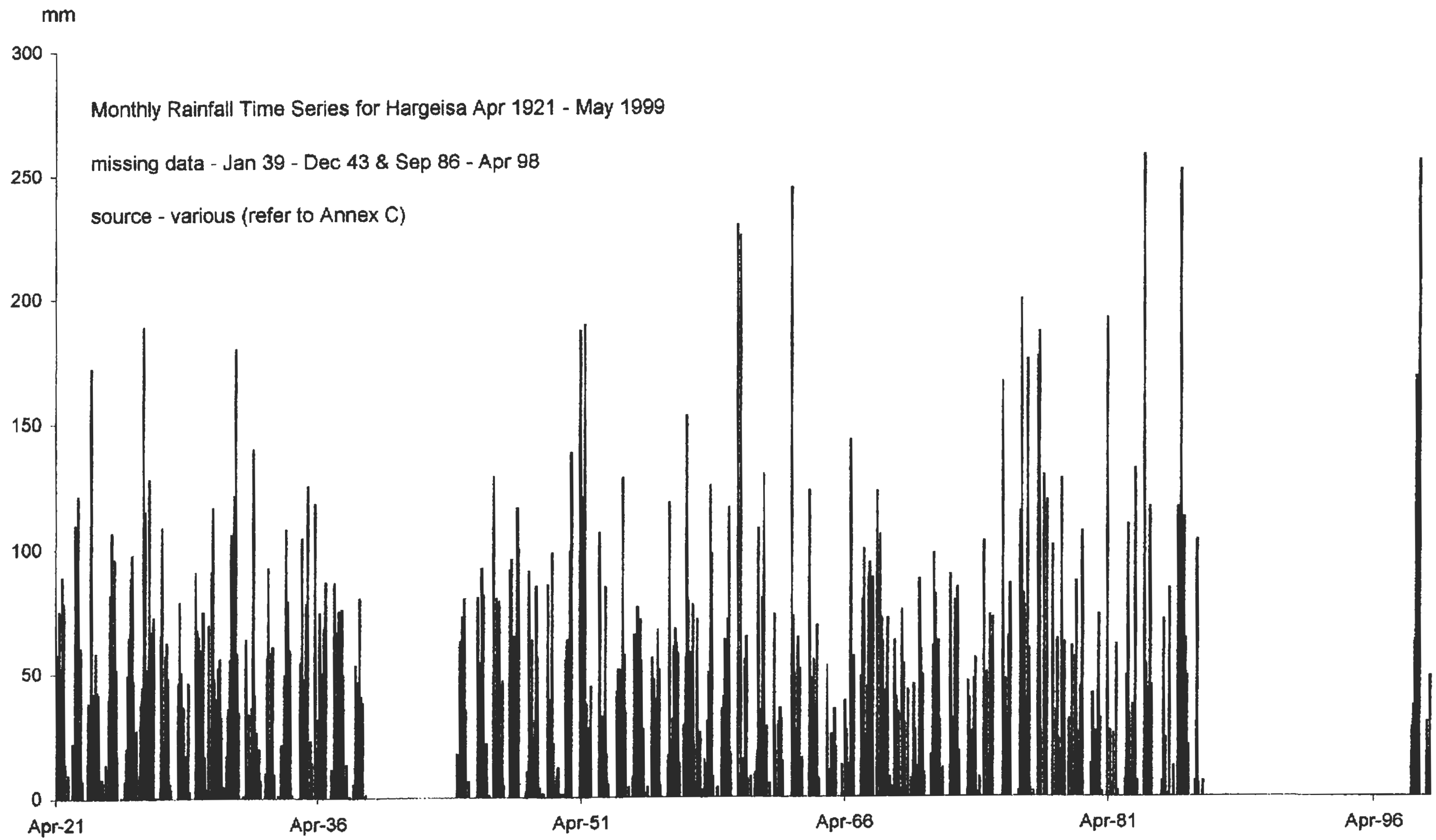
dimensions = mm

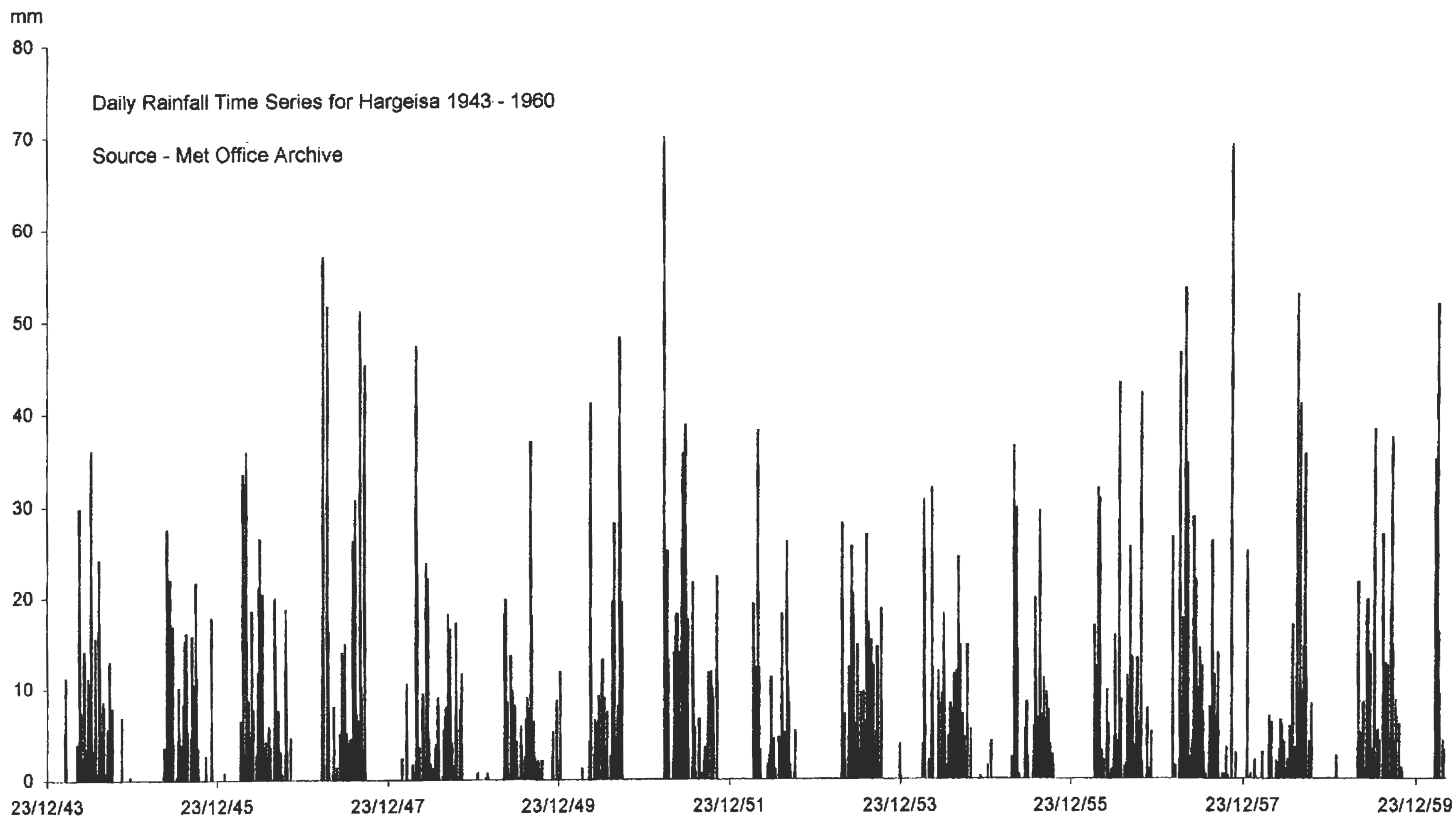
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1921	na	na	na	21.8	57.4	74.9	52.1	88.9	78.0	13.5	0	9.4	396+
1922	0	0	21.6	17.3	109.7	23.6	121.2	27.4	60.2	7.1	0	0	388
1923	tr	37.8	10.2	171.7	10.7	41.7	57.9	42.4	41.4	0.8	7.6	6.1	428
1924	0	13.5	5.3	39.6	81.8	106.7	47.8	95.8	51.6	16.8	0	0	459
1925	0.3	tr	6.9	19.6	49.3	64.3	88.4	97.5	47.0	16.0	27.2	0	416
1926	9.4	37.8	44.5	188.7	115.1	37.8	51.6	128.0	66.5	58.7	72.4	0	811
1927	0.3	0.3	0	65.0	108.7	20.3	56.9	62.0	47.8	5.8	3.3	0	370
1928	0	0	0	46.0	78.5	50.0	36.6	36.1	16.8	4.1	46.0	2.3	316
1929	0	0	0	90.7	67.1	64.5	59.2	56.1	74.4	16.5	3.6	1.5	434
1930	69.3	1.8	90.9	116.3	47.8	39.6	14.7	52.3	55.6	32.0	0	4.6	525
1931	4.1	16.8	35.6	55.4	105.7	33.8	121.4	179.8	57.4	34.0	0	0	644
1932	0.5,	tr	63.2	12.4	33.5	17.0	35.8	139.7	40.9	25.9	0	19.1	388
1933	6.9	0	tr	9.9	56.1	92.2	22.9	57.9	60.2	9.4	0	0	315
1934	0.8	0.5	20.8	9.7	49.0	107.7	78.7	59.2	58.4	1.0	0	0	386
1935	0	0	0	54.1	103.9	47.5	17.8	77.5	125.2	2.0	22.4	13.5	464
1936	0	118.1	19.1	31.0	73.7	43.4	49.8	67.8	86.4	0	0	0	489
1937	11.2	0.3	86.1	37.3	66.0	74.4	34.0	75.2	48.8	6.1	13.2	0	453
1938	0.5	0	0	5.3	52.8	45.2	45.7	79.8	40.1	37.3	0	1.3	308
1939	na	na	na	na	na	na	na	na	na	na	na	na	600
1940												Avg =	447
1941													
1942													
1943													
1944	0	0	17.0	3.8	62.0	72.1	40.6	79.5	34.5	0	6.4	0	316
1945	0	0	0	0	80.0	53.8	35.6	91.9	81.0	4.1	21.1	0	368
1946	0.8	0	0	128.5	30.2	79.8	43.2	78.5	21.1	46.5	4.6	0	433
1947	0	0	91.2	95.5	14.5	64.3	60.7	116.1	99.8	0	0	0	542
1948	0	2.3	10.4	90.4	33.3	62.7	22.9	30.5	84.6	55.9	3.8	0	397
1949	1.3	1.0	0	0	85.1	38.9	11.2	97.8	21.1	3.8	8.1	11.7	280
1950	0	1.0	0	1.0	54.9	62.7	51.8	98.3	137.9	0	0	0	408
1951	0	0	187	37.4	120.6	189.2	37.1	14.4	27.6	44.1	tr	0	657
1952	tr	tr	tr	106	3.6	32.1	11.3	84.2	17	5.2	0	0	259
1953	tr	0	tr	42.2	51	50.4	51	128	56.7	33.7	0	4	417
1954	0	0	8.2	64.8	60.6	76	17.4	71	54.5	27.2	0.3	1.4	381
1955	4	0	0	55.6	46.6	17.6	39.1	66.7	50.8	4.4	tr	0	285
1956	0	0	16.5	118.2	21.5	31.1	60	67.1	61.4	57.2	13.5	0	447
1957	tr	29	55.4	153	78.3	57.6	24.6	76.8	21	4.2	71.1	tr	571
1958	26.1	3	2.8	15	13	30.2	49.7	125	97.3	8	0	tr	370
1959	3.8	0	0	35	39.7	62.8	50.4	71	116	17.4	0	0	396
1960	tr	0	230	8.1	na	na	na	na	na	na	na	na	
1961												Avg =	408
1962													
1963													
1964													
1965													
1966													
1967													
1968													
1969													
1970	7.2	70	52.8										
1971	0	0	16.5	60.3	97.4	81	37.6	62.1	30.2	2.8	11.4	0	399
1972													
1973													
1974													
1975													
1976	0	0	2	114.3	189.5	82.7	77.2	25.3	157.2	59.2	3	0	710
1977													
1978	0	0	0	0	2.1	4.1	10.3	4.4	0	2.9	0.3	0	24
1979	15.6	0	60	3.6	52.3	86	25.5	18	38.5	106.2	0	0	406
1980													
1981													
1982													
1983													
1984													
1985													
1986													
1987													
1988													
1989													
1990													
1991													
1992													
1993													
1994													
1995													
1996													
1997													
1998					27.1	35.6	62.2	168.5	29.6	255.7	0	0	
1999	0	0	29.4	15.5	47.7								

Sources: Period 1921-1938 - MacFadyen (1950)
Period 1944 -1950 - JA Hunt (1952)
Period 1951-1960 - Met Office Archive
Period 1970 -1979 - Office of Statistics, Somali Democratic Republic
Period 1998 -1999 - FEWS Nairobi Office

Year	Rainfall	Diff from mean	normalise	Gu	Diff from Mean	normalise	Deyr	Diff from mean	normalise
1921							180	18	0.30
1922	388	-40	-0.30	172	-22	-0.18	95	-68	-1.14
1923	428	0	0.00	234	40	0.33	92	-70	-1.19
1924	459	31	0.23	233	39	0.32	164	2	0.03
1925	416	-12	-0.09	140	-55	-0.45	188	25	0.43
1926	810	382	2.86	386	192	1.58	325	163	2.75
1927	370	-58	-0.43	194	0	0.00	119	-44	-0.73
1928	316	-112	-0.84	174	-20	-0.17	103	-60	-1.01
1929	434	5	0.04	222	28	0.23	151	-12	-0.20
1930	525	97	0.73	295	100	0.83	140	-22	-0.38
1931	644	216	1.62	231	36	0.30	271	109	1.84
1932	388	-40	-0.30	126	-68	-0.56	207	44	0.74
1933	316	-113	-0.84	158	-36	-0.30	128	-35	-0.59
1934	386	-42	-0.32	187	-7	-0.06	119	-44	-0.74
1935	464	36	0.27	206	11	0.09	227	65	1.09
1936	489	61	0.46	167	-27	-0.23	154	-8	-0.14
1937	453	24	0.18	264	69	0.57	143	-19	-0.32
1938	308	-120	-0.90	103	-91	-0.75	157	-5	-0.09
1939	600	172	1.29	n	0	0.00	n	0	0.00
1940	0	0		n	0	0.00	n	0	0.00
1941	0	0		n	0	0.00	n	0	0.00
1942	0	0		n	0	0.00	n	0	0.00
1943	0	0		n	0	0.00	n	0	0.00
1944	317	-111	-0.83	155	-40	-0.33	114	-48	-0.82
1945	356	-72	-0.54	125	-70	-0.57	195	33	0.56
1946	443	15	0.11	248	54	0.45	151	-12	-0.20
1947	541	113	0.85	265	71	0.59	215	53	0.89
1948	406	-22	-0.17	197	2	0.02	184	22	0.36
1949	277	-151	-1.13	122	-72	-0.60	130	-32	-0.55
1950	382	-46	-0.35	122	-73	-0.60	234	72	1.21
1951	657	229	1.72	551	357	2.95	86	-76	-1.29
1952	259	-169	-1.27	141	-53	-0.44	127	-35	-0.59
1953	417	-11	-0.08	144	-51	-0.42	208	46	0.78
1954	381	-47	-0.35	210	15	0.12	154	-9	-0.15
1955	285	-143	-1.07	120	-75	-0.62	122	-41	-0.68
1956	446	18	0.13	187	-7	-0.06	199	37	0.62
1957	571	143	1.07	344	149	1.23	174	11	0.19
1958	370	-58	-0.44	61	-134	-1.10	231	68	1.15
1959	396	-32	-0.24	138	-57	-0.47	205	42	0.71
1960	623	195	1.46	474	280	2.31	126	-37	-0.62
1961	459	31	0.23	166	-28	-0.23	258	96	1.62
1962	209	-219	-1.64	94	-101	-0.83	80	-82	-1.39
1963	529	101	0.76	366	171	1.42	137	-26	-0.43
1964	374	-54	-0.40	208	13	0.11	112	-51	-0.85
1965	157	-272	-2.04	73	-122	-1.00	59	-103	-1.74
1966	322	-106	-0.79	77	-117	-0.97	227	64	1.09
1967	593	164	1.23	250	56	0.46	298	136	2.30
1968	521	92	0.69	239	44	0.36	113	-49	-0.83
1969	359	-70	-0.52	93	-101	-0.84	129	-34	-0.57
1970	302	-126	-0.95	84	-111	-0.91	117	-46	-0.77
1971	399	-29	-0.22	255	61	0.50	107	-56	-0.94
1972	343	-85	-0.64	125	-70	-0.57	140	-22	-0.38
1973	236	-193	-1.44	98	-96	-0.79	104	-59	-0.99
1974	375	-53	-0.40	169	-26	-0.21	134	-29	-0.48
1975	436	8	0.06	255	61	0.50	149	-13	-0.22
1976	749	321	2.41	397	203	1.67	276	113	1.91
1977	687	258	1.94	390	195	1.61	295	132	2.23
1978	450	22	0.17	121	-74	-0.61	211	49	0.82
1979	444	16	0.12	211	16	0.13	168	6	0.10
1980	207	-221	-1.66	70	-125	-1.03	111	-51	-0.87
1981				223	28	0.23	63	-100	-1.69
1982	386	-43	-0.32	196	2	0.02	180	18	0.30
1983	551	123	0.92	349	154	1.27	160	-2	-0.04
1984				100	-95	-0.78	84	-78	-1.32
1985				437	243	2.00	131	-31	-0.53
1986				114	-81	-0.67			
Sum	24409			5253			4384		
Mean	428.232			194.6			162.4		
S.D.	133.399			121.1			59.2		

Mean Normalised Anomoly for Hargeisa Rainfall - Gu and Deyr seasons using 1941 -1970 as base period


mm
300
250
200
150
100
50
0
Monthly Rainfall Time Series for Hargeisa Apr 1921 - May 1999
missing data - Jan 39 - Dec 43 & Sep 86 - Apr 98
source - various (refer to Annex C)
Apr-21
Apr-36
Apr-51
Apr-66
Apr-81
Apr-96



mm
80
70
60
50
40
30
20
10
0
Daily Rainfall Time Series for Hargeisa 1943 - 1960
Source - Met Office Archive
23/12/43
23/12/45
23/12/47
23/12/49
23/12/51
23/12/53
23/12/55
23/12/57
23/12/59

Station Hargeisa
Lat 9.30'N
Long 44.30'E
Altitude 1370m

Source **Met Office Archive from RAF records**
dimensions = mm
t = trace
blank = no rainfall

1943	**Jan**		**Feb**		**Mar**		**Apr**		**May**		**Jun**		**Jul**		**Aug**		**Sep**		**Oct**		**Nov**		**Dec**	
Day	6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6	
1																								
2																								
3																								
4																								
5																								
6																								
7																								
8																								
9																								
10																								
11																								
12																								
13																								
14																								
15																								
16																								
17																								
18																								
19																								
20																								
21																								
22																							Start	
23																							0	0
24																								
25																								
26																								
27																								
28																								
29																								
30																								
31																								
Sum																							0	0
Total																							**0**	mm

1944	**Jan**		**Feb**		**Mar**		**Apr**		**May**		**Jun**		**Jul**		**Aug**		**Sep**		**Oct**		**Nov**		**Dec**	
Day	6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6	
1									2							5.5	t	0.7						
2									0.5		t				t	24		t						
3									0.9					0.04										
4																	t		t					
5													0.2		12.3		0.3	t			t			
6									1.4						t	t	t	t			6.8			
7											3.4			t			4.5	1.1			t			
8					t								3.2		t	0.7	0.2	5.4			no ob			
9					0.5	0.6			29.7								1				"			
10					5										3.1		t				"			
11					11	0.1															"			
12													t		t						"			
13						t									5.2		t				"			
14										1.7							t				"			
15									t		11.1		4.1	0.7	1.3		12.6	0.3			"			
16													13.5	1.9			0.1				"		0.3	t
17							t		7.4		2.3			t							no ob			
18													t		8.6								t	t
19									2.2				0.7		4.9									
20											0.4				2.1	2.8								
21											10.5		0.1		0.3		t							
22											t				6.4	1.7								
23									1.6		1.8		t		tr									
24											6.8				0.7									
25													t		sick		0.4							
26											t				"		7.9							
27											t				"		t							
28											36		t		"									
29							3.9		14						"									
30					t								15.7	0.6	sick									
31																								
Sum	0		0		16.5	0.7	3.9		59.7	1.7	72.3		37.5	3.24	44.9	34.7	27	7.5			6.8		0.3	
Total	**0**		**0**		**17.2**		**3.9**		**61.4**		**72.3**		**40.7**		**79.6**		**34.5**		**0**		**6.8**		**0.3**	mm

1945	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Day	6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6	
1											8.6		t	0.3	8.4	t		3	0.4					
2											21.8		t		7.1	t								
3											no ob						0.2				2.6			
4											no ob						15.6							
5									0.4			0.1			5	10.1	0.5							
6									2.1	t	t		0.5											
7									3.5	t			4.1				1.5							
8									0.3	t			9.9	t			1.8							
9				t					2.6	0.2					t		t	10.3						
10				t					0.4		2.2		5.2		13.8	2.1								
11									1.8		t		0.9		5	t								
12									t		t		2.3		8	3.9	t	0.5						
13									1.4		0.3						3.4							
14							t		t		16.7	t												
15									t		1.8	2.1			t	t	t							
16									1.3	t	0.3				1	4.2	t	0.5						
17									7.8					t										
18																	1	0.8						
19									t								3.1							
20									27.4				3.8											
21														0.7			21.5							
22													t	t			3.3							
23									21.8								11.1							
24																	t							
25									t		t						0.3	t						
26											t													
27									t				t				t				t			
28									t		t		8.2	t	t						17.7			
29											t				4.5	t	3.5							
30																								
31													t	t		19.6								
Sum				t			t		70.8	0.2	51.7	2.2	34.9	1	52.8	39.9	66.8	15.1	0.4		20.3			
Total	**0**		**t**		**0**		**t**		**80**		**53.9**		**35.9**		**92.7**		**81.9**		**0.4**		**20.3**		**0** mm	

46	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Day	6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6	
1															1.6	3	t							
2																5.5	3							
3																					4.5			
4							6.4		t															
5															1	2.5	1							
6									0.8				7		t		2.2							
7									t				20.2	t										
8									8.6				2.2	1.3		1.1								
9																	t							
10															t	0.9								
11								1			2.7				t		7.5							
12							0.6	4.1									t		11.5	0.2				
13																	0.2		17	1.6				
14							6.8						t				2.9		11.7					
15							3.7	29.7							t				0.3					
16							0.9	0.1	4.7								0.2							
17							2.4				11.6		0.8						3.1	t				
18									t				4.1	t										
19							1.4		t								3							
20											5.6								1					
21											21						0.1							
22									18.4						1.3		t							
23											12.3				1.8									
24		0.7														7								
25															16.9	2.9	0.6							
26											26.2		t		6.1									
27								t	7.6		0.2			t		0.9								
28							32	0.3			t		t	1.8	16		0.5	t						
29							t	35.8	t						0.8									
30							3.3				0.2													
31									t				3	2.7	9.1									
Sum	0.7						57.5	71	30.1		79.8		37.3	5.8	54.6	23.8	21.2		44.6	1.8	4.5			
Total	**0.7**		**0**		**0**		**129**		**30.1**		**79.8**		**43.1**		**78.4**		**21.2**		**46.4**		**4.5**		**0** mm	

1947	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Day	6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6	
1											1.3						10							
2							t			0.5	1.4						1				t			
3																					t			
4													2.5				3							
5										7.9					29.5	1			t					
6																1			t					
7							24.6				2.2													
8							49.7	1.8								t								
9								1.6			13.8		4		7.2		1							
10							1				5					2								
11				t							4				0.5	6.4	1.5							
12							0.1						1		t	t								
13							16.1				3		t				37.5	t						
14					t		0.6				5.5		4.4				t							
15					3						t						t							
16					11.4						1.8						45.2							
17										t					2.8	3.6								
18										1.3						1.9	0.5	t						
19															3.4									
20			t		18																			
21					t						3.5		t		t									
22					29.8	27 1					14.7						t							
23					1.8						3													
24																								
25															0.9									
26			t								t		19		t									
27													t			51								
28											5		26			4								
29										t			1											
30										4.9			1.6											
31															43.8	72.8								
Sum	0		t		64	27.1	92.1	3.4		14.6	64.2		59.5				99.7	t						
Total	**0**		**t**		**91.1**		**95.5**		**14.6**		**64.2**		**59.5**		**117**		**99.7**		**t**		**t**		**0**	mm

1948	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Day	6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6	
1											23.5		1.2				0.7				3.8			
2											2.5								t					
3									1		t	3.3					18		4.2					
4									3.5										4					
5																	10.3							
6											0.6						0.5		7.3					
7							1.6				t		t				3.2		17					
8																	0.2		7.6					
9											21.8								5.7					
10											4.1		0.05											
11					9.3	1					t		3.5	t	t		14.8							
12					t										0.3		16.4							
13									t		4.4		t											
14																								
15									t				3.8											
16											t				5.4		2.7							
17			t						6.3						4.6		t							
18	t		t	t																				
19			t				0.7		9.3		1.7				1.2		4							
20			2.2				t		3.9	2.1					t		1.3			0.2				
21							t	47.2	2.7				0.3							7.6				
22									1.5				8.8		6.8									
23								15.1	t		t		4.4	0.7	7.9				t					
24							1.1				t						1							
25							19.4	5.4			0.6				1									
26											0.3						1.3							
27									1															
28									1.6		t		0.2		3.3									
29									0.3		t											t		
30											t										t			
31									0.1											11.5				
Sum					9.3	1	22.8	67.7	31.2	2.1	59.5	3.3	22.2	0.7	30.5		74.4	10.1	45.8	19.3	3.8			t
Total	**t**		**2.2**		**10.3**		**90.5**		**33.3**		**62.8**		**22.9**		**30.5**		**84.5**		**65.1**		**3.8**		**t**	mm

1949	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		
Day	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	
1									0.6		6.1														
2																	0.1	0.5	0.1						
3									10.9	2.9								0.1	1.1						
4									18						6.5		3.5								
5		0.5							6.8		2.7		0.1		1.5		0.5	0.1	0.1						
6									0.8								6.2		0.5						
7											9.6				2.4										
8		0.7							10.5	9.1	1.1				8.8			2.4							
9													0.3												
10			0.1								3.3						0.4								
11															2.4				2						
12											1.5				7		2.1								
13									0.1						0.6										
14										8.4	1.1												t		
15											8		5.7		0.3		0.2						8.5	t	
16										0.5			0.5										1.5	0.4	
17									1.1				0.5											1.2	
18				0.1																					
19			0.4	0.2							0.1				0.7	0.2									
20			0.3											0.1	7.7										
21											0.1			0.1											
22																									
23											4	0.1			3.9										
24											1.3				22.3	14.6	2								
25																	1.8				0.4				
26																	0.4								
27													0.2								2.5				
28															17.7	0.1					4.8	0.3			
29													2.4								t				
30							0.1						1.3								t				
31									13.5						1.2								10	1.6	
Sum		1.2	0.8	0.3			0.1		62.3	20.9	38.9	0.1	11	0.2	83	14.9	17.2	3.1	3.8		7.7	0.3	11.6		
Total	1.2		1.1		0		0.1		83.2		39		11.2		97.9		20.1		3.8		8		11.6		mm

1950	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		
Day	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	6-18	-6	
1							t									2.5	7.9								
2									t	4.1					t		8								
3							1.1		t		6.1		t												
4													2.1				t								
5													8.8				1.9								
6											1.5														
7																	5.3	t							
8									0.1						11	t	0.8								
9									41		5		2.4		18.3	1	48.1		t						
10									t		6.3		2		t		1.2								
11											9				4.8		0.6								
12													t				0.5								
13																	33.3								
14													3.3				2.1								
15													t	3.3	19.4		1.7								
16													t				0.6								
17													0.5	6.8	27.9										
18	t	t							t						4.4										
19		t															19.2								
20													missing				2.9	0.8							
21	t								t								0.6								
22									2.6						0.5										
23																									
24											10.5		missiing		t										
25															t										
26									t		9.8				0.5	t									
27									6.4																
28											13				t										
29	t	t									1.5						t								
30		t									t				6.4	0.2									
31									0.7							1.5									
Sum	t	t					1.1		50.8	4.1	62.7		29.2		93.2	5.2	135	0.8	t						
Total	t		0		0		1.1		54.9		62.7		29.2		98.4		136		t		0		0		mm

1951	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Day	6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6	
1							t				25						t	1			t			
2							3.2										1.8							
3							1.7	11.3	4															
4							0.9		2.8	0.5									11.6					
5									15.5		35.5						3.5		t	t				
6											13.3		t						2					
7																			9.8					
8									17.7		33.3						t		t					
9															t									
10									13.5	0.8			t		3.7									
11									17.9						t		t		t					
12									9.8						t									
13									t	t			t		6.5				8.8					
14							t		2.1								t		t					
15									1.9				1.2				2.7							
16											38.6													
17											20.2		21.3				5.6							
18					11.9	6.5					0.5			6.9										
19					64	5.9			t	10.9														
20					19.7	5.6			t	13.8	0.9		0.4		3.6?		1.5							
21					7.9	3.3									t		11.5							
22					1.8	t							1.1			0.6								
23					10.2				2.2	0.2				t	t									
24					0.2				7				5.5				t							
25							2.3				17.3			t										
26							1.9				4.6													
27					3	0.3																		
28						20.1	12.9	0.8						0.7										
29					t	0.2	0.8	0.6	t										t	21.9				
30					1.6		1															t		
31					24.6	0.2									t									
Sum					145	42.1	24.7	12.7	94.4	26.2	189		29.5	7.6	13.8	0.6	26.6	1	22.2	21.9				
Total	**0**		**0**		**187**		**37.4**		**121**		**189**		**37.1**		**14.4**		**27.6**		**44.1**		**t**		**0**	mm

52	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Day	6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6	
1																				5.2				
2																		5.5						
3									3.1									8.2						
4								19		0.5		1.6	t			17.9								
5								13.5	t				0.5	t										
6													1											
7													0.5	t				1.6						
8													0.7						t					
9													t											
10											0.5	0.5					t	0.6						
11											2.5						t							
12											t				t			t						
13							0.1									5								
14								12			t													
15											2.1	t												
16			t									t	t		1.5									
17											4	t				t								
18											11				0.3	4								
19	t											t				t	t							
20																1.1		t						
21													t											
22																	t							
23								t					4.5											
24							37.9				1.5				1	3.9								
25								0.3					0.3			25.7								
26							1	6.8																
27						t	12				4.1		0.7		2.5		0.5							
28											t			t	5.4	0.3								
29											4.3	t			4.1		0.6							
30							2.9			t						11.5								
31						t								3.1										
Sum							53.9	51.6	3.1	0.5	30	2.1	8.2	3.1	14.8	69.4	1.1	15.9	t	5.2				
Total	**t**		**t**		**t**		**106**		**3.6**		**32.1**		**11.3**		**84.2**		**17**		**5.2**		**0**		**0**	mm

1953	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		
Day	6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		
1	t	t							1.3	0.6		1.8		t	1.1	25.4			2.1	t					
2										t						10.2				4					
3													2.5					3.2		18.4					
4														2.2		1.2				9.2					
5												20													
6											1.5				t										
7												3	t			4.8	1.6								
8											t			9.3			0.3	t							
9															t			3.5							
10															13.3		0.9								
11											6					17	5.1								
12														5.8			0.2	4.9							
13																	t								
14																									
15																									
16																	14.3								
17							1.4	t	2	2.6							10	3							
18									t	12.1					1.2		1.6	5.1							
19							10	17.8					0.2	9.2		1.5		1.3							
20								0.2						7.5		9.7									
21							0.8	1.3							15.1									t	
22					t		0.6	3.1								0.3							2.4	1.3	
23											t	14.5					t	t						t	
24																		0.2						0.3	
25										1.1							t	1.5							
26																									
27												3.2	5												
28							7			4				1	t										
29								t		25.2		0.4			4.1	0.7									
30											t	t	2.1			12.3									
31									2.1					6.2											
Sum					t		19.8	22.4	5.4	45.6	7.5	42.9	9.8	41.2	34.8	93.1	34	22.7	2.1	31.6			2.4	1.6	
Total	**0**		**0**		**t**		**42.2**		**51**		**50.4**		**51**		**128**		**56.7**		**33.7**		**0**		**4**		mm

1954	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		
Day	6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		
1																7.5	2.2								
2							30.3									0.2									
3										7.8	0.6	11													
4							14.7	7.3	9.2			3.3			t			14.5	14.5	t					
5							9.7	0.3			8.5							5	2	0.2					
6					t			0.5	31.6					1.4			3.6			t					
7																	0.6	t							
8															9	2.3	0.1	t							
9									12							6.7									
10										t							0.6								
11																									
12									t			1.4						1.9							
13												2.1					2	5							
14																	t	7							
15																									
16											0.3	8.9	4.6				0.2								
17														0.3											
18												5.7							5.2						
19																11.6	t		3.1	2.2					
20					t											1.5	0.9								
21							t										t	2.8							
22							2						4.5	3.6			4.5	t							
23							t						t				2								
24														3		0.5	0.6	t							
25												t		t											
26												17.8	t	t											
27					3.7						11.1				24										
28						1.3					0.2	t			t	t									
29					0.8	0.4		t				0.3			t		1.2				t				
30						2						4.8				2						0.3			
31															6.2									1.4	
Sum					4.5	3.7	56.7	8.1	52.8	7.8	20.7	55.3	9.1	8.3	39.2	31.8	18.3	36.2	24.8	2.4		0.3		1.4	
Total	**0**		**0**		**8.2**		**64.8**		**60.6**		**76**		**17.4**		**71**		**54.5**		**27.2**		**0.3**		**1.4**		mm

1955	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Day	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6
1																		6.4						
2																		4.2						
3	t								0.4			t				t		5.6						
4									t	29.4						0.2								
5																6.6								
6																			2.6					
7									13.9										t					
8								t	1.8	0.4										1.6				
9											0.4	t			1.3		2	0.8	0.2					
10												5.4					t	t						
11																		9.3						
12															6.3	22.8		3.8						
13							2.3									2.2								
14		4					t				t				t			1.6						
15									0.4				0.5		t		t							
16										t				5.6			3.2							
17									0.3		5.1	3.2	t					7.4						
18														t										
19	t										t													
20											2.3	t			4.3									
21												1.2				t	t							
22													1.3				t							
23															6.8									
24							26	10.2						19.5		5.4								
25	t						0.5				t		t	11.6										
26							0.1	3.3									3.7							
27		t						0.5			t			0.6			2	0.8						
28	t						11.2	1.5			t													
29															10.8									
30																								
31																								
Sum	t	4					40.1	15.5	16.8	29.8	7.8	9.8	1.8	37.3	29.5	37.2	10.9	33.9	2.8	1.6				
Total	**4**		**0**		**0**		**55.6**		**46.6**		**17.6**		**39.1**		**66.7**		**50.8**		**4.4**		**t**		**0**	mm

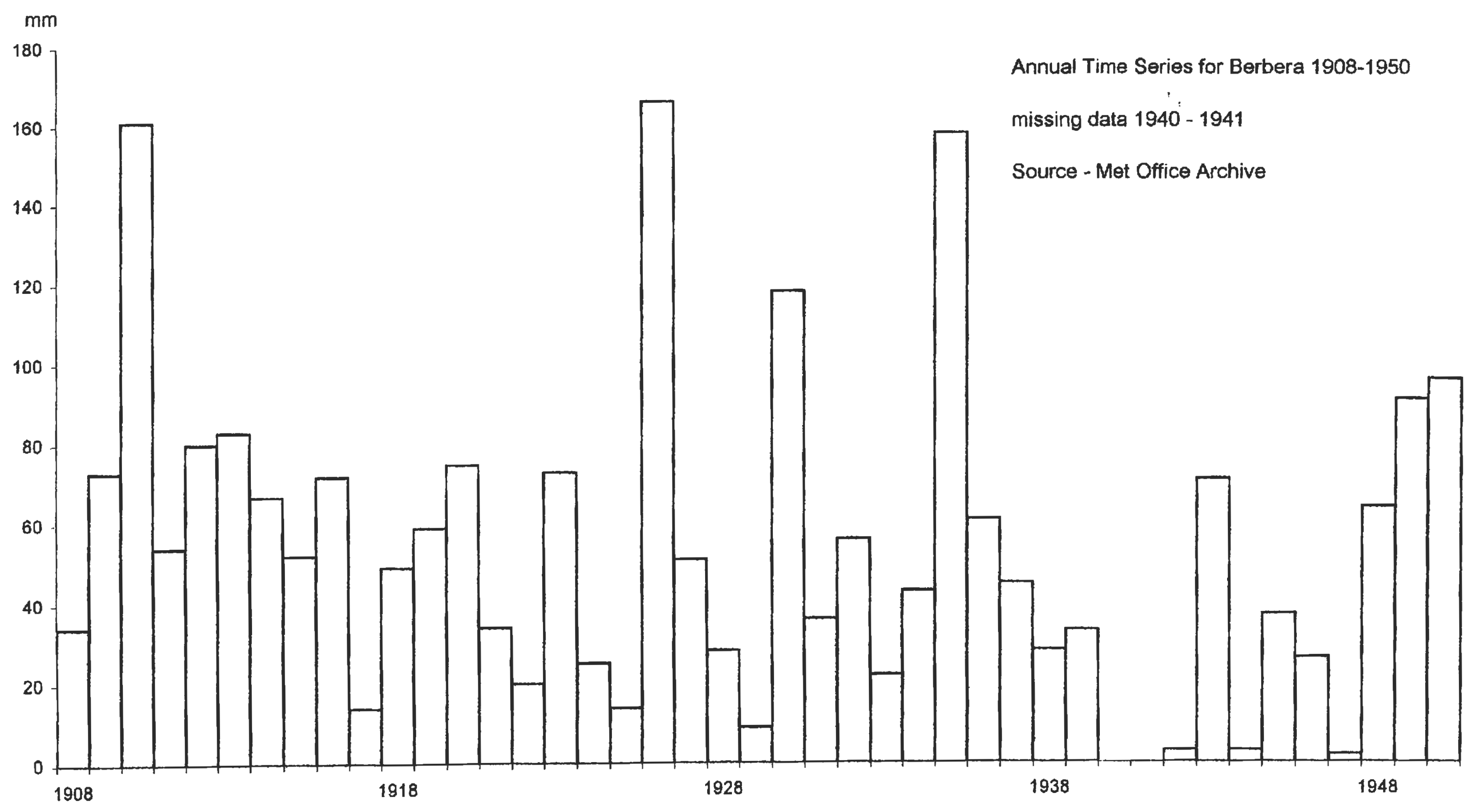
1956	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Day	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6
1											0.4	t								1.7				
2									3								1	5.4	t	0.2				
3									0.3										0.7	t				
4																								
5																								
6							12.1											3	0.3					
7							t	0.1			0.2					1.3		t						
8							1.2					0.4					t	13.2	3.2					
9														1.4					6.1					
10													0.2	3.8								7.5		
11									2					0.5				3.8						
12							1.5				t			2.1	1		t	3.5	0.3					
13							9.8					t				1.6				t				
14							3	0.2					0.1											
15														43.1										
16							1											0.2						
17								31.5			0.4							t	38.4	3.6				
18							2.1									11.1	t			1				
19															5				t					
20								0.8									3.6	t		1.7				
21							0.2	2.8																
22							t	9.3			2		8.5		8			t						
23							7.9											t						
24							30.5		9.5				0.3		9.6			2.5						
25												4.4		t										
26								2.6			2				1.9			9.6						
27								1.6				15.5				1	t							
28									0.6		0.2			t							5			
29										5.9		4.6				1.6	t	2.6			t			
30																25		13						
31					16.5				0.2															
Sum					16.5		69.3	48.5	15.6	5.9	5.2	25.9	9.1	50.9	25.5	41.6	4.6	56.8	49	8.2	5	8.5		
Total	**0**		**0**		**16.5**		**118**		**21.5**		**31.1**		**60**		**67.1**		**61.4**		**57.2**		**13.5**		**0**	mm

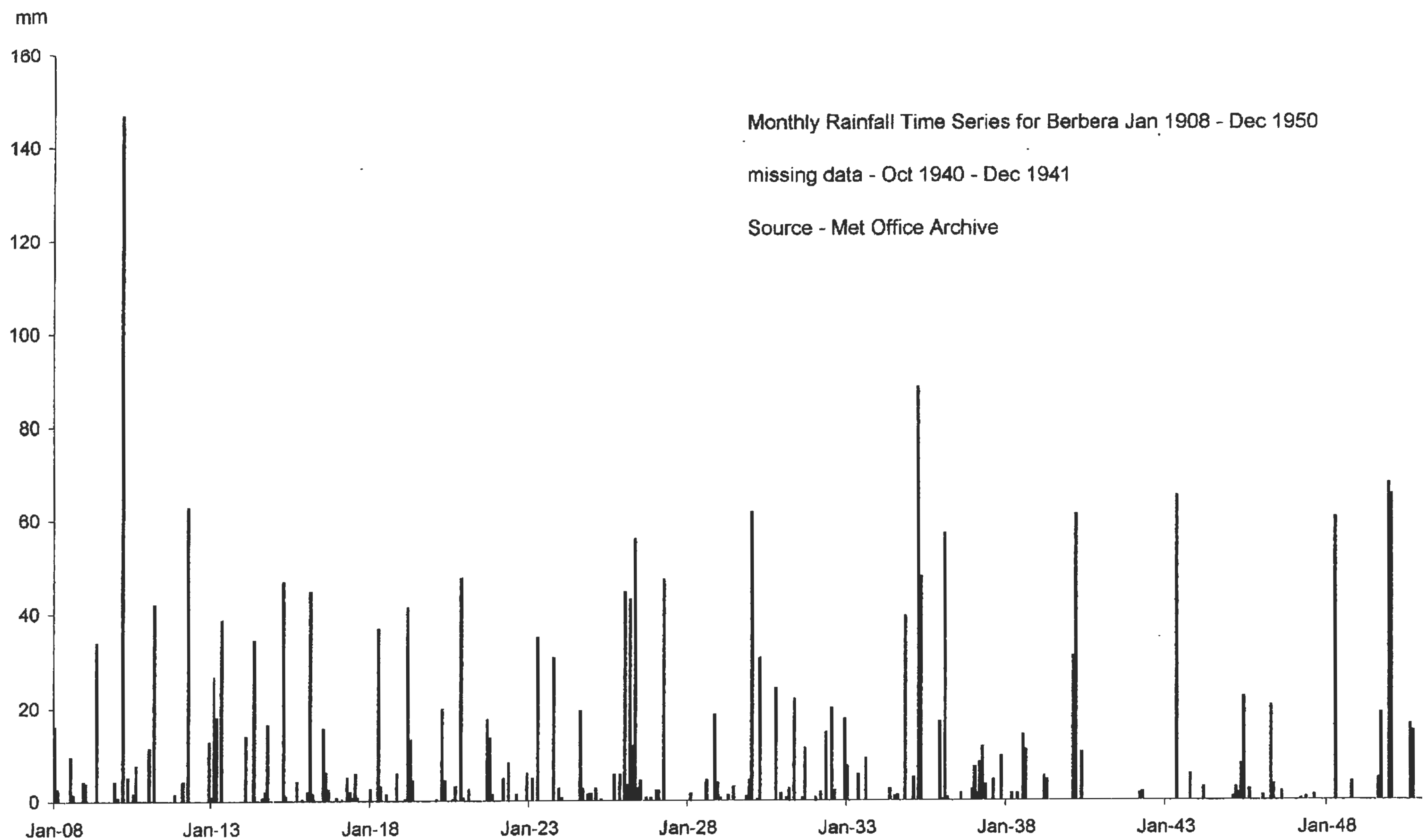
1957	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Day	6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6	
1						1			1.8	3.2		t	t	12.1										t
2									t	25.2		0.5	t			7.6								
3														2.2			t				68.5	0.5		
4			t										7.1											
5												21.4						7.1						
6																			0.4					
7					t								2.8					13.5						
8					t	1.4							t											
9						1.2													t					
10									2.3											t				
11										1.8						t								
12							17.3								25.6					3.3				
13															0.5									
14							t				9.7			0.4		8.5								
15							8.7							t		t								
16							0.3	8.2																
17							1.2	1			t					3.6	t		0.3					
18									0.2	3.4	2.8	t			t				0.2					
19							no ob			0.2	2													
20												1		t			t							
21							53.3				14				1.5						0.7	2		
22							no ob				5.2					11.2								
23									4.3							3.7								
24	t								5															
25									1.1	1.5						5.2								
26			1.7														0.4							
27		t	16.1	10			2.3	3																
28			t	1.2				23.6		28.3					t									
29					46.3		t					t			6.6									
30							32.2	2.1	t															
31					5.5											2.8								
Sum			17.8	11.2	51.8	3.6	115	37.9	14.7	63.6	34.7	22.9	9.9	14.7	34.2	42.6	0.4	20.6	0.9	3.3	69.2	2.5		
Total	t		29		55.4		153		78.3		57.6		24.6		76.8		21		4.2		71.1		t	mm

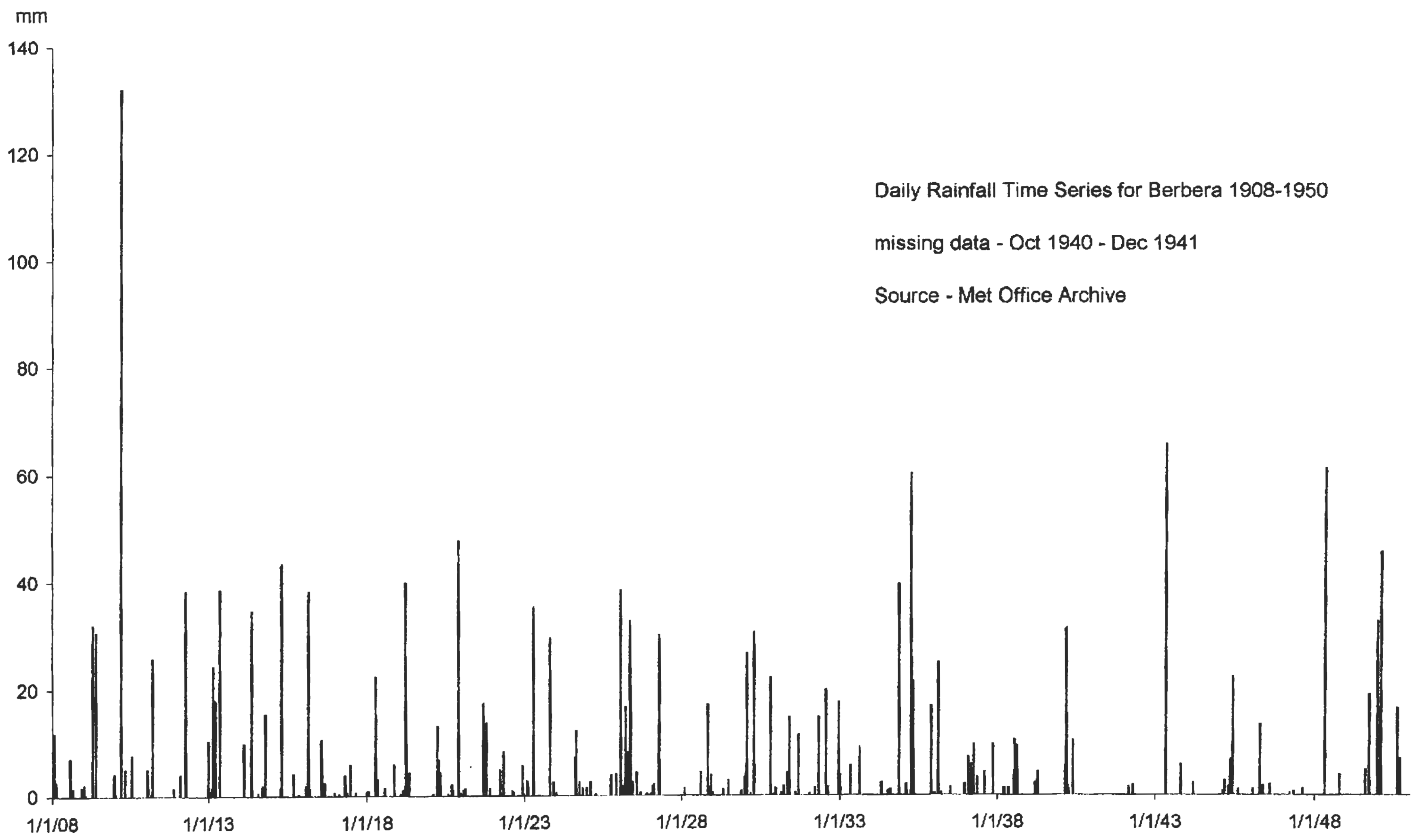
1958	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Day	6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6		6 - 18 - 6	
1												5.8												
2																								
3																	7.8	1.7						
4											5.6						14							
5											4				t				t					
6												4												
7	0.2	0.6		1											12.2	0.1								
8							t								t									
9	21.9	2.6	0.5	1.4								4		5.5		52.6	15.8		6.3	1.7				
10		0.3		t									0.1	4.6										
11							1.3				t		t				34	1.2						
12							6.7		t	1.8					t	t		1.5						
13			0.1								3.8						0.4							
14					2.8											6.2	t	3.1						
15																	t	13.5						
16							1	t					4.6		t	3								
17									1.1							8.8								
18																								
19											t		13.1				t							
20											t	1		16.5	22	18.7	t							
21																	t							
22	0.5						6									3.4	t							
23									0.6				2			1.7			t					
24									t								t							
25									3															
26																								
27									t				3.3				0.1	3.8						
28									0.3								0.4							
29									t															
30											2				7.7									
31									6.2						8.7									
Sum	22.6	3.5	0.6	2.4	2.8		15	t	11.2	1.8	15.4	14.8	23.1	26.6	30.8	94.5	72.5	24.8	6.3	1.7				
Total	26.1		3		2.8		15		13		30.2		49.7		125		97.3		8		0		t	mm

1959	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		
Day	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	
1									t		8.5		38												
2											19.2	t		1.8				0.5	4.3	2.2					
3																			3	3					
4																									
5																									
6												13.7			26.3										
7																									
8									t								t	16							
9									t	t			t					18.4							
10									2	2.2							2	6							
11									7.9		t							t	t						
12									0.8				t					37							
13											13.3			1.2		7		1.8							
14														5.1	t		7	t							
15									8.1								t		5.6	0.2					
16									t		3.1					12.3	7	7.4							
17									t						t	t	0.5								
18																	4								
19									t		0.4		0.3				0.2								
20																									
21													4												
22	2.4										t				t		t								
23							3.2													1.1					
24		1.4					14	7.1							t	0.3									
25	t						2	1.1							t	9.9			0.7	t					
26	t							0.9	1		3.1				t										
27							t				1.1				1.5	1.6									
28															11.8	0.3	6.3	2							
29							1.9																		
30								4.8	8	9.7	0.4						t								
31									t					t											
Sum	2.4	1.4					21.1	13.9	27.8	11.9	49.1	13.7	42.3	8.1	39.6	31.4	27	89.1	10.9	6.5					
Mean	3.8		0		0		35		39.7		62.8		50.4		71		116		17.4		0		0		mm

1960	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		
Day	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	6 - 18	- 6	
1																									
2																									
3																									
4																									
5																									
6																									
7																									
8																									
9																									
10																									
11																									
12					6	28.6	t	t																	
13						1.5	4																		
14					21.2	0.7	1.1	t																	
15						t																			
16					20	4		3																	
17					2.2	3.7																			
18					1.1	10.8																			
19					3.9	11.1																			
20					30.8	20.8																			
21					30	1																			
22																									
23						t																			
24																									
25					t																				
26					15.2	0.6																			
27					4																				
28					t																				
29					3.5																				
30					9		t																		
31	t				t																				
Sum	t				147	82.8	5.1	3																	
Mean	t		0		230		8.1		mm																


Annual Time Series for Berbera 1908-1950
missing data 1940 - 1941
Source - Met Office Archive
mm
180
160
140
120
100
80
60
40
20
0
1908
1918
1928
1938
1948


mm
160
140
120
100
80
60
40
20
0
Jan-08
Jan-13
Jan-18
Jan-23
Jan-28
Jan-33
Jan-38
Jan-43
Jan-48
Monthly Rainfall Time Series for Berbera Jan 1908 - Dec 1950
missing data - Oct 1940 - Dec 1941
Source - Met Office Archive


mm
140
120
100
80
60
40
20
0
1/1/08
1/1/13
1/1/18
1/1/23
1/1/28
1/1/33
1/1/38
1/1/43
1/1/48
Daily Rainfall Time Series for Berbera 1908-1950
missing data - Oct 1940 - Dec 1941
Source - Met Office Archive

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1908

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4												
5												1.5
6												1.3
7												
8												
9												
10												
11												
12												
13												
14												
15		2.5										
16												
17												
18												
19												
20												
21												
22	11.7											
23	1.3											
24												1.3
25												
26												
27												
28												
29	3.1						7.1	1.3				
30		-										
31		-		-		-	2.5		-		-	
Totals	16.1	2.5	0	0	0	0	9.6	1.3	0	0	0	4.1
Annual total	33.6											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1909

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4												
5												
6												
7												
8												
9	1.5											
10	2.0											
11												
12												
13												
14												
15												
16				31.8								
17				2.0								
18												
19												
20												
21												
22												
23	0.2				30.5							
24					1.3							
25												
26												
27												
28												4.1
29		-										
30		-										
31		-		-		-			-		-	
Totals	3.7	0	0	0	33.8	0	0	0	0	0	0	4.1
Annual total	73.4											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1910

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3					5.1							
4												
5												
6												
7												
8												
9												
10												
11												
12												
13	0.5											
14												
15												
16												
17			12.7									
18			132.0				1.5					
19			2.0									
20												
21												
22												
23												
24												
25												
26								7.6				
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	0.5	0	146.7	0	5.1	0	1.5	7.6	0	0	0	0
Annual total	161.4											

DAILY RAINFALL (mm)

STATION : BERBERA

Year : 1911

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4												
5												
6												
7												
8			0.5									
9												
10												
11												
12												
13												
14												
15												
16												
17												
18	5.0											
19			0.5									
20			15.2									
21											1.3	
22	3.8		25.6									
23												
24	1.3											
25												
26												
27												
28												
29	1.3	-										
30		-										
31		-		-		-			-		-	
Totals	11.4	0	41.8	0	0	0	0	0	0	0	1.3	0
Annual total	54.5											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1912

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4												
5		4.1										
6												
7												
8												
9				38.1								
10												
11				17.8								
12												
13												
14												
15												
16												
17				0.8								
18				6.1								
19												
20												
21												
22												
23												
24												
25												
26												
27												2.5
28												10.2
29												
30		–										
31		–		–		–			–		–	
Totals	0	4.1	0	62.8	0	0	0	0	0	0	0	12.7
Annual total	79.6											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1913

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4												
5												
6												
7	0.8											
8		1.5										
9												
10												
11												
12					38.4							
13												
14												
15												
16												
17												
18												
19												
20												
21		24.1										
22		0.8										
23												
24			17.8									
25												
26												
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	0.8	26.4	17.8	0	38.4	0	0	0	0	0	0	0
Annual total	83.4											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1914

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3										0.2		
4												
5												
6												
7								0.5				
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20		9.7										
21		4.1										
22										0.2		
23					34.3				1.8			
24												
25										0.5		
26										15.2		
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	0	13.8	0	0	34.3	0	0	0.5	1.8	16.3	0	0
Annual total	66.7											

DAILY RAINFALL (mm)

STATION : BERBERA   Year : 1915

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3					0.8							
4												
5												
6												
7												
8												
9												
10												
11				1.0								
12												
13									4.1		0.2	
14												
15												
16												
17												
18												
19												
20				1.5								
21												
22												
23				0.2								
24												
25				0.8								
26												
27				43.2								
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	0	0	0	46.7	0.8	0	0	0	4.1	0	0.2	0
Annual total	51.8											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1916

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1		0.5										
2		0.2							2.3			
3		0.2						1.8				
4		-										
5												
6												
7								4.3				
8												
9												
10												
11												
12												
13												
14			1.3									
15												
16												
17												
18												
19												
20												
21												
22		2.8										
23												
24		0.2										
25		1.3										
26		38.1					1.8					
27		1.3					10.4					
28												0.5
29	1.8											
30		-					3.3					
31		-		-		-			-		-	
Totals	1.8	44.6	1.3	0	0	0	15.5	6.1	2.3	0	0	0.5
Annual total	72.1											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1917

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4					1.8							
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15		0.2										
16												
17												
18				0.8								
19												
20				0.5								
21												
22				3.8		0.5	5.8					
23												
24												
25								0.5				
26												
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	0	0.2	0	5.1	1.8	0.5	5.8	0.5	0	0	0	0
Annual total	13.9											

DAILY RAINFALL (mm)

STATION : BERBERA　　　　Year : 1918

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1					3.1							
2												
3	0.5											
4												
5												
6												
7												
8	0.8											
9												
10				22.1								
11												
12												
13												
14												
15				14.5							5.8	
16												
17												
18												
19												
20	0.8											
21												
22												
23												
24	0.2											
25												
26												
27												
28												
29		–										
30		–										
31		–		–		–	1.3		–		–	
Totals	2.3	0	0	36.6	3.1	0	1.3	0	0	0	5.8	0
Annual total	49.1											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1919

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4												
5		0.2		13.0								
6			1.0									
7												
8					4.3							
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27			0.5									
28			39.6									
29		-										
30		-										
31		-		-		-			-		-	
Totals	0	0.2	41.1	13.0	4.3	0	0	0	0	0	0	0
Annual total	58.6											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1920

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4				13.0								
5												
6								0.2				
7												
8					4.3							
9												
10												
11												
12		0.2										
13												
14												
15												
16												
17												
18									2.0			
19												
20												
21												
22				6.6								
23												
24												
25									1.0			
26												
27												
28												
29											47.5	
30		-										
31		-		-		-			-		-	0.5
Totals	0	0.2	0	19.6	4.3	0	0	0.2	3.0	0	47.5	0.5
Annual total	75.3											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1927

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1		1.0										
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13									17.3			
14												
15												
16												
17												
18		1.3										
19										13.5		
20												
21												
22												
23												
24												
25												
26												
27												
28												
29		-										
30		-									1.3	
31		-		-		-			-		-	
Totals	0	2.3	0	0	0	0	0	0	17.3	13.5	1.3	0
Annual total	34.4											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1922

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2					8.1							
3												
4												
5												
6												
7												
8												5.6
9												
10												
11												
12												
13												
14								0.8				
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												0.2
26			4.8									
27								0.5				
28												
29		–										
30		–										
31		–		–		–			–		–	
Totals	0	0	4.8	0	8.1	0	0	1.3	0	0	0	5.8
Annual total	20.0											

DAILY RAINFALL (mm)

STATION : BERBERA   Year : 1923

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4		2.8										
5		2.0										
6												
7												
8												2.5
9												
10												
11												
12												
13				34.8								
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24										1.3		
25										29.2		
26												
27												
28												
29		–										
30		–										
31		–		–		–			–		–	
Totals	0	4.8	0	34.8	0	0	0	0	0	30.5	0	2.5
Annual total	72.6											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1924

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4											1.3	
5												
6												
7	0.5											
8												
9												
10												
11												
12								7.1				
13												
14												
15												
16												
17												
18												
19												
20								12.0				
21												
22												
23												
24												1.5
25												
26												
27									2.5			
28												
29												
30		–										
31		–		–		–			–		–	
Totals	0.5	0	0	0	0	0	0	19.1	2.5	0	1.3	1.5
Annual total	24.9											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1925

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2		2.5										
3												
4				0.2								
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23									1.8			
24												
25												
26											1.6	
27												
28									3.8			
29		-									4.0	
30		-										
31		-		-		-			-		-	
Totals	0	2.5	0	0.2	0	0	0	0	5.6	0	5.6	0
Annual total	13.9											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1926

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1					2.5							
2												
3												
4												
5		1.0			32.3							
6												
7						2.5						
8		0.5							0.5			
9		1.8		8.1								
10												
11					0.8							
12			2.0									
13												
14	1.5											
15	4.1		13.2		20.3							
16	38.1		2.3									
17	0.8										0.2	
18			16.5									
19			0.8									
20												
21			8.1									
22												
23												
24												
25							4.3					
26												
27												
28											0.2	
29		-										
30		-		3.6								
31		-		-		-			-		-	
Totals	44.5	3.3	42.9	11.7	55.9	2.5	4.3	0	0.5	0	0.4	0
Annual total	166.0											

DAILY RAINFALL (mm)

STATION : BEREERA Year : 1927

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1	0.2											
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12				2.5								
13												
14		2.0		15.0								
15				29.7								
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26	1.8											
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	2.0	2.0	0	47.2	0	0	0	0	0	0	0	0
Annual total	51.2											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1928

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1		1.3										
2												
3											16.8	
4												
5												
6												
7												
8												
9												
10								4.3				
11												3.8
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24											1.5	
25												
26												
27												
28												
29												
30		-										
31		-		-		-			-		-	
Totals	0	1.3	0	0	0	0	0	4.3	0	0	18.3	3.8
Annual total	27.7											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1929

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1	0.5											
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21											0.8	
22												
23												
24												
25				1.0								
26												
27						2.8						
28												
29		-										1.0
30		-										3.3
31		-		-		-			-		-	
Totals	0.5	0	0	1.0	0	2.8	0	0	0	0	0.8	4.3
Annual total	9.4											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1930

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												0.2
2												
3												
4												
5												
6												
7												
8												
9												
10			0.2									
11												
12												
13	4.1											
14												
15				30.2								
16												
17												
18												
19												
20												
21												
22												
23	5.8									21.8		
24	13.2									1.3		1.3
25	1.0									0.8		
26	26.4											
27	8.4											
28	2.8											
29		-										
30		-										
31		-		-		-			-		-	
Totals	61.7	0	0.2	30.2	0	0	0	0	0	23.9	0	1.5
Annual total	117.5											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1931

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3					0.5							
4					4.3							
5								0.5				
6					2.3							
7												
8												
9									11.2			
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21			0.5									
22												
23			1.8									
24		0.5										
25					14.5							
26												
27			0.2									
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	0	0.5	2.5	0	21.6	0	0	0.5	11.2	0	0	0
Annual total	36.3											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1932

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3					14.5							
4												
5												
6												
7												
8												
9												
10												
11												
12	0.2											
13	0.2											
14												
15	0.2											
16												
17												
18												17.3
19			1.3					1.5				
20			0.5									
21												
22												
23								0.5				
24												
25												
26							19.6					
27												
28												
29												
30		–										
31		–		–		–			–		–	
Totals	0.6	0	1.8	0	14.5	0	19.6	2.0	0	0	0	17.3
Annual total	55.8											

DAILY RAINFALL (mm)

STATION : BERBERA

Year : 1933

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3	2.0				5.6							
4	3.8											
5												
6												
7	0.2											
8	1.3											
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22								8.9				
23												
24												
25												
26												
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	7.3	0	0	0	5.6	0	0	8.9	0	0	0	0
Annual total	21.8											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1934

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4					2.3							
5												
6												
7												
8												
9												
10												
11							0.8	1.0				
12												
13												
14												
15												
16												
17												
18												
19												
20												
21											39.1	
22												
23												
24												
25												
26												
27												
28												
29		–										
30		–										
31		–		–		–			–		–	
Totals	0	0	0	0	2.3	0	0.8	1.0	0	0	39.1	0
Annual total	43.2											

DAILY RAINFALL (mm)

STATION : BERBERA   Year : 1995

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1					10.7							
2					21.1							16.5
3					0.8							
4					9.7							
5		1.3			2.3							
6					3.1							
7				2.5								
8				59.7								
9												
10												
11												
12		2.0										
13				0.8								
14				25.4								
15												
16		1.5										
17												0.2
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	0	4.8	0	88.4	47.7	0	0	0	0	0	0	16.7
Annual total	157.6											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1937

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2			5.8	9.4								
3								4.3				
4				2.0								
5												
6												
7												
8												
9												
10		0.8										
11		0.8									9.4	
12					3.3							
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26			0.5									
27	7.1		1.0									
28												
29		-	0.8									
30		-										
31		-		-		-			-		-	
Totals	7.1	1.6	8.1	11.4	3.3	0	0	4.3	0	0	9.4	0
Annual total	45.2											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1938

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4												
5								0.5				
6												
7												
8												
9												
10					1.3							
11												
12												
13								0.8				
14							3.8					
15												
16												
17												
18												
19								9.1				
20			1.3									
21								0.5				
22							10.2					
23												
24												
25												
26												
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	0	0	1.3	0	1.3	0	14.0	10.9	0	0	0	0
Annual total	27.5											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1939

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4												
5												
6												
7												
8			2.3									
9				4.3								
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29		–										
30		–	0.8									
31		–	2.0	–		–			–		–	
Totals	0	0	5.1	4.3	0	0	0	0	0	0	0	0
Annual total	9.4											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1940

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3			3.1									
4			30.5									
5			15.0									
6												
7			2.8									
8			6.4									
9												
10												
11												
12												
13												
14												
15			1.8									
16												
17					10.2							
18												
19												
20												
21												
22		5.6										
23												
24												
25												
26												
27												
28												
29		25.2	0.5									
30		-	1.0									
31		-		-		-			-		-	
Totals	0	30.8	61.1	0	10.2	0	0	0	0	0	0	0
Annual total	102.1											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1942

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1			1.5									
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17				1.8								
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	0	0	1.5	1.8	0	0	0	0	0	0	0	0
Annual total	3.3											

DAILY RAINFALL (mm)

STATION : BERBERA   Year : 1943

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3					65.1							
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21										5.6		
22												
23												
24												
25												
26												
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	0	0	0	0	65.1	0	0	0	0	5.6	0	0
Annual total	70.7											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1944

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4												
5												
6												
7												
8												
9			2.2									
10												
11												
12			0.5									
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29		–										
30		–										
31		–		–		–			–		–	
Totals	0	0	2.7	0	0	0	0	–	0	0	0	0
Annual total	2.7											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1945

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2			2.7									
3												
4						21.9		1.0				
5								0.9				
6												
7												
8		0.7			6.6							
9					1.1							
10								0.4				
11												
12												
13												
14												
15				1.6								
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	0	0.7	2.7	1.6	7.7	21.9	0	2.3	0	0	0	0
Annual total	36.9											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1946

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3								1.9				
4												
5												
6												
7												
8												
9												
10												
11												
12												
13				13.0								
14				7.0	1.5							
15					1.8							
16												
17												
18												
19												
20												
21												
22												
23	1.1											
24												
25												
26												
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	1.1	0	0	20.0	3.3	0	0	1.9	0	0	0	0
Annual total	26.3											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1947

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4												
5					0.6							
6												
7												
8												
9												
10												
11												
12												
13												
14												
15								1.1				
16												
17												
18												
19			0.3									
20												
21												
22												
23												
24												
25												
26												
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	0	0	0.3	0	0.6	0	0	1.1	0	0	0	0
Annual total	2.0											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1946

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3								1.9				
4												
5												
6												
7												
8												
9												
10												
11												
12												
13				13.0								
14				7.0	1.5							
15					1.8							
16												
17												
18												
19												
20												
21												
22												
23	1.1											
24												
25												
26												
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	1.1	0	0	20.0	3.3	0	0	1.9	0	0	0	0
Annual total	26.3											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1948

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3												
4												
5												
6												
7										3.8		
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26				60.5								
27												
28												
29												
30		-										
31		-		-		-			-		-	
Totals	0	0	0	60.5	0	0	0	0	0	3.8	0	0
Annual total	64.3											

DAILY RAINFALL (mm)

STATION : BERBERA Year : 1949

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1								4.7				
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12									18.6			
13												
14												
15												32.0
16												29.7
17												6.2
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29		-										
30		-										
31		-		-		-			-		-	
Totals	0	0	0	0	0	0	0	4.7	18.6	0	0	67.9
Annual total	91.2											

DAILY RAINFALL (mm)

STATION : BERBERA   Year : 1950

Mois	J	F	M	A	M	J	J	A	S	O	N	D
1									6.8			
2								16.0				
3												
4												
5									2.4			
6												
7									5.5			
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18	16.0											
19												
20												
21												
22												
23												
24												
25												
26												
27	0.5											
28	45.0											
29		-										
30	3.9	-										
31		-		-		-			-		-	
Totals	65.4	0	0	0	0	0	0	16.0	14.7	0	0	0
Annual total	96.1											

Monthly Rainfall Data for Somaliland (mm)

Map Unit		*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	*Avg Annual*
SO1	**E-Saylac**	2	4	30	34	16	2	4	2	18	54	54	22	242
SO2	**W-Saylac**	4	8	34	46	22	6	0	0	98	54	42	16	330
SO3	**Laghaya**	0	0	36	54	26	8	0	6	20	46	44	22	262
SO4	**N-Boorame**	12	12	30	60	50	26	4	32	90	34	32	12	394
SO5	**C-Baki**	6	4	32	62	52	28	2	50	50	28	40	14	368
SO6	**N-Baki**	0	0	24	46	28	10	0	14	16	18	30	16	202
SO7	**E-Baki**	2	0	24	54	42	18	0	14	20	16	32	14	236
SO8	**S-Boorame**	12	24	34	88	56	38	46	114	94	50	18	6	580
SO9	**S-Baki**	12	20	32	92	56	34	40	104	86	44	14	8	542
SO10	**N-Berbera**	6	2	12	34	26	8	2	10	12	10	12	8	142
SO11	**S-Berbera**	10	6	22	76	52	22	10	30	26	24	22	12	312
SO12	**N-Gabiley**	10	6	24	62	50	26	2	32	40	18	30	10	310
SO13	**N-Hargeysa**	6	8	24	60	50	34	20	46	42	20	16	6	332
SO14	**S-Gabiley**	10	16	32	80	78	58	48	112	84	22	16	4	560
SO15	**SW-Hargeysa**	4	10	30	70	66	62	40	92	62	22	16	2	476
SO16	**SE-Hargeysa**	4	4	22	54	56	56	20	36	46	22	10	2	332
SO17	**Sheekh**	12	10	24	84	72	28	16	34	42	40	22	14	398
SO18	**N-Oodweyne**	4	8	24	52	56	30	22	42	50	34	16	8	346
SO19	**N-Burco**	6	4	14	44	60	22	12	20	38	24	14	6	264
SO20	**S-Oodweyne**	0	4	20	46	62	30	20	32	46	36	16	2	314
SO21	**S-Burco**	2	0	8	34	76	22	12	16	36	34	16	2	258
SO22	**Buuhoodle**	0	0	2	24	68	10	4	6	28	40	14	2	198
SO23	**N-Ceel Afweyn**	12	6	16	38	42	22	4	16	36	8	10	6	216
SO24	**N-Ceerigaabo**	16	10	26	36	80	52	8	26	76	6	14	4	354
SO25	**C-Ceerigaabo**	20	14	36	50	98	70	12	50	140	12	18	6	526
SO26	**N-Badhan**	6	4	12	12	26	14	2	8	22	4	10	4	124
SO27	**CN-Badhan**	8	6	18	26	48	28	6	24	54	10	12	6	246
SO28	**CS-Badhan**	4	4	10	16	24	14	2	12	28	6	8	4	132
SO29	**S-Ceel Afweyn**	12	8	18	36	60	34	6	24	58	12	12	4	284
SO30	**SW-Ceerigaabo**	10	8	22	28	60	36	6	24	62	10	10	4	280
SO31	**SE-Ceerigaabo**	6	4	14	24	48	20	4	16	40	12	8	4	200
SO32	**S-Badhan**	2	2	8	18	32	10	2	10	18	10	6	4	122
SO39	**N-Caynabo**	10	6	16	44	62	26	6	18	50	20	14	6	278
SO40	**S-Caynabo**	4	2	8	24	54	18	4	10	36	20	10	2	192
SO41	**Xudun**	4	2	8	20	44	16	2	10	34	16	6	2	164
SO42	**Taleex**	2	2	6	20	40	8	2	8	16	20	4	4	132
SO43	**Laascaanood**	0	0	2	16	40	4	0	2	16	28	8	2	118

Monthly PET Data for Somaliland (mm)

Map Unit		*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	*Avg Annual*
SO1	**E-Saylac**	142	146	178	188	208	234	246	254	214	190	160	138	2298
SO2	**W-Saylac**	138	140	174	182	200	218	222	226	198	182	154	134	2168
SO3	**Laghaya**	160	164	202	206	226	282	286	294	244	210	176	152	2602
SO4	**N-Boorame**	138	142	176	178	192	222	220	222	196	176	152	134	2148
SO5	**C-Baki**	158	162	200	200	214	266	266	270	232	200	172	148	2488
SO6	**N-Baki**	174	178	220	220	242	324	326	334	272	224	188	160	2862
SO7	**E-Baki**	180	184	228	226	246	338	338	346	280	230	192	164	2952
SO8	**S-Boorame**	136	140	172	172	180	212	208	210	188	168	148	132	2066
SO9	**S-Baki**	142	146	182	180	188	228	226	228	200	178	154	136	2188
SO10	**N-Berbera**	160	150	188	188	224	352	348	376	268	194	156	142	2746
SO11	**S-Berbera**	172	168	210	208	236	360	356	374	280	214	176	152	2906
SO12	**N-Gabiley**	172	178	220	218	232	308	306	312	262	220	186	158	2772
SO13	**N-Hargeysa**	172	178	220	212	228	326	322	330	270	218	182	154	2812
SO14	**S-Gabiley**	150	156	192	186	194	246	242	242	214	186	160	140	2308
SO15	**SW-Hargeysa**	166	176	216	206	212	284	280	280	246	208	178	152	2604
SO16	**SE-Hargeysa**	166	172	212	198	206	282	278	284	244	200	172	152	2566
SO17	**Sheekh**	152	144	180	176	206	324	320	342	250	182	148	134	2558
SO18	**N-Oodweyne**	148	146	182	176	194	294	290	304	234	180	150	132	2430
SO19	**N-Burco**	150	142	178	172	196	296	288	308	236	174	142	132	2414
SO20	**S-Oodweyne**	164	164	204	190	204	290	286	296	242	190	164	148	2542
SO21	**S-Burco**	158	152	190	178	196	272	266	282	230	174	148	144	2390
SO22	**Buuhoodle**	158	146	184	170	186	240	228	246	212	160	138	144	2212
SO23	**N-Ceel Afweyn**	152	140	178	178	208	316	316	338	250	178	138	134	2526
SO24	**N-Ceerigaabo**	152	140	180	180	208	298	306	318	246	174	130	132	2464
SO25	**C-Ceerigaabo**	126	116	148	146	170	236	242	250	200	140	106	108	1988
SO26	**N-Badhan**	142	136	174	176	202	268	290	286	234	160	116	124	2308
SO27	**CN-Badhan**	132	122	158	156	182	238	248	250	210	144	106	114	2060
SO28	**CS-Badhan**	134	120	154	152	178	230	232	240	206	144	106	114	2010
SO29	**S-Ceel Afweyn**	144	132	166	162	186	268	264	282	222	160	126	126	2238
SO30	**SW-Ceerigaab**	136	120	154	150	172	234	228	242	204	144	112	116	2012
SO31	**SE-Ceerigaabc**	150	126	164	158	182	236	218	240	214	152	118	126	2084
SO32	**S-Badhan**	154	130	168	164	196	244	226	246	226	160	120	130	2164
SO39	**N-Caynabo**	142	132	166	160	184	268	262	282	218	160	128	126	2228
SO40	**S-Caynabo**	156	144	180	170	190	262	254	272	224	166	138	138	2294
SO41	**Xudun**	166	144	182	172	194	252	234	258	226	166	134	144	2272
SO42	**Taleex**	172	140	184	174	202	248	214	246	232	170	134	146	2262
SO43	**Laascaanood**	168	146	186	174	194	238	218	240	218	162	138	148	2230

Monthly NDVI Data for Somaliland (index)

Map Unit		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Avg Annual
SO1	**E-Saylac**	0.03	0.03	0.03	0.03	0.04	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.03
SO2	**W-Saylac**	0.05	0.05	0.06	0.06	0.07	0.05	0.03	0.03	0.04	0.05	0.05	0.05	0.05
SO3	**Laghaya**	0.05	0.05	0.06	0.05	0.06	0.05	0.03	0.02	0.03	0.04	0.04	0.05	0.04
SO4	**N-Boorame**	0.09	0.08	0.09	0.12	0.15	0.12	0.08	0.08	0.11	0.12	0.12	0.1	0.11
SO5	**C-Baki**	0.1	0.08	0.08	0.1	0.14	0.11	0.07	0.06	0.08	0.11	0.11	0.1	0.10
SO6	**N-Baki**	0.06	0.05	0.06	0.05	0.06	0.05	0.03	0.02	0.03	0.05	0.06	0.06	0.05
SO7	**E-Baki**	0.08	0.07	0.06	0.07	0.09	0.07	0.04	0.03	0.04	0.07	0.08	0.07	0.06
SO8	**S-Boorame**	0.11	0.1	0.11	0.15	0.2	0.17	0.14	0.14	0.16	0.16	0.15	0.13	0.14
SO9	**S-Baki**	0.11	0.09	0.1	0.14	0.18	0.16	0.12	0.12	0.14	0.14	0.14	0.12	0.13
SO10	**N-Berbera**	0.05	0.04	0.04	0.03	0.04	0.04	0.03	0.02	0.03	0.05	0.05	0.05	0.04
SO11	**S-Berbera**	0.08	0.07	0.07	0.07	0.11	0.1	0.07	0.06	0.06	0.09	0.11	0.09	0.08
SO12	**N-Gabiley**	0.09	0.07	0.07	0.08	0.12	0.1	0.06	0.05	0.07	0.11	0.11	0.1	0.09
SO13	**N-Hargeysa**	0.09	0.08	0.08	0.08	0.11	0.1	0.08	0.07	0.08	0.11	0.11	0.1	0.09
SO14	**S-Gabiley**	0.12	0.1	0.11	0.13	0.18	0.18	0.15	0.15	0.16	0.16	0.15	0.14	0.14
SO15	**SW-Hargeysa**	0.11	0.1	0.1	0.12	0.15	0.16	0.13	0.11	0.13	0.15	0.15	0.13	0.13
SO16	**SE-Hargeysa**	0.1	0.1	0.09	0.09	0.12	0.12	0.09	0.08	0.09	0.12	0.12	0.12	0.10
SO17	**Sheekh**	0.11	0.09	0.09	0.1	0.13	0.12	0.09	0.07	0.09	0.13	0.14	0.13	0.11
SO18	**N-Oodweyne**	0.1	0.09	0.09	0.09	0.11	0.11	0.09	0.08	0.09	0.11	0.12	0.11	0.10
SO19	**N-Burco**	0.1	0.09	0.09	0.09	0.11	0.1	0.08	0.07	0.08	0.11	0.12	0.11	0.10
SO20	**S-Oodweyne**	0.12	0.11	0.11	0.1	0.13	0.12	0.1	0.09	0.1	0.13	0.14	0.13	0.12
SO21	**S-Burco**	0.13	0.13	0.12	0.12	0.15	0.14	0.11	0.09	0.11	0.15	0.16	0.15	0.13
SO22	**Buuhoodle**	0.12	0.11	0.11	0.12	0.14	0.13	0.09	0.08	0.1	0.15	0.15	0.13	0.12
SO23	**N-Ceel Afweyn**	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.03	0.04	0.06	0.07	0.07	0.05
SO24	**N-Ceerigaabo**	0.07	0.07	0.07	0.06	0.09	0.08	0.06	0.05	0.06	0.09	0.1	0.08	0.07
SO25	**C-Ceerigaabo**	0.12	0.1	0.1	0.09	0.11	0.12	0.1	0.09	0.1	0.14	0.14	0.13	0.11
SO26	**N-Badhan**	0.08	0.08	0.07	0.06	0.07	0.06	0.05	0.04	0.04	0.07	0.08	0.08	0.07
SO27	**CN-Badhan**	0.13	0.12	0.12	0.11	0.11	0.12	0.11	0.1	0.11	0.14	0.15	0.14	0.12
SO28	**CS-Badhan**	0.08	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.07	0.08	0.08	0.07
SO29	**S-Ceel Afweyn**	0.08	0.07	0.07	0.06	0.07	0.08	0.06	0.05	0.06	0.08	0.09	0.09	0.07
SO30	**SW-Ceerigaab**	0.09	0.08	0.08	0.07	0.08	0.08	0.06	0.06	0.06	0.08	0.09	0.09	0.08
SO31	**SE-Ceerigaabo**	0.09	0.08	0.08	0.07	0.08	0.08	0.07	0.06	0.06	0.09	0.1	0.09	0.08
SO32	**S-Badhan**	0.09	0.08	0.08	0.07	0.07	0.07	0.06	0.05	0.06	0.09	0.09	0.09	0.08
SO39	**N-Caynabo**	0.11	0.1	0.09	0.09	0.1	0.1	0.08	0.07	0.08	0.11	0.12	0.12	0.10
SO40	**S-Caynabo**	0.09	0.09	0.08	0.08	0.1	0.09	0.07	0.06	0.07	0.1	0.11	0.1	0.09
SO41	**Xudun**	0.08	0.08	0.07	0.07	0.08	0.07	0.06	0.05	0.06	0.08	0.09	0.09	0.07
SO42	**Taleex**	0.08	0.08	0.07	0.07	0.07	0.07	0.06	0.05	0.06	0.09	0.09	0.09	0.07
SO43	**Laascaanood**	0.08	0.08	0.08	0.07	0.09	0.08	0.06	0.06	0.06	0.1	0.1	0.09	0.08

Detailed CPSZ Information for Somaliland

	SO1	SO2	SO3	SO4	SO5
General Data					
CPSZ Map Unit	SO1	SO2	SO3	SO4	SO5
Administrative area (code)	6	6	7	5	4
Administrative area (name)	E-Saylac	W-Saylac	Laghaya	N-Boorama	C-Baki
Administrative region (name)	Awdal	Awdal	Awdal	Awdal	Awdal
Number of mapunits in administrative area.	2	2	1	2	4
Area	3723 km2	3095 km2	3611 km2	2275 km2	1157 km2
Area occupied by mapunit (% of admin area)	55%	45%	100%	81%	32%
Longitude of the centre of mapunit	43.38 ø	42.99 ø	43.81 ø	43.17 ø	43.60 ø
Latitude of the centre of mapunit	11.12 ø	10.74 ø	10.88 ø	10.26 ø	10.20 ø
Crop Data					
CPSZ code	0	0.1	0	0.1	0.1
Crop and Pasture Zone (Grouped)	Desert Zone	Desert Zone	Desert Zone	Transitional Desert/Marginal Pasture Zone	Transitional Desert/Marginal Pasture Zone
Maize in the cropping system	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Sorghum in the cropping system	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Cowpea in the cropping system	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Sesame in the cropping system	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Vegetables in the cropping system	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Maize yield	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Sorghum yield	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Cowpea yield	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Physical Data					
CPSZ code	1	1.1	1	2.1	2.1
Irrigation status	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)
Thermal zone	Warm (> 25øC)	Warm (> 25øC)	Warm (> 25øC)	Moderately Warm (20-25 øC)	Moderately Warm (20-25 øC)
Length of growing period	Hyperarid (0 days of growing period)	Arid (1-59 days of growing period)	Hyperarid (0 days of growing period)	Arid (1-59 days of growing period)	Arid (1-59 days of growing period)
Number of growing periods	None (no growing period)	One or two short/unreliable growing periods	None (no growing period)	One or two short/unreliable growing periods	One or two short/unreliable growing periods
Number of planting seasons	no planting season)	no planting season)	no planting season)	no planting season)	no planting season)
Average altitude	98 m	528 m	300 m	1140 m	972 m
Maximum altitude	480 m	1224 m	788 m	1536 m	1488 m
Minimum altitude	12 m	84 m	12 m	612 m	684 m
Altitude geographical SD	108 m	336 m	228 m	288 m	276 m
Annual mean temperature	29.3 øC	26.7 øC	28.1 øC	23.1 øC	24.1 øC
Highest annual mean temperature	29.8 øC	29.4 øC	29.8 øC	26.2 øC	25.8 øC
Lowest annual mean temperature	27.0 øC	22.6 øC	25.3 øC	20.7 øC	21.0 øC
Temperature geographical SD	0.6 øC	2.0 øC	1.4 øC	1.7 øC	1.7 øC
Start growing period (climate)	Not applicable	Sep I	Not applicable	Sep I	Apr II
Start growing season (derived from NDVI)	Not applicable	Not applicable	Not applicable	Mar I	Not applicable
Interannual SD of start growing season (NDVI)	Not applicable	Not applicable	Not applicable	0.2 dekads	Not applicable
End growing period (climate)	Not applicable	Sep II	Not applicable	Sep II	Apr III
End growing season (derived from NDVI)	Not applicable	Not applicable	Not applicable	Jun I	Not applicable
Interannual SD of end growing season (NDVI)	Not applicable	Not applicable	Not applicable	0.1 dekads	Not applicable
Length growing period (climate)	Not applicable	1 dekads	Not applicable	1 dekads	1 dekads
Length growing season (NDVI)	Not applicable	Not applicable	Not applicable	10 dekads	Not applicable
Interannual SD of length growing season (NDVI)	Not applicable	Not applicable	Not applicable	0.1 dekads	Not applicable
Start growing period (climate)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Start growing season (NDVI)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Interannual SD of start growing period (NDVI)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
End growing period (climate)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
End growing season (crop calendar)	Not available	Not available	Not available	Not available	Not available
End growing season (NDVI)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Interannual SD of end growing season (NDVI)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Length growing period (climate)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Length growing season (NDVI)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Interannual SD of length growing season (NDVI)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Readily available soil moisture	74 mm	36 mm	74 mm	87 mm	67 mm
SD readily available soil moisture	17 mm	23 mm	17 mm	23 mm	23 mm
Inherent soil fertility class	Low-medium	Low-medium	Low-medium	Medium-low	Medium-low
Average terrain/slope characteristics	12%	27%	12%	17%	17%
Slope class	5 (class)	9 (class)	5 (class)	7 (class)	7 (class)
Waterlogging/ponding hazard (%)	3%	1%	3%	6%	6%
NDVI average (1982-90)	0.03 (index)	0.05 (index)	0.05 (index)	0.11 (index)	0.09 (index)
NDVI geographical SD	0.02 (index)	0.03 (index)	0.01 (index)	0.03 (index)	0.02 (index)

Detailed CPSZ information for Somaliland

Physical Data					
Rainfall January	2 mm	4 mm	0 mm	12 mm	6 mm
Rainfall February	4 mm	8 mm	0 mm	12 mm	4 mm
Rainfall March	30 mm	34 mm	38 mm	30 mm	32 mm
Rainfall April	34 mm	46 mm	54 mm	60 mm	62 mm
Rainfall May	16 mm	22 mm	28 mm	50 mm	52 mm
Rainfall June	2 mm	6 mm	8 mm	26 mm	28 mm
Rainfall July	4 mm	0 mm	0 mm	4 mm	2 mm
Rainfall August	2 mm	0 mm	6 mm	32 mm	50 mm
Rainfall September	18 mm	98 mm	20 mm	90 mm	50 mm
Rainfall October	54 mm	64 mm	46 mm	34 mm	28 mm
Rainfall November	54 mm	42 mm	44 mm	32 mm	40 mm
Rainfall December	22 mm	16 mm	22 mm	12 mm	14 mm
Average annual rainfall	242 mm	330 mm	282 mm	394 mm	368 mm
PET January	142 mm	136 mm	160 mm	138 mm	156 mm
PET February	146 mm	140 mm	164 mm	142 mm	162 mm
PET March	178 mm	174 mm	202 mm	176 mm	200 mm
PET April	188 mm	182 mm	206 mm	178 mm	200 mm
PET May	206 mm	200 mm	226 mm	192 mm	214 mm
PET June	234 mm	218 mm	282 mm	222 mm	268 mm
PET July	246 mm	222 mm	288 mm	220 mm	268 mm
PET August	254 mm	226 mm	294 mm	222 mm	270 mm
PET September	214 mm	198 mm	244 mm	198 mm	232 mm
PET October	190 mm	182 mm	210 mm	178 mm	200 mm
PET November	160 mm	154 mm	176 mm	152 mm	172 mm
PET December	138 mm	134 mm	152 mm	134 mm	148 mm
Average annual PET	2298 mm	2168 mm	2602 mm	2148 mm	2488 mm
NDVI January	0.03 (index)	0.05 (index)	0.05 (index)	0.09 (index)	0.10 (index)
NDVI February	0.03 (index)	0.05 (index)	0.05 (index)	0.08 (index)	0.08 (index)
NDVI March	0.03 (index)	0.06 (index)	0.06 (index)	0.09 (index)	0.08 (index)
NDVI April	0.03 (index)	0.06 (index)	0.05 (index)	0.12 (index)	0.10 (index)
NDVI May	0.04 (index)	0.07 (index)	0.06 (index)	0.15 (index)	0.14 (index)
NDVI June	0.03 (index)	0.05 (index)	0.05 (index)	0.12 (index)	0.11 (index)
NDVI July	0.02 (index)	0.03 (index)	0.03 (index)	0.08 (index)	0.07 (index)
NDVI August	0.02 (index)	0.03 (index)	0.02 (index)	0.08 (index)	0.06 (index)
NDVI September	0.02 (index)	0.04 (index)	0.03 (index)	0.11 (index)	0.08 (index)
NDVI October	0.03 (index)	0.05 (index)	0.04 (index)	0.12 (index)	0.11 (index)
NDVI November	0.03 (index)	0.05 (index)	0.04 (index)	0.12 (index)	0.11 (index)
NDVI December	0.03 (index)	0.05 (index)	0.05 (index)	0.10 (index)	0.10 (index)
Average annual NDVI	0.03 (index)	0.05 (index)	0.04 (index)	0.11 (index)	0.10 (index)
Agronomic Data					
Cropping density	No crops	No crops	No crops	No crops	No crops
Dominant cropping pattern	Not available	Not available	Not available	Not available	Not available
Associated cropping pattern	Not available	Not available	Not available	Not available	Not available
Dominant crop	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Second crop	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Third crop	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Fourth crop	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Yield, crop 1 - season 1	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Yield, crop 1 - season 2	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Yield, crop 2 - season 1	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Yield, crop 2 - season 2	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Yield, crop 3 - season 1	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Yield, crop 3 - season 2	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Livestock Data					
Livestock system	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Cattle in the herd composition	6 % of herd	6 % of herd	6 % of herd	6 % of herd	6 % of herd
Sheep in the herd composition	45 % of herd	45 % of herd	45 % of herd	45 % of herd	45 % of herd
Goat in the herd composition	45 % of herd	45 % of herd	45 % of herd	45 % of herd	45 % of herd
Equine in the herd composition	0 % of herd	0 % of herd	0 % of herd	0 % of herd	0 % of herd
Camel in the herd composition	4 % of herd	4 % of herd	4 % of herd	4 % of herd	4 % of herd
Livestock/crop ratio	95%	95%	95%	95%	95%

Source: Crop Production Systems of the IGADD Sub-Region - IGADD/FAO 1995

SO6	SO7	SO8	SO9	SO10	SO11
4	4	5	4	3	3
N-Baki	E-Baki	S-Boorame	S-Baki	N-Berbera	S-Berbera
Awdal	Awdal	Awdal	Awdal	West Galbeed	West Galbeed
4	4	2	4	2	2
1949 km2	178 km2	517 km2	324 km2	8889 km2	1732 km2
54%	5%	19%	9%	84%	16%
43.93 ø	44.01 ø	43.26 ø	43.41 ø	45.38 ø	44.73 ø
10.42 ø	10.24 ø	9.92 ø	9.93 ø	10.42 ø	10.12 ø
0	0 1	0.2	0.2	0	0.1
Desert Zone	Transitional Desert/Marginal Pasture Zone	Sorghum/Maize - Sesame Zone	Sorghum/Maize - Sesame Zone	Desert Zone	Marginal Pasture Zone
Not or low importance	Not or low importance	Dominant	Dominant	Not or low importance	Not or low importance
Not or low importance	Not or low importance	Dominant	Dominant	Not or low importance	Dominant
Not or low importance	Not or low importance	Secundary importance	Secundary importance	Not or low importance	Dominant
Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not or low importance	Not or low importance	Secundary importance	Secundary importance	Not or low importance	Not or low importance
Not applicable	Not applicable	0.6 ton/ha	0.6 ton/ha	Not applicable	Not applicable
Not applicable	Not applicable	0.6 ton/ha	0.6 ton/ha	Not applicable	0.3 ton/ha
Not applicable	Not applicable	0.2 ton/ha	0.2 ton/ha	Not applicable	0.1 ton/ha
1	2.1	2.2	2.2	1	2.1
No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)
Warm (> 25øC)	Moderately Warm (20-25 øC)	Moderately Warm (20-25 øC)	Moderately Warm (20-25 øC)	Warm (> 25øC)	Moderately Warm (20-25 øC)
Hyperarid (0 days of growing period)	Arid (1-59 days of growing period)	Dry semiarid (60-119 days of growing period)	Dry semiarid (60-119 days of growing period)	Hyperarid (0 days of growing period)	Arid (1-59 days of growing period)
None (no growing period)	One or two short/unreliable growing periods	One or two short/unreliable growing periods	One or two short/unreliable growing periods	None (no growing period)	One or two short/unreliable growing periods
no planting season)	no planting season)	three planting seasons	three planting seasons	no planting season)	three planting seasons
420 m	576 m	1512 m	1428 m	516 m	936 m
792 m	768 m	1560 m	1524 m	1260 m	1596 m
36 m	264 m	1452 m	1260 m	72 m	468 m
252 m	192 m	36 m	144 m	288 m	408 m
27.4 øC	28.4 øC	20.6 øC	21.3 øC	26.8 øC	24.3 øC
29.7 øC	28.3 øC	21.2 øC	22.3 øC	29.5 øC	27.1 øC
25.1 øC	25.3 øC	20.5 øC	20.8 øC	22.3 øC	20.3 øC
1.5 øC	1 2 øC	0.2 øC	0.9 øC	1.7 øC	2.4 øC
Not applicable	Apr II	Apr II	Apr I	Not applicable	Apr II
Not applicable	Not applicable	Mar I	Mar I	Not applicable	Not applicable
Not applicable	Not applicable	0.2 dekads	0.2 dekads	Not applicable	Not applicable
Not applicable	Apr III	May I	May I	Not applicable	Apr III
Not applicable	Not applicable	Jun II	Jun II	Not applicable	Not applicable
Not applicable	Not applicable	0.1 dekads	0.1 dekads	Not applicable	Not applicable
Not applicable	1 dekads	2 dekads	3 dekads	Not applicable	1 dekads
Not applicable	Not applicable	10 dekads	11 dekads	Not applicable	Not applicable
Not applicable	Not applicable	0.1 dekads	0.1 dekads	Not applicable	Not applicable
Not applicable	Not applicable	Aug II	Jul I	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Sep II	Aug I	Not applicable	Not applicable
Not available	Not available	Not available	Not available	Not available	Not available
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	4 dekads	3 dekads	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
74 mm	67 mm	78 mm	78 mm	74 mm	67 mm
17 mm	23 mm	23 mm	23 mm	17 mm	23 mm
Low-medium	Medium-low	High-medium	High-medium	Low-medium	Medium-low
12%	17%	20%	20%	12%	17%
5 (class)	7 (class)	8 (class)	8 (class)	5 (class)	7 (class)
3%	6%	13%	13%	3%	6%
0.05 (index)	0.07 (index)	0.14 (index)	0 13 (index)	0.04 (index)	0.08 (index)
0.02 (index)	0.02 (index)	0.03 (index)	0.02 (index)	0.02 (index)	0.05 (index)

0 mm	2 mm	12 mm	12 mm	6 mm	10 mm
0 mm	0 mm	24 mm	20 mm	2 mm	6 mm
24 mm	24 mm	34 mm	32 mm	12 mm	22 mm
46 mm	54 mm	68 mm	92 mm	34 mm	76 mm
28 mm	42 mm	56 mm	56 mm	26 mm	52 mm
10 mm	16 mm	36 mm	34 mm	8 mm	22 mm
0 mm	0 mm	46 mm	40 mm	2 mm	10 mm
14 mm	14 mm	114 mm	104 mm	10 mm	30 mm
16 mm	20 mm	94 mm	88 mm	12 mm	26 mm
18 mm	16 mm	50 mm	44 mm	10 mm	24 mm
30 mm	32 mm	18 mm	14 mm	12 mm	22 mm
18 mm	14 mm	6 mm	8 mm	8 mm	12 mm
202 mm	236 mm	580 mm	542 mm	142 mm	312 mm
174 mm	180 mm	136 mm	142 mm	160 mm	172 mm
178 mm	184 mm	140 mm	146 mm	150 mm	168 mm
220 mm	228 mm	172 mm	182 mm	188 mm	210 mm
220 mm	226 mm	172 mm	180 mm	188 mm	208 mm
242 mm	246 mm	180 mm	188 mm	224 mm	236 mm
324 mm	338 mm	212 mm	226 mm	352 mm	360 mm
326 mm	338 mm	208 mm	226 mm	348 mm	356 mm
334 mm	346 mm	210 mm	228 mm	376 mm	374 mm
272 mm	280 mm	188 mm	200 mm	268 mm	280 mm
224 mm	230 mm	168 mm	178 mm	194 mm	214 mm
188 mm	192 mm	148 mm	154 mm	158 mm	176 mm
160 mm	164 mm	132 mm	136 mm	142 mm	152 mm
2862 mm	2952 mm	2068 mm	2188 mm	2746 mm	2906 mm
0.06 (index)	0.06 (index)	0.11 (index)	0 11 (index)	0.05 (index)	0.08 (index)
0.05 (index)	0.07 (index)	0.10 (index)	0.09 (index)	0.04 (index)	0.07 (index)
0.06 (index)	0.06 (index)	0.11 (index)	0.10 (index)	0.04 (index)	0.07 (index)
0.05 (index)	0.07 (index)	0.15 (index)	0.14 (index)	0.03 (index)	0.07 (index)
0.06 (index)	0.09 (index)	0.20 (index)	0.16 (index)	0.04 (index)	0.11 (index)
0.05 (index)	0.07 (index)	0.17 (index)	0.16 (index)	0.04 (index)	0.10 (index)
0.03 (index)	0.04 (index)	0.14 (index)	0.12 (index)	0.03 (index)	0 07 (index)
0.02 (index)	0.03 (index)	0.14 (index)	0.12 (index)	0.02 (index)	0.06 (index)
0 03 (index)	0.04 (index)	0.16 (index)	0.14 (index)	0.03 (index)	0.08 (index)
0.05 (index)	0 07 (index)	0.16 (index)	0.14 (index)	0.05 (index)	0.09 (index)
0.06 (index)	0.08 (index)	0.15 (index)	0 14 (index)	0.05 (index)	0.11 (index)
0.06 (index)	0.07 (index)	0.13 (index)	0 12 (index)	0.05 (index)	0 09 (index)
0.05 (index)	0.06 (index)	0.14 (index)	0.13 (index)	0.04 (index)	0.08 (index)
No crops	No crops	Sparsely cropped	Sparsely cropped	No crops	No crops
Not available	Not available	Not available	Not available	Not available	Not available
Not available	Not available	Not available	Not available	Not available	Not available
Not applicable	Not applicable	Sorghum	Sorghum	Not applicable	Sorghum
Not applicable	Not applicable	Maize	Maize	Not applicable	Cowpea
Not applicable	Not applicable	Cowpea	Cowpea	Not applicable	Not applicable
Not applicable	Not applicable	Vegetables	Vegetables	Not applicable	Not applicable
Not applicable	Not applicable	0 6 ton/ha	0.6 ton/ha	Not applicable	0.3 ton/ha
Not applicable	Not applicable	0.6 ton/ha	0 6 ton/ha	Not applicable	0.3 ton/ha
Not applicable	Not applicable	0.6 ton/ha	0.6 ton/ha	Not applicable	0.1 ton/ha
Not applicable	Not applicable	0.6 ton/ha	0.6 ton/ha	Not applicable	0 1 ton/ha
Not applicable	Not applicable	0.2 ton/ha	0.2 ton/ha	Not applicable	Not applicable
Not applicable	Not applicable	0.2 ton/ha	0.2 ton/ha	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
8 % of herd	8 % of herd	6 % of herd	8 % of herd	3 % of herd	3 % of herd
45 % of herd	45 % of herd	45 % of herd	45 % of herd	43 % of herd	43 % of herd
45 % of herd	45 % of herd	45 % of herd	45 % of herd	43 % of herd	43 % of herd
0 % of herd	0 % of herd	0 % of herd	0 % of herd	0 % of herd	0 % of herd
4 % of herd	4 % of herd	4 % of herd	4 % of herd	11 % of herd	11 % of herd
95%	95%	85%	85%	95%	95%

SO12	SO13	SO14	SO15	SO16	SO17
2	1	2	1	1	8
N-Gabiley	N-Hargeysa	S-Gabiley	SW-Hargeysa	SE-Hargeysa	Sheekh
West Galbeed	West Galbeed	West Galbeed	West Galbeed	West Galbeed	Tog-Dheer
2	3	2	3	3	1
1659 km2	7027 km2	2498 km2	4198 km2	2264 km2	3256 km2
40%	52%	60%	31%	17%	100%
43.83 ø	44.41 ø	43.60 ø	43.98 ø	44.47 ø	45.43 ø
10.09 ø	9.75 ø	9.73 ø	9.41 ø	9.05 ø	10.01 ø
0.1	0.1	0.2	0.2	0.1	0.1
Transitional Desert/Marginal Pasture Zone	Transitional Desert/Marginal Pasture Zone	Sorghum/Maize - Sesame Zone	Sorghum/Maize - Sesame Zone	Marginal Pasture Zone	Marginal Pasture Zone
Not or low importance	Not or low importance	Dominant	Dominant	Not or low importance	Not or low importance
Dominant	Not or low importance	Dominant	Dominant	Dominant	Not or low importance
Dominant	Not or low importance	Secundary importance	Secundary importance	Dominant	Not or low importance
Not or low importance	Not or low importance	Secundary importance	Not or low importance	Not or low importance	Not or low importance
Secundary importance	Not or low importance	Secundary importance	Secundary importance	Not or low importance	Not or low importance
Not applicable	Not applicable	0.6 ton/ha	0.6 ton/ha	Not applicable	Not applicable
0.3 ton/ha	Not applicable	0.6 ton/ha	0.6 ton/ha	0.3 ton/ha	Not applicable
0.1 ton/ha	Not applicable	0.2 ton/ha	0.2 ton/ha	0.1 ton/ha	Not applicable
2.1	2.1	2.2	2.2	1.1	2.1
No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)
Moderately Warm (20-25 øC)	Moderately Warm (20-25 øC)	Moderately Warm (20-25 øC)	Moderately Warm (20-25 øC)	Warm (> 25øC)	Moderately Warm (20-25 øC)
Arid (1-59 days of growing period)	Arid (1-59 days of growing period)	Dry semiarid (60-119 days of growing period)	Dry semiarid (60-119 days of growing period)	Arid (1-59 days of growing period)	Arid (1-59 days of growing period)
One or two short/unreliable growing periods	One or two short/unreliable growing periods	One or two short/unreliable growing periods	One or two short/unreliable growing periods	One or two short/unreliable growing periods	One or two short/unreliable growing periods
three planting seasons	no planting season)	three planting seasons	three planting seasons	three planting seasons	no planting season)
924 m	1092 m	1368 m	1272 m	1044 m	1140 m
1272 m	1500 m	1536 m	1380 m	1200 m	1332 m
456 m	264 m	1080 m	1044 m	948 m	840 m
288 m	228 m	108 m	84 m	60 m	132 m
24.4 øC	23.3 øC	21.7 øC	22.3 øC	23.8 øC	23.1 øC
27.2 øC	28.3 øC	23.4 øC	23.6 øC	24.2 øC	24.9 øC
22.3 øC	20.9 øC	20.7 øC	21.6 øC	22.7 øC	21.9 øC
1.7 øC	1.4 øC	0.8 øC	0.5 øC	0.4 øC	0.8 øC
Apr II	Apr I	Apr I	Apr I	May I	Apr I
Not applicable	Not applicable	Mar II	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	0.2 dekads	Not applicable	Not applicable	Not applicable
Apr III	Apr II	May I	May I	May II	Apr II
Not applicable	Not applicable	Jun II	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	0.1 dekads	Not applicable	Not applicable	Not applicable
1 dekads	1 dekads	3 dekads	3 dekads	1 dekads	1 dekads
Not applicable	Not applicable	10 dekads	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	0.2 dekads	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Aug I	Aug I	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Sep I
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	0.1 dekads
Not applicable	Not applicable	Sep I	Sep I	Not applicable	Not applicable
Not available	Not available	Not available	Not available	Not available	Not available
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Nov III
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	0.1 dekads
Not applicable	Not applicable	3 dekads	3 dekads	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	10 dekads
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	0.2 dekads
67 mm	67 mm	78 mm	78 mm	78 mm	67 mm
23 mm	23 mm	23 mm	23 mm	17 mm	23 mm
Medium-low	Medium-low	High-medium	High-medium	Low-medium	Medium-low
17%	17%	20%	20%	12%	17%
7 (class)	7 (class)	8 (class)	8 (class)	5 (class)	7 (class)
6%	6%	13%	13%	5%	6%
0.09 (index)	0.09 (index)	0.14 (index)	0.13 (index)	0.10 (index)	0.11 (index)
0.02 (index)	0.02 (index)	0.03 (index)	0.02 (index)	0.00 (index)	0.04 (index)

10 mm	6 mm	10 mm	4 mm	4 mm	12 mm
6 mm	8 mm	16 mm	10 mm	4 mm	10 mm
24 mm	24 mm	32 mm	30 mm	22 mm	24 mm
62 mm	60 mm	80 mm	70 mm	64 mm	84 mm
50 mm	50 mm	78 mm	66 mm	58 mm	72 mm
26 mm	34 mm	58 mm	62 mm	56 mm	28 mm
2 mm	20 mm	48 mm	40 mm	20 mm	16 mm
32 mm	46 mm	112 mm	92 mm	36 mm	34 mm
40 mm	42 mm	64 mm	62 mm	46 mm	42 mm
18 mm	20 mm	22 mm	22 mm	22 mm	40 mm
30 mm	16 mm	16 mm	16 mm	10 mm	22 mm
10 mm	6 mm	4 mm	2 mm	2 mm	14 mm
310 mm	332 mm	560 mm	476 mm	332 mm	398 mm
172 mm	172 mm	150 mm	186 mm	188 mm	152 mm
178 mm	178 mm	156 mm	176 mm	172 mm	144 mm
220 mm	220 mm	192 mm	216 mm	212 mm	180 mm
218 mm	212 mm	188 mm	206 mm	198 mm	176 mm
232 mm	228 mm	194 mm	212 mm	206 mm	206 mm
308 mm	326 mm	246 mm	284 mm	282 mm	324 mm
306 mm	322 mm	242 mm	280 mm	278 mm	320 mm
312 mm	330 mm	242 mm	280 mm	284 mm	342 mm
282 mm	270 mm	214 mm	246 mm	244 mm	250 mm
220 mm	218 mm	186 mm	208 mm	200 mm	182 mm
186 mm	182 mm	160 mm	178 mm	172 mm	148 mm
158 mm	154 mm	140 mm	152 mm	152 mm	134 mm
2772 mm	2812 mm	2308 mm	2604 mm	2566 mm	2558 mm
0.09 (index)	0.09 (index)	0.12 (index)	0.11 (index)	0.10 (index)	0.11 (index)
0.07 (index)	0.08 (index)	0.10 (index)	0.10 (index)	0.10 (index)	0.08 (index)
0.07 (index)	0.08 (index)	0.11 (index)	0.10 (index)	0.09 (index)	0.09 (index)
0.08 (index)	0.08 (index)	0.13 (index)	0.12 (index)	0.09 (index)	0.10 (index)
0.12 (index)	0.11 (index)	0.18 (index)	0.15 (index)	0.12 (index)	0.13 (index)
0.10 (index)	0.10 (index)	0.18 (index)	0.16 (index)	0.12 (index)	0.12 (index)
0.08 (index)	0.08 (index)	0.15 (index)	0.13 (index)	0.09 (index)	0.09 (index)
0.05 (index)	0.07 (index)	0.15 (index)	0.11 (index)	0.08 (index)	0.07 (index)
0.07 (index)	0.08 (index)	0.18 (index)	0.13 (index)	0.09 (index)	0.09 (index)
0.11 (index)	0.11 (index)	0.18 (index)	0.15 (index)	0.12 (index)	0.13 (index)
0.11 (index)	0.11 (index)	0.15 (index)	0.15 (index)	0.12 (index)	0.14 (index)
0.10 (index)	0.10 (index)	0.14 (index)	0.13 (index)	0.12 (index)	0.13 (index)
0.09 (index)	0.09 (index)	0.14 (index)	0.13 (index)	0.10 (index)	0.11 (index)
No crops	No crops	Sparsely cropped	Sparsely cropped	No crops	No crops
Not available	Not available	Not available	Not available	Not available	Not available
Not available	Not available	Not available	Not available	Not available	Not available
Sorghum	Not applicable	Sorghum	Sorghum	Sorghum	Not applicable
Cowpea	Not applicable	Maize	Maize	Cowpea	Not applicable
Vegetables	Not applicable	Cowpea	Cowpea	Not applicable	Not applicable
Not applicable	Not applicable	Vegetables	Vegetables	Not applicable	Not applicable
0.3 ton/ha	Not applicable	0.8 ton/ha	0.8 ton/ha	0.3 ton/ha	Not applicable
0.3 ton/ha	Not applicable	0.6 ton/ha	0.6 ton/ha	0.3 ton/ha	Not applicable
0.1 ton/ha	Not applicable	0.6 ton/ha	0.6 ton/ha	0.1 ton/ha	Not applicable
0.1 ton/ha	Not applicable	0.6 ton/ha	0.6 ton/ha	0.1 ton/ha	Not applicable
-4.0 ton/ha	Not applicable	0.2 ton/ha	0.2 ton/ha	Not applicable	Not applicable
-4.0 ton/ha	Not applicable	0.2 ton/ha	0.2 ton/ha	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
3 % of herd	3 % of herd	3 % of herd	3 % of herd	3 % of herd	2 % of herd
43 % of herd	43 % of herd	43 % of herd	43 % of herd	43 % of herd	43 % of herd
43 % of herd	43 % of herd	43 % of herd	43 % of herd	43 % of herd	42 % of herd
0 % of herd	0 % of herd	0 % of herd	0 % of herd	0 % of herd	0 % of herd
11 % of herd	11 % of herd	11 % of herd	11 % of herd	11 % of herd	14 % of herd
95%	95%	90%	90%	95%	95%

SO18	SO19	SO20	SO21	SO22	SO23
10	8	10	8	11	14
N-Oodweyne	N-Burco	S-Oodweyne	S-Burco	Buuhoodle	N-Ceel Afweyn
Tog-Dheer	Tog-Dheer	Tog-Dheer	Tog-Dheer	Tog-Dheer	Sanaag
2	2	2	2	1	2
3264 km2	4496 km2	4898 km2	11375 km2	6729 km2	3070 km2
40%	28%	60%	72%	100%	20%
45.01 ø	45.73 ø	45.01 ø	45.77 ø	46.68 ø	46.38 ø
9.63 ø	9.70 ø	9.03 ø	8.94 ø	8.48 ø	10.58 ø
0.1	0.1	0.1	0.1	0.1	0
Transitional Desert/Marginal Pasture Zone	Transitional Desert/Marginal Pasture Zone	Marginal Pasture Zone	Marginal Pasture Zone	Transitional Desert/Marginal Pasture Zone	Desert Zone
Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Dominant	Dominant	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Dominant	Dominant	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
0.3 ton/ha	0.3 ton/ha	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
2.1	2.1	1.1	1.1	1.1	1
No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)
Moderately Warm (20-25 øC)	Moderately Warm (20-25 øC)	Warm (> 25øC)	Warm (> 25øC)	Warm (> 25øC)	Warm (> 25øC)
Arid (1-59 days of growing period)	Arid (1-59 days of growing period)	Arid (1-59 days of growing period)	Arid (1-59 days of growing period)	Arid (1-59 days of growing period)	Hyperarid (0 days of growing period)
One or two short/unreliable growing periods	One or two short/unreliable growing periods	One or two short/unreliable growing periods	One or two short/unreliable growing periods	One or two short/unreliable growing periods	None (no growing period)
three planting seasons	three planting seasons	no planting season)	no planting season)	no planting season)	no planting season)
1128 m	1020 m	924 m	876 m	780 m	696 m
1468 m	1260 m	1032 m	1164 m	912 m	1584 m
900 m	876 m	840 m	708 m	624 m	108 m
156 m	120 m	60 m	96 m	84 m	396 m
23.1 øC	23.8 øC	24.4 øC	24.8 øC	26.2 øC	25.7 øC
24.5 øC	24.6 øC	24.9 øC	25.7 øC	28.2 øC	29.3 øC
21.0 øC	22.3 øC	23.7 øC	22.9 øC	24.4 øC	20.4 øC
0.9 øC	0.7 øC	0.4 øC	0.6 øC	0.5 øC	2.4 øC
May II	May I	May I	May II	May I	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
May III	May III	May II	May III	May II	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
1 dekads	1 dekads	1 dekads	1 dekads	1 dekads	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Sep I	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	0.1 dekads	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not available	Not available	Not available	Not available	Not available	Not available
Not applicable	Not applicable	Not applicable	Not applicable	Nov III	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	0.1 dekads	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	10 dekads	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	0.1 dekads	Not applicable
87 mm	87 mm	76 mm	76 mm	76 mm	74 mm
23 mm	23 mm	17 mm	17 mm	17 mm	17 mm
Medium-low	Medium-low	Low-medium	Low-medium	Low-medium	Low-medium
17%	17%	12%	12%	12%	12%
7 (class)	7 (class)	5 (class)	5 (class)	5 (class)	5 (class)
6%	6%	5%	5%	5%	3%
0.10 (index)	0.10 (index)	0.11 (index)	0.13 (index)	0.12 (index)	0.05 (index)
0.01 (index)	0.01 (index)	0.01 (index)	0.02 (index)	0.02 (index)	0.02 (index)

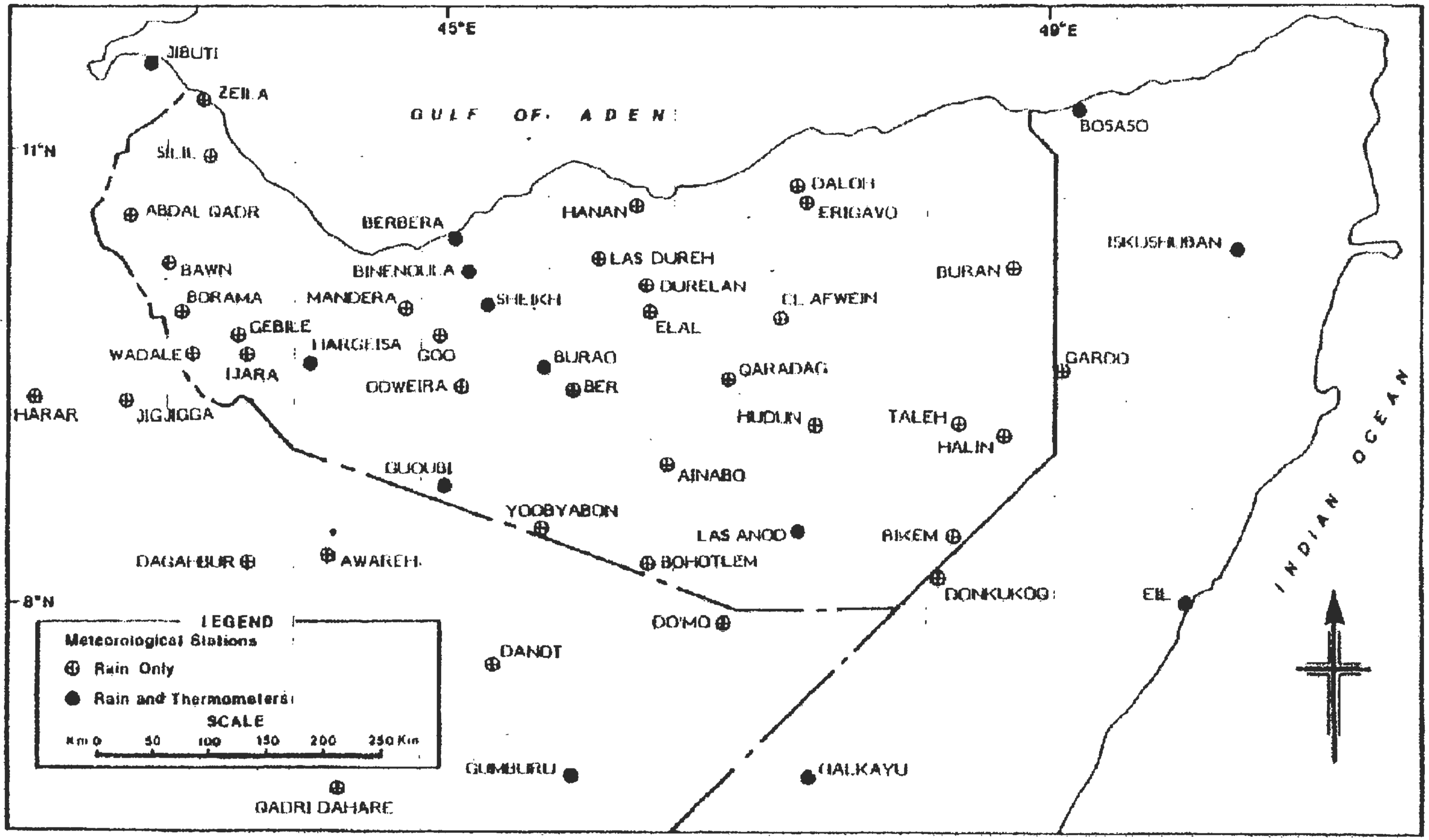
4 mm	6 mm	0 mm	2 mm	0 mm	12 mm
8 mm	4 mm	4 mm	0 mm	0 mm	6 mm
24 mm	14 mm	20 mm	8 mm	2 mm	16 mm
52 mm	44 mm	48 mm	34 mm	24 mm	38 mm
58 mm	60 mm	62 mm	76 mm	66 mm	42 mm
30 mm	22 mm	30 mm	22 mm	10 mm	22 mm
22 mm	12 mm	20 mm	12 mm	4 mm	4 mm
42 mm	20 mm	32 mm	16 mm	6 mm	18 mm
60 mm	38 mm	46 mm	36 mm	28 mm	36 mm
34 mm	24 mm	36 mm	34 mm	40 mm	8 mm
16 mm	14 mm	16 mm	16 mm	14 mm	10 mm
8 mm	6 mm	2 mm	2 mm	2 mm	6 mm
346 mm	284 mm	314 mm	258 mm	198 mm	216 mm
148 mm	160 mm	164 mm	168 mm	168 mm	152 mm
146 mm	142 mm	164 mm	152 mm	148 mm	140 mm
182 mm	178 mm	204 mm	180 mm	184 mm	178 mm
178 mm	172 mm	190 mm	178 mm	170 mm	178 mm
194 mm	198 mm	204 mm	196 mm	186 mm	208 mm
294 mm	298 mm	290 mm	272 mm	240 mm	316 mm
290 mm	288 mm	286 mm	266 mm	228 mm	316 mm
304 mm	308 mm	298 mm	282 mm	246 mm	338 mm
234 mm	236 mm	242 mm	230 mm	212 mm	250 mm
180 mm	174 mm	190 mm	174 mm	160 mm	178 mm
150 mm	142 mm	164 mm	148 mm	138 mm	136 mm
132 mm	132 mm	148 mm	144 mm	144 mm	134 mm
2430 mm	2414 mm	2542 mm	2390 mm	2212 mm	2526 mm
0.10 (index)	0.10 (index)	0.12 (index)	0.13 (index)	0.12 (index)	0.06 (index)
0.09 (index)	0.09 (index)	0 11 (index)	0.13 (index)	0 11 (index)	0.05 (index)
0.09 (index)	0.09 (index)	0.11 (index)	0.12 (index)	0.11 (index)	0.05 (index)
0.09 (index)	0.09 (index)	0.10 (index)	0 12 (index)	0.12 (index)	0.05 (index)
0.11 (index)	0.11 (index)	0.13 (index)	0.15 (index)	0.14 (index)	0.05 (index)
0.11 (index)	0.10 (index)	0.12 (index)	0.14 (index)	0.13 (index)	0.05 (index)
0.09 (index)	0.08 (index)	0.10 (index)	0.11 (index)	0.09 (index)	0.04 (index)
0.08 (index)	0.07 (index)	0.09 (index)	0.09 (index)	0.08 (index)	0.03 (index)
0.08 (index)	0.08 (index)	0.10 (index)	0.11 (index)	0.10 (index)	0.04 (index)
0.11 (index)	0.11 (index)	0.13 (index)	0.15 (index)	0.15 (index)	0.06 (index)
0.12 (index)	0.12 (index)	0.14 (index)	0.16 (index)	0.15 (index)	0.07 (index)
0.11 (index)	0.11 (index)	0.13 (index)	0.15 (index)	0.13 (index)	0.07 (index)
0.10 (index)	0.10 (index)	0.11 (index)	0.13 (index)	0.12 (index)	0.05 (index)
No crops	No crops	No crops	No crops	No crops	No crops
Not available	Not available	Not available	Not available	Not available	Not available
Not available	Not available	Not available	Not available	Not available	Not available
Sorghum	Sorghum	Not applicable	Not applicable	Not applicable	Not applicable
Vegetables	Vegetables	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
0.3 ton/ha	0.3 ton/ha	Not applicable	Not applicable	Not applicable	Not applicable
0.3 ton/ha	0.3 ton/ha	Not applicable	Not applicable	Not applicable	Not applicable
-4.0 ton/ha	-4.0 ton/ha	Not applicable	Not applicable	Not applicable	Not applicable
-4.0 ton/ha	-4.0 ton/ha	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
2 % of herd	2 % of herd	2 % of herd	2 % of herd	2 % of herd	3 % of herd
43 % of herd	43 % of herd	43 % of herd	43 % of herd	43 % of herd	62 % of herd
42 % of herd	42 % of herd	42 % of herd	42 % of herd	42 % of herd	28 % of herd
0 % of herd	0 % of herd	0 % of herd	0 % of herd	0 % of herd	0 % of herd
14 % of herd	14 % of herd	14 % of herd	14 % of herd	14 % of herd	6 % of herd
95%	95%	95%	95%	95%	95%

SO24	SO25	SO26	SO27	SO28	SO29	SO30
12	12	13	13	13	14	12
N-Ceerigaabo	C-Ceerigaabo	N-Badhan	CN-Badhan	CS-Badhan	S-Ceel Afweyn	SW-Ceerigaabo
Sanaag	Sanaag	Sanaag	Sanaag	Sanaag	Sanaag	Sanaag
4	4	4	4	4	2	4
2400 km2	5047 km2	2284 km2	3811 km2	404 km2	12260 km2	11798 km2
9%	20%	18%	31%	3%	60%	46%
47.30 ø	47.59 ø	48.57 ø	48.59 ø	48.59 ø	46.78 ø	47.75 ø
10.98 ø	10.79 ø	11.16 ø	10.88 ø	10.63 ø	10.05 ø	10.20 ø
0	0.1	0	0.1	0	0	0
Desert Zone	Marginal Pasture Zone	Desert Zone	Marginal Pasture Zone	Desert Zone	Desert Zone	Desert Zone
Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not or low importance	Dominant	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not or low importance	Dominant	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	0.3 ton/ha	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	0.1 ton/ha	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
1	3.1	1	3.1	2	2	2
No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)
Warm (> 25øC)	Moderately Cool (15-20 øC)	Warm (> 25øC)	Moderately Cool (15-20 øC)	Moderately Warm (20-25 øC)	Moderately Warm (20-25 øC)	Moderately Warm (20-25 øC)
Hyperarid (0 days of growing period)	Arid (1-59 days of growing period)	Hyperarid (0 days of growing period)	Arid (1-59 days of growing period)	Hyperarid (0 days of growing period)	Hyperarid (0 days of growing period)	Hyperarid (0 days of growing period)
None (no growing period)	One or two short/unreliable growing periods	None (no growing period)	One or two short/unreliable growing periods	None (no growing period)	None (no growing period)	None (no growing period)
no planting season)	two planting seasons	no planting season)	no planting season)	no planting season)	no planting season)	no planting season)
1080 m	1308 m	432 m	900 m	804 m	936 m	1056 m
1608 m	1740 m	948 m	1380 m	888 m	1584 m	1620 m
348 m	960 m	60 m	504 m	708 m	540 m	624 m
360 m	216 m	276 m	288 m	60 m	264 m	192 m
23.4 øC	22.1 øC	27.3 øC	24.5 øC	25.1 øC	24.3 øC	23.6 øC
27.8 øC	24.1 øC	29.5 øC	26.9 øC	25.7 øC	28.7 øC	26.2 øC
20.3 øC	19.5 øC	24.2 øC	21.6 øC	24.0 øC	20.4 øC	20.2 øC
2.2 øC	1.3 øC	1.7 øC	1.7 øC	0.4 øC	1.6 øC	1.2 øC
Not applicable	May I	Not applicable	Sep I	Not applicable	Not applicable	Not applicable
Mar II	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
0.4 dekads	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	May II	Not applicable	Sep II	Not applicable	Not applicable	Not applicable
May III	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
0.5 dekads	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	1 dekads	Not applicable	1 dekads	Not applicable	Not applicable	Not applicable
9 dekads	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
0.2 dekads	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not available	Not available	Not available	Not available	Not available	Not available	Not available
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
74 mm	71 mm	74 mm	71 mm	74 mm	71 mm	71 mm
17 mm	22 mm	17 mm	22 mm	17 mm	18 mm	18 mm
Low-medium	Low-medium	Low-medium	Low-medium	Low-medium	Low-medium	Low-medium
12%	11%	12%	11%	12%	11%	11%
5 (class)	5 (class)	5 (class)	5 (class)	5 (class)	5 (class)	5 (class)
3%	5%	3%	5%	3%	2%	2%
0.07 (index)	0.11 (index)	0.07 (index)	0.12 (index)	0.07 (index)	0.07 (index)	0.08 (index)
0.05 (index)	0.05 (index)	0.04 (index)	0.06 (index)	0.01 (index)	0.02 (index)	0.01 (index)

16 mm	20 mm	6 mm	8 mm	4 mm	12 mm	10 mm
10 mm	14 mm	4 mm	6 mm	4 mm	8 mm	8 mm
26 mm	38 mm	12 mm	16 mm	10 mm	18 mm	22 mm
36 mm	50 mm	12 mm	26 mm	16 mm	36 mm	28 mm
80 mm	98 mm	26 mm	48 mm	24 mm	60 mm	60 mm
52 mm	70 mm	14 mm	28 mm	14 mm	34 mm	36 mm
8 mm	12 mm	2 mm	6 mm	2 mm	6 mm	6 mm
26 mm	50 mm	8 mm	24 mm	12 mm	24 mm	24 mm
76 mm	140 mm	22 mm	54 mm	28 mm	58 mm	62 mm
6 mm	12 mm	4 mm	10 mm	6 mm	12 mm	10 mm
14 mm	18 mm	10 mm	12 mm	8 mm	12 mm	10 mm
4 mm	6 mm	4 mm	6 mm	4 mm	4 mm	4 mm
354 mm	526 mm	124 mm	246 mm	132 mm	264 mm	280 mm
152 mm	128 mm	142 mm	132 mm	134 mm	144 mm	138 mm
140 mm	116 mm	136 mm	122 mm	120 mm	132 mm	120 mm
180 mm	148 mm	174 mm	158 mm	154 mm	166 mm	154 mm
180 mm	146 mm	176 mm	156 mm	152 mm	162 mm	150 mm
208 mm	170 mm	202 mm	182 mm	178 mm	168 mm	172 mm
298 mm	238 mm	268 mm	238 mm	230 mm	268 mm	234 mm
306 mm	242 mm	290 mm	248 mm	232 mm	264 mm	228 mm
318 mm	250 mm	266 mm	250 mm	240 mm	282 mm	242 mm
246 mm	200 mm	234 mm	210 mm	206 mm	222 mm	204 mm
174 mm	140 mm	160 mm	144 mm	144 mm	160 mm	144 mm
130 mm	106 mm	116 mm	108 mm	108 mm	126 mm	112 mm
132 mm	108 mm	124 mm	114 mm	114 mm	126 mm	116 mm
2464 mm	1988 mm	2308 mm	2080 mm	2010 mm	2238 mm	2012 mm
0.07 (index)	0.12 (index)	0.08 (index)	0.13 (index)	0.08 (index)	0.08 (index)	0.09 (index)
0.07 (index)	0.10 (index)	0.08 (index)	0.12 (index)	0.07 (index)	0.07 (index)	0.08 (index)
0.07 (index)	0.10 (index)	0.07 (index)	0.12 (index)	0.07 (index)	0.07 (index)	0.08 (index)
0.06 (index)	0.09 (index)	0.06 (index)	0.11 (index)	0.06 (index)	0.06 (index)	0.07 (index)
0.09 (index)	0.11 (index)	0.07 (index)	0.11 (index)	0.06 (index)	0.07 (index)	0.08 (index)
0.08 (index)	0.12 (index)	0.06 (index)	0.12 (index)	0.08 (index)	0.08 (index)	0.08 (index)
0.08 (index)	0.10 (index)	0.05 (index)	0.11 (index)	0.05 (index)	0.06 (index)	0.08 (index)
0.05 (index)	0.09 (index)	0.04 (index)	0.10 (index)	0.05 (index)	0.05 (index)	0.08 (index)
0.08 (index)	0.10 (index)	0.04 (index)	0.11 (index)	0.05 (index)	0.06 (index)	0.08 (index)
0.09 (index)	0.14 (index)	0.07 (index)	0.14 (index)	0.07 (index)	0.08 (index)	0.08 (index)
0.10 (index)	0.14 (index)	0.08 (index)	0.15 (index)	0.08 (index)	0.09 (index)	0.09 (index)
0.08 (index)	0.13 (index)	0.08 (index)	0.14 (index)	0.08 (index)	0.09 (index)	0.09 (index)
0.07 (index)	0.11 (index)	0.07 (index)	0.12 (index)	0.07 (index)	0.07 (index)	0.08 (index)
No crops	No crops	No crops	No crops	No crops	No crops	No crops
Not available	Not available	Not available	Not available	Not available	Not available	Not available
Not available	Not available	Not available	Not available	Not available	Not available	Not available
Not applicable	Sorghum	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Cowpea	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	0.3 ton/ha	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	0.3 ton/ha	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	0.1 ton/ha	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	0.1 ton/ha	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
3 % of herd	3 % of herd	3 % of herd	3 % of herd	3 % of herd	3 % of herd	3 % of herd
62 % of herd	62 % of herd	62 % of herd	62 % of herd	62 % of herd	62 % of herd	62 % of herd
28 % of herd	28 % of herd	28 % of herd	28 % of herd	28 % of herd	28 % of herd	28 % of herd
0 % of herd	0 % of herd	0 % of herd	0 % of herd	0 % of herd	0 % of herd	0 % of herd
8 % of herd	8 % of herd	8 % of herd	8 % of herd	8 % of herd	8 % of herd	8 % of herd
95%	95%	95%	95%	95%	95%	95%

SO31	SO32	SO39	SO40	SO41	SO42	SO43
12	13	18	18	17	16	15
SE-Ceerigaabo	S-Badhan	N-Caynabo	S-Caynabo	Xudun	Taleex	Laascaanood
Sanaag	Sanaag	Sool	Sool	Sool	Sool	Sool
4	4	2	2	1	1	1
8570 km2	5972 km2	2476 km2	6130 km2	9094 km2	9049 km2	11068 km2
25%	48%	29%	71%	100%	100%	100%
48.25 ø	48.84 ø	46.32 ø	46.57 ø	47.62 ø	48.55 ø	47.68 ø
9.90 ø	10.11 ø	9.69 ø	9.14 ø	9.15 ø	9.20 ø	8.45 ø
0	0	0.1	0.1	0	0	0
Desert Zone	Desert Zone	Transitional Desert/Marginal Pasture Zone	Transitional Desert/Marginal Pasture Zone	Desert Zone	Desert Zone	Transitional Desert/Marginal
Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance	Not or low importance
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
1	1	2.1	1.1	1	1	1
No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappable)	No irrigation (or not mappab
Warm (> 25øC)	Warm (> 25øC)	Moderately Warm (20-25 øC)	Warm (> 25øC)	Warm (> 25øC)	Warm (> 25øC)	Warm (> 25øC)
Hyperarid (0 days of growing period)	Hyperarid (0 days of growing period)	Arid (1-59 days of growing period)	Arid (1-59 days of growing period)	Hyperarid (0 days of growing period)	Hyperarid (0 days of growing period)	Hyperarid (0 days of growing
None (no growing period)	None (no growing period)	One or two short/unreliable growing periods	One or two short/unreliable growing periods	None (no growing period)	None (no growing period)	None (no growing period)
no planting season)	no planting season)	no planting season)	no planting season)	no planting season)	no planting season)	no planting season)
1008 m	816 m	972 m	792 m	660 m	660 m	696 m
1104 m	984 m	1248 m	1032 m	1032 m	1032 m	936 m
840 m	576 m	756 m	600 m	492 m	384 m	432 m
72 m	108 m	156 m	108 m	144 m	168 m	132 m
23.9 øC	25.0 øC	24.1 øC	25.1 øC	25.9 øC	25.9 øC	25.7 øC
24.9 øC	26.4 øC	25.4 øC	28.3 øC	28.9 øC	27.6 øC	27.3 øC
23.3 øC	24.0 øC	22.4 øC	23.7 øC	23.7 øC	23.7 øC	24.3 øC
0.4 øC	0.6 øC	0.9 øC	0.8 øC	0.9 øC	1.0 øC	0.8 øC
Not applicable	Not applicable	May II	May I	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	May III	May II	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	1 dekads	1 dekads	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not available	Not available	Not available	Not available	Not available	Not available	Not available
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
74 mm	74 mm	67 mm	76 mm	74 mm	74 mm	74 mm
17 mm	17 mm	23 mm	17 mm	17 mm	17 mm	17 mm
Low-medium	Low-medium	Medium-low	Low-medium	Low-medium	Low-medium	Low-medium
12%	12%	17%	12%	12%	12%	12%
5 (class)	5 (class)	7 (class)	5 (class)	5 (class)	5 (class)	5 (class)
3%	3%	6%	5%	3%	3%	3%
0.08 (index)	0.07 (index)	0.10 (index)	0.09 (index)	0.07 (index)	0.07 (index)	0.08 (index)
0.01 (index)	0.01 (index)	0.01 (index)	0.01 (index)	0.01 (index)	0.01 (index)	0.02 (index)

8 mm	2 mm	10 mm	4 mm	4 mm	2 mm	0 mm
4 mm	2 mm	8 mm	2 mm	2 mm	2 mm	0 mm
14 mm	8 mm	16 mm	8 mm	8 mm	6 mm	2 mm
24 mm	18 mm	44 mm	24 mm	20 mm	20 mm	16 mm
48 mm	32 mm	82 mm	54 mm	44 mm	40 mm	40 mm
20 mm	10 mm	28 mm	18 mm	18 mm	8 mm	4 mm
4 mm	2 mm	6 mm	4 mm	2 mm	2 mm	0 mm
16 mm	10 mm	18 mm	10 mm	10 mm	8 mm	2 mm
40 mm	18 mm	50 mm	36 mm	34 mm	16 mm	16 mm
12 mm	10 mm	20 mm	20 mm	18 mm	20 mm	28 mm
8 mm	8 mm	14 mm	10 mm	6 mm	4 mm	8 mm
4 mm	4 mm	6 mm	2 mm	2 mm	4 mm	2 mm
200 mm	122 mm	278 mm	192 mm	184 mm	132 mm	118 mm
160 mm	154 mm	142 mm	156 mm	166 mm	172 mm	168 mm
126 mm	130 mm	132 mm	144 mm	144 mm	140 mm	146 mm
164 mm	168 mm	166 mm	180 mm	182 mm	184 mm	186 mm
158 mm	164 mm	160 mm	170 mm	172 mm	174 mm	174 mm
182 mm	198 mm	184 mm	190 mm	194 mm	202 mm	194 mm
238 mm	244 mm	268 mm	262 mm	252 mm	248 mm	238 mm
218 mm	226 mm	262 mm	264 mm	234 mm	214 mm	218 mm
240 mm	248 mm	282 mm	272 mm	258 mm	246 mm	240 mm
214 mm	226 mm	218 mm	224 mm	228 mm	232 mm	218 mm
152 mm	160 mm	160 mm	168 mm	168 mm	170 mm	162 mm
118 mm	120 mm	128 mm	138 mm	134 mm	134 mm	138 mm
126 mm	130 mm	126 mm	138 mm	144 mm	146 mm	148 mm
2084 mm	2184 mm	2228 mm	2294 mm	2272 mm	2262 mm	2230 mm
0.09 (index)	0.09 (index)	0.11 (index)	0.09 (index)	0.08 (index)	0.08 (index)	0.08 (index)
0 08 (index)	0.08 (index)	0.10 (index)	0 09 (index)	0.08 (index)	0.08 (index)	0.08 (index)
0.08 (index)	0.08 (index)	0.09 (index)	0.08 (index)	0.07 (index)	0.07 (index)	0.08 (index)
0.07 (index)	0.07 (index)	0.09 (index)	0.08 (index)	0.07 (index)	0.07 (index)	0.07 (index)
0.08 (index)	0.07 (index)	0.10 (index)	0.10 (index)	0.08 (index)	0.07 (index)	0.09 (index)
0.08 (index)	0.07 (index)	0.10 (index)	0.09 (index)	0.07 (index)	0.07 (index)	0.08 (index)
0.07 (index)	0.08 (index)	0.08 (index)	0.07 (index)	0.08 (index)	0.08 (index)	0.06 (index)
0.06 (index)	0.05 (index)	0.07 (index)	0.08 (index)	0.05 (index)	0.05 (index)	0.06 (index)
0.06 (index)	0.08 (index)	0.08 (index)	0.07 (index)	0.08 (index)	0.08 (index)	0.06 (index)
0.09 (index)	0.09 (index)	0.11 (index)	0.10 (index)	0.08 (index)	0.09 (index)	0.10 (index)
0.10 (index)	0.09 (index)	0.12 (index)	0.11 (index)	0.09 (index)	0.09 (index)	0 10 (index)
0.09 (index)	0.09 (index)	0.12 (index)	0.10 (index)	0 09 (index)	0.09 (index)	0.09 (index)
0.08 (index)	0.07 (index)	0.10 (index)	0.09 (index)	0.07 (index)	0 07 (index)	0.08 (index)
No crops	No crops	No crops	No crops	No crops	No crops	No crops
Not available	Not available	Not available	Not available	Not available	Not available	Not available
Not available	Not available	Not available	Not available	Not available	Not available	Not available
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
3 % of herd	3 % of herd	5 % of herd	5 % of herd	5 % of herd	5 % of herd	5 % of herd
82 % of herd	82 % of herd	40 % of herd	40 % of herd	40 % of herd	40 % of herd	40 % of herd
28 % of herd	28 % of herd	40 % of herd	40 % of herd	40 % of herd	40 % of herd	40 % of herd
0 % of herd	0 % of herd	0 % of herd	0 % of herd	0 % of herd	0 % of herd	0 % of herd
8 % of herd	8 % of herd	15 % of herd	15 % of herd	15 % of herd	15 % of herd	15 % of herd
95%	95%	95%	95%	95%	95%	95%



45°E
49°E
11°N
8°N
GULF OF ADEN
INDIAN OCEAN
JIBUTI
ZEILA
SILIL
ABDAL QADR
BAWN
BORAMA
GEBILE
WADALE
IJARA
HARGEISA
HARAR
JIGJIGGA
BERBERA
BINENOLA
MANDERA
SHEIKH
GOO
ODWEIRA
BURAO
BER
HANAN
LAS DUREH
DURELAN
ELAL
DALOH
ERIGAVO
EL AFWEIN
QARADAG
HUDUN
TALEH
HALIN
BURAN
GARDO
BOSASO
ISKUSHUBAN
AINABO
GUOUBI
YOOBYABON
LAS ANOD
BOHOTLEM
BIKEM
DONKUKOG
EIL
DO'MO
DAGAHBUR
AWAREH
DANOT
GUMBURU
GALKAYU
QADRI DAHARE
LEGEND
Meteorological Stations
Rain Only
Rain and Thermometers
SCALE
Km 0 50 100 150 200 250 Km

TAL 5

DETAILED MONTHLY RAINFALL RECORDS IN INCHES, 1944–50

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
1. WAJALE ... 1944	0·00	0·00	4·30	4·30	2·59	0·71	1·50	4·80	9·10	3·27	4·07	1·79	9·13	18·23	0·00	1·86	1·84	3·70	21·93	1944
1945	0·00	0·00	0·00	0·00	1·54	4·35	1·53	7·42	7·42	2·03	3·42	4·61	10·06	17·48	0·13	0·30	0·00	0·43	17·91	1945
1946	0·00	0·00	0·45	0·45	6·01	2·12	1·34	9·47	9·92	5·57	4·54	2·33	12·44	22·36	0·60	0·00	0·00	0·60	22·96	1946
1947	0·00	2·69	4·50	7·19	2·14	0·71	2·06	4·91	12·10	2·69	2·81	1·70	7·20	19·30	0·00	0·17	0·00	0·17	19·47	1947
1948	0·00	0·18	0·11	0·29	2·16	3·61	3·01	8·78	9·07	1·95	2·74	4·00	8·69	17·76	0·15	0·00	0·00	0·15	17·91	1948
1949	0·00	0·00	0·37	0·37	0·25	6·39	2·72	9·36	9·73	1·23	4·50	2·44	8·17	17·90	0·67	2·14	0·33	3·14	21·04	1949
1950	0·33	0·00	0·00	0·33	1·02	1·89	3·86	6·77	7·10	2·85	3·49	4·14	10·48	17·58	0·36	0·00	0·00	0·36	17·94	1950
Total, 7 years ...	0·33	2·87	9·73	12·93	15·71	19·78	16·02	51·51	64·44	19·59	25·57	21·01	66·17	130·61	1·91	4·47	2·17	8·55	139·16	
1944–50 Average ...	0·05	0·41	1·39	1·85	2·24	2·83	2·29	7·36	9·21	2·80	3·65	3·00	9·45	18·66	0·27	0·64	0·31	1·22	19·88	Average
Minimum	0·00	0·00	0·00	0·00	0·25	0·71	1·34	4·80	7·10	1·23	2·74	1·70	7·20	17·48	0·00	0·00	0·00	0·15	17·94	Minimum (1950)
Maximum	0·33	2·69	4·50	7·19	6·01	6·39	3·86	9·47	12·10	5·57	4·54	4·61	12·44	22·36	0·67	2·14	1·84	3·70	22·96	Maximum (1946)
2. GEBILE/IJARA ... 1944	0·00	0·00	3·50	3·50	1·24	0·73	2·26	4·23	7·73	1·65	1·13	2·51	5·29	13·02	0·00	0·00	0·00	0·00	13·02	1944
1945	0·00	0·00	0·00	0·00	0·00	3·40	6·64	10·04	10·04	1·84	5·03	2·00	8·87	18·91	0·00	1·79	0·00	1·79	20·70	1945
1946	0·00	0·00	0·00	0·00	3·48	1·60	1·82	6·90	6·90	3·47	4·77	0·92	9·16	16·06	2·11	0·00	0·00	2·11	18·17	1946
1947	0·00	0·00	4·07	4·07	0·89	0·30	1·72	2·91	6·98	1·70	4·07	4·30	10·07	17·05	0·00	0·70	0·00	0·70	17·75	1947
1948	0·43	1·05	0·73	2·21	1·42	1·52	3·28	6·22	8·43	1·82	1·62	1·46	4·90	13·33	0·73	0·00	0·00	0·73	14·06	1948
1949	0·00	0·00	0·03	0·03	0·20	6·71	0·78	7·69	7·72	1·63	5·49	1·11	8·23	15·95	0·85	1·83	0·66	3·34	19·29	1949
1950	0·21	0·00	0·00	0·21	0·00	2·88	2·01	4·89	5·10	6·02	6·31	3·41	15·74	20·84	0·00	0·00	0·00	0·00	20·84	1950
Total, 7 years ...	0·64	1·05	8·33	10·02	2·73	17·14	18·51	42·88	52·90	18·13	28·42	15·71	62·26	115·16	3·69	4·32	0·66	8·67	123·83	
1944–50 Average ...	0·09	0·15	1·19	1·43	1·03	2·45	2·64	6·13	7·56	2·59	4·06	2·24	8·89	16·45	0·53	0·62	0·09	1·24	17·69	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·30	0·78	2·91	5·10	1·63	1·13	0·92	4·90	13·02	0·00	0·00	0·00	0·00	13·02	Minimum (1944)
Maximum	0·43	1·05	4·07	4·07	3·48	6·71	6·64	10·04	10·04	6·02	6·31	4·30	15·74	20·84	2·11	1·83	0·66	3·34	20·84	Maximum (1950)
(Note : Gebile from 1.1.44–31.12.45 and from 1.6.50–31.12.50)																				
3. GO'O 1946	0·00	0·00	0·50	0·50	5·63	7·85	4·30	17·78	18·28	6·97	8·49	4·64	20·10	38·38	2·91	2·39	0·00	5·30	43·68	1946
1947	0·00	0·33	3·16	3·49	4·28	4·26	5·21	13·75	17·24	0·95	2·49	3·42	6·86	24·10	1·17	1·69	0·05	2·91	27·01	1947
1948	0·00	0·81	0·70	1·51	2·16	0·92	4·19	7·27	8·78	0·45	1·85	4·59	6·89	15·67	3·35	0·34	0·00	3·69	19·36	1948
1949	0·25	0·54	0·30	1·09	0·49	4·64	1·71	6·84	7·93	0·82	2·04	4·44	7·30	15·23	1·63	2·10	1·23	4·96	20·19	1949
1950	0·70	0·00	0·23	0·93	0·91	0·79	1·23	2·93	3·86	1·35	1·45	3·52	6·32	10·18	0·38	0·00	0·00	0·38	10·56	1950
Total, 5 years ...	0·95	1·68	4·89	7·52	13·47	18·46	16·64	48·57	56·09	10·54	16·32	20·61	47·47	103·56	9·44	6·52	1·28	17·24	120·80	
1946–50 Average ...	0·19	0·34	0·98	1·50	2·69	3·69	3·33	9·71	11·22	2·11	3·26	4·12	9·49	20·71	1·89	1·30	0·26	3·45	24·16	Average
Minimum	0·00	0·00	0·23	0·50	0·49	0·79	1·23	2·93	3·86	0·45	1·45	3·42	6·32	10·18	0·38	0·00	0·00	0·38	10·56	Minimum (1950)
Maximum	0·70	0·81	3·16	3·49	5·63	7·85	5·21	17·78	18·28	6·97	8·49	4·64	20·10	38·38	3·35	2·39	1·23	5·30	43·68	Maximum (1946)
I. ODWEINA ... 1944	0·00	0·00	0·56	0·56	0·14	1·85	0·36	2·35	2·91	0·34	0·55	0·64	1·53	4·44	0·05	0·05	0·00	0·10	4·54	1944
1945	0·00	0·00	0·00	0·00	0·00	2·58	0·71	3·29	3·29	1·43	0·34	1·89	3·66	6·95	0·00	0·12	0·00	0·12	7·07	1945
1946	0·00	0·00	0·00	0·00	2·60	0·78	1·06	4·44	4·44	0·73	1·04	3·22	4·99	9·43	0·18	0·00	0·00	0·18	9·61	1946
1947	0·00	0·00	1·29	1·29	2·29	0·76	0·50	3·55	4·84	1·81	0·11	1·15	3·07	7·91	0·14	0·00	0·14	0·28	8·19	1947
1948	0·00	0·00	0·00	0·00	3·22	0·59	4·88	8·69	8·69	0·08	0·12	0·54	0·74	9·43	1·57	0·16	0·00	1·73	11·16	1948
1949	0·00	0·00	0·05	0·05	0·00	2·93	1·93	4·86	4·91	0·41	0·99	2·36	3·76	8·67	0·00	0·00	0·90	0·90	9·57	1949
1950	0·28	0·00	0·00	0·28	0·15	0·11	1·41	1·67	1·95	0·34	1·25	3·07	4·66	6·61	0·00	0·00	0·00	0·00	6·61	1950
Total, 7 years ...	0·28	0·00	1·90	2·18	8·40	9·60	10·85	28·85	31·03	5·14	4·40	12·87	22·41	53·44	1·94	0·33	1·04	3·31	56·75	
1944–50 Average ...	0·04	0·00	0·27	0·31	1·20	1·37	1·55	4·12	4·43	0·73	0·63	1·84	3·20	7·63	0·28	0·05	0·15	0·47	8·11	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·11	0·36	1·67	1·95	0·08	0·11	0·54	0·74	4·44	0·00	0·00	0·00	0·00	4·54	Minimum (1944)
Maximum	0·28	0·00	1·29	1·29	3·22	2·93	4·88	8·69	8·69	1·81	1·25	3·22	4·99	9·43	1·57	0·16	0·90	1·73	11·16	Maximum (1948)

TABLE 5—*continued*

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
5. GUDUBI ... 1944	0·00	0·00	0·40	0·40	0·29	2·51	0·58	3·38	3·78	0·00	0·25	2·60	2·85	6·63	0·00	0·00	0·00	0·00	6·63	1944
1945	0·00	0·00	0·00	0·00	0·00	3·02	1·21	4·23	4·23	0·00	0·00	1·44	1·44	5·67	0·04	1·70	0·00	1·74	7·41	1945
1946	0·00	0·00	0·00	0·00	3·82	2·86	0·76	7·44	7·44	1·06	1·81	0·50	3·37	10·81	3·23	0·16	0·00	3·39	14·20	1946
1947	0·00	0·00	0·96	0·96	0·12	0·68	0·04	0·84	1·80	0·07	0·00	1·19	1·26	3·06	0·20	1·93	0·00	2·13	5·19	1947
1948	0·00	0·00	0·04	0·04	0·10	0·62	0·94	1·66	1·70	0·60	0·00	0·92	1·52	3·22	2·11	1·07	0·00	3·18	6·40	1948
1949	0·00	0·00	0·00	0·00	0·00	3·05	0·00	3·05	3·05	0·15	0·19	0·06	0·40	3·45	0·33	0·00	0·27	0·60	4·05	1949
1950	1·90	0·10	0·00	2·00	0·00	0·85	0·08	0·93	2·93	0·00	0·02	2·08	2·10	5·03	0·00	0·00	0·00	0·00	5·03	1950
Total, 7 years ...	1·90	0·10	1·40	3·40	4·33	13·59	3·61	21·53	24·93	1·88	2·27	8·79	12·94	37·87	5·91	4·86	0·27	11·04	48·91	
1944–50 Average ...	0·27	0·01	0·20	0·49	0·62	1·94	0·52	3·08	3·56	0·27	0·32	1·26	1·85	5·41	0·84	0·69	0·04	1·58	6·99	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·62	0·00	0·84	1·70	0·00	0·00	0·06	0·40	3·06	0·00	0·00	0·00	0·00	4·05	Minimum (1949)
Maximum	1·90	0·10	0·96	2·00	3·82	3·05	1·21	7·44	7·44	1·06	1·81	2·60	3·37	10·81	3·23	1·93	0·27	3·39	14·20	Maximum (1946)
6. DANOT 1944	0·00	0·00	0·12	0·12	0·00	2·64	0·00	2·64	2·76	0·05	0·00	1·38	1·43	4·19	2·05	0·00	0·07	2·12	6·31	1944
1945	0·00	0·00	0·00	0·00	0·00	5·11	0·00	5·11	5·11	0·07	0·00	0·40	0·47	5·58	0·62	0·60	0·00	1·22	6·80	1945
1946	0·00	0·00	0·00	0·00	4·51		0·00	4·51	4·51	0·03	0·27	0·10	0·40	4·91	3·50	1·92	0·03	5·45	10·36	1946
1947	0·00	0·00	0·71	0·71	2·43	4·75	0·00	7·18	7·89	0·00	0·00	0·08	0·08	7·97	1·15	0·10	0·15	1·40	9·37	1947
1948	0·03	0·00	1·68	1·71	3·43	3·28	0·00	6·71	8·42	0·00	0·00	1·67	1·67	10·09	1·97	0·65	0·04	2·66	12·75	1948
1949	0·00	0·00	0·05	0·05	0·30	0·81	0·00	1·11	1·16	0·07	0·03	0·53	0·63	1·79	1·38	0·11	0·04	1·53	3·32	1949
1950	0·03	0·00	0·00	0·03	0·00	8·53	0·00	8·53	8·56	0·00	0·00	0·69	0·69	9·25	4·20	0·33	0·00	4·53	13·78	1950
Total, 7 years ...	0·06	0·00	2·56	2·62	35·79		0·00	35·79	38·41	0·22	0·30	4·85	5·37	43·78	14·87	3·71	0·33	18·91	62·69	
1944–50 Average ...	0·01	0·00	0·37	0·37	5·11		0·00	5·11	5·49	0·03	0·04	0·69	0·77	6·25	2·12	0·53	0·05	2·70	8·96	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·81	0·00	1·11	1·16	0·00	0·00	0·08	0·40	1·79	0·62	0·00	0·00	1·22	3·32	Minimum (1949)
Maximum	0·03	0·00	1·68	1·71	3·43	8·53	0·00	8·53	8·56	0·07	0·27	1·67	1·67	10·09	4·20	1·92	0·15	5·45	13·78	Maximum (1950)
7. AINABO 1944	0·00	0·00	0·10	0·10	0·09	2·18	0·00	2·27	2·37	0·06	0·38	0·36	0·80	3·17	0·00	1·13	0·00	1·13	4·30	1944
1945	0·00	0·00	0·26	0·26	0·00	6·07	1·21	7·28	7·54	0·00	0·00	1·10	1·10	8·64	0·60	2·57	0·00	3·17	11·81	1945
1946	0·00	0·00	0·00	0·00	2·06	2·67	0·00	4·73	4·73	0·00	0·00	0·37	0·37	5·10	1·36	0·84	0·00	2·20	7·30	1946
1947	0·00	0·00	0·22	0·22	2·78	1·80	0·23	4·81	5·03	0·00	0·00	0·20	0·20	5·23	0·52	0·15	0·00	0·67	5·90	1947
1948	0·00	0·00	0·00	0·00	0·04	2·40	0·10	2·54	2·54	0·00	0·00	0·02	0·02	2·56	1·97	0·00	0·00	1·97	4·53	1948
1949	0·84	0·00	0·26	1·10	0·21	2·40	0·34	2·95	4·05	0·00	0·00	0·47	0·47	4·52	0·05	0·31	0·09	0·45	4·97	1949
1950	0·00	0·00	0·00	0·00	0·00	1·20	0·00	1·20	1·20	0·00	0·00	0·08	0·08	1·28	0·00	0·00	0·00	0·00	1·28	1950
Total, 7 years ...	0·84	0·00	0·84	1·68	5·18	18·72	1·88	25·78	27·46	0·06	0·38	2·60	3·04	30·50	4·50	5·00	0·09	9·59	40·09	
1944–50 Average ...	0·12	0·00	0·12	0·24	0·74	2·67	0·27	3·68	3·92	0·01	0·05	0·34	0·43	4·36	0·64	0·71	0·01	1·36	5·73	Average
Minimum	0·00	0·00	0·00	0·00	0·00	1·20	0·00	1·20	1·20	0·00	0·00	0·02	0·02	1·28	0·00	0·00	0·00	0·00	1·28	Minimum (1950)
Maximum	0·84	0·00	0·26	1·10	2·78	6·07	1·21	7·28	7·54	0·06	0·38	1·10	1·10	8·64	1·97	2·57	0·09	3·17	11·81	Maximum (1945)
8. YO'OBYABOH ... 1945	0·00	0·00	0·03	0·03	0·00	3·02	0·76	3·78	3·81	0·02	0·00	1·17	1·19	5·00	0·84	1·06	0·00	1·90	6·90	1945
1946	0·00	0·00	0·00	0·00	7·93	4·07	0·19	12·19	12·19	0·07	0·00	0·69	0·76	12·95	2·65	0·20	0·00	2·85	15·80	1946
1947	0·00	0·00	0·95	0·95	0·91	3·18	0·00	4·09	5·04	0·00	0·00	0·00	0·00	5·04	0·16	0·02	0·02	0·20	5·24	1947
1948	0·00	0·00	0·10	0·10	0·53	2·40	0·60	3·53	3·63	0·00	0·00	0·55	0·55	4·18	2·61	0·04	0·00	2·65	6·83	1948
1949	0·06	0·13	0·00	0·19	0·00	2·65	0·00	2·65	2·84	0·05	0·30	0·91	1·26	4·10	0·56	0·37	0·33	1·26	5·36	1949
1950	0·53	0·00	0·00	0·53	0·03	2·00	0·05	2·08	2·61	0·00	0·00	0·20	0·20	2·81	0·20	0·00	0·00	0·20	3·01	1950
Total, 6 years ...	0·59	0·13	1·08	1·80	9·40	17·32	1·60	28·32	30·12	0·14	0·30	3·52	3·96	34·08	7·02	1·69	0·35	9·06	43·14	
1945–50 Average ...	0·10	0·02	0·18	0·30	1·57	2·89	0·27	4·72	5·02	0·02	0·05	0·59	0·66	5·68	1·17	0·28	0·06	1·51	7·19	Average
Minimum	0·00	0·00	0·00	0·00	0·00	2·00	0·00	2·08	2·61	0·00	0·00	0·00	0·00	2·81	0·16	0·00	0·00	0·20	3·01	Minimum (1950)
Maximum	0·53	0·13	0·95	0·95	7·93	4·07	0·76	12·19	12·19	0·07	0·30	1·17	1·26	12·95	2·65	1·06	0·33	2·85	15·80	Maximum (1946)

TABL[illegible]—*continued*

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
9. BER 1944	0·00	0·00	0·40	0·40	0·22	2·00	0·00	2·22	2·62	0·15	0·35	0·70	1·20	3·82	0·00	0·00	0·00	0·00	3·82	1944
1945	0·00	0·00	0·00	0·00	0·00	5·13	0·75	5·88	5·88	0·00	0·00	0·85	0·85	6·73	0·15	0·35	0·00	0·50	7·23	1945
1946	0·15	0·00	0·00	0·15	0·60	1·47	0·88	2·95	3·10	0·00	0·11	1·55	1·66	4·76	2·75	0·00	0·00	2·75	7·51	1946
1947	0·00	0·00	0·00	0·00	1·67	0·95	0·29	2·91	2·91	0·00	0·00	0·65	0·65	3·56	0·00	0·49	0·00	0·49	4·05	1947
1948	0·00	0·00	0·00	0·00	1·98	1·10	1·86	4·94	4·94	0·00	0·00	0·35	0·35	5·29	? 1·80	0·00	0·00	1·80	7·09	1948
1949	0·00	0·00	0·00	0·00	0·00	3·07	4·40	7·47	7·47	0·00	1·40	1·29	2·69	10·16	0·03	0·00	0·50	0·53	10·69	1949
1950	0·20	0·00	0·00	0·20	0·00	0·17	0·50	0·67	0·87	0·00	0·00	1·97	1·97	2·84	0·00	0·00	0·00	0·00	2·84	1950
Total, 7 years ...	0·35	0·00	0·40	0·75	4·47	13·89	8·68	27·04	27·79	0·15	1·86	7·36	9·37	37·16	4·73	0·84	0·50	6·07	43·23	
1944–50 Average ...	0·05	0·00	0·06	0·11	0·64	1·98	1·24	3·86	3·97	0·02	0·27	1·05	1·34	5·31	0·68	0·12	0·07	0·87	6·18	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·17	0·00	0·67	0·87	0·00	0·00	0·35	0·35	2·84	0·00	0·00	0·00	0·00	2·84	Minimum (1950)
Maximum	0·20	0·00	0·40	0·40	1·98	5·13	4·40	7·47	7·47	0·15	1·40	1·97	2·69	10·16	2·75	0·49	0·50	2·75	10·69	Maximum (1949)
10. LAS ANOD ... 1944	0·00	0·00	0·00	0·00	0·50	1·00	0·00	1·50	1·50	0·00	0·00	0·88	0·88	2·38	0·33	0·56	0·07	0·96	3·34	1944
1945	0·00	0·00	0·00	0·00	0·00	2·62	0·57	3·19	3·19	0·00	0·00	0·27	0·27	3·46	0·11	0·00	0·00	0·11	3·57	1945
1946	0·15	0·00	0·00	0·15	1·72	3·90	0·04	5·66	5·81	0·02	0·00	0·02	0·04	5·85	2·36	0·00	0·03	2·39	8·24	1946
1947	0·00	0·00	0·00	0·00	1·78	1·89	0·00	3·67	3·67	0·00	0·00	0·16	0·16	3·83	0·56	? 2·02	0·40	2·98	6·81	1947
1948	0·00	0·00	0·25	0·25	0·00	0·00	0·00	0·00	0·25	0·00	0·00	0·00	0·00	0·25	4·18	0·00	0·00	4·18	4·43	1948
1949	0·00	0·00	0·00	0·00	0·00	0·29	0·00	0·29	0·29	0·00	0·00	1·00	1·00	1·29	0·62	0·00	0·56	1·18	2·47	1949
1950	0·00	0·00	0·00	0·00	0·00	1·23	0·00	1·23	1·23	0·00	0·00	3·10	3·10	4·33	0·40	0·00	0·00	0·40	4·73	1950
Total, 7 years ...	0·15	0·00	0·25	0·40	4·00	10·93	0·61	15·54	15·94	0·02	0·00	5·43	5·45	21·39	8·56	2·58	1·06	12·20	33·59	
1944–50 Average ...	0·02	0·00	0·04	0·06	0·57	1·56	0·09	2·22	2·28	0·00	0·00	0·78	0·78	3·06	1·22	0·37	0·15	1·74	4·80	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·25	0·00	0·00	0·00	0·00	0·25	0·11	0·00	0·00	0·11	2·47	Minimum (1949)
Maximum	0·15	0·00	0·25	0·25	1·78	3·90	0·57	5·66	5·81	0·02	0·00	3·10	3·10	5·85	4·18	2·02	0·56	4·18	8·24	Maximum (1946)
11. DONKUKOQ ... 1944	0·00	0·00	0·00	0·00	1·09	2·38	0·00	3·47	3·47	0·00	0·00	1·10	1·10	4·57	0·90	0·50	0·15	1·55	6·12	1944
1945	0·00	0·00	0·00	0·00	0·00	2·78	0·00	2·78	2·78	0·00	0·00	0·00	0·00	2·78	0·00	0·13	0·00	0·13	2·91	1945
1946	0·00	0·00	0·00	0·00	0·92	3·17	0·00	4·09	4·09	0·00	0·00	0·00	0·00	4·09	0·96	0·15	0·00	1·11	5·20	1946
1947	0·13	0·00	0·00	0·13	0·17	2·98	0·00	3·15	3·28	0·00	0·00	0·00	0·00	3·28	0·18	0·28	0·00	0·46	3·74	1947
1948	0·00	0·30	0·12	0·42	0·80	0·78	0·30	1·88	2·30	0·00	0·00	0·00	0·00	2·30	1·40	0·00	0·00	1·40	3·70	1948
Total, 5 years ...	0·13	0·30	0·12	0·55	2·98	12·09	0·30	15·37	15·92	0·00	0·00	1·10	1·10	17·02	3·44	1·06	0·15	4·65	21·67	
1944–48 Average ...	0·03	0·06	0·02	0·11	0·60	2·42	0·06	3·07	3·18	0·00	0·00	0·22	0·22	3·40	0·69	0·21	0·03	0·93	4·33	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·78	0·00	1·88	2·30	0·00	0·00	0·00	0·00	2·30	0·00	0·00	0·00	0·13	2·91	Minimum (1945)
Maximum	0·13	0·30	0·12	0·42	1·09	3·17	0·30	4·09	4·09	0·00	0·00	1·10	1·10	4·57	1·40	0·50	0·15	1·55	6·12	Maximum (1944)
12. AWAREH ... 1944	0·00	0·00	1·02	1·02	0·41	4·25	0·00	4·66	5·68	0·36	0·00	1·45	1·81	7·49	0·78	0·60	0·40	1·78	9·27	1944
1945	0·00	0·00	0·00	0·00	0·20	13·80	1·10	15·10	15·10	0·00	0·00	0·92	0·92	16·02	1·18	2·20	0·00	3·38	19·40	1945
1946	0·00	0·00	0·00	0·00	4·58	0·84	0·69	6·11	6·11	0·10	0·40	1·92	2·42	8·53	3·16	0·08	0·00	3·24	11·77	1946
1947	0·00	0·00	0·95	0·95	1·70	3·49	0·65	5·84	6·79	0·00	0·10	0·36	0·46	7·25	1·90	0·17	0·00	2·07	9·32	1947
1948	0·00	0·00	0·82	0·82	2·62	3·79	0·00	6·41	7·23	0·10	0·00	1·95	2·05	9·28	5·35	0·30	0·12	5·77	15·05	1948
1949	0·00	0·00	0·60	0·60	0·10	2·99	0·19	3·28	3·88	0·00	0·41	0·40	0·81	4·69	3·44	0·69	0·70	4·83	9·52	1949
1950	0·18	0·00	0·10	0·28	0·80	1·60	0·00	2·40	2·68	0·00	0·00	0·93	0·93	3·61	0·40	0·00	0·00	0·40	4·01	1950
Total, 7 years ...	0·18	0·00	3·49	3·67	10·41	30·76	2·63	43·80	47·47	0·56	0·91	7·93	9·40	56·87	16·21	4·04	1·22	21·47	78·34	
1944–50 Average ...	0·03	0·00	0·50	0·52	1·49	4·39	0·38	6·26	6·78	0·08	0·13	1·13	1·34	8·12	2·31	0·58	0·17	3·07	11·19	Average
Minimum	0·00	0·00	0·00	0·00	0·10	0·84	0·00	2·40	2·68	0·00	0·00	0·36	0·46	3·61	0·40	0·00	0·00	0·40	4·01	Minimum (1950)
Maximum	0·18	0·00	1·02	1·02	4·58	13·80	1·10	15·10	15·10	0·36	0·41	1·95	2·42	16·02	5·35	2·20	0·70	5·77	19·40	Maximum (1945)

TABLE 5—*continued*

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
13. GARDO 1944	0·00	0·00	0·00	0·00	0·10	1·35	0·00	1·45	1·45	0·41	0·00	0·10	0·51	1·96	0·00	0·20	0·05	0·25	2·21	1944
1945	0·00	0·01	0·06	0·07	0·09	1·55	1·06	2·70	2·77	0·02	0·00	0·43	0·45	3·22	0·00	0·00	0·00	0·00	3·22	1945
1946	0·28	0·00	0·00	0·28	2·00	2·40	0·70	5·10	5·38	0·00	0·00	0·00	0·00	5·38	0·30	0·70	0·00	1·00	6·38	1946
1947	0·00	0·00	0·00	0·00	1·14	1·47	0·10	2·71	2·71	0·00	0·00	0·00	0·00	2·71	0·00	0·05	—	0·05	2·76	1947
1948	0·00	0·00	0·50	0·50	0·51	1·89	0·00	2·40	2·90	0·00	0·00	0·29	0·29	3·19	0·75	0·00	0·00	0·75	3·94	1948
1949	0·00	0·00	0·81	0·81	0·00	2·40	0·60	3·00	3·81	0·00	0·00	2·34	2·34	6·15	0·00	0·53	0·00	0·53	6·68	1949
Total, 6 years ...	0·28	0·01	1·37	1·66	3·84	11·06	2·46	17·36	19·02	0·43	0·00	3·16	3·59	22·61	1·05	1·48	0·05	2·58	25·19	
1944–49 Average ...	0·05	0·00	0·23	0·28	0·64	1·84	0·41	2·89	3·17	0·07	0·00	0·53	0·60	3·77	0·18	0·25	0·01	0·43	4·20	Average
Minimum	0·00	0·00	0·00	0·00	0·00	1·35	0·00	1·45	1·45	0·00	0·00	0·00	0·00	1·96	0·00	0·00	0·00	0·00	2·21	Minimum (1944)
Maximum	0·28	0·01	0·81	0·81	2·00	2·40	1·06	5·10	5·38	0·41	0·00	2·34	2·34	6·15	0·75	0·70	0·05	1·00	6·68	Maximum (1949)
14. BURAN 1945	0·00	0·00	0·00	0·00	0·00	1·42	1·23	2·65	2·65	0·00	0·00	0·00	0·00	2·65	0·00	0·00	0·00	0·00	2·65	1945
1946	0·00	0·00	0·00	0·00	1·80	0·00	0·47	2·27	2·27	0·00	0·00	0·41	0·41	2·68	0·24	0·86	0·00	1·10	3·78	1946
1947	0·00	0·00	0·00	0·00	0·00	1·99	0·09	2·08	2·08	0·00	0·00	0·07	0·07	2·15	0·00	0·00	0·00	0·00	2·15	1947
1948	0·00	0·00	0·17	0·17	0·21	2·02	0·08	2·31	2·48	0·00	0·00	1·02	1·02	3·50	0·55	0·00	0·00	0·55	4·05	1948
1949	0·00	0·00	0·56	0·56	0·00	0·58	0·00	0·58	1·14	0·00	0·00	0·80	0·80	1·94	0·04	0·00	0·00	0·04	1·98	1949
1950	0·94	0·00	0·00	0·94	0·00	0·00	0·31	0·31	1·25	0·00	0·00	0·12	0·12	1·37	0·00	0·15	0·00	0·15	1·52	1950
Total, 6 years ...	0·94	0·00	0·73	1·67	2·01	6·01	2·18	10·20	11·87	0·00	0·00	2·42	2·42	14·29	0·83	1·01	0·00	1·84	16·13	
1945–50 Average ...	0·16	0·00	0·12	0·28	0·34	1·00	0·36	1·70	1·98	0·00	0·00	0·40	0·40	2·38	0·14	0·17	0·00	0·31	2·69	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·31	1·14	0·00	0·00	0·00	0·00	1·37	0·00	0·00	0·00	0·00	1·52	Minimum (1950)
Maximum	0·94	0·00	0·56	0·94	1·80	2·02	1·23	2·65	2·65	0·00	0·00	1·02	1·02	3·50	0·55	0·86	0·00	1·10	4·05	Maximum (1948)
15. HUDUN ... 1944	0·00	0·00	0·00	0·00	0·09	0·40	0·00	0·49	0·49	0·32	0·00	0·40	0·72	1·21	0·00	1·26	0·15	1·41	2·62	1944
1945	0·00	0·00	0·00	0·00	0·00	3·88	2·20	6·08	6·08	0·00	0·00	0·24	0·24	6·32	0·25	0·23	0·00	0·48	6·80	1945
1946	0·00	0·00	0·00	0·00	0·09	2·25	0·00	2·34	2·34	0·00	0·00	0·00	0·00	2·34	1·85	0·00	0·00	1·85	4·19	1946
1947	0·00	0·00	0·09	0·09	0·60	2·80	0·22	3·62	3·71	0·00	0·00	0·00	0·00	3·71	1·27	0·00	0·15	1·42	5·13	1947
1948	0·00	0·00	0·29	0·29	0·00	1·18	0·58	1·76	2·05	0·00	0·00	0·24	0·24	2·29	0·98	0·00	0·00	0·98	3·27	1948
1949	0·00	0·00	0·11	0·11	0·00	0·66	0·66	1·32	1·43	0·00	0·00	1·92	1·92	3·35	0·12	0·00	0·00	0·12	3·47	1949
1950	0·03	0·00	0·00	0·03	0·00	1·56	0·00	1·56	1·59	0·00	0·00	0·77	0·77	2·36	0·00	0·08	0·00	0·08	2·44	1950
Total, 7 years ...	0·03	0·00	0·49	0·52	0·78	12·73	3·66	17·17	17·69	0·32	0·00	3·57	3·89	21·58	4·47	1·57	0·30	6·34	27·92	
1944–50 Average ...	0·00	0·00	0·07	0·07	0·11	1·82	0·52	2·45	2·53	0·05	0·00	0·51	0·56	3·09	0·64	0·22	0·04	0·91	3·99	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·40	0·00	0·49	0·49	0·00	0·00	0·00	0·00	1·21	0·00	0·00	0·00	0·08	2·44	Minimum (1950)
Maximum	0·03	0·00	0·29	0·29	0·60	3·88	2·20	6·08	6·08	0·32	0·00	1·92	1·92	6·32	1·85	1·26	0·15	1·85	6·80	Maximum (1945)
16. DO'MO 1944	0·00	0·00	0·00	0·00	0·80	3·09	0·00	3·89	3·89	0·30	0·00	1·15	1·45	5·34	3·04	1·20	0·00	4·24	9·58	1944
1945	0·00	0·00	0·00	0·00	0·00	4·15	1·24	5·39	5·39	0·00	0·00	0·00	0·00	5·39	0·10	0·10	0·00	0·20	5·59	1945
1946	0·00	0·00	0·00	0·00	1·91	2·55	0·00	4·46	4·46	0·00	0·00	0·16	0·16	4·62	1·35	0·20	0·00	1·55	6·17	1946
1947	0·00	0·00	0·00	0·00	3·00	3·25	0·00	6·25	6·25	0·00	0·00	0·00	0·00	6·25	2·90	0·40	0·00	3·30	9·55	1947
1948	0·00	0·00	0·62	0·62	0·35	3·53	0·00	3·88	4·50	0·00	0·00	0·28	0·28	4·78	1·82	0·18	0·00	2·00	6·78	1948
1949	0·10	0·00	0·00	0·10	0·00	5·60	0·00	5·60	5·70	0·00	0·00	0·00	0·00	5·70	2·04	0·27	0·10	2·41	8·11	1959
1950	0·00	0·00	0·00	0·00	0·00	0·11	0·00	0·11	0·11	0·00	0·00	0·95	0·95	1·06	0·50	0·00	0·00	0·50	1·56	1950
Total, 7 years ...	0·10	0·00	0·62	0·72	6·06	22·28	1·24	29·58	30·30	0·30	0·00	2·54	2·84	33·14	11·75	2·35	0·10	14·20	47·34	
1944–50 Average ...	0·01	0·00	0·09	0·10	0·87	3·18	0·18	4·23	4·33	0·04	0·00	0·36	0·41	4·73	1·68	0·34	0·01	2·03	6·76	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·11	0·00	0·11	0·11	0·00	0·00	0·00	0·00	1·06	0·10	0·00	0·00	0·20	1·56	Minimum (1950)
Maximum	0·10	0·00	0·62	0·62	3·00	5·60	1·24	6·25	6·25	0·30	0·00	1·15	1·45	6·25	3·04	1·20	0·10	4·24	9·58	Maximum (1944)

TABLE 5—*continued*

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
17. QARADAG ... 1945	0·00	0·00	0·00	0·00	0·00	2·10	0·20	2·30	2·30	0·00	0·00	0·15	0·15	2·45	0·00	0·00	0·00	0·00	2·45	1945
1946	0·55	0·00	0·00	0·55	1·65	0·25	0·30	2·20	2·75	0·00	0·50	0·65	1·15	3·90	1·05	1·15	0·00	2·20	6·10	1946
1947	0·00	0·00	0·84	0·84	0·74	1·17	0·31	2·22	3·06	0·00	0·00	0·00	0·00	3·06	0·00	2·50	0·00	2·50	5·56	1947
1948	0·00	0·00	0·00	0·00	3·53	0·55	0·00	4·08	4·08	0·00	0·00	0·00	0·00	4·08	0·65	0·00	0·00	0·65	4·73	1948
1949	0·50	0·00	0·00	0·50	0·00	1·62	0·16	1·78	2·28	0·00	0·00	0·60	0·60	2·28	0·00	0·40	0·00	0·40	3·28	1949
1950	0·00	0·00	0·00	0·00	0·00	0·00	0·90	0·90	0·90	0·00	0·00	0·30	0·30	1·20	0·00	0·00	0·00	0·00	1·20	1950
Total, 6 years ...	1·05	0·00	0·84	1·89	5·92	5·69	1·87	13·48	15·37	0·00	0·50	1·70	2·20	17·57	1·60	4·05	0·00	5·75	23·32	
1945-50 Average ...	0·18	0·00	0·14	0·32	0·99	0·95	0·31	2·24	2·56	0·00	0·08	0·28	0·37	2·93	0·27	0·68	0·00	0·96	3·89	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·90	0·90	0·00	0·00	0·00	0·00	1·20	0·00	0·00	0·00	0·00	1·20	Minimum (1950)
Maximum	0·55	0·00	0·84	0·84	3·53	2·10	0·90	4·08	4·08	0·00	0·50	0·65	1·15	4·08	1·05	2·50	0·00	2·50	6·10	Maximum (1946)
18. BIHEN ... (Nogal) ... 1945	0·00	0·00	0·00	0·00	0·00	14·66	3·86	18·52	18·52	0·00	0·00	0·00	0·00	18·25	0·00	0·37	0·00	0·37	18·89	1945
1946	0·36	0·00	0·00	0·36	0·09	0·32	0·00	0·41	0·77	0·00	0·00	0·09	0·09	0·86	3·30	0·00	0·00	3·30	4·16	1946
1947	0·00	0·00	0·00	0·00	0·20	0·38	0·00	0·58	0·58	0·00	0·00	0·00	0·00	0·58	0·00	0·00	0·00	0·00	0·58	1947
1948	0·00	0·30	0·00	0·30	0·30	1·58	0·00	1·88	2·18	0·00	0·00	0·00	0·00	2·18	1·10	0·10	0·00	1·20	3·38	1948
1949	0·00	0·00	0·00	0·00	0·00	0·32	0·00	0·32	0·32	0·00	0·00	0·00	0·00	0·32	0·00	0·65	0·00	0·65	0·97	1949
1950	0·00	0·00	0·00	0·00	0·00	2·10	0·00	2·10	2·10	0·00	0·00	0·00	0·00	2·10	0·00	0·00	0·00	0·00	2·10	1950
Total, 6 years ...	0·36	0·30	0·00	0·66	0·59	19·36	3·86	23·81	24·47	0·00	0·00	0·09	0·09	24·56	4·40	1·12	0·00	5·52	30·08	
1945-50 Average ...	0·06	0·05	0·00	0·11	0·10	3·23	0·64	(3·97)	(4·08)	0·00	0·00	0·02	0·02	(4·09)	0·73	0·19	0·00	0·92	5·01	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·32	0·00	0·32	0·32	0·00	0·00	0·00	0·00	0·32	0·00	0·00	0·00	0·00	0·58	Minimum (1947)
Maximum	0·36	0·30	0·00	0·36	0·30	14·66	3·86	18·52	18·52	0·00	0·00	0·09	0·09	18·52	3·30	0·65	0·00	3·30	18·89	Maximum (1945)
19. EL AFWEIN ... 1944	0·00	0·00	0·40	0·40	1·78	1·20	?	? 2·98	3·38	0·00	0·00	0·77	0·77	4·15	0·00	1·34	0·27	1·61	5·76	1944
1945	0·00	0·00	0·00	0·00	0·00	2·41	1·97	4·38	4·38	0·00	0·00	0·32	0·32	4·70	0·00	0·96	0·00	0·96	5·66	1945
1946	1·00	0·00	0·00	1·00	0·30	0·68	0·06	1·04	2·04	0·00	0·23	0·16	0·39	2·43	2·66	0·00	0·00	2·66	5·09	1946
1947	0·00	0·02	0·00	0·02	0·54	3·10	0·74	4·38	4·40	0·00	0·00	0·85	0·85	5·25	0·71	0·98	0·00	1·69	6·94	1947
1948	0·00	0·00	0·09	0·09	5·77	0·00	0·00	5·77	5·86	0·00	0·00	0·45	0·45	6·31	0·55	0·35	0·00	0·90	7·21	1948
1949	0·68	0·00	0·07	0·75	0·06	1·16	1·98	3·20	3·95	0·00	0·15	0·35	0·50	4·45	0·00	0·00	0·25	0·25	4·70	1949
1950	1·35	0·00	0·00	1·35	0·00	0·06	0·48	0·54	1·89	0·00	0·00	0·21	0·21	2·10	0·00	0·00	0·00	0·00	2·10	1950
Total, 7 years ...	3·03	0·02	0·56	3·61	8·45	8·61	5·23	22·29	25·90	0·00	0·38	3·11	3·49	29·39	3·92	3·63	0·52	8·07	37·46	
1944-50 Average ...	0·43	0·00	0·08	0·52	1·21	1·23	0·75	3·19	3·70	0·00	0·05	0·44	0·50	4·20	0·56	0·52	0·07	1·15	5·35	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·54	1·89	0·00	0·00	0·16	0·21	2·10	0·00	0·00	0·00	0·00	2·10	Minimum (1950)
Maximum	1·35	0·02	0·40	1·35	5·77	3·10	1·98	4·38	5·86	0·00	0·23	0·85	0·85	6·31	2·66	1·34	0·27	2·66	7·21	Maximum (1948)
20. (HALIN) TALEH 1944	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·95	0·95	0·95	0·50	0·20	0·00	0·70	1·65	1944
1945	0·00	0·00	0·00	0·00	0·00	2·45	0·50	2·95	2·95	0·00	0·00	0·64	0·64	3·59	0·00	0·00	0·00	0·00	3·59	1945
1946	0·05	0·00	0·00	0·05	1·84	0·21	0·95	3·00	3·05	0·00	0·00	0·09	0·09	3·14	1·75	0·00	0·00	1·75	4·89	1946
1947	0·00	0·00	0·00	0·00	0·21	1·43	0·00	1·64	1·64	0·00	0·00	0·21	0·21	1·85	0·05	0·00	0·00	0·05	1·90	1947
1948	0·00	0·00	0·30	0·30	0·06	2·06	0·61	2·73	3·03	0·00	0·00	0·43	0·43	3·46	1·61	0·00	0·00	1·61	5·07	1948
1949	0·05	0·00	0·13	0·18	0·00	2·42	0·00	2·42	2·60	0·00	0·00	0·42	0·42	3·02	0·23	1·14	0·00	1·37	4·39	1949
1950	0·00	0·00	0·00	0·00	0·00	0·41	0·00	0·41	0·41	0·00	0·00	0·07	0·07	0·48	0·00	0·00	0·00	0·00	0·48	1950
Total, 7 years ...	0·10	0·00	0·43	0·53	2·11	8·98	2·06	13·15	13·68	0·00	0·00	2·81	2·81	16·49	4·14	1·34	0·00	5·48	21·97	
1944-50 Average ...	0·01	0·00	0·06	0·08	0·30	1·28	0·29	1·88	1·95	0·00	0·00	0·40	0·40	2·36	0·59	0·19	0·00	0·78	3·14	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·21	0·00	0·41	0·00	0·00	0·00	0·07	0·07	0·48	0·00	0·00	0·00	0·00	0·48	Minimum (1950)
Maximum	0·05	0·00	0·30	0·30	1·84	2·45	0·95	3·00	3·05	0·00	0·00	0·95	0·95	3·59	1·75	1·14	0·00	1·75	5·07	Maximum (1948)

NOTE.—Halin 1.1.44—31.12.44

TABLE 5—*continued*

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
21. HANAN ... 1944	0·00	0·00	0·00	0·00	0·00	1·00	0·00	1·00	1·00	0·40	0·00	0·42	0·82	1·82	0·00	0·00	5·43	5·43	7·25	1944
1945	0·00	0·00	0·00	0·00	0·00	1·05	0·00	1·05	1·05	0·00	0·00	0·00	0·00	1·05	0·00	0·00	0·00	0·00	1·05	1945
1946	0·13	0·00	0·00	0·13	0·00	0·00	0·00	0·00	0·13	0·00	0·10	0·00	0·10	0·23	1·60	0·00	0·00	1·60	1·83	1946
1947	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	1947
1948	0·25	0·00	0·60	0·85	0·48	1·50	0·00	1·98	2·83	0·00	0·00	0·00	0·00	2·83	0·15	0·00	0·00	0·15	2·98	1948
Total, 5 years ...	0·38	0·00	0·60	0·98	0·48	3·55	0·00	4·03	5·01	0·40	0·10	0·42	0·92	5·93	1·75	0·00	5·43	7·18	13·11	
1944–48 Average ...	0·08	0·00	0·12	0·20	0·10	0·71	0·00	0·81	1·00	0·08	0·02	0·08	0·18	1·19	0·35	0·00	1·09	1·44	2·62	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	Minimum (1947)
Maximum	0·25	0·00	0·60	0·85	0·48	1·50	0·00	1·98	2·83	0·40	0·10	0·42	0·82	2·83	1·60	0·00	5·43	5·43	7·25	Maximum (1944)
22. DUR ELAN ... 1944	0·00	0·00	0·20	0·20	0·00	2·00	0·00	2·00	2·20	0·00	0·00	0·77	0·77	2·97	0·00	0·00	0·90	0·90	3·87	1944
1945	0·00	0·00	0·00	0·00	0·00	4·33	0·95	5·28	5·28	0·00	0·17	0·22	0·39	5·67	0·00	0·00	0·00	0·00	5·67	1945
1946	0·03	0·00	0·06	0·09	1·26	0·68	0·00	1·94	2·03	0·00	0·00	0·29	0·29	2·32	0·00	0·00	0·04	0·04	2·36	1946
1947	0·00	0·18	0·00	0·18	0·22	0·93	0·00	1·15	1·33	0·00	0·05	0·18	0·23	1·56	0·00	0·13	0·00	0·13	1·69	1947
1948	0·00	0·00	0·85	0·85	4·28	0·10	0·00	4·38	5·23	0·00	0·00	0·00	0·00	5·23	0·71	0·00	0·00	0·71	5·94	1948
Total, 5 years ...	0·03	0·18	1·11	1·32	5·76	8·04	0·95	14·75	16·07	0·00	0·22	1·46	1·68	17·75	0·71	0·13	0·94	1·78	19·53	
1944–48 Average ...	0·01	0·04	0·22	0·26	1·15	1·61	0·19	2·95	3·21	0·00	0·04	0·29	0·34	3·55	0·14	0·03	0·19	0·36	3·91	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·10	0·00	1·15	1·33	0·00	0·00	0·00	0·00	1·56	0·00	0·00	0·00	0·00	1·69	Minimum (1947)
Maximum	0·03	0·18	0·85	0·85	4·28	4·33	0·95	5·28	5·28	0·00	0·17	0·77	0·77	5·67	0·71	0·13	0·90	0·90	5·94	Maximum (1945)
23. BAWN 1944	0·00	0·00	0·90	0·90	1·91	0·15	0·30	2·36	3·26	0·50	1·60	1·52	3·62	6·88	0·00	0·00	0·00	0·00	6·88	1944
1945	0·00	0·00	0·00	0·00	0·56	0·59	0·31	1·46	1·46	1·64	3·36	5·29	10·29	11·75	0·30	0·52	0·00	0·82	12·57	1945
1946	0·00	0·00	0·33	0·33	4·56	1·59	0·00	6·15	6·48	2·61	2·79	2·04	7·44	13·92	0·38	0·00	0·00	0·38	14·30	1946
1947	0·00	0·74	6·12	6·86	3·77	0·54	0·08	4·39	11·25	1·04	2·09	1·70	4·83	16·08	0·00	1·27	0·08	1·35	17·43	1947
1948	0·05	1·39	0·00	1·44	2·95	2·67	0·78	6·40	7·84	0·47	0·18	1·48	2·13	9·97	1·53	0·00	0·00	1·53	11·50	1948
1949	0·00	0·00	0·05	0·05	0·00	1·90	0·89	2·79	2·84	2·48	1·74	1·86	6·08	8·92	0·74	6·16	0·71	7·61	16·53	1949
1950	0·12	0·15	0·87	1·14	1·61	1·01	0·39	3·01	4·15	0·88	3·39	1·25	5·52	9·67	0·32	0·00	0·00	0·32	9·99	1950
Total, 7 years ...	0·17	2·28	8·27	10·72	15·36	8·45	2·75	26·56	37·28	9·62	15·15	15·14	39·91	77·19	3·27	7·95	0·79	12·01	89·20	
1944–50 Average ...	0·02	0·33	1·18	1·53	2·19	1·21	0·39	3·79	5·33	1·37	2·16	2·16	5·70	11·03	0·47	1·14	0·11	1·72	12·74	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·15	0·00	1·46	1·46	0·47	0·18	1·25	2·13	6·88	0·00	0·00	0·00	0·00	6·88	Minimum (1944)
Maximum	0·12	1·39	6·12	6·86	4·56	2·67	0·89	6·40	11·25	2·61	3·39	5·29	10·29	16·08	1·53	6·16	0·71	7·61	17·43	Maximum (1947)
24. ELAL 1944	0·00	0·00	0·39	0·39	0·20	3·28	0·00	3·48	3·87	0·29	0·00	3·25	3·54	7·41	0·00	0·00	1·21	1·21	8·62	1944
1945	0·00	0·00	0·00	0·00	0·38	2·13	2·64	5·15	5·15	0·00	0·36	1·80	2·16	7·31	0·00	0·90	0·00	0·90	8·21	1945
1946	0·14	0·00	0·44	0·58	6·15	1·04	0·00	7·19	7·77	0·00	1·12	0·70	1·82	9·59	3·46	0·10	0·00	3·56	13·15	1946
1947	0·00	0·30	0·25	0·55	4·89	0·97	0·00	5·86	6·41	0·00	0·35	0·07	0·42	6·83	0·42	0·73	0·00	1·15	7·98	1947
1948	0·00	0·00	0·90	0·90	5·65	0·70	0·00	6·35	7·25	0·00	0·00	0·15	0·15	7·40	1·14	2·70	0·00	3·84	11·24	1948
1949	0·00	0·00	2·19	2·19	0·00	3·44	0·55	3·99	6·18	0·00	0·17	0·87	1·04	7·22	0·00	0·83	1·36	2·19	9·41	1949
1950	1·45	0·00	0·10	1·55	0·00	0·38	0·18	0·56	2·11	0·00	0·54	0·77	1·31	3·42	0·00	0·00	0·00	0·00	3·42	1950
Total, 7 years ...	1·59	0·30	4·27	6·16	17·27	11·94	3·37	32·58	38·74	0·29	2·54	7·61	10·44	49·18	5·02	5·26	2·57	12·85	62·03	
1944–50 Average ...	0·23	0·04	0·61	0·88	2·47	1·71	0·48	4·65	5·53	0·04	0·36	1·09	1·49	7·03	0·72	0·75	0·37	1·84	8·86	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·38	0·00	0·56	2·11	0·00	0·00	0·07	0·15	3·42	0·00	0·00	0·00	0·00	3·42	Minimum (1950)
Maximum	1·45	0·30	2·19	2·19	6·15	3·44	2·64	7·19	7·77	0·29	1·12	3·25	3·54	9·59	3·46	2·70	1·36	3·84	13·15	Maximum (1946)

TABLE 5—*continued*

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
25. DALOH ... 1945	0·00	0·00	0·00	0·00	0·00	6·97	1·90	8·87	8·87	2·21	9·16	19·67	31·04	39·91	0·71	0·49	0·00	1·20	41·11	1945
1946	0·09	0·00	0·14	0·23	7·69	5·23	0·00	12·92	13·15	0·00	0·24	5·11	5·35	18·50	1·79	0·34	0·00	2·13	20·63	1946
1947	0·00	0·00	1·65	1·65	5·90	4·14	7·52	17·56	19·21	0·00	2·04	6·88	8·92	28·13	3·09	0·00	0·00	3·09	31·22	1947
1948	0·00	0·00	0·00	0·00	5·48	4·14	3·17	12·79	12·79	2·19	0·33	10·27	12·79	25·58	1·46	0·00	0·00	1·46	27·04	1948
1949	0·00	0·00	0·39	0·39	0·00	12·34	19·00	31·34	31·73	1·55	7·59	4·11	13·25	44·98	2·63	0·68	1·97	5·28	50·26	1949
1950	3·75	0·00	0·00	3·75	0·00	3·90	4·19	8·09	11·84	0·00	9·68	4·97	14·65	26·49	0·00	0·00	0·00	0·00	26·49	1950
Total, 6 years ...	3·84	0·00	2·18	6·02	19·07	36·72	35·78	91·57	97·59	5·95	29·04	51·01	86·00	183·59	9·68	1·51	1·97	13·16	196·75	
1945–50 Average ...	0·64	0·00	0·36	1·00	3·18	6·12	5·96	15·26	16·27	0·99	4·84	8·50	14·33	30·60	1·61	0·25	0·33	2·19	32·79	Average
Minimum	0·00	0·00	0·00	0·00	0·00	3·90	0·00	8·09	8·87	0·00	0·24	4·11	5·35	18·50	0·00	0·00	0·00	0·00	20·63	Minimum (1946)
Maximum	3·75	0·00	1·65	3·75	7·69	12·34	19·00	31·34	31·73	2·21	9·68	19·67	31·04	44·98	3·09	0·68	1·97	5·28	50·26	Maximum (1949)
26. BURAO 1944	0·00	0·00	0·30	0·30	0·00	2·27	0·00	2·27	2·57	0·00	0·67	1·72	2·39	4·96	0·00	0·00	0·00	0·00	4·96	1944
1945	0·00	0·00	0·00	0·00	0·00	2·12	0·77	2·89	2·89	0·00	0·34	0·64	0·98	3·87	0·70	1·12	0·00	1·82	5·69	1945
1946	0·01	0·00	0·00	0·01	2·88	0·86	1·26	5·00	5·01	0·96	0·78	1·94	3·68	8·69	1·32	0·09	0·00	1·41	10·10	1946
1947	0·00	0·00	0·18	0·18	1·15	1·49	0·28	2·92	3·10	0·12	0·38	2·04	2·54	5·64	0·02	0·03	0·00	0·05	5·69	1947
1948	0·00	0·00	0·00	0·00	1·55	0·02	0·77	2·34	2·34	0·25	0·31	0·11	0·67	3·01	1·58	0·00	0·00	1·58	4·59	1948
1949	0·00	0·01	0·61	0·62	0·00	2·03	0·90	2·93	3·55	0·05	1·63	1·24	2·92	6·47	0·28	0·11	0·33	0·72	7·19	1949
1950	0·15	0·00	0·00	0·15	0·00	0·16	0·65	0·81	0·96	0·02	0·28	0·48	0·78	1·74	0·15	0·00	0·00	0·15	1·89	1950
Total, 7 years ...	0·16	0·01	1·09	1·26	5·58	8·95	4·63	19·16	20·42	1·40	4·39	8·17	13·96	34·38	4·05	1·35	0·33	5·73	40·11	
1944–50 Average ...	0·02	0·00	0·16	0·18	0·80	1·28	0·66	2·74	2·92	0·20	0·63	1·17	1·99	4·91	0·58	0·19	0·05	0·82	5·73	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·02	0·00	0·81	0·96	0·00	0·28	0·11	0·67	1·74	0·00	0·00	0·00	0·00	1·89	Minimum (1950)
Maximum	0·15	0·01	0·61	0·62	2·88	2·27	1·26	5·00	5·01	0·96	1·63	2·04	3·68	8·69	1·58	1·12	0·33	1·82	10·10	Maximum (1946)
27. MANJA ASSEH BIHENDULA 1946	0·10	0·00	0·30	0·40	1·84	1·89	0·00	3·73	4·13	0·00	0·00	0·00	0·00	4·13	6·20	0·00	0·00	6·20	10·33	1946
1947	0·00	0·03	1·57	1·60	0·51	3·54	0·00	4·05	5·65	0·54	0·60	0·20	1·34	6·99	0·05	0·00	0·00	0·05	7·04	1947
1948	0·00	0·00	0·20	0·20	6·97	1·50	0·90	9·37	9·57	0·00	0·00	0·00	0·00	9·57	4·47	0·00	0·00	4·47	14·04	1948
1949	0·00	0·96	0·54	1·50	0·00	3·59	0·20	3·79	5·29	0·00	0·50	1·50	2·00	7·29	1·40	3·73	4·11	9·24	16·53	1949
1950	0·60	0·05	0·00	0·65	0·14	0·75	0·09	0·98	1·63	0·10	0·81	0·35	1·26	2·89	0·00	0·00	0·00	0·00	2·89	1950
Total, 5 years ...	0·70	1·04	2·61	4·35	9·46	11·27	1·19	21·92	26·27	0·64	1·91	2·05	4·60	30·87	12·12	3·73	4·11	19·96	50·83	
1946–50 Average ...	0·14	0·21	0·52	0·87	1·89	2·25	0·24	4·38	5·25	0·13	0·38	0·41	0·92	6·17	2·42	0·75	0·82	3·99	10·17	Average
Minimum	0·00	0·00	0·00	0·20	0·00	0·75	0·00	0·98	1·63	0·00	0·00	0·00	0·00	2·89	0·00	0·00	0·00	0·00	2·89	Minimum (1950)
Maximum	0·60	0·96	1·57	1·60	6·97	3·59	0·90	9·37	9·57	0·54	0·81	1·50	2·00	9·57	6·20	3·73	4·11	9·24	16·53	Maximum (1949)

NOTE.—Manja Asseh 1.1.46–31.12.46 ; 1944 and 1945 not reliable.

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
28. SILIL 1945	0·00	0·23	0·00	0·23	0·00	0·04	0·01	0·05	0·28	0·00	0·00	0·68	0·68	0·96	0·15	0·47	0·12	0·74	1·70	1945
1946	0·00	0·00	? 0·00	? 0·00	1·45	0·20	0·00	1·65	1·65	0·00	0·40	0·00	0·40	2·05	0·00	0·10	0·00	0·10	2·15	1946
1947	0·00	0·22	0·21	0·43	0·00	0·95	0·00	0·95	1·38	0·00	0·30	0·00	0·30	1·68	0·00	1·08	0·10	1·18	2·86	1947
1948	0·20	0·03	0·00	0·23	0·00	0·00	0·00	0·00	0·23	0·00	0·08	0·20	0·28	0·51	0·13	0·00	0·21	0·34	0·85	1948
1949	0·53	0·19	0·50	1·22	0·00	0·02	0·00	0·02	1·24	0·06	0·37	0·10	0·53	1·77	0·06	2·07	2·99	5·12	6·89	1949
1950	2·20	0·85	0·00	3·05	0·00	0·00	0·00	0·00	3·05	1·45	0·44	0·00	1·89	4·94	0·06	0·00	0·00	0·06	5·00	1950
Total, 6 years ...	2·93	1·52	0·71	5·16	1·45	1·21	0·01	2·67	7·83	1·51	1·59	0·98	4·08	11·91	0·40	3·72	3·42	7·54	19·45	
1945–50 Average ...	0·49	0·25	0·12	0·86	0·24	0·20	0·00	0·45	1·31	0·25	0·27	0·16	0·68	1·99	0·07	0·62	0·57	1·26	3·26	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·23	0·00	0·00	0·00	0·28	0·51	0·00	0·00	0·00	0·06	0·85	Minimum (1948)
Maximum	2·20	0·85	0·50	3·05	1·45	0·95	0·01	1·65	3·05	1·45	0·44	0·68	1·89	4·94	0·15	2·07	2·99	5·12	6·89	Maximum (1949)

TABLE 5—*continued*

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
29. ABDAL QADR ... 1945	0·06	0·00	0·00	0·06	0·00	0·17	0·00	0·21	0·27	0·75	4·77	4·39	9·91	10·18	0·00	0·30	0·00	0·30	10·48	1945
1946	0·00	0·00	3·00	3·00	4·00	0·20	? 0·00	4·20	7·20	2·30	1·70	1·70	5·70	12·90	0·00	0·59	0·00	0·59	13·49	1946
1947	0·00	1·45	2·15	3·60	0·00	? 0·00	0·90	0·90	4·50	0·00	2·90	2·00	4·90	9·40	0·00	0·86	? 0·00	0·86	10·26	1947
1948	0·08	1·87	? 0·00	1·95	3·62	2·50	? 0·00	6·12	8·07	0·00	0·90	0·37	1·27	9·34	1·25	0·00	0·00	1·25	10·59	1948
1949	0·00	0·00	0·00	0·00	0·00	0·19	0·77	0·96	0·96	1·58	1·13	1·38	4·09	5·05	? 0·00	? 3·00	? 0·00	? 3·00	8·05	1949
?Total, 5 years ...	0·14	3·32	5·15	8·61	7·62	3·06	1·71	12·39	21·00	4·63	11·40	9·84	25·87	46·87	1·25	4·75	0·00	6·00	52·87	
1945–49 Average ...	0·03	0·66	1·03	1·72	1·52	0·61	0·34	2·48	4·20	0·93	2·28	1·97	5·17	9·37	0·25	0·95	0·00	1·20	10·57	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·21	0·27	0·00	0·90	0·37	1·27	5·05	0·00	0·00	0·00	0·30	8·05	Minimum (1949)
Maximum	0·08	1·87	3·00	3·60	4·00	2·50	0·90	6·12	8·07	2·30	4·77	4·39	9·91	12·90	1·25	3·00	0·00	3·00	13·49	Maximum (1946)

(NOTE.—Not reliable in any year)

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
30. SHEIKH ... 1944	0·00	0·00	0·93	0·93	0·50	3·73	0·03	4·26	5.19	2·30	1·15	3·09	6·54	11·73	0·00	0·00	0·61	0·61	12·34	1944
1945	0·00	0·13	0·01	0·14	0·00	6·14	2·21	8·35	8·49	0·88	1·09	3·55	5·52	14·01	1·92	1·57	0·00	3·49	17·50	1945
1946	0·48	0·00	0·11	0·59	6·78	3·12	1·20	11·10	11·69	0·60	2·41	2·36	5·37	17·06	3·22	0·79	0·00	4·01	21·07	1946
1947	0·00	0·05	0·91	0·96	4·41	1·56	1·28	7·25	8·21	0·27	0·95	1·43	2·65	10·86	2·35	1·74	2·20	6·29	17·15	1947
1948	0·14	0·00	0·01	0·15	5·87	2·03	6·65	14·55	14·70	0·00	0·33	2·82	3·15	17·85	5·68	0·49	0·00	6·17	24·02	1948
1949	0·11	0·50	1·98	2·59	2·78	2·98	0·80	6·56	9·15	0·59	3·53	1·23	5·35	14·50	2·17	1·94	3·12	7·23	21·73	1949
1950	0·17	0·05	0·03	0·25	1·30	1·32	1·96	4·58	4·83	1·67	0·97	1·70	4·34	9·17	2·97	0·00	0·00	2·97	12·14	1950
Total, 7 years ...	0·90	0·73	3·98	5·61	21·64	20·88	14·13	56·65	62·26	6·31	10·43	16·18	32·92	95·18	18·31	6·53	5·93	30·77	125·95	
1944–50 Average ...	0·13	0·10	0·57	0·80	3·09	2·98	2·02	8·09	8·89	0·90	1·49	2·31	4·70	13·60	2·62	0·93	0·85	4·40	17·99	Average
Minimum	0·00	0·00	0·01	0·14	0·00	1·32	0·03	4·26	4·83	0·00	0·33	1·23	2·65	9·17	0·00	0·00	0·00	0·61	12·14	Minimum (1950)
Maximum	0·48	0·50	1·98	2·59	6·78	6·14	6·65	14·55	14·70	2·30	2·41	3·55	6·54	17·85	5·68	1·94	3·12	7·23	24·02	Maximum (1948)
31. BERBERA (R.A.F.) 1944	0·00	0·00	0·10	0·10	0·00	0·00	0·00	0·00	0·10	0·00	0·00	0·00	0·00	0·10	0·00	0·00	0·00	0·00	0·10	1944
1945	0·30	0·03	0·11	0·44	0·06	0·30	0·87	1·23	1·67	0·00	0·09	0·00	0·09	1·76	0·00	0·00	0·00	0·00	1·76	1945
1946	0·04	0·00	0·00	0·04	0·79	0·13	0·00	0·92	0·96	0·00	0·07	0·00	0·07	1·03	0·00	0·00	0·00	0·00	1·03	1946
1947	0·00	0·00	0·01	0·01	0·00	0·02	0·00	0·02	0·03	0·00	0·04	0·00	0·04	0·07	0·00	0·00	0·00	0·00	0·07	1947
1948	0·00	0·00	0·00	0·00	2·38	0·00	0·00	2·38	2·38	0·00	0·00	0·00	0·00	2·38	0·15	0·31	0·00	0·46	2·84	1948
1949	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·19	0·73	0·92	0·92	0·00	0·00	2·67	2·67	3·59	1949
1950	2·57	0·00	0·00	2·57	0·00	0·00	0·00	0·00	2·57	0·00	0·63	0·58	1·21	3·78	0·00	0·00	0·01	0·01	3·79	1950
Total, 7 years ...	2·91	0·03	0·22	3·16	3·23	0·45	0·87	4·55	7·71	0·00	1·02	1·31	2·33	10·04	0·15	0·31	2·68	3·14	13·18	
1944–50 Average ...	0·42	0·00	0·03	0·45	0·46	0·06	0·12	0·65	1·10	0·00	0·15	0·19	0·33	1·43	0·02	0·04	0·38	0·45	1·88	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·07	0·00	0·00	0·00	0·00	0·07	Minimum (1947)
Maximum	2·57	0·03	0·11	2·57	2·38	0·30	0·87	2·38	2·57	0·00	0·63	0·73	1·21	3·78	0·15	0·31	2·67	2·67	3·79	Maximum (1950)

NOTE.—Observers withdrawn without warning on 14.12.50 : D.C. reports only 5-minute shower between 14.12.50 and 31.12.50 on December 25th, estimated by me at 0·01. J. A. H.

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
32. HARGEISA (R.A.F.) 1944	0·00	0·00	0·67	0·67	0·15	2·44	2·84	5·43	6·10	1·60	3·13	1·36	6·09	12·19	0·00	0·25	0·00	0·25	12·44	1944
1945	0·00	0·00	0·00	0·00	0·00	3·15	2·12	5·27	5·27	1·40	3·62	3·19	8·21	13·48	0·16	0·83	0·00	0·99	14·47	1945
1946	0·03	0·00	0·00	0·03	5·06	1·19	3·14	9·39	9·42	1·70	3·09	0·83	5·62	15·04	1·83	0·18	0·00	2·01	17·05	1946
1947	0·00	0·00	3·59	3·59	3·76	0·57	2·53	6·86	10·45	2·39	4·57	3·93	10·89	21·34	0·00	0·00	0·00	0·00	21·34	1947
1948	0·00	0·09	0·41	0·50	3·56	1·31	2·47	7·34	7·84	0·90	1·20	3·33	5·43	13·27	2·20	0·15	0·00	2·35	15·62	1948
1949	0·05	0·04	0·00	0·09	0·00	3·35	1·53	4·88	4·97	0·44	3·85	0·83	5·12	10·09	0·15	0·32	0·46	0·93	11·02	1949
1950	0·00	0·04	0·00	0·04	0·04	2·16	2·47	4·67	4·71	?2·04	3·87	5·43	11·34	16·05	0·00	0·00	0·00	0·00	16·05	1950
Total, 7 years ...	0·08	0·17	4·67	4·92	12·57	14·17	17·10	43·84	48·76	10·47	23·33	18·90	52·70	101·46	4·34	1·73	0·46	6·53	107·99	
1944–50 Average ...	0·01	0·02	0·67	0·70	1·80	2·02	2·44	6·26	6·97	1·50	3·33	2·70	7·53	14·49	0·62	0·25	0·07	0·93	15·43	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·57	1·53	4·67	4·71	0·44	1·20	0·83	5·12	10·09	0·00	0·00	0·00	0·00	11·02	Minimum (1949)
Maximum	0·05	0·09	3·59	3·59	5·06	3·35	3·14	9·39	10·45	2·39	4·57	5·33	11·34	21·34	2·20	0·83	0·46	2·35	21·34	Maximum (1947)

NOTE.—On new landing ground at 4,500 ft., except for 19.7.50–31.12.50 on old L.G. in valley at 4,100 ft.

TABLE 5—*continued*

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
33. Hargeisa S.A.O. 1947	0·00	0·00	3·87	3·87	2·86	0·57	2·44	5·87	9·74	2·02	2·66	1·12	5·80	15·54	0·00	0·21	0·00	0·21	15·75	1947
1948	0·00	0·00	0·28	0·28	2·12	0·83	2·57	5·52	5·80	0·88	1·78	3·00	5·66	11·46	0·55	0·00	0·00	0·55	12·01	1948
1949	0·00	0·00	0·02	0·02	0·00	3·46	1·15	4·61	4·63	0·15	2·13	1·91	4·19	8·82	0·84	1·10	0·30	2·24	11·06	1949
Total, 3 years ...	0·00	0·00	4·17	4·17	4·98	4·86	6·16	16·00	20·17	3·05	6·57	6·03	15·65	35·82	1·39	1·31	0·30	3·00	38·82	
1947–49 Average ...	0·00	0·00	1·39	1·39	1·66	1·62	2·05	5·33	6·72	1·01	2·19	2·01	5·22	11·94	0·46	0·44	0·10	1·00	12·94	Average
Minimum	0·00	0·00	0·02	0·02	0·00	0·57	1·15	4·61	4·63	0·15	1·78	1·12	4·19	8·82	0·00	0·00	0·00	0·21	11·06	Minimum (1949)
Maximum	0·00	0·00	3·87	3·87	2·86	3·46	2·57	5·87	9·74	2·02	2·66	3·00	5·80	15·54	0·84	1·10	0·30	2·24	15·75	Maximum (1947)
34. Hargeisa D.C. 1947	0·00	0·00	5·72	5·72	3·00	0·61	2·23	5·84	11·56	2·36	2·58	1·09	6·03	17·59	0·00	0·00	0·00	0·00	17·59	1947
1948	0·00	0·00	0·27	0·27	1·83	0·72	2·10	4·65	4·92	0·88	1·83	3·07	5·78	10·70	0·48	0·00	0·00	0·48	11·18	1948
1949	0·00	0·00	0·06	0·06	0·00	3·16	1·31	4·47	4·53	0·67	2·40	1·49	4·56	9·09	0·44	1·39	0·29	2·12	11·21	1949
Total, 3 years ...	0·00	0·00	6·05	6·05	4·83	4·49	5·64	14·96	21·01	3·91	6·81	5·65	16·37	37·38	0·92	1·39	0·29	2·60	39·98	
1947–49 Average ...	0·00	0·00	2·02	2·02	1·61	1·49	1·88	4·99	7·00	1·30	2·27	1·88	5·46	12·46	0·31	0·46	0·10	0·87	13·33	Average
Minimum	0·00	0·00	0·06	0·06	0·00	0·61	1·31	4·47	4·53	0·67	1·83	1·09	4·56	9·09	0·00	0·00	0·00	0·00	11·18	Minimum (1948)
Maximum	0·00	0·00	5·72	5·72	3·00	3·16	2·23	5·84	11·56	2·36	2·58	3·07	6·03	17·59	0·48	1·39	0·29	2·12	17·59	Maximum (1947)
35. Galkayu ... 1945	0·00	0·00	0·00	0·00	0·00	3·72	0·75	4·47	4·47	0·00	0·00	0·00	0·00	4·47	1·14	0·00	0·00	1·14	5·61	1945
1946	0·00	0·00	0·00	0·00	2·31	2·13	0·27	4·71	4·71	0·04	0·00	0·28	0·32	5·03	1·10	0·00	0·00	1·10	6·13	1946
1947	0·00	0·00	0·00	0·00	0·08	2·27	0·00	2·35	2·35	0·00	0·12	0·00	0·12	2·47	0·31	0·08	0·00	0·39	2·86	1947
1948	0·00	0·12	0·00	0·12	0·02	2·79	0·00	2·81	2·93	0·00	0·00	0·00	0·00	2·93	2·40	0·14	0·00	2·54	5·47	1948
1949	0·00	0·00	0·00	0·00	0·00	0·46	0·00	0·46	0·46	0·00	0·00	0·00	0·00	0·46	0·81	0·00	0·05	0·86	1·32	1949
Total, 5 years ...	0·00	0·12	0·00	0·12	2·41	11·37	1·02	14·80	14·92	0·04	0·12	0·28	0·44	15·36	5·76	0·22	0·05	6·03	21·39	
1945–49 Average ...	0·00	0·02	0·00	0·02	0·48	2·27	0·20	2·96	2·98	0·01	0·02	0·06	0·09	3·07	1·15	0·04	0·01	1·21	4·28	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·46	0·00	0·46	0·46	0·00	0·00	0·00	0·00	0·46	0·31	0·00	0·00	0·39	1·32	Minimum (1949)
Maximum	0·00	0·12	0·00	0·12	2·31	3·72	0·75	4·71	4·71	0·04	0·12	0·28	0·32	5·03	2·40	0·14	0·05	2·54	6·13	Maximum (1946)
36. Qabri Dahare 1945	0·00	0·00	0·00	0·00	0·00	3·26	0·23	3·49	3·49	0·15	0·00	0·00	0·15	3·64	1·20	0·70	0·10	2·00	5·64	1945
1946	0·00	0·00	0·00	0·00	2·79	1·10	0·00	3·89	3·89	0·02	0·23	0·21	0·46	4·35	4·73	1·47	0·00	6·20	10·55	1946
1947	0·00	0·00	0·59	0·59	2·81	6·17	0·00	8·98	9·57	0·00	0·00	0·00	0·00	9·57	5·42	0·49	0·03	5·94	15·51	1947
Total, 3 years ...	0·00	0·00	0·59	0·59	5·60	10·53	0·23	16·36	16·95	0·17	0·23	0·21	0·61	17·56	11·35	2·66	0·13	14·14	31·70	
1945–47 Average ...	0·00	0·00	0·20	0·20	1·87	3·51	0·07	5·45	5·65	0·06	0·08	0·07	0·20	5·85	3·78	0·89	0·04	4·71	10·57	Average
Minimum	0·00	0·00	0·00	0·00	0·00	1·10	0·00	3·49	3·49	0·00	0·00	0·00	0·00	3·64	1·20	0·49	0·00	2·00	5·64	Minimum (1945)
Maximum	0·00	0·00	0·59	0·59	2·81	6·17	0·23	8·98	9·57	0·15	0·23	0·21	0·46	9·57	5·42	1·47	0·10	6·20	15·51	Maximum (1947)
37. Zeila 1947	0·00	0·05	0·00	0·05	0·00	0·90	0·00	0·90	0·95	0·00	0·00	0·00	0·00	0·95	0·00	1·12	0·26	1·38	2·33	1947
1948	0·03	0·00	0·60	0·63	0·02	0·00	0·00	0·02	0·65	0·00	0·00	0·00	0·00	0·65	0·65	0·12	0·00	0·77	1·42	1948
1949	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·02	0·00	0·00	0·02	0·02	0·00	2·35	0·80	3·15	3·17	1949
1950	0·70	0·00	0·00	0·70	0·08	0·00	0·00	0·08	0·78	1·35	0·00	0·00	1·35	2·13	0·18	0·00	0·00	0·18	2·31	1950
Total, 4 years ...	0·73	0·05	0·60	1·38	0·10	0·90	0·00	1·00	2·38	1·37	0·00	0·00	1·37	3·75	0·83	3·59	1·06	5·48	9·23	
1947–50 Average ...	0·18	0·01	0·15	0·35	0·03	0·23	0·00	0·25	0·60	0·34	0·00	0·00	0·34	0·94	0·21	0·90	0·27	1·37	2·31	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·02	0·00	0·00	0·00	0·18	1·42	Minimum (1948)
Maximum	0·70	0·05	0·60	0·70	0·02	0·90	0·00	0·90	0·95	1·35	0·00	0·00	1·35	2·13	0·65	2·35	0·80	3·15	3·17	Maximum (1949)

TABLE 5—*continued*

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
38. MANDERA ... 1947	0·00	0·00	0·00	0·00	0·00	1·35	0·72	2·07	2·07	0·99	0·00	0·00	0·99	3·06	1·55	0·00	0·00	1·55	4·61	1947
1948	0·00	0·06	2·26	2·32	4·72	2·11	0·60	7·43	9·75	0·18	0·00	2·12	2·30	12·05	4·06	0·17	0·00	4·23	16·28	1948
1949	0·05	0·00	1·78	1·83	0·05	4·95	0·84	5·84	7·67	0·59	2·14	1·08	3·81	11·48	1·42	3·26	3·35	8·03	19·51	1949
1950	1·60	0·00	0·06	1·66	1·37	2·99	0·40	4·76	6·42	2·20	2·43	4·75	9·38	15·80	0·25	0·00	0·00	0·25	16·05	1950
Total, 4 years ...	1·65	0·06	4·10	5·81	6·14	11·40	2·56	20·10	25·91	3·96	4·57	7·95	16·48	42·39	7·28	3·43	3·35	14·06	56·45	
1947–50 Average ...	0·41	0·02	1·03	1·45	1·54	2·85	0·64	5·03	6·48	0·99	1·14	1·99	4·12	10·60	1·82	0·86	0·84	3·52	14·11	Average
Minimum	0·00	0·00	0·00	0·00	0·00	1·35	0·40	2·07	2·07	0·18	0·00	0·00	0·99	3·06	0·25	0·00	0·00	0·25	4·61	Minimum (1947)
Maximum	1·60	0·06	2·26	2·32	4·72	4·95	0·84	7·43	9·75	2·20	2·43	4·75	9·38	15·80	4·06	3·26	3·35	8·03	19·51	Maximum (1949)
39. BORAMA ... 1947	0·00	0·93	4·18	5·11	4·07	4·38	0·82	9·27	14·38	2·03	2·62	2·83	7·48	21·86	0·00	0·75	0·00	0·75	22·61	1947
1948	1·68	0·81	0·14	2·63	4·70	0·29	0·76	5·75	8·38	1·72	1·32	3·08	6·12	14·50	1·25	0·12	0·00	1·37	15·87	1948
1949	0·00	0·00	0·24	0·24	0·16	1·49	1·76	3·41	3·65	3·25	5·71	3·98	12·94	16·59	0·32	2·19	0·59	3·10	19·69	1949
1950	0·56	0·00	0·00	0·56	0·68	1·75	1·50	3·93	4·49	2·95	4·84	4·91	12·70	17·19	0·00	0·00	0·00	0·00	17·19	1950
Total, 4 years ...	2·24	1·74	4·56	8·54	9·61	7·91	4·84	22·36	30·90	9·95	14·49	14·80	39·24	70·14	1·57	3·06	0·59	5·22	75·36	
1947–50 Average ...	0·56	0·44	1·14	2·14	2·40	1·98	1·21	5·59	7·73	2·49	3·62	3·70	9·81	17·54	0·39	0·77	0·15	1·31	18·84	Average
Minimum	0·00	0·00	0·00	0·24	0·16	0·29	0·76	3·41	3·65	1·72	1·32	2·83	6·12	14·59	0·00	0·00	0·00	0·00	15·87	Minimum (1948)
Maximum	1·68	0·93	4·18	5·11	4·70	4·38	1·76	9·27	14·38	3·25	5·71	4·91	12·94	21·86	1·25	2·19	0·59	3·10	22·61	Maximum (1947)
40. ERIGAVO ... 1947	0·95	0·30	1·24	2·49	0·40	3·13	2·34	5·87	8·36	0·00	0·00	3·77	3·77	12·13	0·00	0·11	0·00	0·11	12·24	1947
1948	0·00	0·00	0·50	0·50	3·82	2·59	1·84	8·25	8·75	1·00	0·40	2·25	3·65	12·40	0·86	0·00	0·00	0·86	13·26	1948
1949	0·00	0·00	0·36	0·36	0·40	0·00	2·00	2·40	2·76	1·24	3·30	4·13	8·67	11·43	0·00	0·39	0·11	0·50	11·93	1949
1950	3·67	0·00	? 0·00	3·67	? 0·00	0·86	? 3·75	4·61	8·28	0·00	5·75	7·24	12·99	21·27	0·36	0·00	0·00	0·36	21·63	1950
Total, 4 years ...	4·62	0·30	2·10	7·02	4·62	6·58	9·93	21·13	28·15	2·24	9·45	17·39	29·08	57·23	1·22	0·50	0·11	1·83	59·06	
1947–50 Average ...	1·16	0·08	0·53	1·76	1·16	1·65	2·48	5·28	7·04	0·56	2·36	4·35	7·27	14·31	0·31	0·12	0·03	0·46	14·77	Average
Minimum	0·00	0·00	0·00	0·36	0·00	0·00	1·84	2·40	2·76	0·00	0·00	2·25	3·65	11·43	0·00	0·00	0·00	0·11	11·93	Minimum (1949)
Maximum	3·67	0·30	1·24	3·67	3·82	3·13	3·75	8·24	8·75	1·24	5·75	7·24	12·99	21·27	0·86	0·39	0·11	0·86	21·63	Maximum (1950)
41. LAS DUREH ... 1948	0·00	0·27	0·00	0·27	1·96	1·15	0·18	3·29	3·56	0·00	0·00	0·32	0·32	3·88	0·30	0·42	0·00	0·72	4·60	1948
1949	0·00	0·11	0·09	0·20	0·14	0·20	0·00	0·34	0·54	0·00	0·14	0·29	0·43	0·97	1·87	0·70	0·80	3·37	4·34	1949
1950	0·76	0·00	0·20	0·96	0·00	0·23	0·00	0·23	1·19	0·00	0·20	1·30	1·50	2·69	0·00	0·00	0·00	0·00	2·69	1950
Total, 3 years ...	0·76	0·38	0·29	1·43	2·10	1·58	0·18	3·86	5·29	0·00	0·34	1·91	2·25	7·54	2·17	1·12	0·80	4·09	11·63	
1948–50 Average ...	0·25	0·13	0·09	0·48	0·70	0·53	0·06	1·29	1·76	0·00	0·11	0·64	0·75	2·51	0·72	0·37	0·27	1·36	3·88	Average
Minimum	0·00	0·00	0·00	0·20	0·00	0·20	0·00	0·23	0·54	0·00	0·00	0·29	0·32	0·97	0·00	0·00	0·00	0·00	2·69	Minimum (1950)
Maximum	0·76	0·27	0·20	0·96	1·96	1·15	0·18	3·29	3·56	0·00	0·20	1·30	1·50	3·88	1·87	0·70	0·80	3·37	4·60	Maximum (1948)
42. ADADLEH ... 1944	0·00	0·00	1·30	1·30	2·20	2·05	0·80	5·05	6·35	3·75	0·00	4·85	8·60	14·95	0·00	0·00	0·00	0·00	14·95	1944
1945	0·00	0·00	0·00	0·00	0·00	2·69	0·80	3·49	3·49	0·30	3·20	2·80	6·30	9·79	0·00	0·90	0·00	0·90	10·69	1945
43. BOHOTLEH ... 1944	0·00	0·00	0·00	0·00	0·43	4·85	0·00	5·28	5·28	0·00	0·00	0·25	0·25	5·53	0·42	0·63	0·00	1·05	6·58	1944

	Jan.	Feb.	Mar.	First Quarter	Apr.	May	June	Second Quarter	Jan.–June	July	Aug.	Sept.	Third Quarter	Jan.–Sept.	Oct.	Nov.	Dec.	Fourth Quarter	Whole Year	
44. Bosaso (R.A.F.) 1944	0·04	0·00	0·00	0·04	0·00	0·00	0·00	0·00	0·04	0·00	0·00	0·00	0·00	0·04	0·30	0·00	0·90	1·20	1·24	1944
1945	0·00	0·00	0·00	0·00	0·00	0·00	0·04	0·04	0·04	0·00	0·00	0·00	0·00	0·04	0·00	0·00	0·00	0·10	0·14	1945
1946	0·04	0·00	0·00	0·04	0·00	0·00	0·00	0·00	0·04	0·00	0·00	0·00	0·00	0·04	0·00	—	—	—	—	1946
Total, 2–3 years ...	0·08	0·00	0·00	0·08	0·00	0·00	0·04	0·04	0·12	0·00	0·00	0·00	0·00	0·12	0·30	0·10	0·90	1·30	1·38	
1944-46 Average ...	0·03	0·00	0·00	0·03	0·00	0·00	0·01	0·01	0·04	0·00	0·00	0·00	0·00	0·04	0·10	0·05	0·45	0·65	0·69	Average
Minimum	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·04	0·00	0·00	0·00	0·00	0·04	0·00	0·00	0·00	0·10	0·14	Minimum (1945)
Maximum	0·04	0·00	0·00	0·04	0·00	0·00	0·04	0·04	0·04	0·00	0·00	0·00	0·00	0·04	0·30	0·10	0·90	1·20	1·24	Maximum (1944)
45. Isskushuban (R.A.F.) 1944	0·00	0·00	0·00	0·00	0·65	0·12	0·08	0·85	0·85	0·00	0·00	1·18	1·18	2·03	0·00	0·05	0·42	0·47	2·50	1944
1945	0·14	0·04	0·00	0·18	0·00	0·38	—	—												
46. Jigjigga ... 1947	—	0·00	rain	rain	rain	0·35	1·55	1·90+	1·90+	2·33	4·05	2·80	9·18	11·08+	0·08	3·51	0·00	3·59	14·67+	1947
47. Jibuti 1944	0·00	0·01	0·02	0·03	1·01	0·00	0·00	1·01	1·04	0·58	0·00	0·00	0·58	1·62	0·00	0·00	0·82	0·82	2·44	1944
1945	0·04	0·01	0·08	0·13	0·00	0·17	0·00	0·17	0·30	0·00	0·00	0·00	0·00	0·30	1·87	5·31	0·14	7·32	7·62	1945
1946	0·00	0·04	1·66	1·70	0·12	1·06	0·00	1·18	2·88	0·03	0·13	0·14	0·30	3·18	0·22	3·22	0·00	3·44	6·62	1946
1947	0·06	0·76	0·00	0·82	0·01	0·33	0·00	0·34	1·16	0·00	0·75	0·00	0·75	1·91	0·06	0·46	0·95	1·47	3·38	1947
1948	0·43	1·19	0·81	2·43	0·02	0·13	0·00	0·15	2·58	0·00	0·00	0·00	0·00	2·58	1·62	0·06	0·24	1·92	4·50	1948
1949	0·30	0·20	0·00	0·50	0·00	0·01	0·00	0·01	0·51	0·86	0·00	0·02	0·88	1·39	0·00	0·87	1·13	2·00	3·39	1949
Total, 6 years ...	0·83	2·21	2·57	5·61	1·16	1·70	0·00	2·86	8·47	1·47	0·88	0·16	2·51	10·98	3·77	9·92	3·28	16·97	27·95	
1944-49 Average ...	0·14	0·37	0·43	0·94	0·19	0·29	0·00	0·48	1·41	0·25	0·15	0·03	0·42	1·83	0·63	1·65	0·55	2·83	4·66	Average
Minimum	0·00	0·01	0·00	0·03	0·00	0·00	0·00	0·01	0·30	0·00	0·00	0·00	0·00	0·30	0·00	0·00	0·00	0·82	2·44	Minimum (1944)
Maximum	0·43	1·19	1·66	2·43	1·01	1·06	0·00	1·18	2.88	0·86	0·75	0·14	0·88	3·18	1·87	5·31	0·95	7·32	7·62	Maximum (1945)
Note.—From "Bull. Ann. Ser. Mét." of French Somaliland																				
48. Eil 1937	0·00	0·00	0·37	0·37	3·96	2·48	0·09	6·53	6·90	0·00	0·00	0·60	0·60	7·50	2·64	1·40	0·00	4·04	11·54	
1938	0·11	0·00	0·00	0·11	0·00	3·19	0·00	3·19	3·30	0·00	0·00	0·00	0·00	3·30	1·26	0·20	0·00	1·46	4·76	
1939	0·12	0·00	0·47	0·59	0·00	0·24	0·00	0·24	0·83	0·00	0·00	0·00	0·00	0·83	1·89	0·00	0·35	2·24	3·07	
Total, 3 years ...	0·23	0·00	0·84	1·07	3·96	5·91	0·09	9·96	11·03	0·00	0·00	0·60	0·60	11·63	5·79	1·60	0·35	7·74	19·37	
1937-39 Average ...	0·08	0·00	0·28	0·36	1·32	1·97	0·03	3·32	3·68	0·00	0·00	0·20	0·20	3·88	1·93	0·53	0·12	2·58	6·46	Average
Minimum	0·00	0·00	0·00	0·11	0·00	0·24	0·00	0·24	0·83	0·00	0·00	0·00	0·00	0·83	1·26	0·00	0·00	1·46	3·07	Minimum (1939)
Maximum	0·12	0·00	0·47	0·59	3·96	3·19	0·09	6·53	6·90	0·00	0·00	0·60	0·60	7·50	2·64	1·40	0·35	4·04	11·54	Maximum (1937)
49. Gumburu Hills 1950	—	—	—	—	0·00	1·47	0·00	1·47	1·47+	0·10	0·00	8·90	9·00	10·47+	3·48	0·02	0·00	3·50	13·97+	

TABLE 6

SUMMARY OF THE RAINFALL IN INCHES

	Max.	(Year)	Min.	(Year)	Average	(Years)	Latitude N.	Longitude E.	Altitude (ft.)	
1. Wajale	22·96	(1946)	17·94	(1950)	19·88	(1944–50)	9° 37′	43° 17′	5,127	1. Wajale.
2. Ijara	20·84	(1950)	13·02	(1944)	17·69	(1944–50)	9° 35′	43° 38′	5,130	2. Ijara.
Gebile							9° 42′	43° 37′	4,790	Gebile.
3. Go'o	43·68	(1946)	10·56	(1950)	24·16	(1946–50)	9° 47′	44° 56′	5,220	3. Go'o.
4. Odweina	11·16	(1948)	4·54	(1944)	8·11	(1944–50)	9° 24′	45° 04′	3,460	4. Odweina.
5. Gudubi	14·20	(1946)	4·05	(1949)	6·99	(1944–50)	8° 49′	45° 00′	3,335	5. Gudubi.
6. Danot	13·78	(1950)	3·32	(1949)	8·96	(1944–50)	7° 23′	45° 18′	2,220	6. Danot.
7. Ainabo	11·81	(1945)	1·28	(1950)	5·73	(1944–50)	8° 57′	46° 26′	2,579	7. Ainabo.
8. Yo'obyaboh	15·80	(1946)	3·01	(1950)	7·19	(1945–50)	8° 30′	45° 33′	2,710	8. Yo'obyaboh.
9. Ber	10·69	(1949)	2·84	(1950)	6·18	(1944–50)	9° 22′	45° 47′	3,050	9. Ber.
10. Las Anod	8·24	(1946)	2·47	(1949)	4·80	(1944–50)	8° 28′	47° 22′	2,313	10. Las Anod.
11. Donkuqoq	6·12	(1944)	2·91	(1945)	4·33	(1944–48)	8° 10′	48° 11′	2,500	11. Donkuqoq.
12. Awareh	19·40	(1945)	4·01	(1950)	11·19	(1944–50)	8° 16′	44° 09′	3,730	12. Awareh.
13. Gardo	6·68	(1949)	2·21	(1944)	4·20	(1944–49)	9° 29′	49° 02′	2,460	13. Gardo.
14. Buran	4·05	(1948)	1·52	(1950)	2·69	(1945–50)	10° 13′	48° 47′	3,140	14. Buran.
15. Hudun	6·80	(1945)	2·44	(1950)	3·99	(1944–50)	9° 09′	47° 29′	2,051	15. Hudun.
16. Do'mo	9·58	(1944)	1·56	(1950)	6·76	(1944–50)	7° 53′	46° 51′	1,820	16. Do'mo.
17. Garadag	6·10	(1946)	1·20	(1950)	3·89	(1945–50)	9° 29′	46° 53′	2,600	17. Garadag.
18. Bihen	18·89	(1945)	0·58	(1947)	5·01	(1945–50)	8° 26′	48° 25′	1,475	18. Bihen.
19. El Afwein	7·21	(1948)	2·10	(1950)	5·35	(1944–50)	9° 55′	47° 15′	3,346	19. El Afwein.
20. Halin	5·07	(1948)	0·48	(1950)	3·14	(1944–50)	9° 06′	48° 38′	2,035	20. Halin.
Taleh							9° 09′	48° 25′	2,093	Taleh.
21. Hanan	7·25	(1944)	0·00	(1947)	2·62	(1944–48)	10° 35′	46° 18′	410	21. Hanan.
22. Dur Elan	5·94	(1948)	1·69	(1947)	3·91	(1944–48)	10° 08′	46° 22′	2,125	22. Dur Elan.
23. Bawn	17·43	(1947)	6·88	(1944)	12·74	(1944–50)	10° 12′	43° 06′	4,340	23. Bawn.
24. Elal	13·15	(1946)	3·42	(1950)	8·86	(1944–50)	9° 56′	46° 17′	3,565	24. Elal.
25. Daloh	50·26	(1949)	20·63	(1946)	32·79	(1945–50)	10° 47′	47° 18′	6,780	25. Daloh.
26. Burao	10·10	(1946)	1·89	(1950)	5·73	(1944–50)	9° 31′	45° 34′	3,420	26. Burao.
27. Bihendula	16·53	(1949)	2·89	(1950)	10·17	(1946–50)	10° 10′	45° 08′	1,900	27. Bihendula.
28. Silil	6·89	(1949)	0·85	(1948)	3·26	(1945–50)	10° 59′	43° 26′	242	28. Silil.
29. Abdul Qadr	13·49	(1946)	8·05	(1949)	10·57	(1945–49)	10° 31′	42° 53′	2,400	29. Abdul Qadr.
30. Sheikh	24·02	(1948)	12·14	(1950)	17·99	(1944–50)	9° 56′	45° 12′	4,726	30. Sheikh.
31. Berbera (R.A.F.)	3·79	(1950)	0·07	(1947)	1·88	(1944–50)	10° 26′	45° 02′	25	31. Berbera.
32. Hargeisa (R.A.F.)	21·34	(1947)	11·02	(1949)	15·43	(1944–50)	9° 31′	44° 06′	4,500	32. Hargeisa (R.A.F.).
33. Hargeisa (S.A.O.)	15·75	(1947)	11·06	(1949)	12·94	(1947–49)	9° 33′	44° 04′	4,100	33. Hargeisa (S.A.O.).
34. Hargeisa (D.C.)	17·59	(1947)	11·18	(1948)	13.33	(1947–48)	9° 33′	44° 04′	4,100	34. Hargeisa (D.C.).
35. Galkayu	6·13	(1946)	1·32	(1949)	4·28	(1945–49)	6° 47′	47° 26′	951	35. Galkayu.
36. Qabridahare	15·51	(1947)	5·64	(1945)	10·57	(1945–47)	6° 45′	44° 17′	1,395	36. Qabridahare.
37. Zeila	3·17	(1949)	1·42	(1948)	2·31	(1947–50)	11° 21′	43° 29′	1	37. Zeila.
38. Mandera	19·51	(1949)	4·61	(1947)	14·11	(1947–50)	9° 55′	44° 43′	2,895	38. Mandera.
39. Borama	22·61	(1947)	15·87	(1948)	18·84	(1947–50)	9° 56′	43° 11′	4,770	39. Borama.
40. Erigavo	21·63	(1950)	11·93	(1949)	14·77	(1947–50)	10° 37′	47° 22′	5,722	40. Erigavo.
41. Las Dureh	4·60	(1948)	2·69	(1950)	3·88	(1948–50)	10° 11′	46° 00′	1,755	41. Las Dureh.
42. Adadleh	14·95	(1944)	10·69	(1945)	12·82	(1944–45)	9° 46′	44° 40′	4,127	42. Adadleh.
43. Bohotleh	—		—		6·58	(1944 only)	8° 14′	46° 19′	2,165	43. Bohotleh.
44. Bosaso (R.A.F.)	1·24	(1944)	0·14	(1945)	0·69	(1944–45)	11° 17′	49° 11′	S.L.	44. Bosaso.
45. Isskushuban (R.A.F.)	—		—		2·50	(1944 only)	10° 17′	50° 14′	?2,296	45. Isskushuban.
46. Jigjiga	—		—		14·67	(1947 only)	9° 20′	42° 48′	5,688	46. Jigjiga.
47. Jibuti	7·62	(1945)	2·44	(1944)	4·66	(1944–49)	11° 36′	43° 09′	11	47. Jibuti.
48. Eil (Italian)	11·54	(1937)	3·07	(1939)	6·44	(1937–39)	7° 59′	49° 49′	S.L.	48. Eil (Italian).
49. Gumburu Hills	—		—		13·97	(1950 only)	6° 55′	45° 49′	1,748	49. Gumburu Hills.

TABLE 7

DATE OF THE BEGINNING OF "GU" MAIN RAINS (SECOND QUARTER)

	1944	1945	1946	1947	1948	1949	1950	(Statistical) Average
4. ODWEINA ...	13.4	7.5	5.4	8.4	22.4	4.5	4.4	18.4
6. DANOT	1.5	7.5	? April	8.4	26.4	10.4	3.5	23.4
10. LAS ANOD ...	17.4	7.5	19.4	14.4	Nil	8.5	16.5	29.4
13. GARDO	12.4	20.4	19.4	16.4	23.4	29.4	17.5	24.4
26. BURAO	3.5	6.5	13.4	9.4	23.4	4.5	3.5	26.4
30. SHEIKH	7.4	6.5	3.4	7.4	16.4	13.4	18.4	14.4
32. HARGEISA... ...	7.4	Early May	15.4	7.4	7.4	30.4	3.4	15.4
39. BORAMA	6.4	13.4	9.4	7.4	8.4	3.5	25.4	14.4
40. ERIGAVO ...	8.4	6.5	April	11.4	7.4	5.5	9.5	22.4 (Mean 21.4)
Beginning of widespread Gu rains ... ... (From detailed monthly maps and records.)	April 7–17	May 4–7	April 4	April 7–12	April 26	May 4	May 2–4	22.4

Note.—Despite statistical averages the likeliest dates for beginning of Gu widespread rains are April 7th or May 4th.

TABLE 8

GENERAL IMPRESSION OF RAINFALL VALUE FOR PROTECTORATE AND GRAZING AREAS AS A WHOLE (NOT FOR SMALL AREAS)

Rainfall quarter	1944	1945	1946	1947	1948	1949	1950
First: January–March ...	good	fair	fair	good	fair	fair	fair
Second: April–June	poor	fair	good	poor	fair	poor	bad
Third: July–September ...	good	fair	fair	fair	fair	fair	fair
Fourth: October–December ...	good	fair	good	fair	fair	good	bad
Whole year	poor	fair	good	poor	fair	fair	bad

TABLE 9

TABLE OF ANNUAL RAINFALL IN INCHES (1906–1939 COLLECTED BY DR. W. A. MACFADYEN)

Year / General Survey Station No.	31 Berbera	39 Borama	26 Burao	40 Erigavo	2 Gebile*	32 Hargeisa	30 Sheikh	37 Zeila	Notes
1906	7·02	—	—	—	—	—	—	—	
1907	0·94	—	—	—	—	—	—	—	
1908	1·26	—	—	—	—	—	—	—	
1909	2·89	—	—	—	—	—	—	—	
1910	6·36	—	—	—	—	—	—	—	Floods in March.
1911	1·35	—	—	—	—	—	—	—	
1912	2·50	—	—	—	—	—	—	—	
1913	3·27	—	—	—	—	—	—	—	
1914	2·63	—	—	—	—	—	—	—	Major drought (Jahwein).
1915	0·58	—	—	—	—	—	—	—	
1916	2·89	—	—	—	—	—	—	—	
1917	0·55	—	—	—	—	—	—	—	
1918	1·93	—	—	—	—	—	—	—	
1919	2·31	—	—	—	—	—	—	—	
1920	2·29	—	—	—	—	—	—	—	
1921	1·35	—	3·85	—	—	—	—	—	
1922	0·79	—	—	—	18·52	15·28	17·12	—	
1923	2·86	—	9·90	—	21·56	16·86	47·14	—	
1924	0·98	—	8·96	—	—	18·06	23·51	—	
1925	0·56	—	11·89	12·62	—	16·39	20·59	2·04	Drought (Duryanleh).
1926	6·54	—	12·30	18·25	—	31·91	27·38	10·81	
1927	2·02	—	9·78	15·29	—	14·58	11·70	8·42	
1928	1·09	15·99	9·07	10·50	—	12·45	19·90	3·08	Major drought (Baha).
1929	0·37	16·42	9·25	11·90	—	17·07	25·04	1·81	Destitute camps, Bulhar (?22,000) and at Buran. Locusts.
1930	4·63	22·55	6·50	12·84	—	20·67	27·02	8·83	
1931	1·43	20·24	9·79	10·53	—	25·35	19·43	0·66	
1932	2·20	25·99	5·58	11·07	—	15·28	18·79	8·12	
1933	0·86	15·90	5·58	9·81	—	12·42	17·07	2·05	Drought (Gabato).
1934	1·70	18·37	6·88	12·53	—	15·19	18·17	5·46	
1935	6·20	25·99	7·26	13·53	—	18·26	16·58	3·29	
1936	2·43	26·52	9·15	13·19	—	19·26	17·76	0·50	
1937	1·79	25·26	9·86	18·42	—	17·82	20·82	5·75	
1938	1·08	13·65	4·78	8·82	—	12·13	10·93	1·28	Drought.
1939	0·37	17·39	16·17	13·45	—	23·61	19·51	3·41	... ... May. Locusts.
1940	4·03	—	—	—	—	—	—	—	Fair rains (good Dhair).
1941	—	—	—	—	—	—	—	—	Heavy widespread rains ... ... From Sept. Locusts.
1942	—	—	—	—	—	—	—	—	Fair rains ... ... Locusts.
1943	2·78	—	—	—	—	—	—	—	Poor rains (destitutes Borama) ... ... Locusts.
1944	0·10	—	4·96	—	13·02	12·44	12·34	—	... ... Locusts.
1945	1·76	—	5·69	—	20·70	14·47	17·50	—	... ... Locusts.
1946	1·03	—	10·10	—	18·17	17·05	21·07	—	Very good rains ... ... Locusts.
1947	0·07	22·61	5·69	12·24	17·75	21·34	17·15	2·33	... ... Until Sept. Locusts.
1948	2·84	15·87	4·59	13·26	14·06	15·62	24·02	1·42	
1949	3·59	19·69	7·19	11·93	19·29	11·02	21·73	3·17	... ... From Dec. Locusts.
1950	3·79	17·19	1·89	21·63	20·84	16·05	12·14	2·31	Drought ... ... Locusts.

* Gebile recording made at Ijara from 1.1.46–31.5.50.
Jibuti.—Records have been kept at Jibuti (Bulletin Annuel du Service Météorologique Côte Française des Somalis) since 1901 without a break. The average annual rainfall from 1901 to 1947 was 4·95 inches, and the maximum annual rainfall in that period was 11·10 inches in 1937.
Harar.—The average annual rainfall at Harar from 1909 to 1918 was 35·27 inches.

APPENDIX J

RUNOFF FROM A SMALL TRIAL CATCHMENT

Appendix to Howard Humphreys and Sons' letter dated
16 October, 1961, to Mr C. F. Hemming

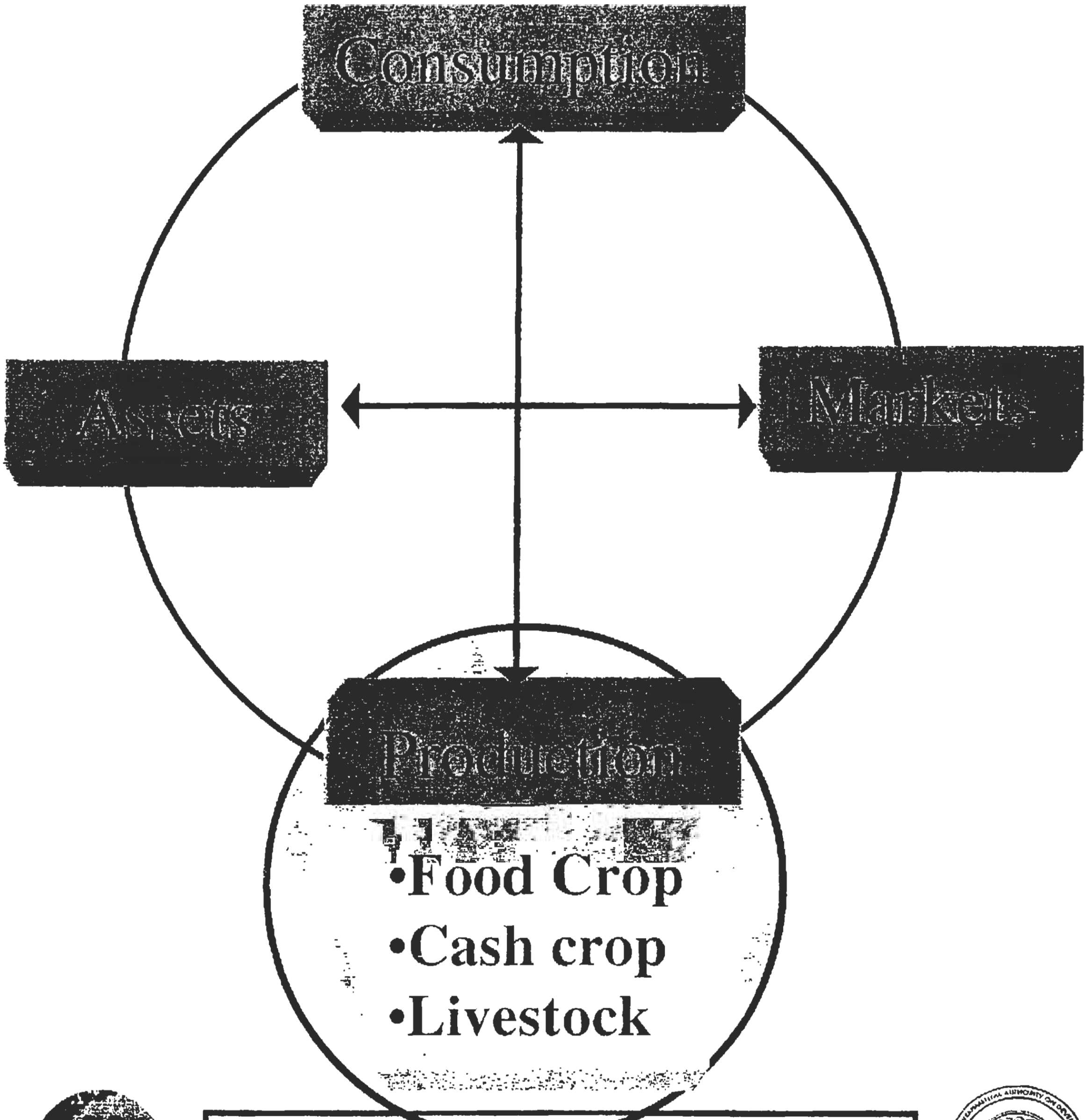
Hargeisa Water Supply—One Acre Experimental Catchment Area

Date	*Rainfall (ins.)*	*Duration (min.)*	*Intensity (in./hr.)*	*Run-off (gallons)*
1958				
June 4	0·03	?	?	—
5	0·18	15	0·72	—
15	0·28	6	2·60	—
16	0·21	32	0·39	—
17	0·22	13	1·02	—
25	0·24	32	0·45	—
27	0·06	?	?	—
July 9	0·47	244	0·12	—
10	0·57	67	0·52	—
15	0·40	103	0·23	6
16	0·22	27	0·50	4
19	0·15	9	0·95	2
20	0·06	—	—	—
21	0·06	—	—	—
23	0·31	59	0·32	7
24	0·08	15	0·31	—
Aug. 2	0·03	—	—	—
5	0·02	—	—	—
7	0·10	9	0·63	—
8	0·10	12	0·52	1
Aug. 9	0·55	64	0·52	383
11	0·08	5	0·95	—
16	0·11	8	0·84	—
17	0·69	33	1·27	32
18	0·22	9	1·39	1
20	0·28	20	0·84	33
28	0·07	—	—	—
29	0·93	54	1·03	954
30	0·23	9	1·46	3
31	0·19	21	0·56	—
Sept. 2	0·26	18	0·85	7
3	0·78	109	0·43	331
4	0·20	20	0·57	3
14	0·10	20	0·32	—
28	0·32	29	0·66	1
Oct. 5	0·19	13	0·87	0·2
1959				
Jan. 22	0·18	165	0·05	—
24	0·09	—	—	—
25	0·08	160	0·03	—
Feb. 17	0·05	195	0·01	—
Apr. 24	0·22	21	0·63	—
26	0·26	44	0·29	—
27	1·22	23	3·18	10,937
29	1·72	206	0·50	5,209
May 1	0·06	24	0·15	—
7	0·25	37	0·41	3
8	0·16	12	0·80	—
11	0·02	—	—	—
15	0·10	16	0·28	—
16	0·04	6	0·40	—
18	0·03	38	0·02	—

ANNEX D

IGAD-FEWS EARLY WARNING SYSTEM
TRAINING MATERIAL

Determinants of Food Security at a Rural Household Level



A Basic Early Warning System

Data Collection
- **Regular data on FS determinants**
- **Baseline data**

↕

Data analysis
- **Image analysis**
- **Statistical analysis**
- **GIS**

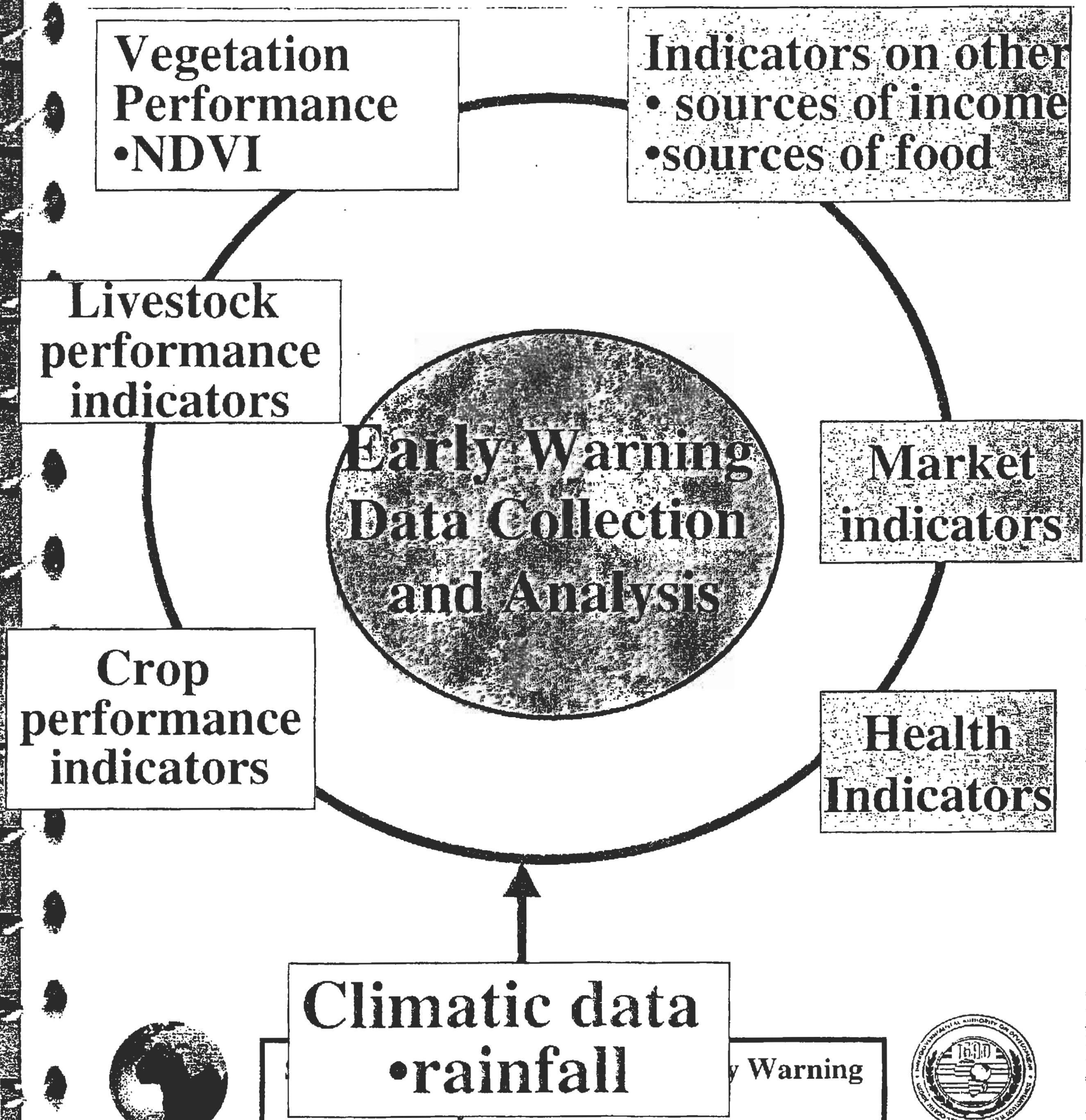
↕

Communication of Early Warning
- **Bulletin**
- **Press release**
- **email**

↕

Response and Mitigation
- **Governments**
- **Donors & NGOs**
- **Farmers**

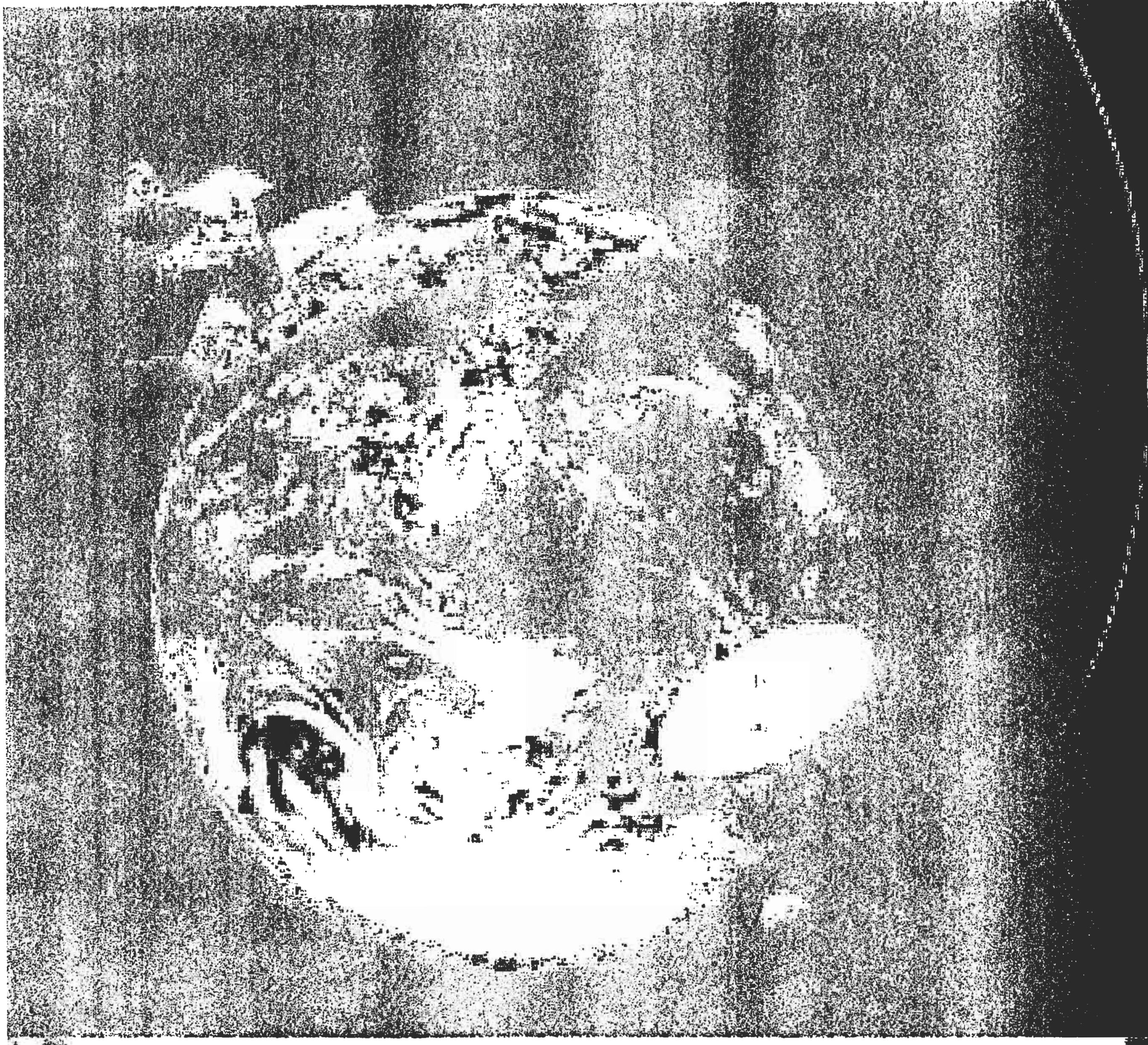
Some Early Warning Indicators and Analysis



Rainfall Monitoring for Food Security/Early Warning

- A rainfall monitoring system should integrate
  - seasonal forecasts if they exist
  - rainfall from station data
  - rainfall estimates (RFE) using remote sensing (Satellite data)
  - qualitative information on rainfall (monthly reported by the monitors in the field)

Introduction to the basics of remote sensing

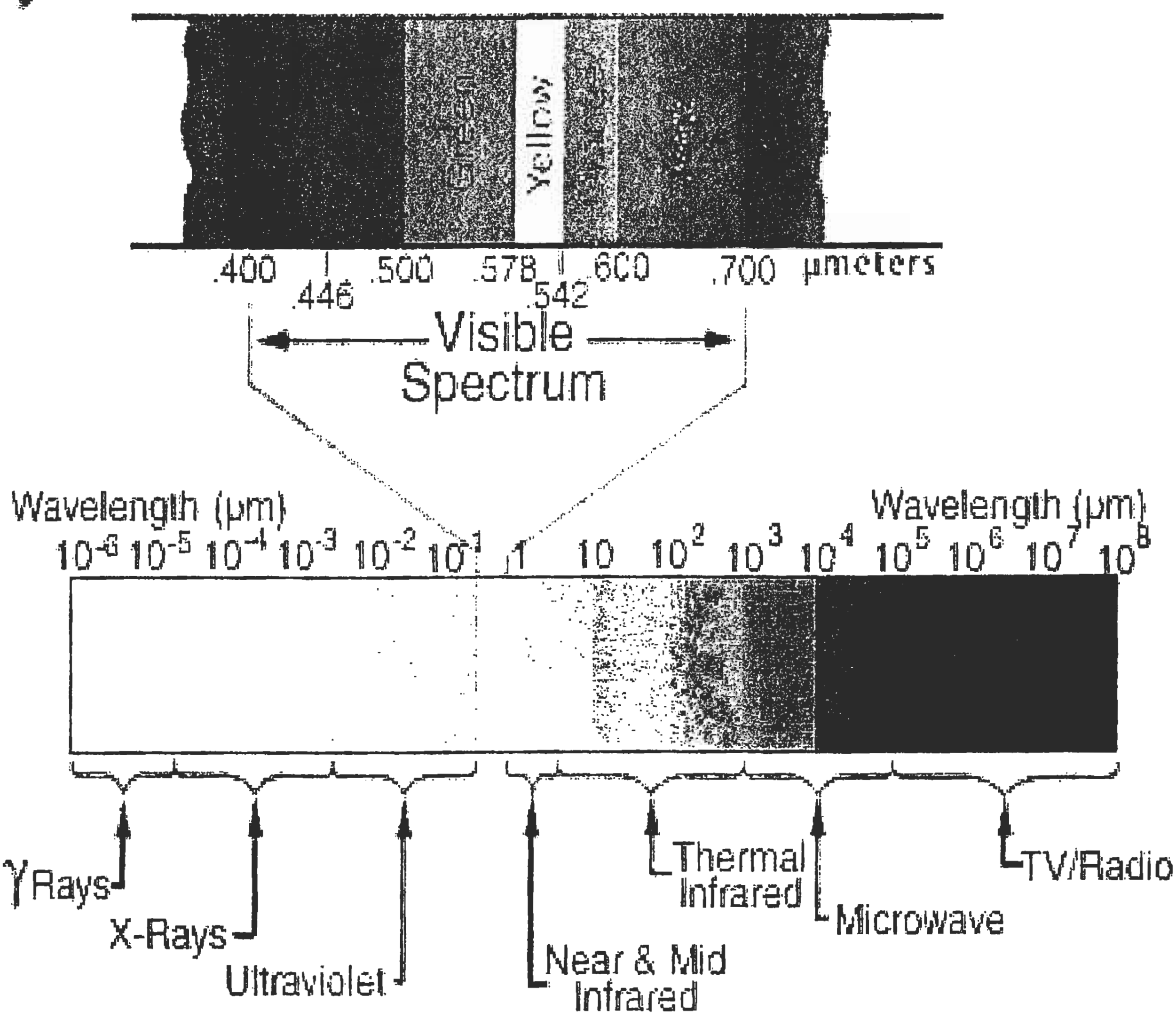


Satellite imagery training for Early Warning
by FEWS and IGAD

Basic components of a remote sensing system are

- energy source (EM)
- transmission path (Atmosphere with all its constituents)
- target (such as clouds and vegetation)
- sensors or measuring equipment (such as radiometers on board satellites)

The Electromagnetic Spectrum

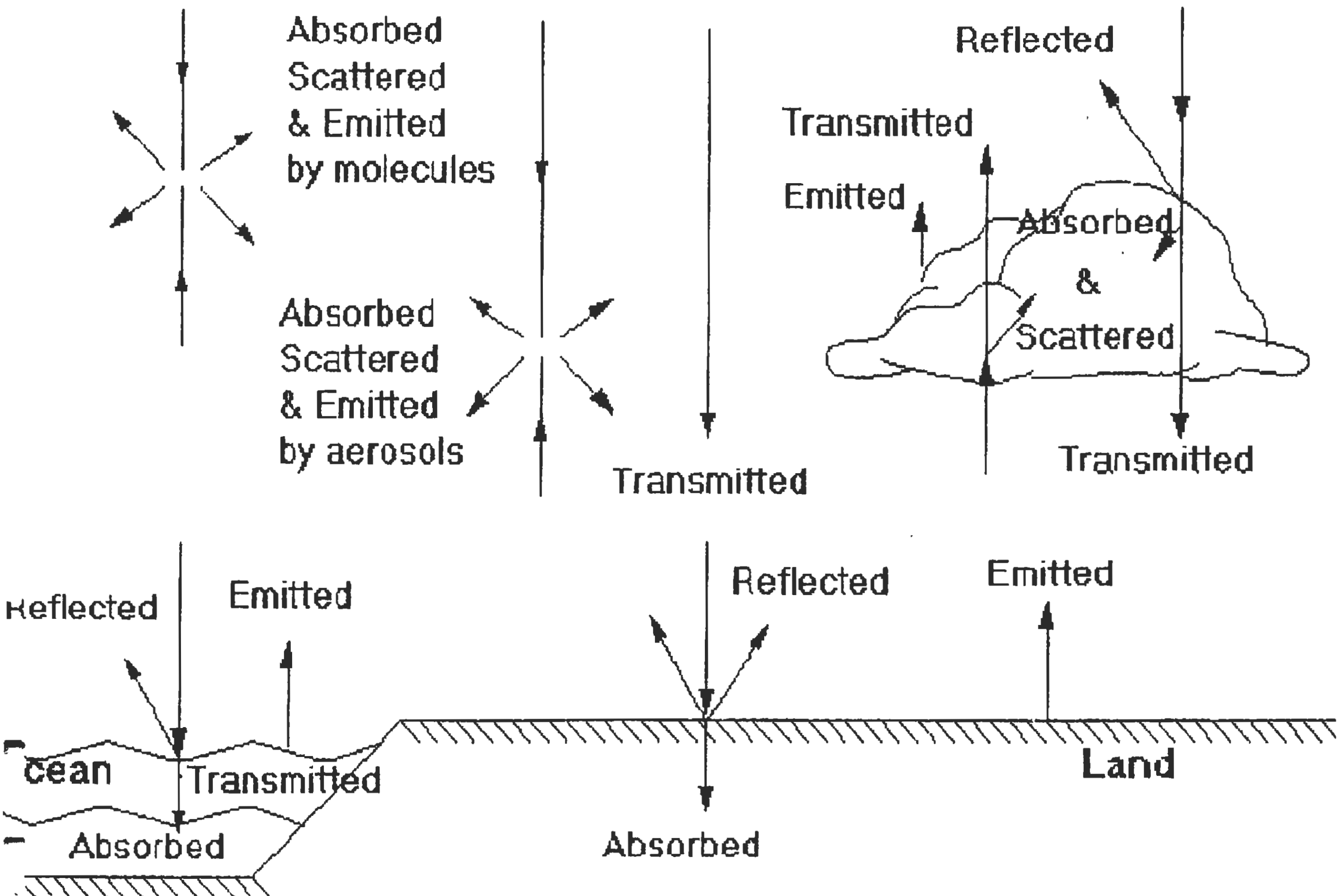


Basic Processes of Atmospheric Radiation

- Transmission
- Absorption
- Reflection
- Scattering

Diagram showing how radiation is affected by the atmosphere

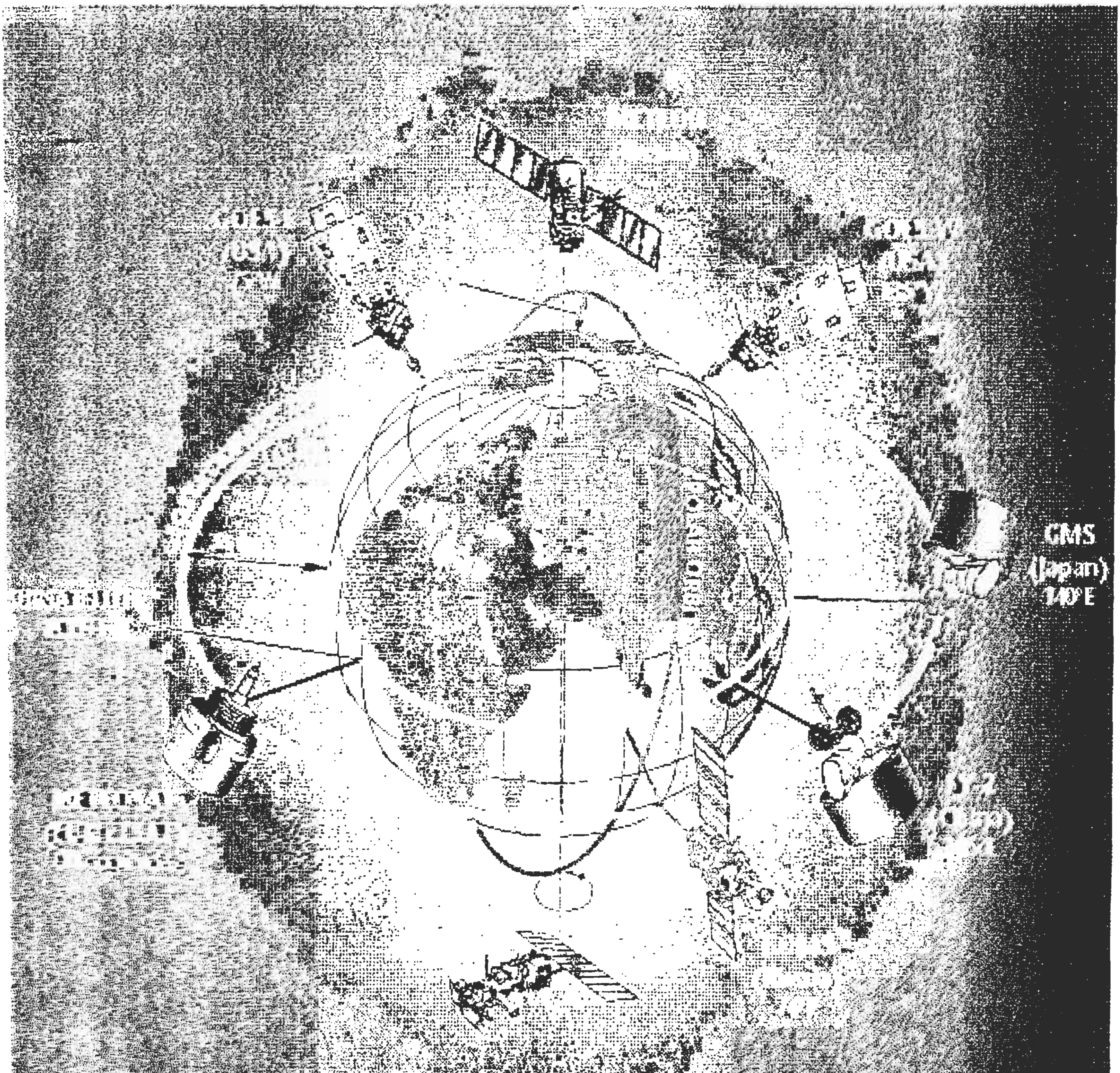
Processes of Atmospheric Radiation



Meteorological Satellite Systems

Global Observing System

Space-based subsystem

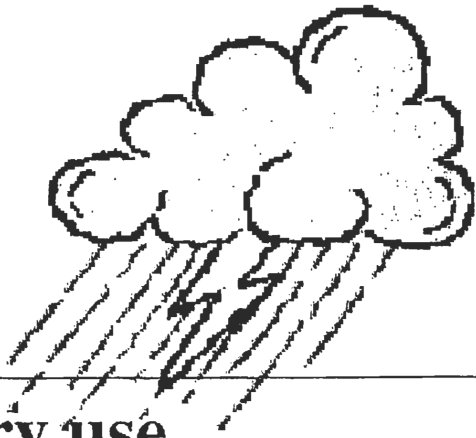


Geo-stationary Meteorological Satellites

Main characteristics:

- Altitude of the satellite: around 35,800Km fixed above the equator
- Temporal resolution: one image every 30 min. Spatial Resolution: 5.0 X 5.0 KM
- Carries on board a radiometer with three channels

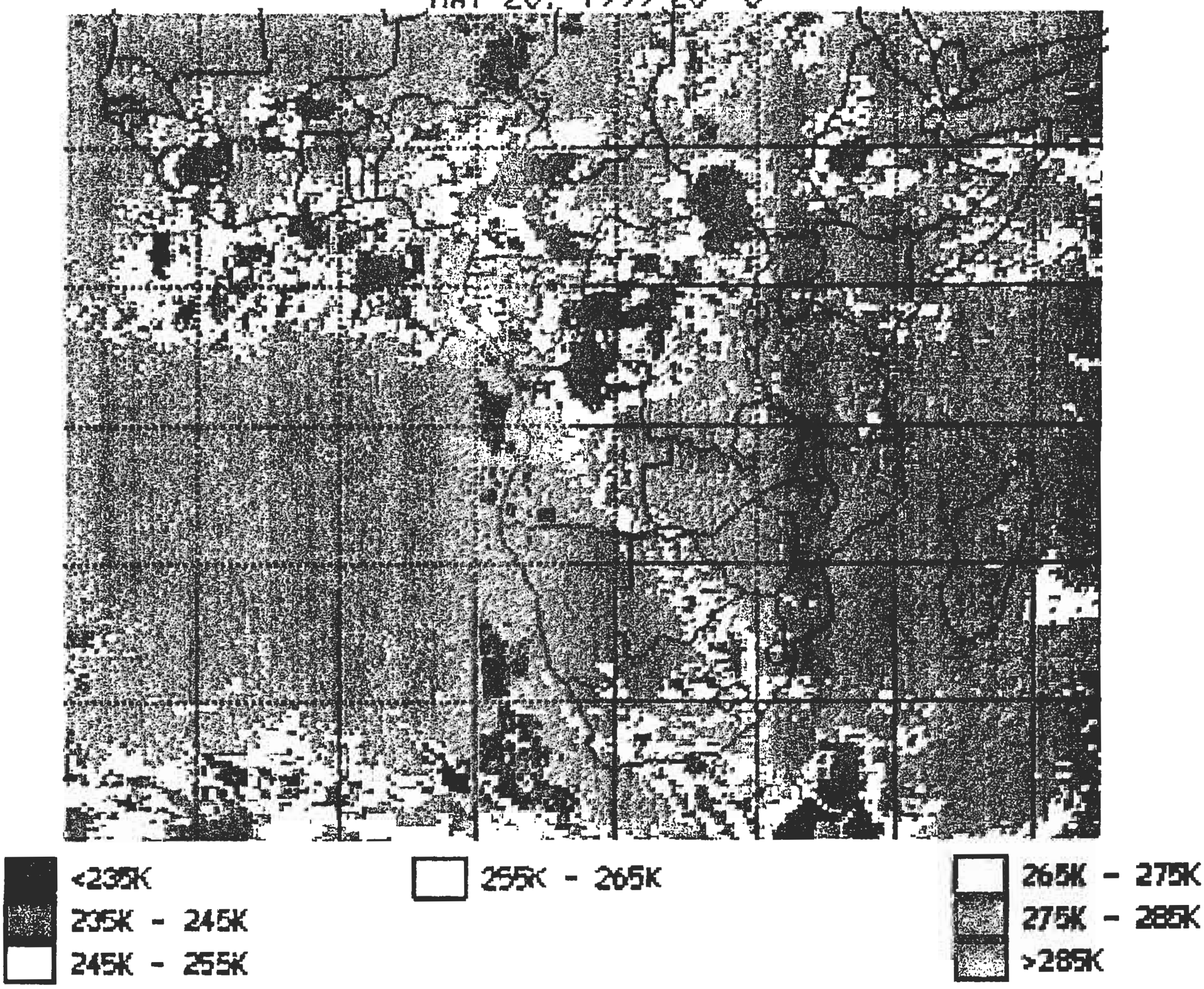
Geostationary Meteorological Satellites

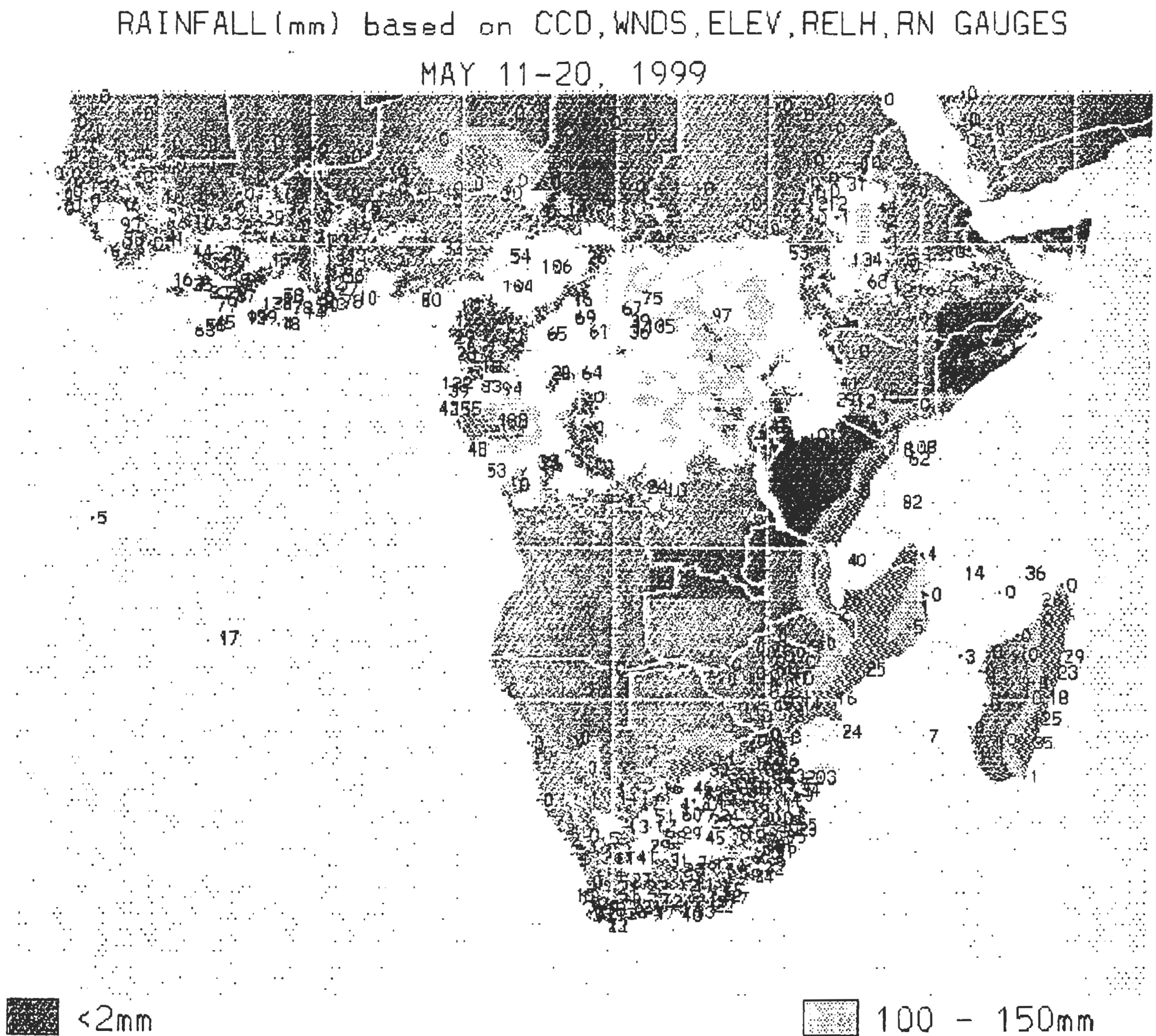


ch	(μm)	Primary use
1	0.3-0.7 (VIS)	Daytime Cloud and Surface Mapping
2	5.6-7.0 (WV)	Water vapour mapping
3	**10.5-12.5 (IR)**	**Surface Temperature, Day/Night Cloud Mapping**

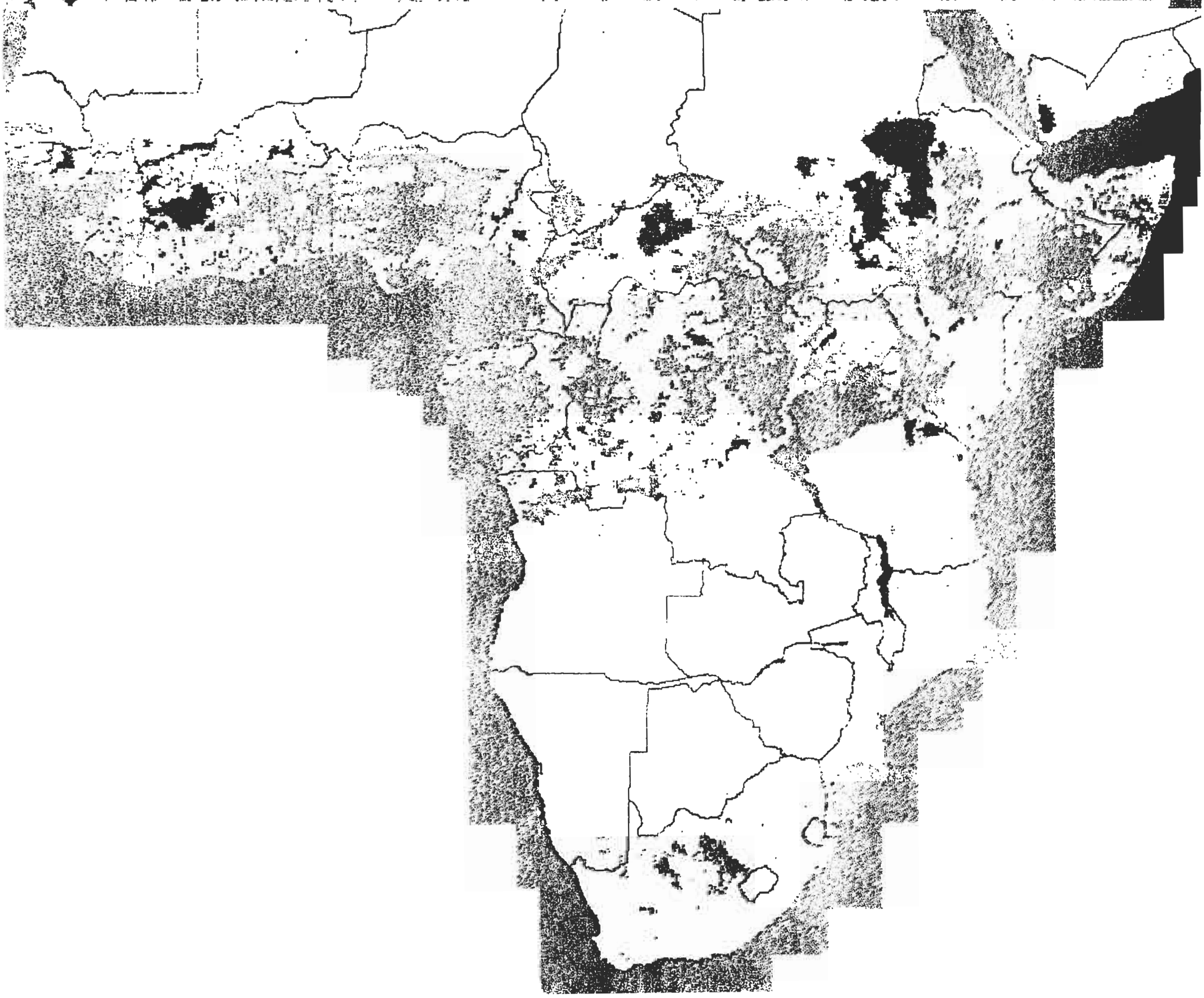
CLOUD TOP TEMPERATURES

MAY 20, 1999 20 0




RAINFALL(mm) based on CCD,WNDS,ELEV,RELH,RN GAUGES
MAY 11-20, 1999
<2mm
>2 & <10mm
10 - 25mm
25 - 50mm
50 - 100mm
100 - 150mm
150 - 200mm
>200mm

RFE (May1999 2nd dekad)-(Long term mean May 2nd dekad)



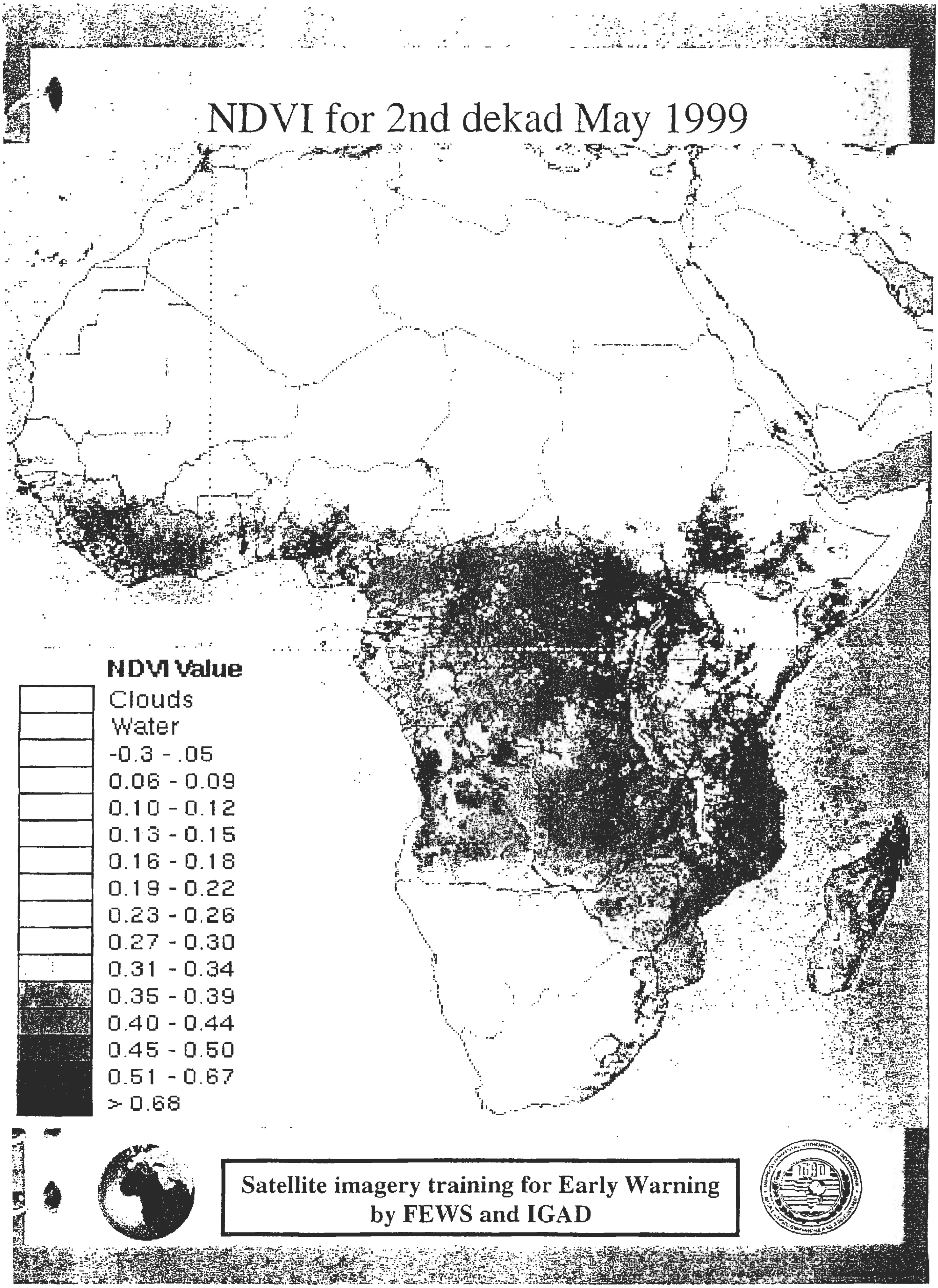
Meteorological Satellite Systems NOAA-AVHRR

Main characteristics

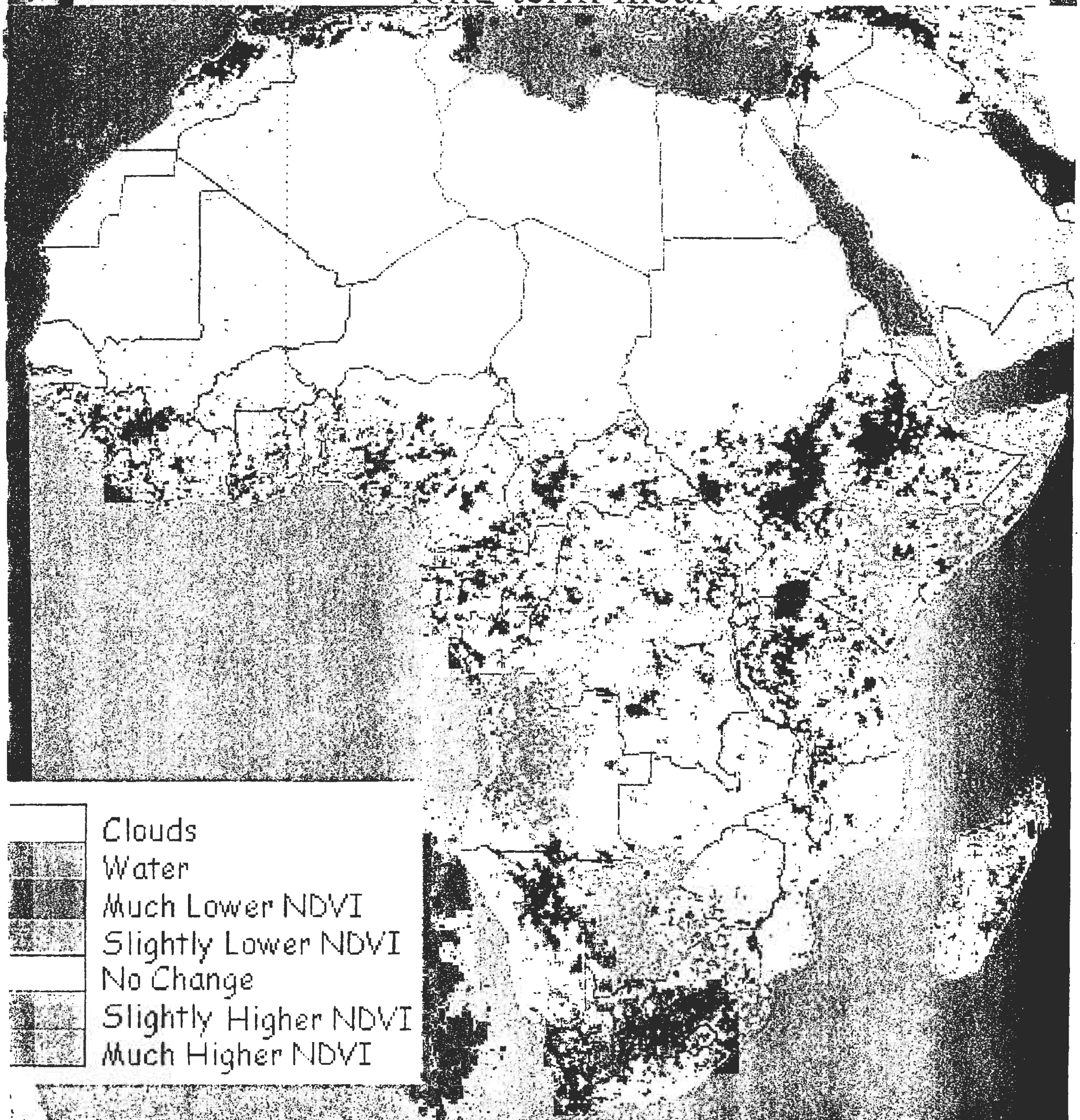
- Altitude of the satellite: around 850Km
- Temporal resolution: one image in 12 hrs. (One during night one during day time)
- Spatial Resolution: 1.1X1.1 KM
- Carries on board the AVHRR (Advanced Very High Resolution Radiometer)

Spectral Channels of the Advanced Very High Resolution Radiometer (AVHRR)

Ch	(µm)	Primary use
1	0.58-0.68	Daytime Cloud and Surface Mapping
2	0.72-1.10	Surface Water Delineation Vegetation Cover
3	3.55-3.93	Sea Surface Temperature (SST),Night time Cloud Mapping
4	10.3-11.3	Surface Temperature, Day/Night Cloud Mapping
5	11.5-12.5	Surface Temperature


NDVI for 2nd dekad May 1999
NDVI Value
Clouds
Water
-0.3 - .05
0.06 - 0.09
0.10 - 0.12
0.13 - 0.15
0.16 - 0.18
0.19 - 0.22
0.23 - 0.26
0.27 - 0.30
0.31 - 0.34
0.35 - 0.39
0.40 - 0.44
0.45 - 0.50
0.51 - 0.67
> 0.68
Satellite imagery training for Early Warning
by FEWS and IGAD

NDVI difference May 2nd dekad 1999 and long term mean

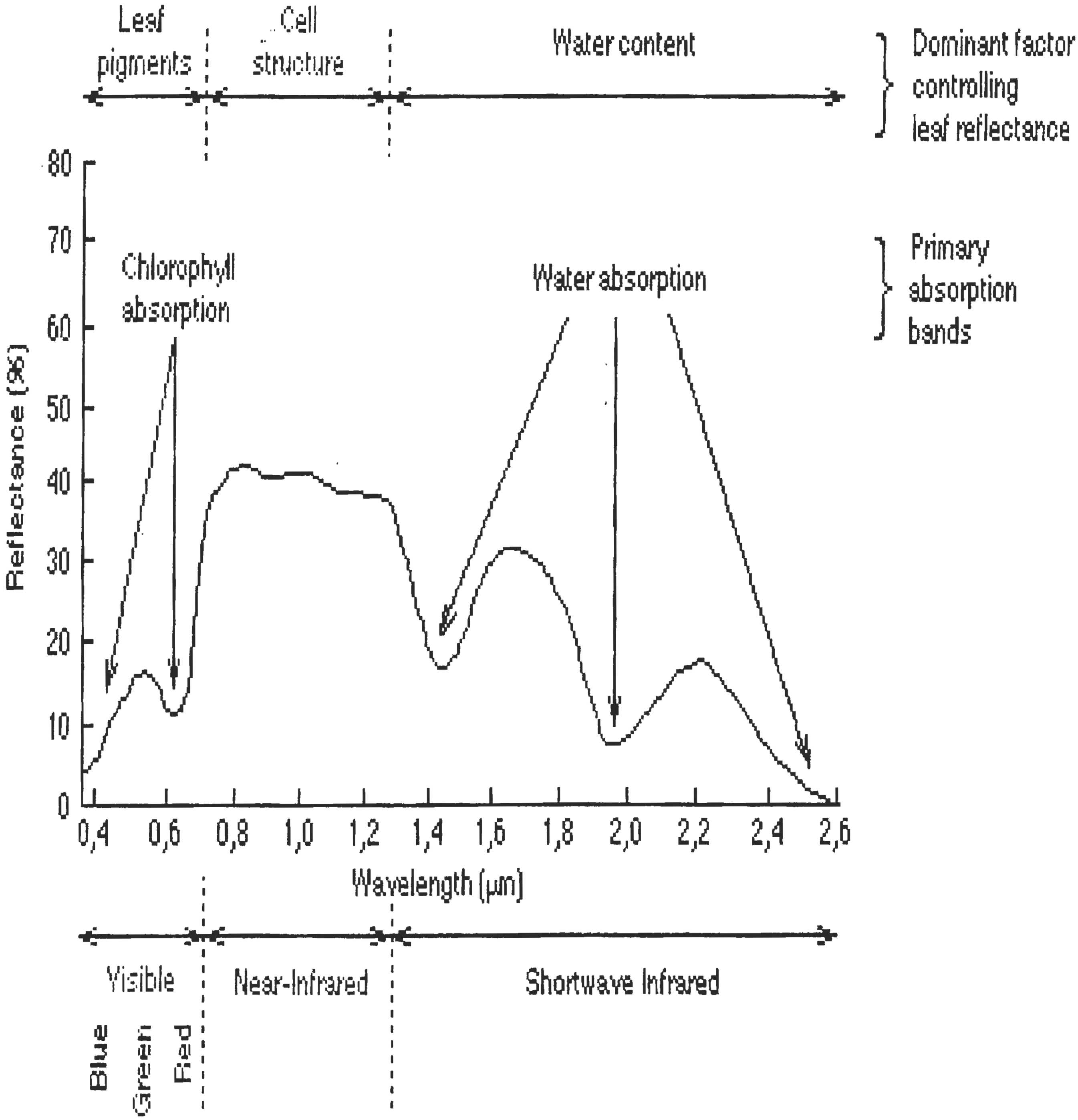


Satellite imagery training for Early Warning
by FEWS and IGAD

Applications of satellite remote sensing for Vegetation Monitoring

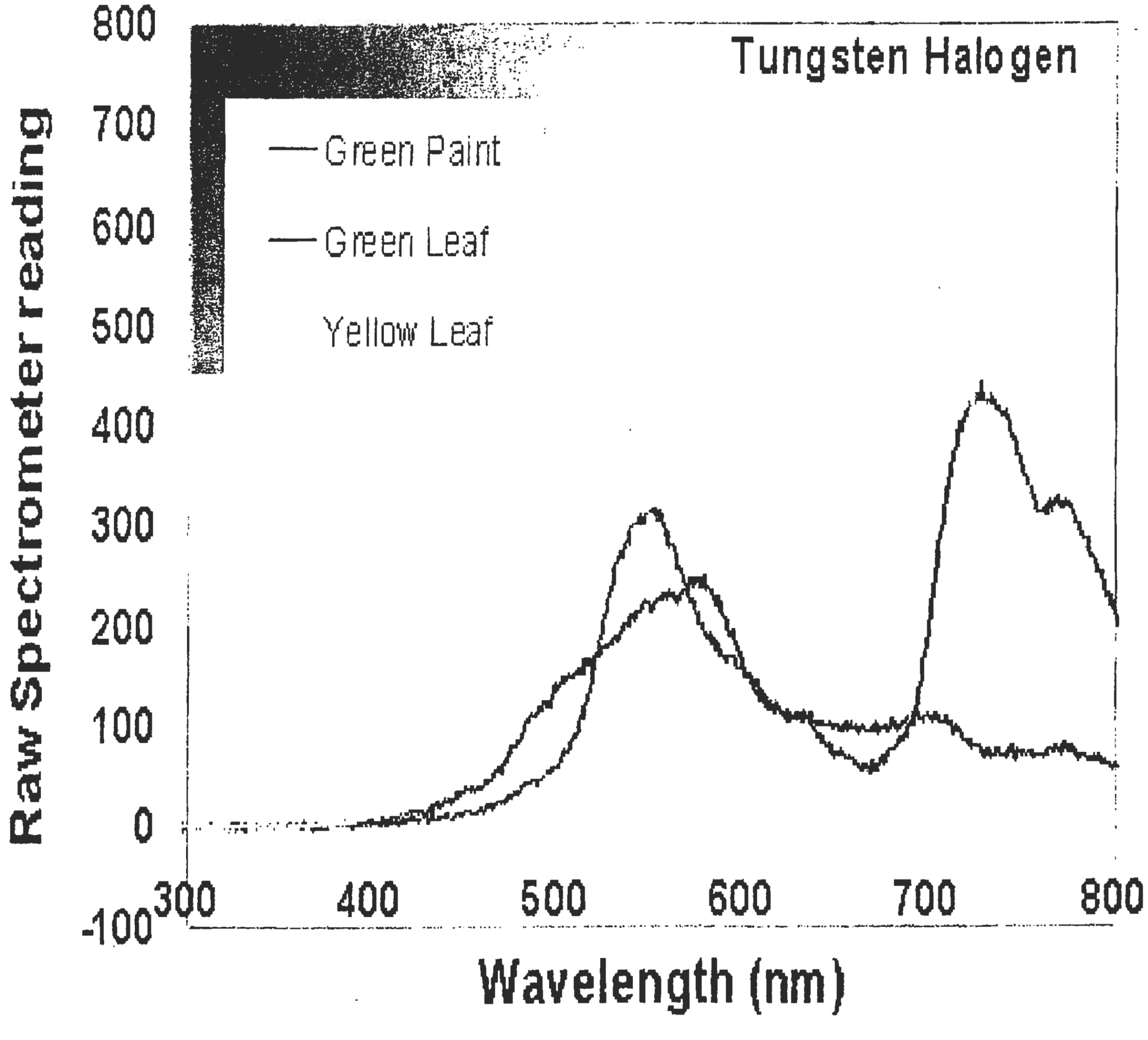
- The spectral properties of vegetation associated with
  - Photosynthesis (enhanced absorption in 0.4-0.7)
  - Leaf structure (enhanced reflection in the 0.7-1.3)
  - Water content (enhanced absorption in 1.3-2.5)
- Enable the use of remote sensing for vegetation monitoring.

Typical spectral response characteristics of green vegetation



Typical Leaf Spectra

Spectrometer reading vs. Wavelength



Normalised Difference Vegetation Index (NDVI)

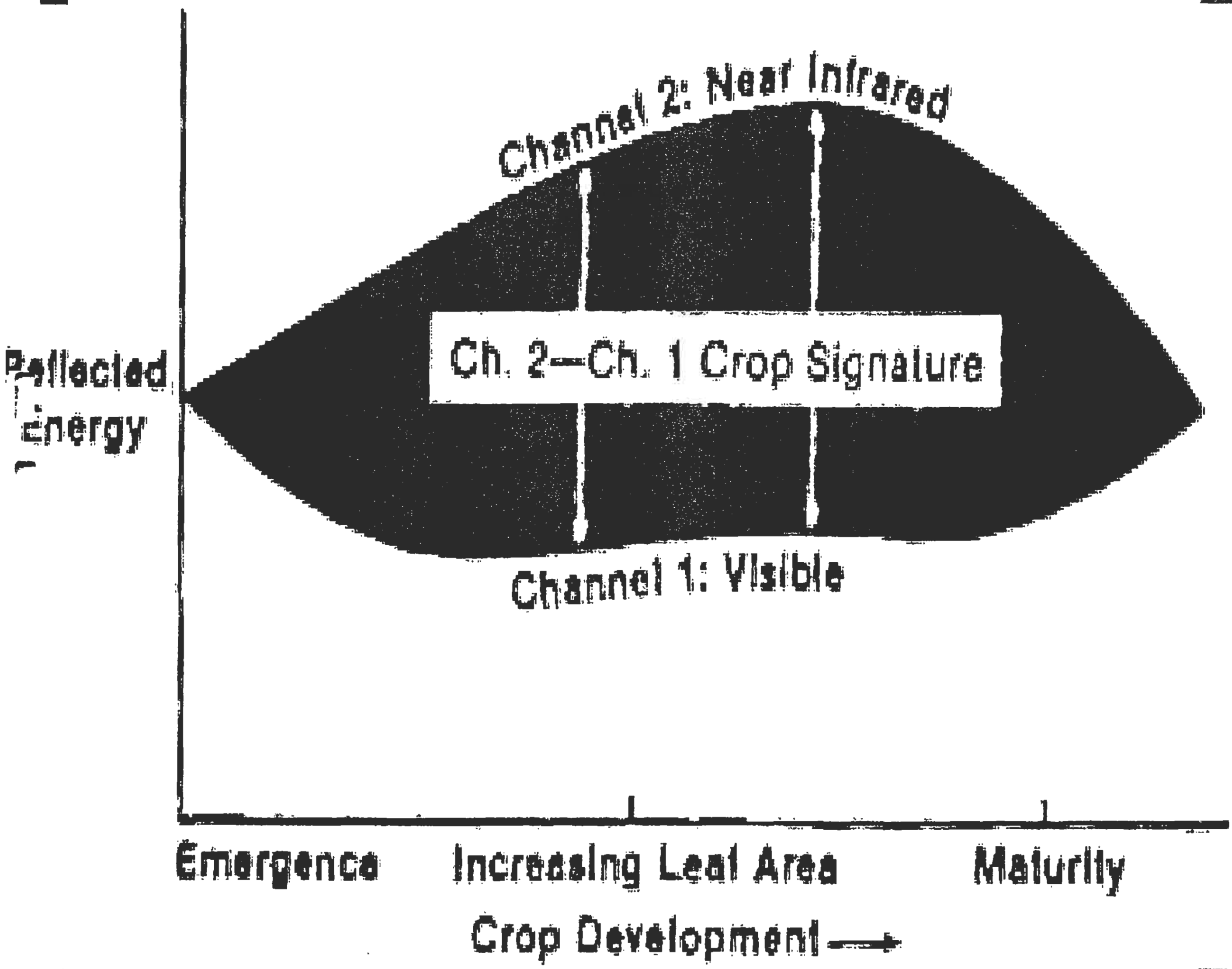
- NDVI is defined as follows

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Where
NIR = reflectance in the near infrared band
RED = reflectance in the red band

NDVI has the values ranging -1 and 1
Vegetated areas have high NDVI values.

Crop cycle and NDVI values



Application of NDVI in crop dependent areas

- Observe crop condition and development throughout the growing season.
- Determine where crops are late/early to emerge (using NDVI time series).
- Determine times of peak maturity and see how crops are doing.
- Compare current crop development to previous 10 day period, to last year, and to the mean.
- See how crops are responding to weather and environmental conditions.

Application of NDVI in livestock dependent areas

- When vegetation (grass) starts to appear and when it is finished
- Estimate biomass production
- Identify areas with favorable pasture
- Compare current pasture development to previous 10 day period, to last year, and to the mean.