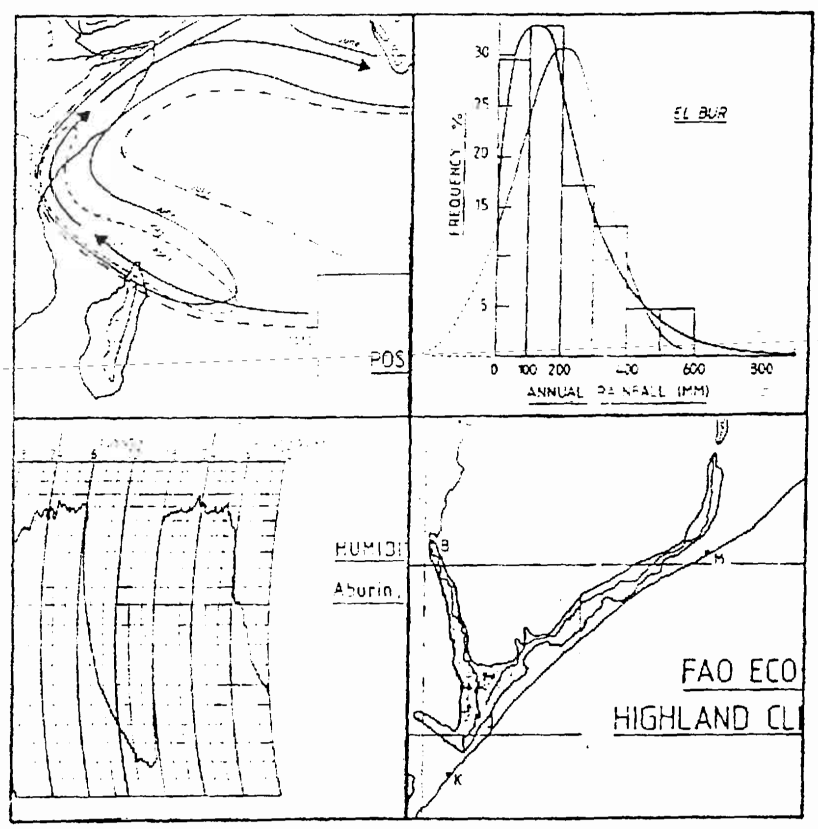
SOMALI DEMOCRATIC REPUBLIC

MINISTRY OF AGRICULTURE

FOOD EARLY WARNING DEPARTMENT

THE AGROCLIMATOLOGY OF SOMALIA



Technical Report No. 12.

F.E.W.S. Project.

Michel LeBlanc
F.E.W.S.

ON the second visit, the snake said to the soothsayer;

"Tell the sultan who sent you that a wasting drought will come.
Tell him that the dihi, maajcen and duur grass will wither away altogether.
Tell him that of the groves and of the great trees standing alone, some will die.
Tell him that all the weak and poor and all the flocks will perish.
Tell him that the strong camels and black-headed sheep will remain.
Tell him that men who are enterprising and industrious will survive".

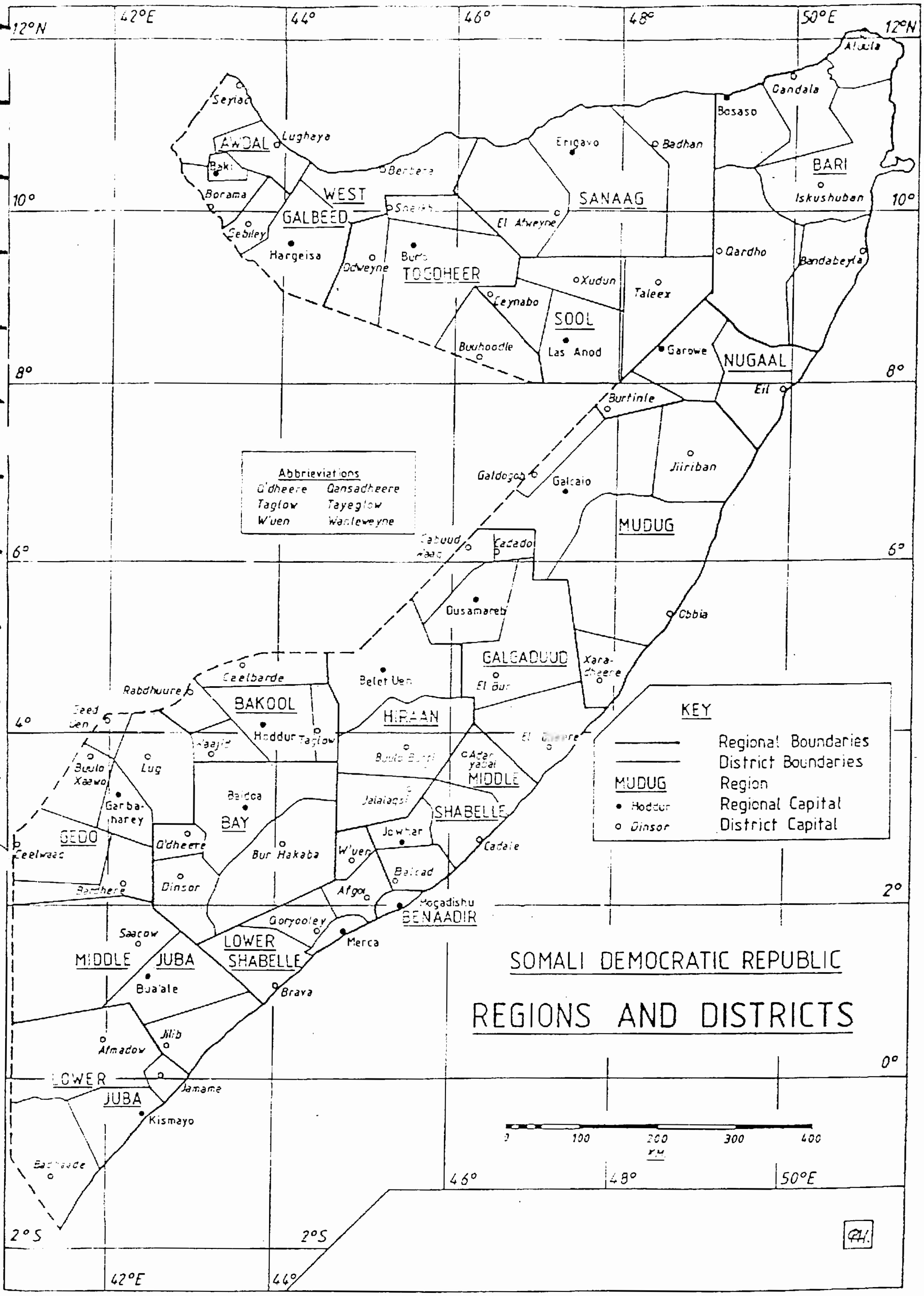
The soothsayer set off in a great hurry and after some time he came to the assembly. He recited the poem and when he had finished, the people ran towards him and lifted him from the ground in their joy. The sultan, very pleased, got up, shook hands with him, patted his head and blessed him. Then the people paid him great honour, entertained him, and made a riding display for him.

Next day the sultan assembled his clan. "It has been foretold for us that a time of drought is approaching. Everyone must store away something for himself", he told them. So every man made a storage place with racks, on which he placed such food as would keep.

After some months the drought began. The autumn rains did not come and there was no rain during the following spring.

All over the country clouds of dust were blown about by the wind, the land became bare, the trees withered, the ponds dried up, and all the shallow wells and water-holes were exhausted, except for the deep spring-fed wells. Then all those animals which cannot live for a long time without water, and all the animals with horns, died, and no livestock could be found except for the big strong camels. Other people were not prepared for the drought and they and their animals perished, but the sultan and his clan turned to their stores and survived the hard times.

From the traditional Somali Story of the Snake and the Soothsayer.


SOMALI DEMOCRATIC REPUBLIC
REGIONS AND DISTRICTS
KEY
Regional Boundaries
District Boundaries
MUDUG Region
Hoddur Regional Capital
Dinsor District Capital
Abbrieviations
O'dheere Qansadheere
Taglow Tayeglow
W'uen Wanleweyne
AWDAL
WEST GALBEED
TOGDHEER
SANAAG
BARI
SOOL
NUGAAL
MUDUG
GALGADUUD
HIRAAN
BAKOOL
BAY
GEDO
MIDDLE SHABELLE
BENAADIR
LOWER SHABELLE
MIDDLE JUBA
LOWER JUBA
Seylac
Lughaya
Baki
Borama
Gebiley
Hargeisa
Berbera
Sheikh
Odweyne
Burao
Erigavo
Badhan
El Afweyne
Bosaso
Qandala
Alula
Iskushuban
Qardho
Bandabeyla
Xudun
Taleex
Ceynabo
Las Anod
Buuhoodle
Garowe
Eil
Burtinle
Jiiriban
Galdogob
Galcaio
Cadado
Dusamareb
Obbia
Xaradheere
El Bur
Belet Uen
Ceelbarde
Rabdhuure
Hoddur
Taglow
Lug
Garbaharey
Baidoa
Bur Hakaba
O'dheere
Dinsor
Bardhere
Ceelwaac
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KM

P R E F A C E .

Since the publication of Fantoli's "Contributo alla Climatologia della Somalia" in 1965, very little has appeared in print concerning any aspect of the Meteorology, Climatology or Agroclimatology of Somalia, and this 'Agroclimatology of Somalia" therefore represents an important contribution to the scientific data base of Somalia, which will be found useful by engineers, scientists, economists, consultants and Governmental and International personnel for many years to come.

Other publications by the Food Early Warning Department include ten Technical Publications listing the entire annual, monthly and daily rainfall record of Somalia, and an Agricultural Statistics Compendium, all of which are further vital additions to the nation's data base.

The authors are to be congratulated on a volume, which not only explains the fundamentals of the Agroclimatology of Somalia in such a clear and lucid manner, but also includes tables, diagrams and analyses never before published.

Eng. Ali Abdi Odawa, Director,
Food Early Warning Department.

INTRODUCTION

This volume is intended to be used by scientists, engineers, consultants, students, and others who wish to gain a greater understanding of the Agroclimatology of Somalia. It does not assume any prior knowledge of the subject, but it has been written with the intelligent mind in view. It does not pretend to present in full all available information on the Agroclimatology of Somalia, since, for rainfall at least, these have been presented elsewhere, but it does offer comprehensive information on certain subject matter which is not foreseen to be published elsewhere. Rather, does it intend to provide the reader with the basis of knowledge to enable the best use to be made of any agroclimatic information.

Agrometeorology as a discipline is concerned with the interaction of plants with the weather and climate, therefore we have considered it appropriate that chapter 1 consists of a review of the synoptic climatology of Somalia and the whole African region. The chapter is so structured that each section provides a rounded body of knowledge of increasing depth from section to section, so that the reader may miss some of the chapter, with only a loss of depth of knowledge rather than a basic understanding. However, we consider it important that the cloud images are studied closely. No set of words or diagrams illustrates the weather patterns as vividly as do these pictures.

Chapter two is a review of the climate of Somalia. We have relied on published information, as well as data from various original sources in order to give a rounded appreciation of the Climate. Much of the information has either never been previously published, or is so difficult to obtain that it is worth repeating. Many of the analyses are our own work, also never previously published, and all the figures are new.

In chapter three we apply this information to some aspects of Agriculture in Somalia. We have been hampered in this by a lack of accurate scientific information on Somali farming. However, a section on climatic classification is included, in which each classification has an agricultural or botanical base, thus providing useful information on the agricultural potential of the country. We also deal directly with the Agriculture, in respect of the major crops, and the manner in which climate affects the distribution, and weather the year to year yield of the crops. We have dealt at some length on theoretical approaches to identifying the maximum possible yields. We have done this, not in the expectation that such yields can be obtained, but to indicate methods whereby it may be identified what are the best possible courses to follow in order to improve yields and production.

We have not dealt with all aspects of Agroclimatology. Matters of Agronomy are left to other publications to be produced by the FEWS Project. Also, for example, the relation between locust attacks and the weather is important, but no real time weather forecasting capabilities exist in Somalia, at present. Food storage in relation to Climate is another area where study could provide great benefits to the Country.

This publication is a product of the Food Early Warning Department of the Ministry of Agriculture, Somali Democratic Republic, supported by the Food Early Warning System Project (No.5.100.39.47.030) financed by the European Development Fund and executed by TRANSTEC S.A. of Brussels. The authors are Technical Expert Agroclimatologist and Head of the Agroclimatology Section, Food Early Warning Department respectively.

The authors wish to acknowledge the financial support of the organisations mentioned above, and the support of the Director of the Department, Mr. Ali Abdi Odawa, and the General Manager of the Project, Mr. M. Cervesato. In addition support has been forthcoming from the British Meteorological office, who provided the satellite images, as well as historical data. Mr. Peter Ede of the Hydrology Project provided the analysis of extreme rainfalls and Probable Maximum Precipitation. Dr. Rod Bowen assisted in the preparation of the section on Agroforestry.

While all drawings have been done by the authors, they wish to acknowledge the assistance of the Computer Centre of the Department, Ms. Nura Ahmed Ismael, Manager and Ms. Luul Abdi Muse assistant, and Mrs. Shukri Abdi Yusuf, who has done the word processing.

Peter Hutchinson & Olga Polishchouk

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Mogadishu, Somali Democratic Republic,

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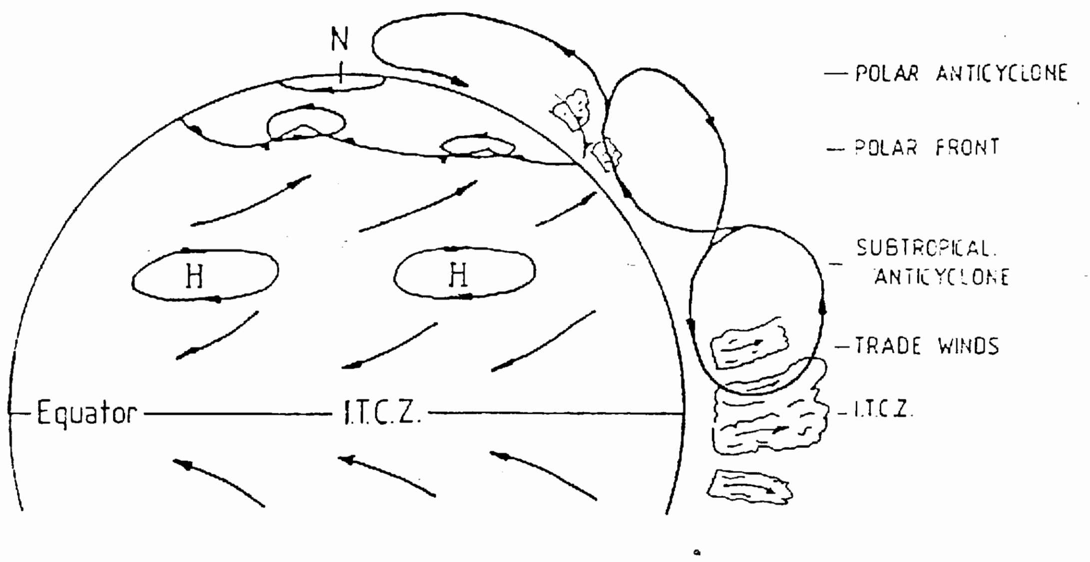
CHAPTER 1. THE GENERAL CIRCULATION AND SOMALIA

1. THE GENERAL CIRCULATION OF THE ATMOSPHERE.

The weather and climate of any one area or place results from the interaction of the Meteorological elements over a large part of the earth's surface, and cannot be understood nor explained without a consideration of the entire system of pressures and winds, which is known as the General Circulation of the Atmosphere.

This may be illustrated in several ways, but is conventionally shown as in figure 1, in which the vertical components of air movement are shown outside the circle, which represents the Globe, and the horizontal components within the circle. At the equator, neglecting for the moment the seasonal variations, solar radiation supplies the energy to heat the ground surface and lower levels of the atmosphere, resulting in an upward movement of the air, and a zone, at the surface, of low atmospheric pressure. Air from higher latitudes flows into the equatorial low pressure area, but is deflected by the earths rotation, forming the northeast and southeast trade winds, according to the hemisphere. To balance this, the air rising above the equator flows outwards at higher levels and subsides at about 30° of latitude, north and south, thus completing circulation "cells". As the air subsides in the subtropical areas,



THE GENERAL CIRCULATION OF THE ATMOSPHERE. FIG.1.

P.H.

so the subtropical high pressure belt is formed. This high pressure belt is characterised by the existence of quasi-stationary anticylones, from which air flows at low levels towards the equator being the trade winds, and towards the poles being known as tropical air masses in the higher latitudes. The polar regions, being cold at lower levels, are also anticyclonic, with air flowing outwards towards the lower latitudes. The interaction between this air flowing from the poles at low levels, and the air flowing from the subtropical anticyclonic areas form the temperate zones, the boundaries between these two types of air masses being the 'cold' and 'warm' fronts typical of the zones.

The actual circulation is, of course, very much more complicated than the simplified pattern described, and is subject to daily, seasonal and long-term variations. Of particular interest in tropical areas are the seasonal variations of the general circulation.

The Intertropical Convergence Zone.

Between the subtropical anticyclonic belts, the winds flow towards the equator, being deflected by the rotation of the earth into the northeasterly and southeasterly trade winds, though this is a simplification of the true situation. Where these winds from the northern hemisphere and from the southern hemisphere, meet is the Intertropical Front (ITF), sometimes known as the Intertropical Boundary (ITB). The two sets of winds do not meet head-on but are deflected latitudinally, that is, from northeast to east, and southeast to east. Where these deflections occur is known as the Intertropical Convergence Zone (ITCZ). Depending on both the locality and the season, the ITF and the ITCZ provide more or less suitable conditions for atmospheric uplift, resulting in convectional activity and rainfall.

Movement of the Intertropical Convergence Zone. Neither the ITF nor ITCZ are stationary. As the sun apparently moves north and south of the equator according to the season, so the heating of the earth and lower atmospheric levels varies, resulting in a north and south oscillation of both the ITF and ITCZ. This oscillation is not in phase with the apparent movement of the sun, but lags it, that is, it is later, by a month or more. The amplititude of the movement also varies according to the location. It is much greater over land than over sea, because of the differential rates of heating of soil and water, and is greater over some land masses than others, depending on the configuration of the continents.

It is this movement of the ITF and ITCZ which provides the different weather seasons in the tropical areas, including the monsoons.

2. THE SITUATION AFFECTING SOMALIA

The General Situation.

Somalia, lying, as it does, between 2°S and 12°N is entirely between the two subtropical anticyclonic belts. The movement of the ITF and ITCZ are therefore the most important factors in the succession of the weather seasons.

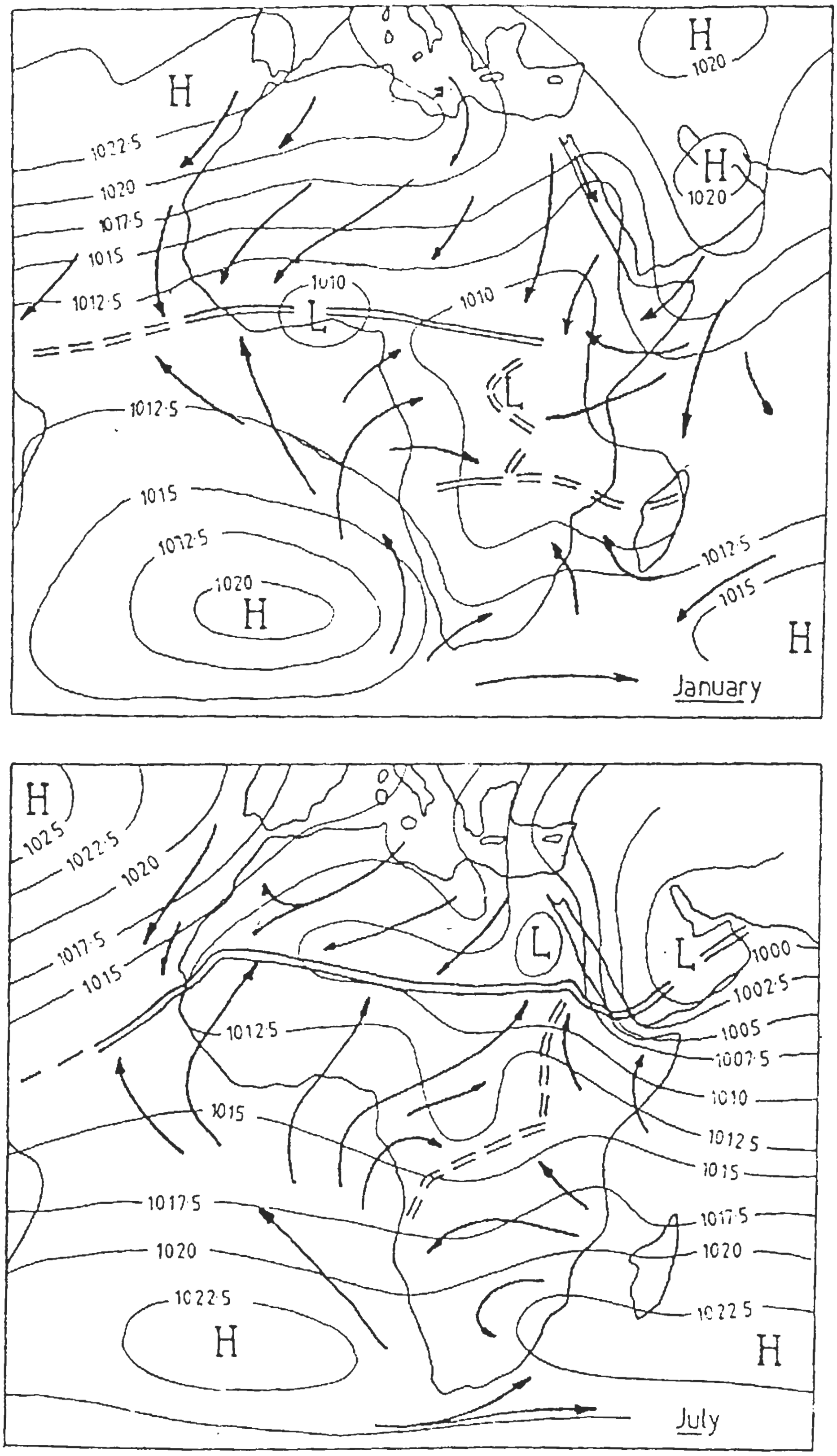
As mentioned, although the ITCZ lags the apparent movement of the sun by about one month, the earth's surface affects the amplitude of the movement and the intensity of the weather activity. The features of the earth's surface which are significant in this respect, are the shape of Africa, the existence, to the north, of the Arabian Peninsula, and the mass of Asia itself to the northeast, and the Western Indian Ocean. On a more local scale, the Kenya-Ethiopia-N.Somalia highlands also affects the wind flow at lower atmospheric levels.

The Seasonal Variation at the Surface.

In January (Fig.2) the sun is far to the south, and the ITCZ is at its furthest south, lying somewhere along the Equator over West Africa, dipping southwards over Central Africa, to reach a position at about 10°S over Eastern Africa and the Western Indian Ocean, or just to the north of Madagascar. Minimum surface pressure along the ITCZ is about 1008 to 1010 mb. Because it is winter in the northern Hemisphere, it is cold over Asia and Arabia, with consequent high pressure, featuring an anticyclonic system with maximum surface pressure of 1020 mb. over Arabia and the Persian Gulf. Airflow is thus northeasterly over Somalia, though curving rather more to the east further inland, where it meets a corresponding airflow round the Azores anticyclone, situated somewhere to the west of north Africa and Spain. These two airflows do form an airmass boundary, the movement of which has an uncertain effect on the weather of Somalia.

As the year progresses, so the sun moves apparently northwards. The high pressure system over Asia weakens, gradually being replaced by low pressure of about 1000 mb at its lowest in July with a trough extending to cover Arabia and the Persian Gulf, the same area that experiences the anticyclonic feature in January. In a corresponding manner, the subtropical high pressure zone to the south intensifies and moves northwards, from about 35°S to 30°S. The pressure gradient over Somalia therefore reverses, thus so does the windflow, which becomes southerly, though because of a secondary low pressure trough in the western Indian Ocean, and the shape of the Indian-Arabian-Asian landmass, the resultant wind recurves from south east to the south of the Equator, through south to southwest over Somalia.

As the sun once more apparently moves southwards, between July and January, so the reverse process occurs, with the ITCZ slipping southwards, and pressure once more building up over Asia and Arabia.



GENERAL SITUATION AT LOWER LEVELS IN JANUARY AND JULY

FIG. 2.

Upper Level Winds.

Though the surface winds and pressure are the elements readily observed, no understanding can be complete without a consideration of the upper atmosphere.

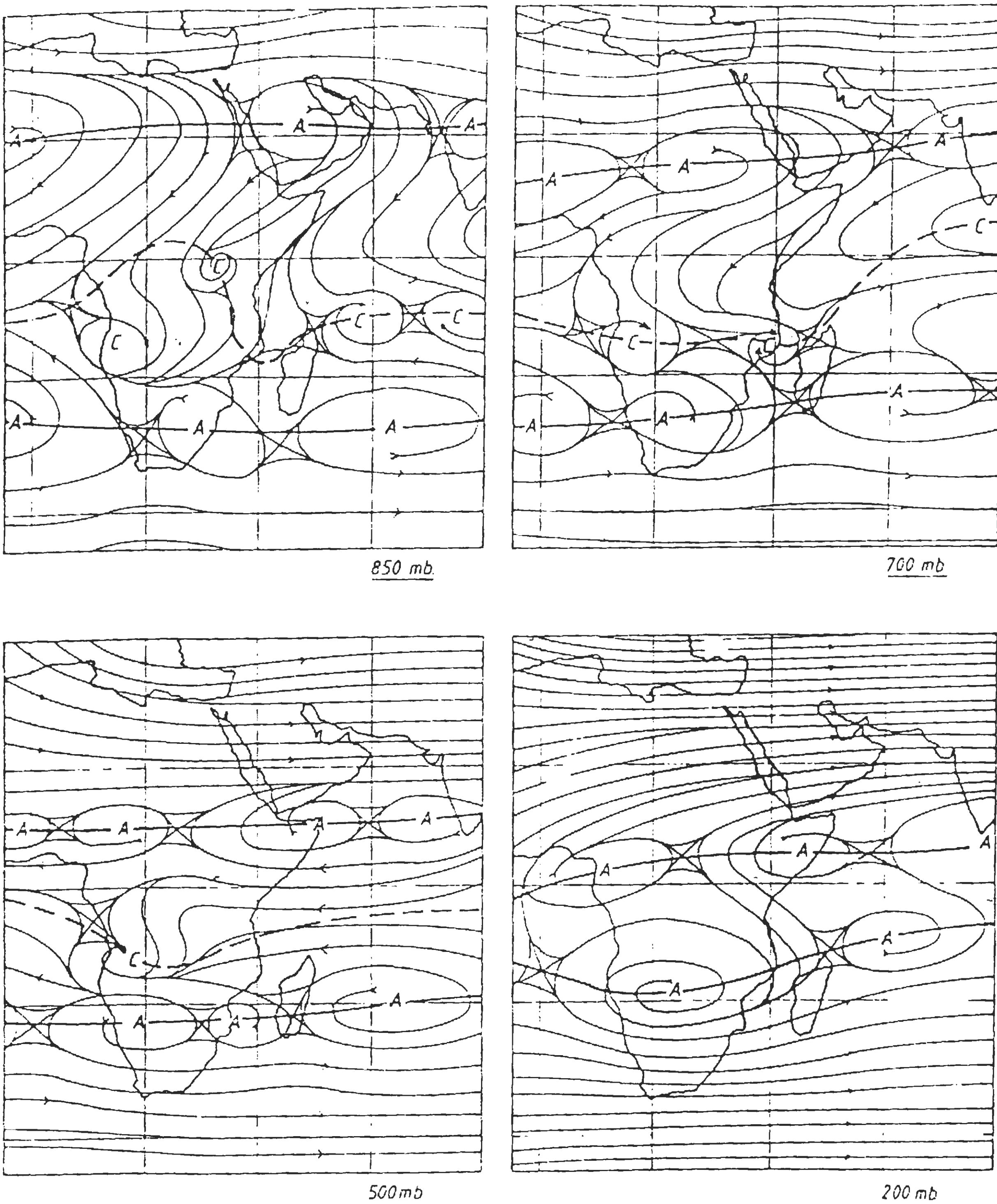
Circulation at Various Levels. Meteorological charts of the Upper Atmosphere are usually shown for particular pressure levels, a practice followed here for 850 mb, 700 mb, 500 mb, and 200 mb, which correspond approximately to heights of 1500, 3000, 6000 & 12000 metres respectively above ground level. The data displayed on such charts may be of various kinds, though the most popular are the height of the particular pressure surface, and, as used here, the wind flow, in the form of streamlines, which represent the tracks of individual particles of air over the area represented by the chart. The speeds are represented by the closeness of the streamlines, and, at particular points, by wind velocity arrows.

January. Flow at lower levels (850 mb) in January are similar to those at the surface, with the subtropical ridge lines lying at latitudes 20°N and 30°S, and low pressure at 10°S, but varying with longitude, dipping to the south over the Mozambique channel and to the north over Central Africa. In the northern hemisphere, flow is northeasterly towards the low pressure trough. As altitude increases, so the axes of high pressure are displaced towards the equator, with the low pressure axis smoothing out into a more direct east-west pattern, but virtually disappearing at the upper levels (200 mb), where the two high level pressure zones almost coalesce, resulting in a large area of low winds from 5°N to 20°S. Note the high speed flow at 200 mb, from west to east north of about 20°N.

April. By April, (Fig. 3(b)), though there has been little change in the high pressure axis at low and middle levels the low pressure trough has pushed northwards along the east African coast. At the upper levels, the southern high pressure axis has shifted northwards over Central Africa, with the resultant development of high speed westerlies over southern Africa and the southern Indian Ocean.

July. Solar heating has, by July, (Fig. 3(c)), caused the formation of the low pressure to the north of Somalia, at the lower levels, only, and the low pressure trough lies across the Sahara, dipping to the south along the Red Sea, then curving over the Arabian Peninsula. At 500 mb, anticyclonic (high pressure) circulation exists over the low level low pressure axis. Cyclonic development over the western Indian Ocean intensifies, with the resulting formation of the Somali Jet Stream flowing round its western quadrant (see below). In July, however, the northerly of the two high pressure axes moves to the north, allowing the development of an easterly airstream over Somalia at high levels.

October. By October, (Fig. 3(d)), the reverse movement of the entire system is underway, particularly with the rise of pressure at lower levels round 20°N, and the southerly displacement of the low pressure axis. At higher levels, the northerly anticyclonic ridge pushes south, squeezing out the easterly flow.

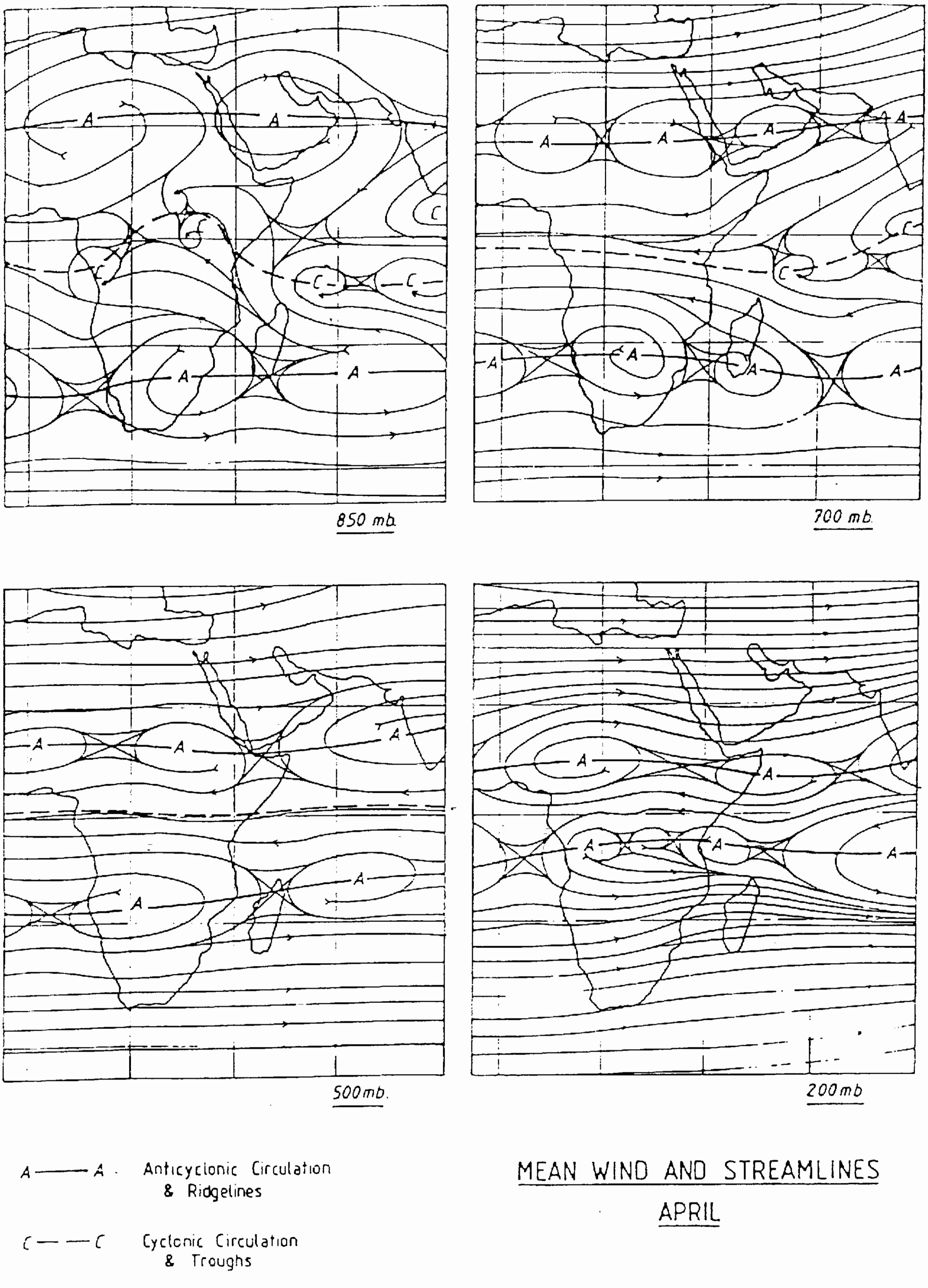


A ——— A Anticyclonic Circulation & Ridgelines

C - - - C Cyclonic Circulation & Troughs

MEAN WIND AND STREAMLINES
JANUARY

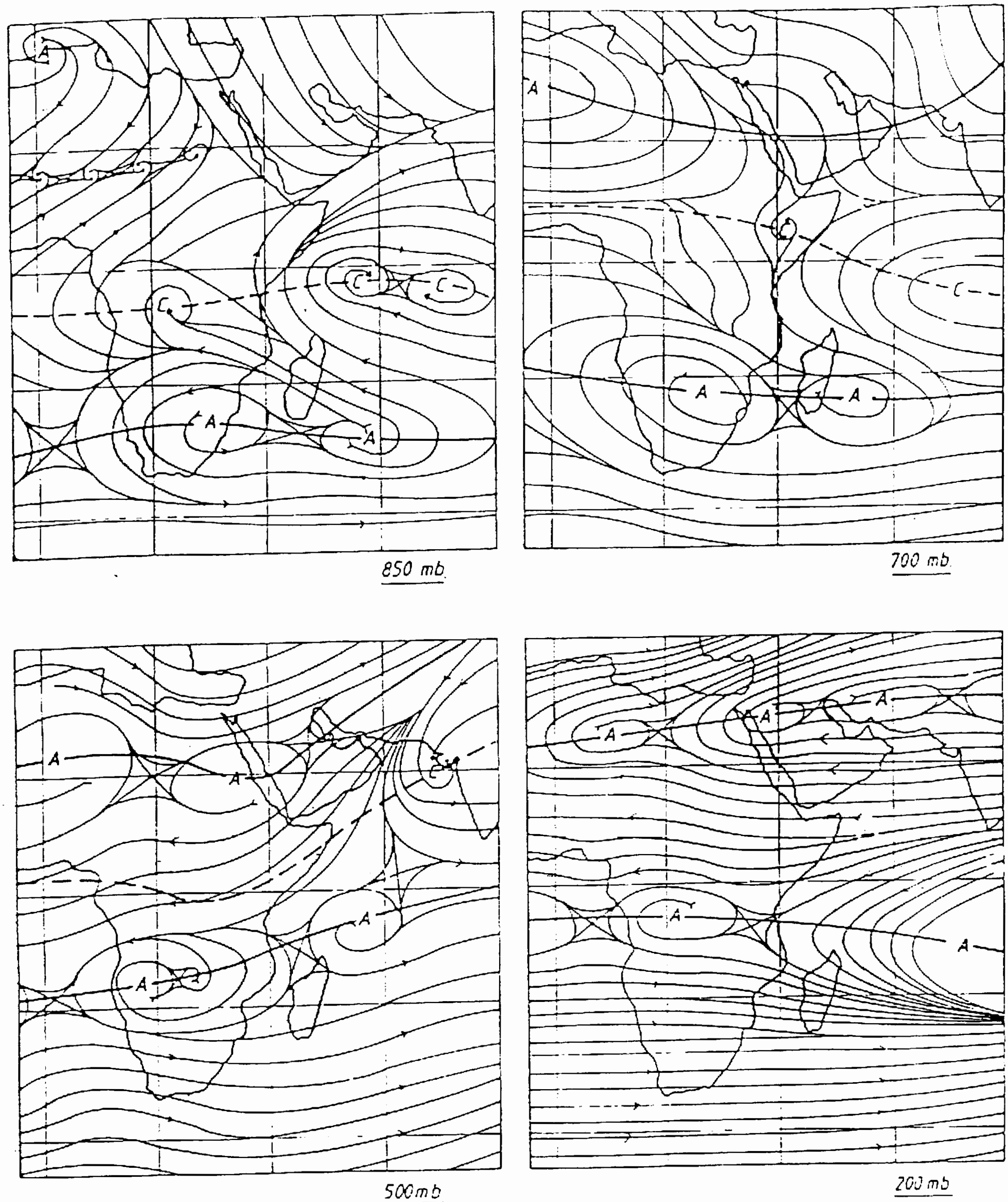
FIG 3(a) RH



MEAN WIND AND STREAMLINES

APRIL

FIG. 3(b)



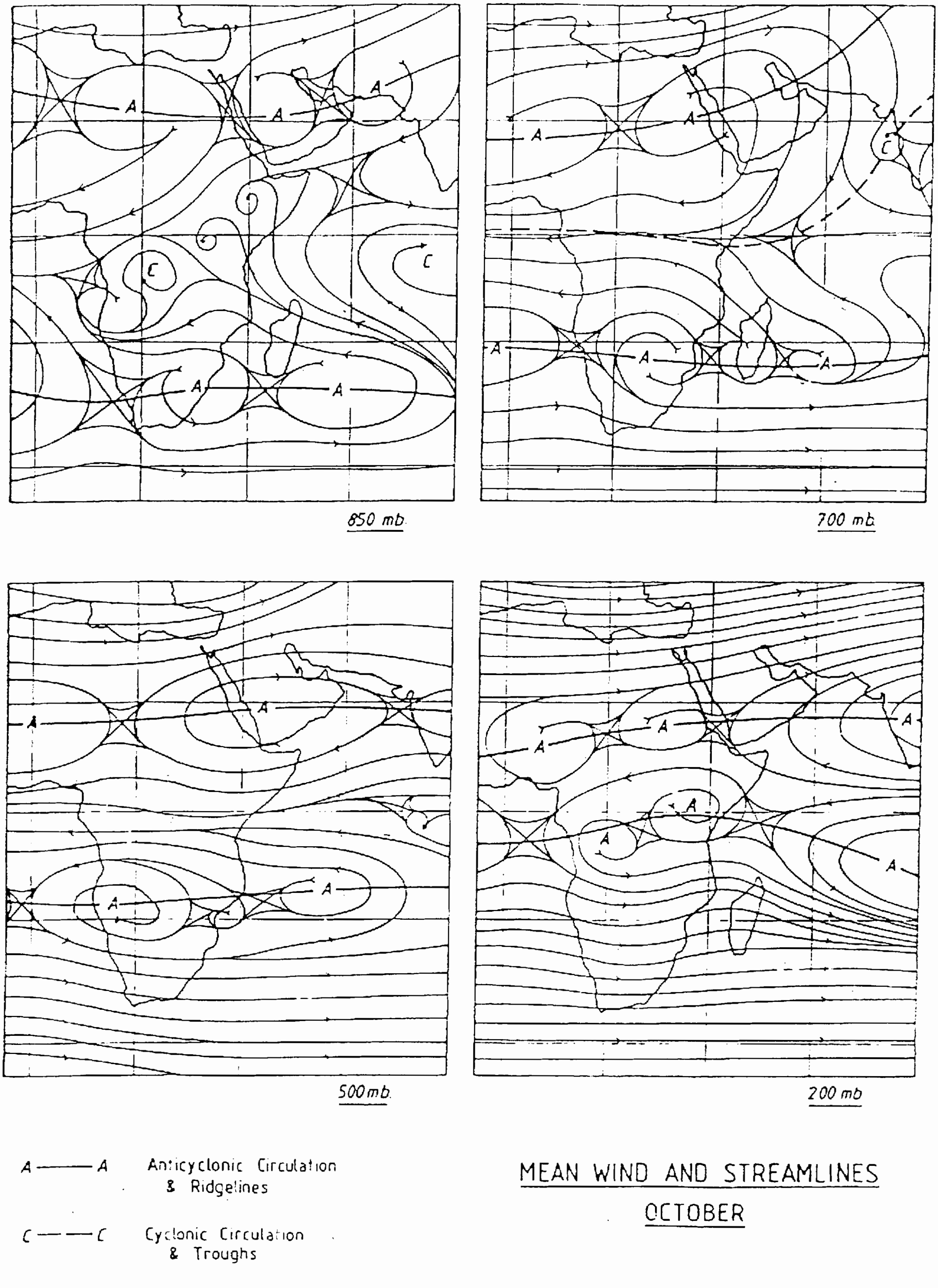
A —— A Anticyclonic Circulation & Ridgelines

C - - - C Cyclonic Circulation & Troughs

MEAN WIND AND STREAMLINES

JULY

FIG. 3(c)



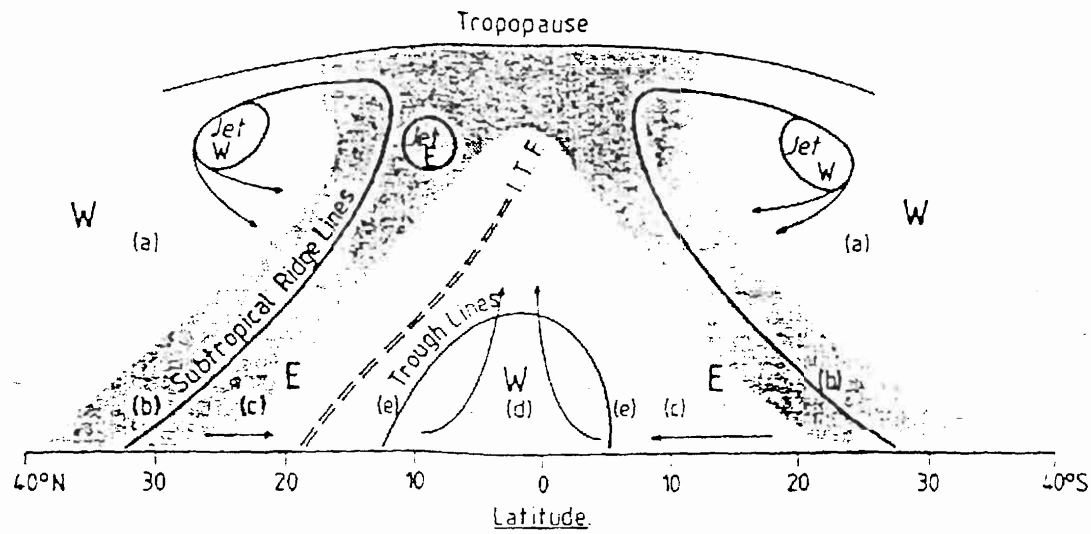
MEAN WIND AND STREAMLINES
OCTOBER

FIG. 3(d)

Zonal Winds. Fig. 4 illustrates in more detail the vertical structure of the atmospheric movement pattern outlined in Fig. 1. It shows the zonal (that is, east and west) components of winds on a longitude of 45°E, which is representative of what happens above the whole of Somalia.

The upper air is characterised by a number of features which are of interest to Somalia.

a) Extra-tropical westerlies, which occur at all levels in the temperate regions. Though outside the tropics at the surface, the westerlies are closer to the equator at the upper levels, and the maximum speeds occur at 200 mb between 25°N and 30°N but 45°S and 50°S in the southern hemisphere (Frost, 1969). A westerly jet appears in this zone in the northern hemisphere, with maximum speeds of 100 kts, but does not appear in the southern hemisphere, at this longitude.

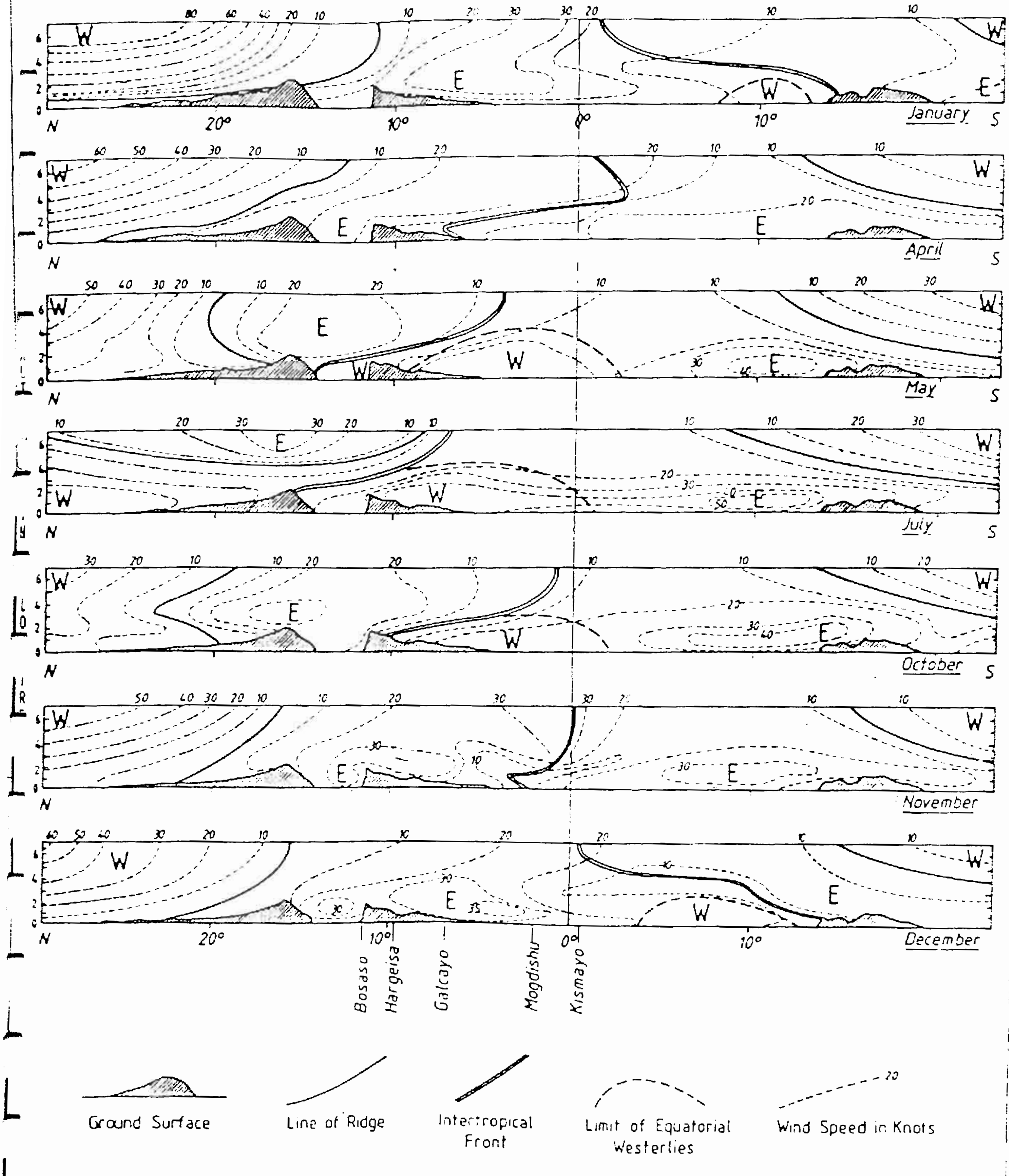


ZONAL WINDS AT 45°E

FIG 4

b) The subtropical ridge lines are defined as the surfaces separating the extra tropical westerlies from the tropical easterlies, and may be thought of as the ridge lines of the subtropical anticyclonic belts. In general, the ridge lines move only slightly at the surface, a matter of 5° at most, but fluctuate rather more at upper levels.

c) The Equatorial Easterlies, are the familiar trade winds, northeasterly and southeasterly, of which only the former affect Somalia. The easterlies extend to the upper levels, actually combining to form one high level equatorial easterly system between the subtropical ridge lines. The easterlies embody a seasonal (northern summer) easterly jet at 200 mb at 15°N.



MERIDIONAL SECTION OF THE ATMOSPHERE AT 45°E

Fig 5

d) The low level equatorial westerlies are, as already indicated, the southeast trades, which recurve to the southwest. It is these winds which produce the wet monsoons of Somalia. They are esentially a low level feature, not reaching up to the 500 mb level (5 Km.).

e) The low level westerlies are separated from the equatorial easterlies by the low level equatorial trough lines, the axes through which the zonal wind changes sign (i.e. east to west). These are not the same as the Intertropical Front (ITF) which indicates the boundary between the drier northerly airmass and the southerly, more moist, rain bearing airmass. The trough line lies to the south of the ITF, at the surface.

f) The meteorological equator, a term used by Leroux (1983) has not been included, for the sake of simplicicity. This is the axis of minimum atmospheric pressure, at the surface and upwards through the atmosphere. It is actually a surface from the ground level into the upper atmosphere, notionally surrounding the Earth.

All these features are sensitive to the movement of the sun, fluctuating north and south according to the season.

Zonal Winds at Lower Levels. The connection between this complex pattern of winds and actual weather may best be understood by a closer look at the zonal winds closer to the ground (Fig. 5).

In January, the eastern part of the equatorial easterlies cover the entire country. The equatorial trough is well to the south, with the ITF lying at about 10^{o}S at the surface, but sloping to the north. As the year progresses, so does the entire pattern move to the north, though this movement is very slow in the first few months. By March, little change has occured. However, a rather sudden northerly shift occurs in April, particularly at the lowest levels, resulting in a reversal of the slope of the ITF which now slopes upwards to the south, though easterly winds still cover the country, but with winds from southeast rather than northeast over the southern half.

In May the ITF at the surface has pushed through to the Gulf of Aden, though at upper levels it still lies over the northern part of the country. In addition, the Somalia low level Jet (see below) is developing, and is evidenced in May by a maximum westerly speed of 30 Kts. at 1 Km. altitude, at 5^{o}N, and a maximum easterly speed of 25 Kts. at 10^{o}S, at the same altitude.

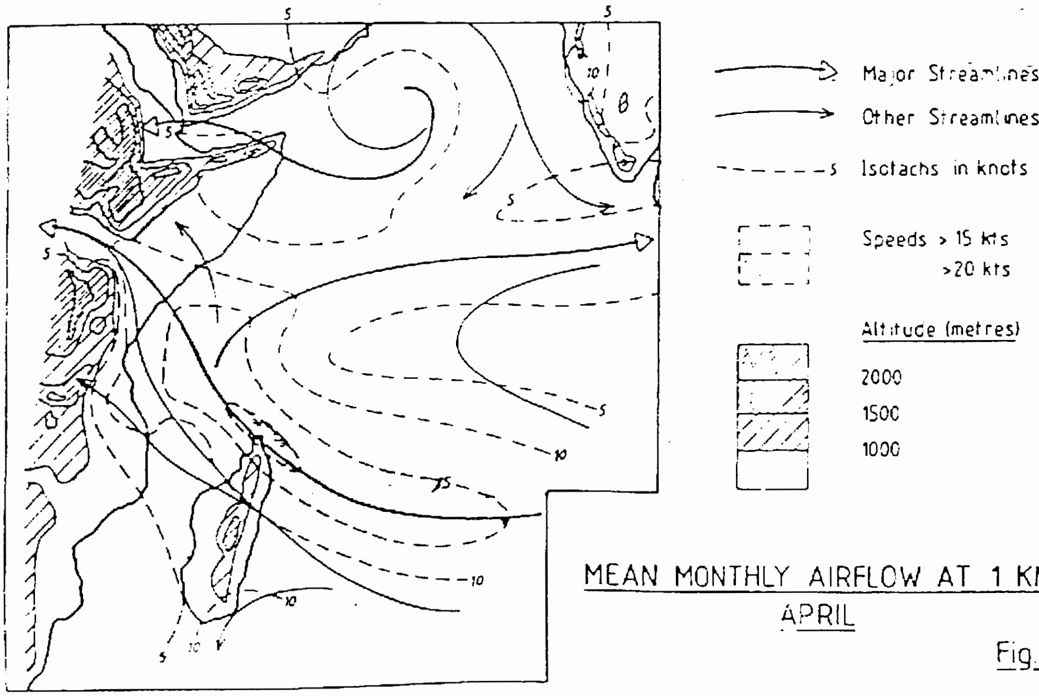
By July, the general movement has stabilized in its most northerly position, with westerlies extensive far to the north of Somalia, and the Somalia Jet at its maximum development with speeds in excess of 35 Kts. In the far south of Somalia, winds have backed to southerly at the surface and the southern equatorial trough line very nearly reaches the southern tip of the country. There is a suggestion by both Leroux (1983) and Findlater (1971) that there is intrusion of westerly air from the north, that is, circulated behind the Asia-Arabian low pressure area. This intrusion may only brush the northern coastal areas, but may go some way to explain the low rainfall at the north coastal stations.

The retreat, (southerly movement) is slight in August and September, but in the last three months of the year the movement does span some 25° of latitude, though it is much reduced at the upper levels. In October, the ITF has retreated to a position so that, on the surface it lies just to the south of the Escarpment. Thereafter, the ITF moves much more rapidly near the surface, so that it folds under itself, thus sloping from the surface to the north, then at about 1000 m asl. changing to slope to the south. For this reason the atmosphere is rather more stable, thus rainfall during the latter part of the year is generally less than in the earlier part of the year. Additionally, the westerlies disappear, and the Somali Jet weakens and withdraws to the south. By December, the situation is establishing itself at its most southerly extent, with persistent easterly winds over the entire country to the upper levels.

The Somali Low Level Jet.

A very significant feature of the atmospheric flow is the Somali Jet, which occurs at low levels, between 1000 and 3000 m above sea level, between May and September.

The Jet consists of an intensification, during the northern summer, of the flow found in the western quadrant of the secondary low pressure area over the Indian Ocean. Due to the Kenya-Ethiopian-N.Somalia Uplands, the flow is squeezed as it curves into southerly across the equator and thence southwesterly over northern Somalia, being guided by the shape of the uplands.



MEAN MONTHLY AIRFLOW AT 1 KM.
APRIL

Fig. 6(a)

The origin of the flow is to the east of Madagascar, where the flow is east-south-easterly throughout the year. During the early months, however, the strong northeasterly flow from the Arabian Sea prevents extension of the flow to the west of Madagascar. By March, the northeast monsoon

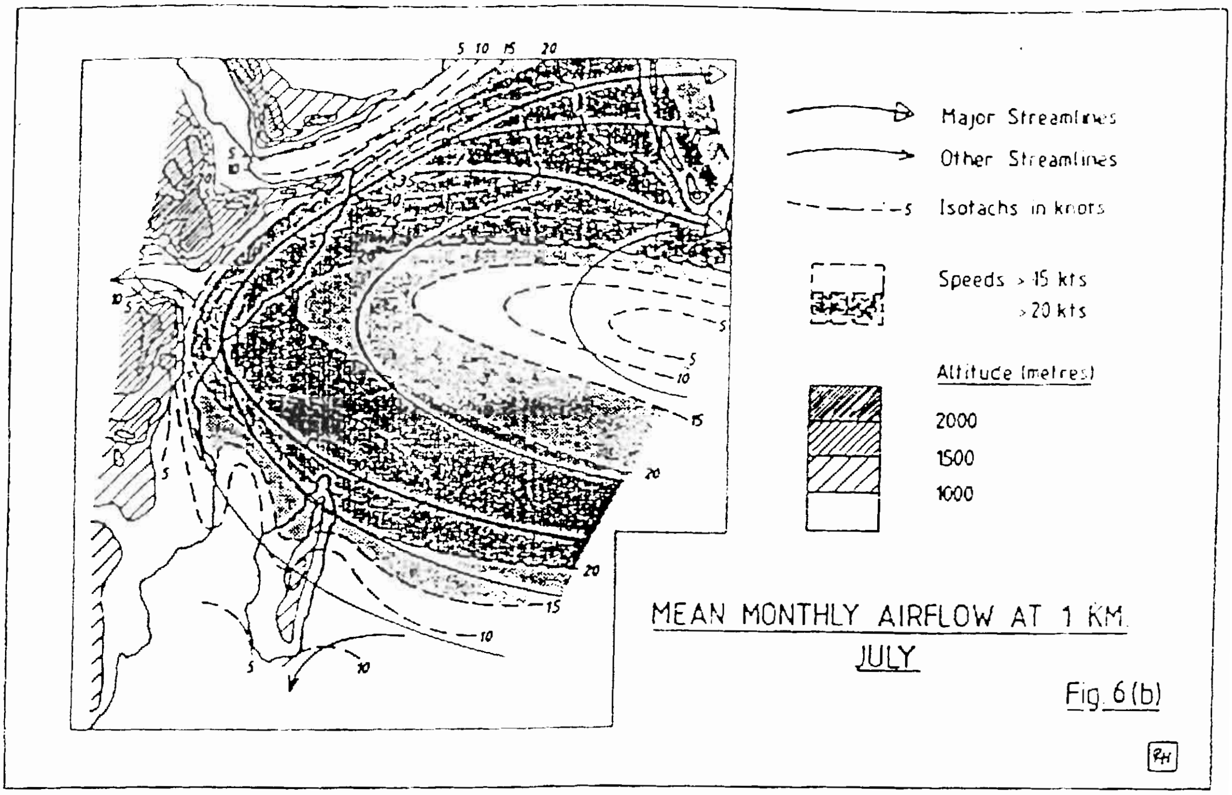


Fig 6(b)

weakens, and the southeasterly flow strengthens somewhat and extends into the Mozambique Channel, a process which continues in April, when the northeast monsoon disappears, except as an anticyclonic eddy centred off the coast of Arabia. The southeasterlies push into Somalia, more especially at lower levels (1000 m), though at 3000 m the flow is easterly, pushing directly across the Kenyan Highlands (Fig. 6(a),from Findlater,1974).

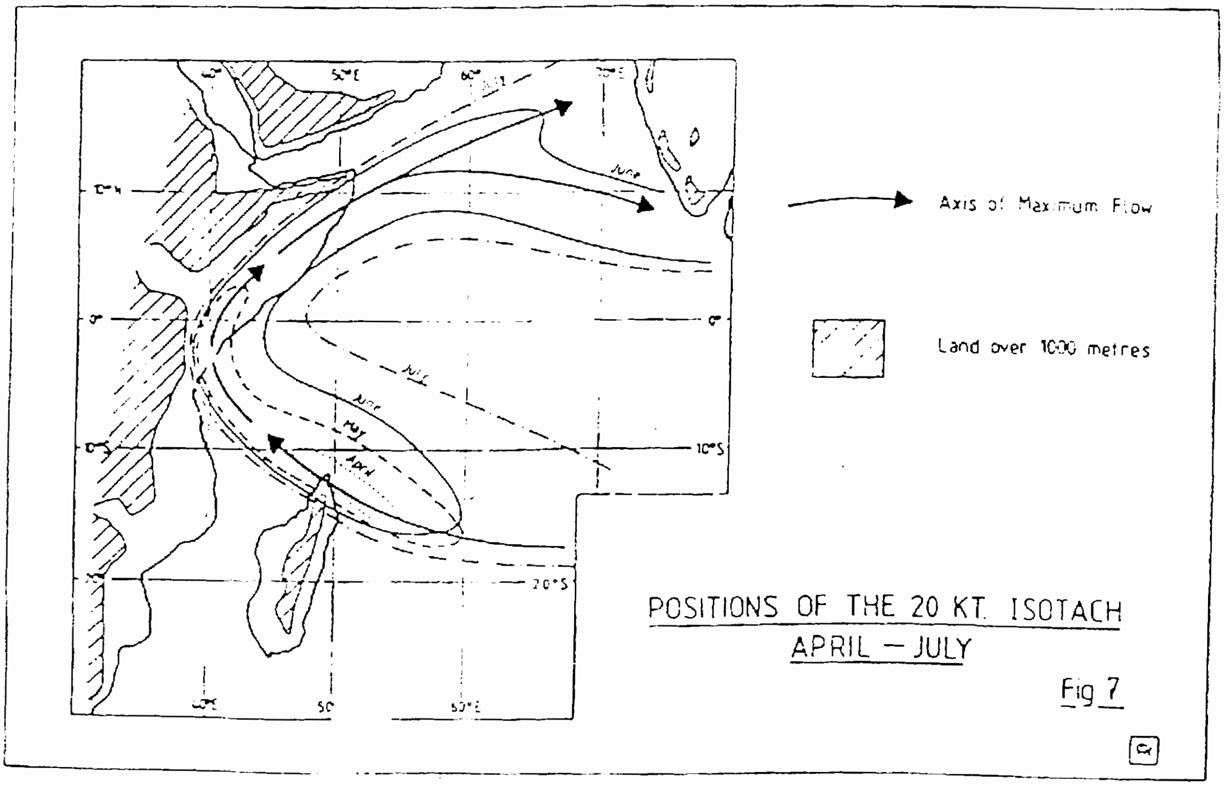
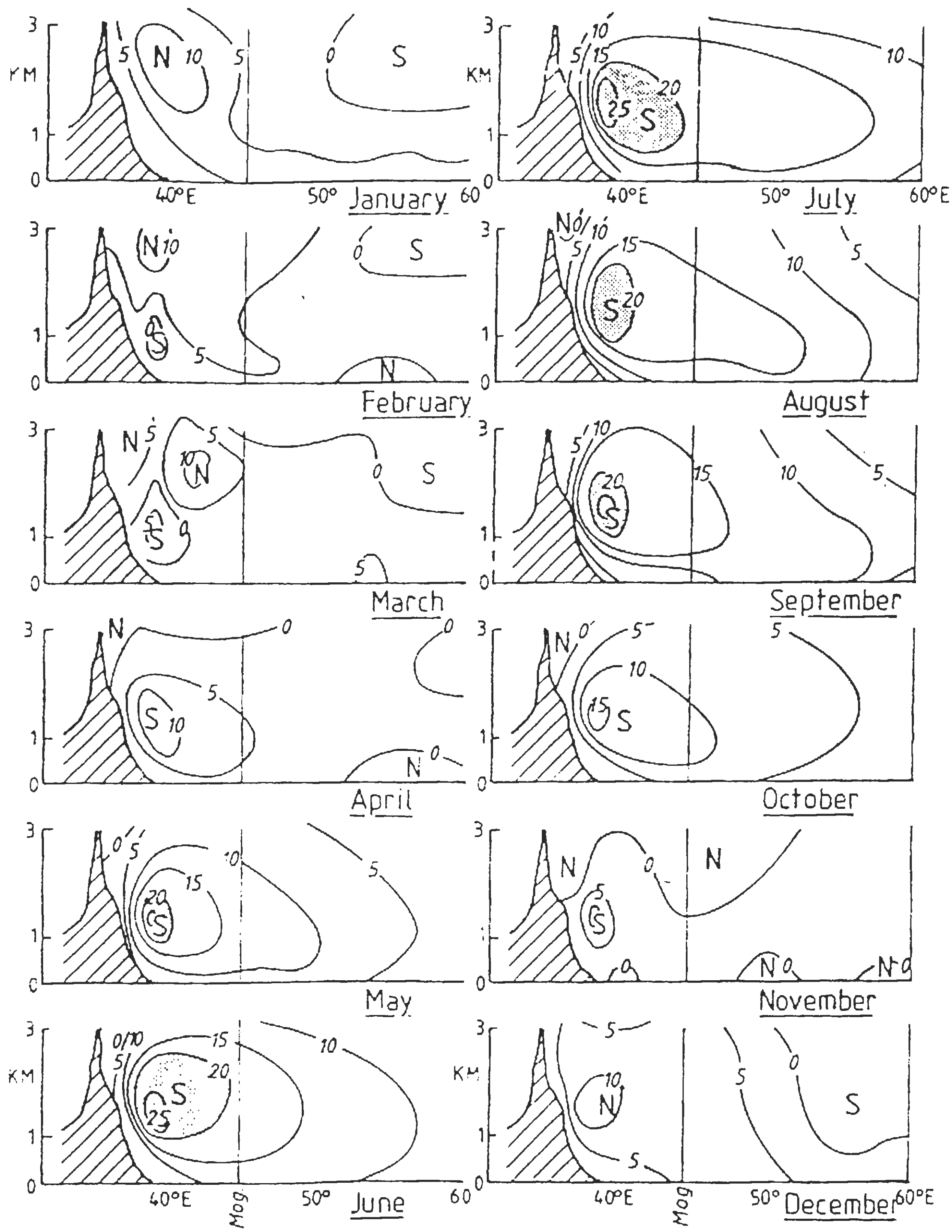


Fig 7



MERIDIONAL FLOW ACROSS THE EQUATOR

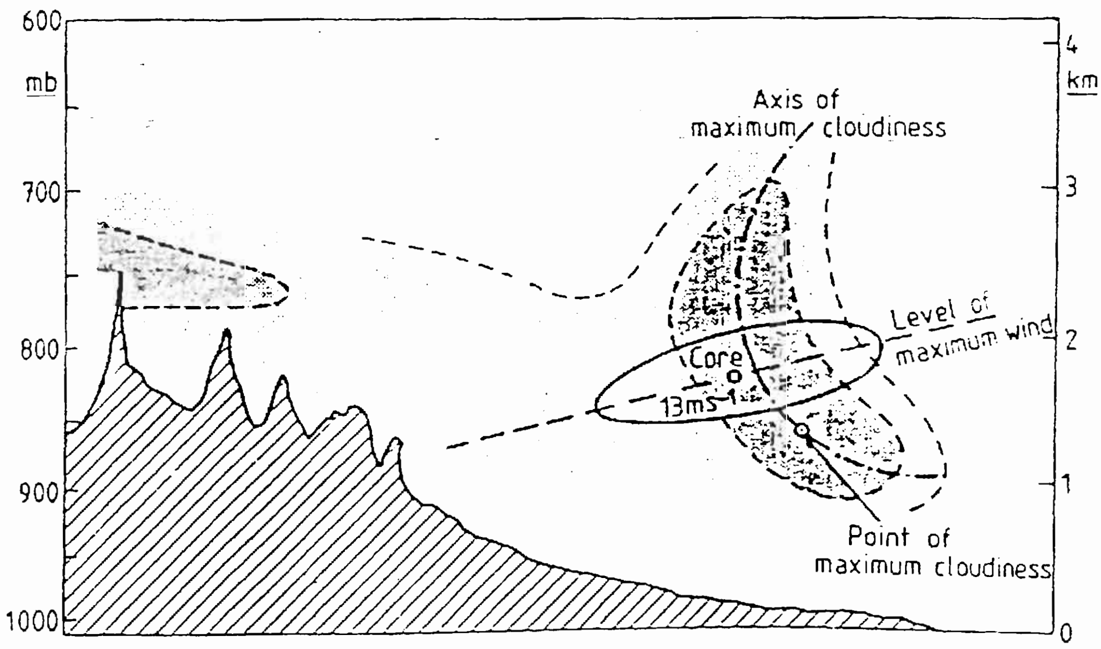
Speeds in knots FIG 8 P.H.

During May, the Jet becomes well established over the whole of Somalia, with higher wind speeds of 25 kts. or more at the lower levels. In June and July the Jet attains its maximum speeds of up to 35 kts. (average) and areal extent, extending eastwards as far as India and Sri Lanka. Maximum activity is at 1000 m or a little higher (Fig.6(b)).

In October, the northeast monsoon pushes southwards to reach the coast of Somalia, with a consequent reduction in the length of the Jet and its displacement southwards, and by December, the northeasterlies cover the African coast, with the east-south-easterly flow pushed to the east of Madagascar.

Though speeds over large areas (see Fig. 7) average over 20 kts., the Jet itself does experience high speed pulses travelling along the path of the Jet, where maximum speeds are considerably greater. A plot of the extreme maximum winds shows a pattern similar to that of fig. 6(b), but with a tube of 100 kts. or more along the major axis from 6°S to 10°N, with 60 kts. or more being deduced as the maximum over most of Somalia, usually at heights of 100 to 1500 m.

The importance of the highlands in the formation of the jet is shown in Fig 9, which is a cross-section along the equator. Interestingly, a southerly airflow is first noticed as early as February at 40°E, which is at the foothills of the Kenyan Uplands. The southerlies increase in March, but are still overlain by the seasonal northerly flow. The wind shear between these flows lies at 40-43°E, which may well be a factor



CROSSECTION THROUGH CORE OF JET

Fig.9

contributing to the earlier start of the rains in inland southern Somalia, compared to coastal areas (see below). Steady intensification of the flow continues, reaching ground level in April and maximum extent and intensity in July.

Friction with the ground surface of the highlands causes a very high wind speed gradient on the west of the jet, but to the east, the gradient is rather more gradual, with 10 and 15 kts (5 and 7.5 m/s) winds occuring as far east as 60°E in July. The jet gradually dies away over the second half of the year, but there is still a small area of southerly flow as late as November, a month after the northerlies have established themselves at ground level.

The Horn of Africa is unique in the world, in the sense that its Indian Ocean 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 dropped its load of rain over equatorial areas, it is dry as it crosses the Horn as an offshore, and not an onshore wind.

The effect of the Jet on Somali weather has, so far, not been investigated. However, from the nature of the jet, certain conclusions may be drawn. Findlater (1972) has shown that along the line of the centre of the core of the jet, air is rising, thus producing more cloud in this area (fig.10). Either side of the core, the air is descending, thus there is less cloud, and thus less rainfall. In addition, the air to the west of the core is more moist than that actually in the core or to the east. Thus there is likely to be less rainfall to the east of the jet than in the centre or to the west. Examination of the rainfall distribution map indicates the correspondence between the track of the jet and annual rainfall amounts. This is particularly evident in the sense of a rainfall maximum, lying from Jilib through Baidoa, which lie below the Jet, and the lower rainfall areas along the coast, which lie to the east.

3. SOME TYPICAL SITUATIONS.

Apart from its use in Weather Forecasting and Applied Climatology, remote sensing of clouds provides a first-class tool for teaching and explaining. We have, therefore included a number of satellite images of typical meteorological situations, to illustrate the weather conditions over Somalia described in the previous sections.

For each situation is presented the visible image and a simplified nephanalysis (cloud analysis), with a brief description and, where relevant, available surface records. Infra-red images have been used in the analyses, but are included only where they are essential for illustrating important features of the situations.

The images are annotated according to the following scheme:-

The main forms of the clouds are:

Ci	Cirrus
Cc	Cirrocumulus
Ac	Altocumulus
As	Altostratus
Ns	Nimbostratus
Sc	Stratocumulus
St	Stratus
Cu	Cumulus
Cb	Cumulonimbus

The species (subtypes) of clouds are:

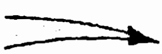
con	congestus
flo	floccus
len	lenticularis
med	mediocris
op	opacus
ra	radiatus
un	undulatus
ve	vertebratus

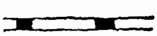
Other symbols used on the charts are:

 Axis of Jet

 Wind direction at Somali Stations

 Surface Winds (General Flow)

 Large scale flows (Upper winds)

 Intertropical Front

 Cyclonic circulation

 Anticyclonic circulation

The definitions of these cloud types are as follows:

Cirrus (Ci) High level clouds. Detached clouds in the form of white delicate filaments or white patches or narrow bands.

Cirrocumulus (Cc) Thin, white patch sheet of clouds without shading, composed of very small elements in the form of grains, ripples, etc. more or less regularly arranged.

Altocumulus (Ac) Middle level clouds. Patch, sheet or layer, generally with shading, composed of small elements, rounded masses or rolls, which may be merged.

Altostratus (As) Greyish or bluish sheet or layer, striated or fibrous appearance, totally or partly covering the sky.

Nimbostratus (Ns) Low level clouds. Grey cloud layer, often dark, mostly covering the entire sky. Appearance often rendered diffuse by falling rain.

Stratocumulus (Sc) Grey and/or white patch, sheet or layer, which almost always has dark parts, composed of rounded masses, which may or may not be merged. Regularly arranged elements.

Stratus (St) Low level clouds. Grey cloud layer with a fairly uniform base, which may give drizzle.

Cumulus (Cu) Clouds of vertical development. Detached clouds, generally dense and with sharp outlines, developing vertically in the form of rising mounds. The sunlit parts are brilliant white: their base is relatively dark and nearly horizontal.

Cumulonimbus (Cb) Clouds of vertical development. Heavy and dense with a considerable vertical extent, in the form of mountain or huge towers. At least part of the upper portion is usually smooth and nearly always flattened: this part often spreads out in the shape of an anvil. The base of these clouds are often very dark, with rainfall, which falls sometimes in the form of virga (vertical streaks).

congestus (con) Cumulus clouds with marked vertical movement and often of great vertical extent: their bulging upper surface often resembles a mango tree.

floccus (flo) Each cloud is a small tuft with a cumuliform appearance, the lower part of which is ragged and often accompanied by virga.

lenticularis (len) Clouds having the shape of lenses or almonds, often very elongated and usually with well-defined outlines. Usually associated with clouds of orographic origin.

mediocris (med) Cumulus clouds of moderate vertical extent, the tops of which show fairly small protuberances.

opacus (op) An extensive cloud patch, sheet or layer, the greater part of which is sufficiently opaque to mask completely the Sun or Moon.

radiatus (ra) Clouds showing broad parallel bands or arranged in parallel bands, which, owing to the effect of perspective seem to converge towards a point on the horizon or, when the bands cross the whole sky, towards two opposite points on the horizon.

undulatus (und) Cloud patches, sheets or layers showing undulations. These undulations may be observed in fairly uniform cloud layers or in clouds composed of elements, separate or merged.

vertebratus (ve) Clouds, the elements of which are arranged in a manner suggestive of vertebrae, ribs or a fish skeleton.

It should be remembered, when viewing the images, that METEOSAT is at 0^{o} longitude, thus the cloud formations are not viewed from directly overhead, but at an angle of about 45^{o} over Somalia, and towards the eastern horizon, the clouds are viewed nearly horizontally. The first image illustrates this quite well.

METEOSAT 1988 MONTH 1 DAY 12 TIME 1155 GMT (NORTH) CH. VIS 2
NOMINAL SCAN/RAW DATA AREA B47 COPYRIGHT- ESA -

Fig. 10(a)

12 January 1988. Gilaal Dry Season.

The image shows the typical situation over the region in the northern winter months.

The large area from 20° to 55°E and 15°N to 4°S is mostly free from heavy cloud cover. Some 'Fohn' clouds of the types Altocumulus lenticularis (Ac len) and Stratocumulus lenticularis (Sc len) have formed over the highlands of Kenya, Ethiopia and northern Somalia, while a ribbon of sea breeze front clouds are evident along the coastline.

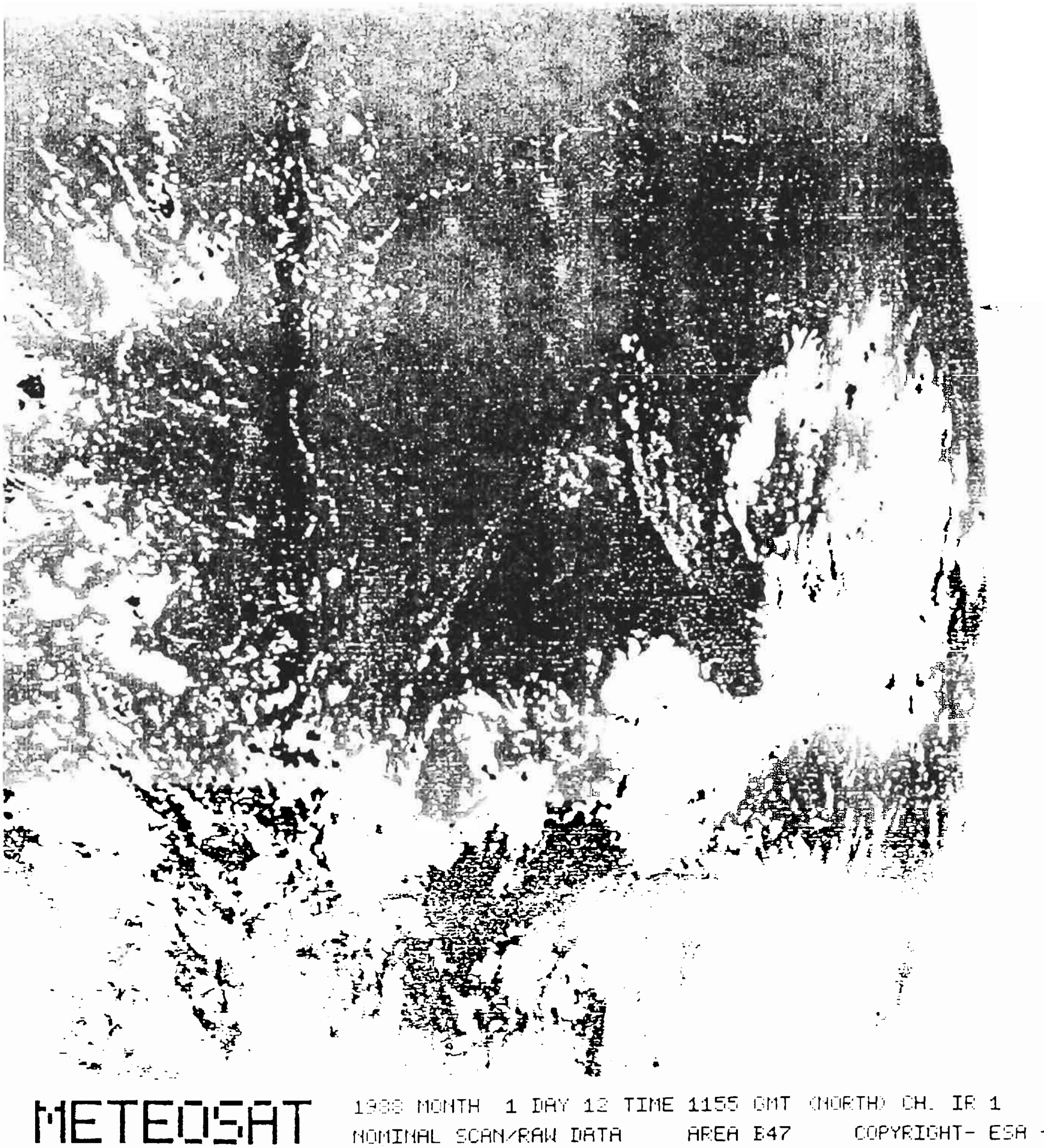
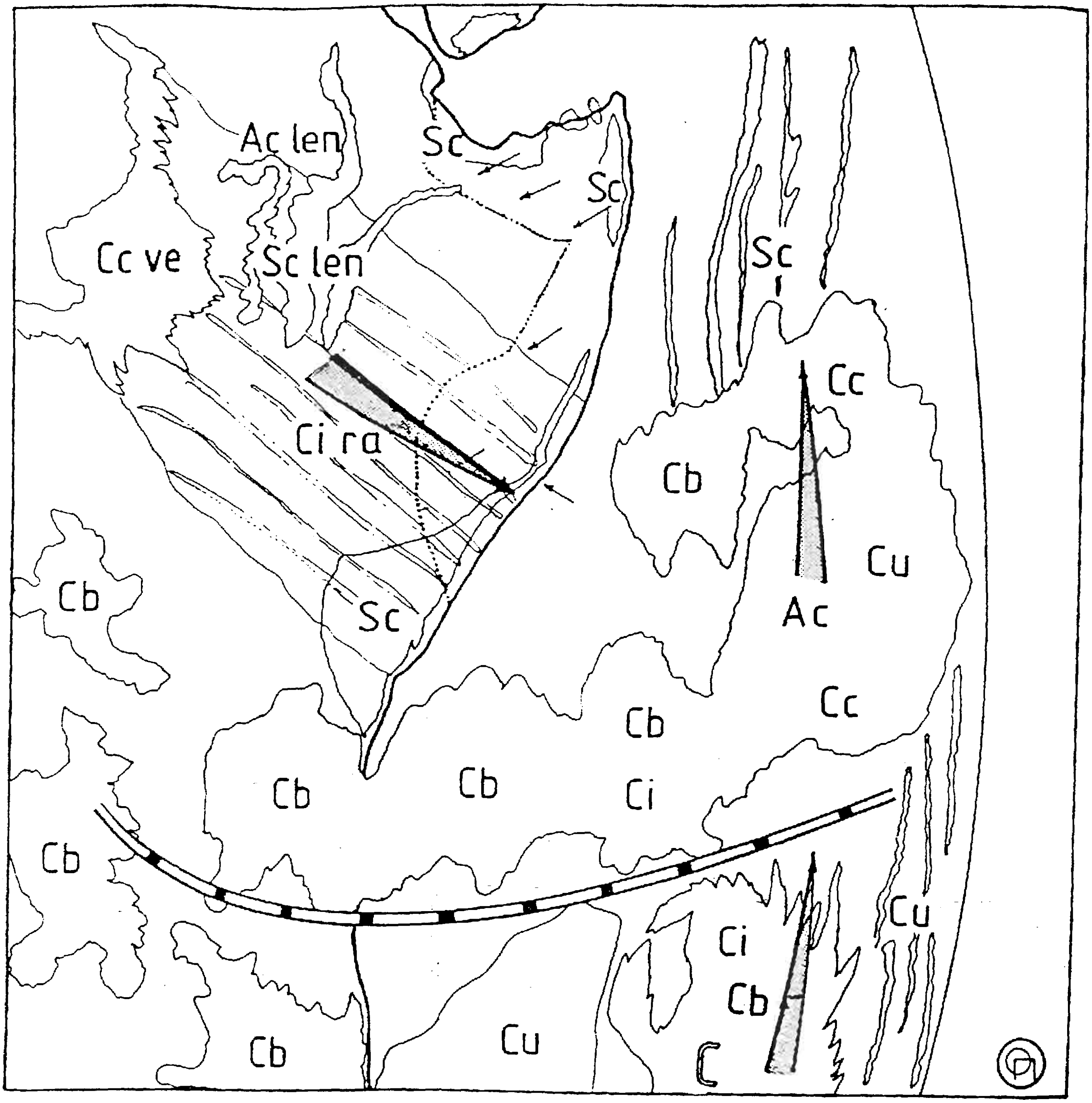


Fig. 10(

The upper tropospheric flow lies over Somalia and Kenya from northwest to southeast, evident from the upper level Cirrocumulus vertebratus (Cc ve) and Cirrus radiatus (Ci ra), best seen in the Infra-red image.

But south of 5°S lies the Intertropical Convergence Zone, with masses of different types of clouds, including Cumulus congestus (Cu con), Altocumulus (Ac) and Stratocumulus (Sc), particularly at the Intertropical Front itself, which lies east to west.



SITUATION 12 January 1988 Fig. 10(c)

Rainfall is quite rare in January, with clear skies almost everywhere, values of about 2 oktas being average, though with rather more cloud in the south. Exceptionally, Cape Guardafui reports 4 oktas for January, the highest for the station for the year, and the highest for the month for the whole country.

METEOSAT 1988 MONTH 3 DAY 23 TIME 1155 GMT (NORTH) CH. VIS 2
NOMINAL SCAN/RAW DATA AREA E47 COPYRIGHT- ESA

Fig. 11(

23 March 1988. Early Gu Season.

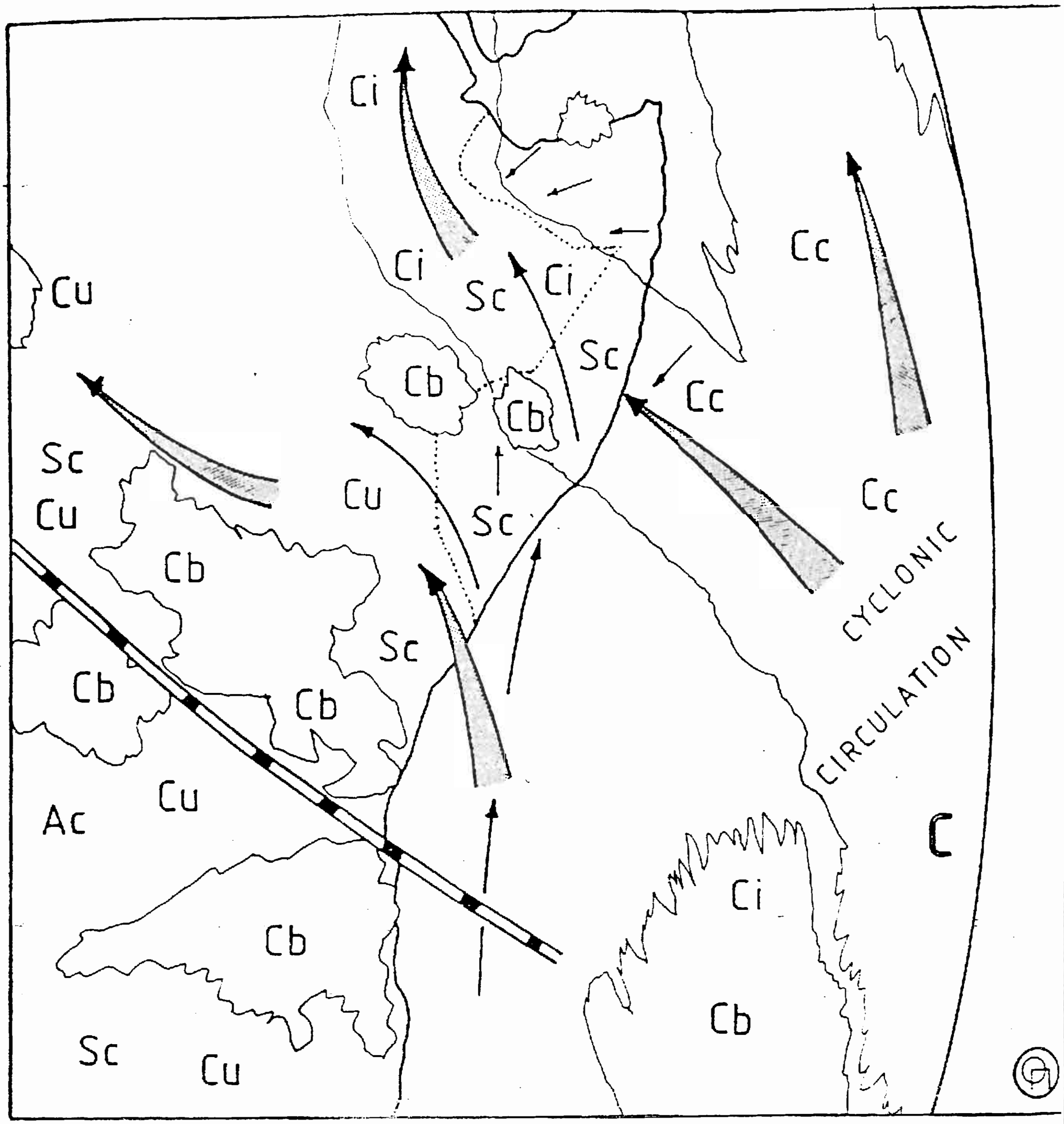
The bottom right side of the image, from the Equator to 10° S, shows a large cloud system, or cluster, indicating a large cyclonic circulation, in which the clouds move in a circular direction. Visible are low and middle level clouds showing slight northeasterly airflow. In particular, the cloud streaks along the shore of Somalia shows a northeasterly direction, though more northerly south of Kismayo. In the same area of the image, the high level clouds extend over a very wide area, and flow through Somalian territory, indicating the strong intertropical transfer of air.

Fig. 11(b)

Clearly indicated are three strong branches of air crossing Somalia. From the centre of the cyclonic circulation, the first branch crosses Somalia over the very south of the country, and is guided by the shape of the highlands. The second passes over Obbia and curves to the south of the Horn, while the third passes to the east of the Horn.

The Intertropical Convergence Zone promotes widespread cloud formation on the left of the image, in particular masses of Cumulus congestus (Cu con), a common feature of the start of the season.

Further north, over the Kenya-Ethiopia highlands, a 'Fohn' effect is visible, indicated by the lenticular clouds at the three levels, lower, middle and upper.



SITUATION 23 March 1988 Fig. 11(c

All Somalia, from Eil southwards is covered by compact lower and middle level clouds of the types Stratocumulus (Sc), Cumulus (Cu) and Altocumulus (Ac), the latter undulatus extending along the the airstream.

An interesting effect is seen along the coastline of Somalia, in that the coast itself is clear, but the clouds form about 15 - 20 km inland.

The images show early rains occuring before the synoptic onset of the season, in particular, two Cumulonimbus (Cb) cells which have broken away from the general cloud system associated with the ITF to the south. The Easterly of the two cells has passed over the Bay Region, with rainfall at Jilib (12.0mm), Dinsor (4.0mm), Bardera (12.6mm) and Baidoa (6.5mm).

METEOSAT 1986 MONTH 6 DAY 11 TIME 1155 GMT (NORTH) CH. VIS 2
NOMINAL SCAN/RAW DATA AREA B47 COPYRIGHT- ESA -

Fig. 12(a)

11 June 1986. Gu Season.

By June, the ITCZ and ITF have moved well to the north, and both Somalia and Ethiopia are in a southerly airstream. The image shows that the highlands of Ethiopia and areas to the west are covered by huge Cumulonimbus (Cb) clusters, from which rain is falling. However the situation over Somalia is rather more complicated, because of the different wind directions at the various levels. During this season, the Somali Low-level Jet is well established, and its curvature from southeast to southwest can clearly be seen.

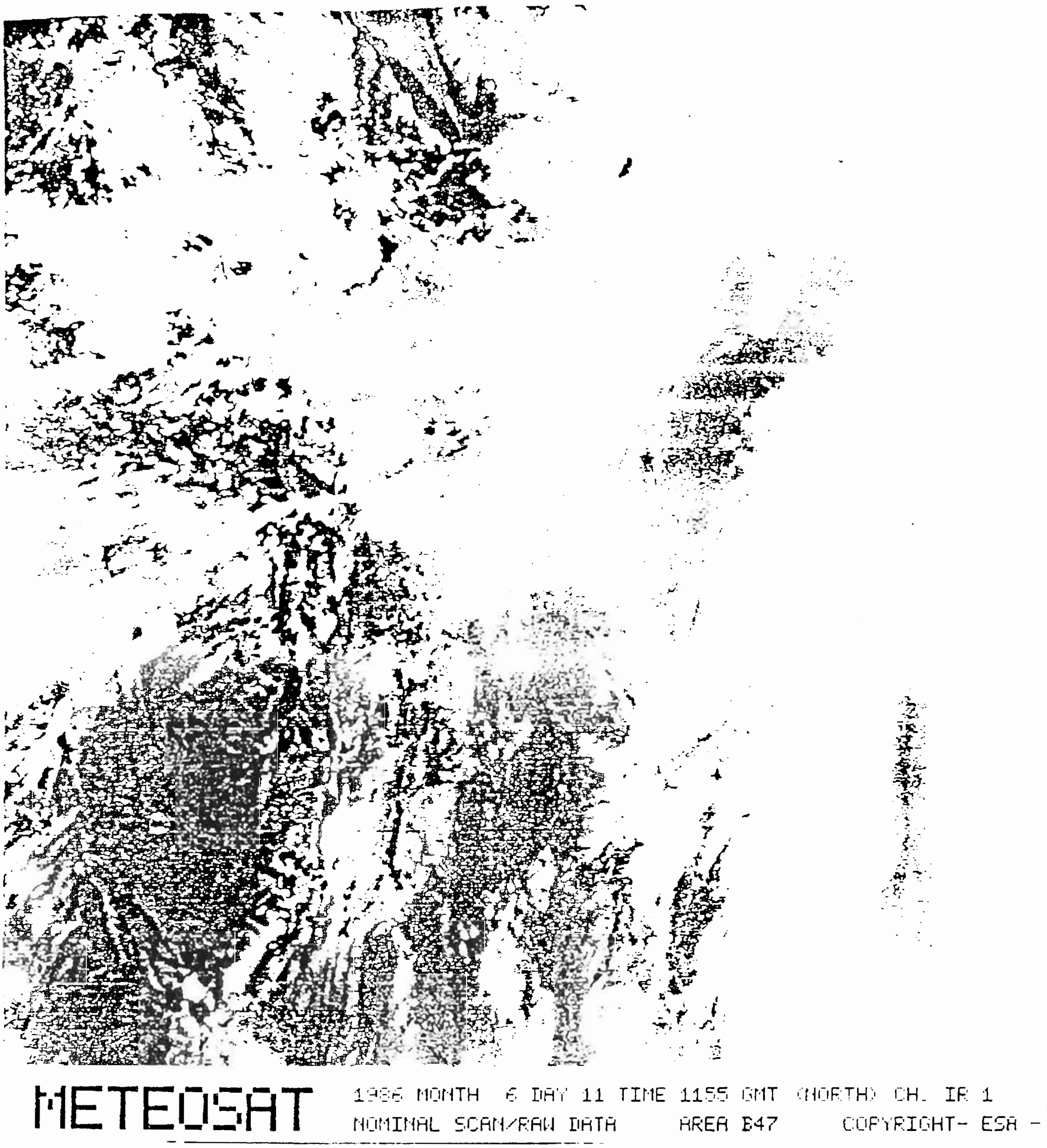
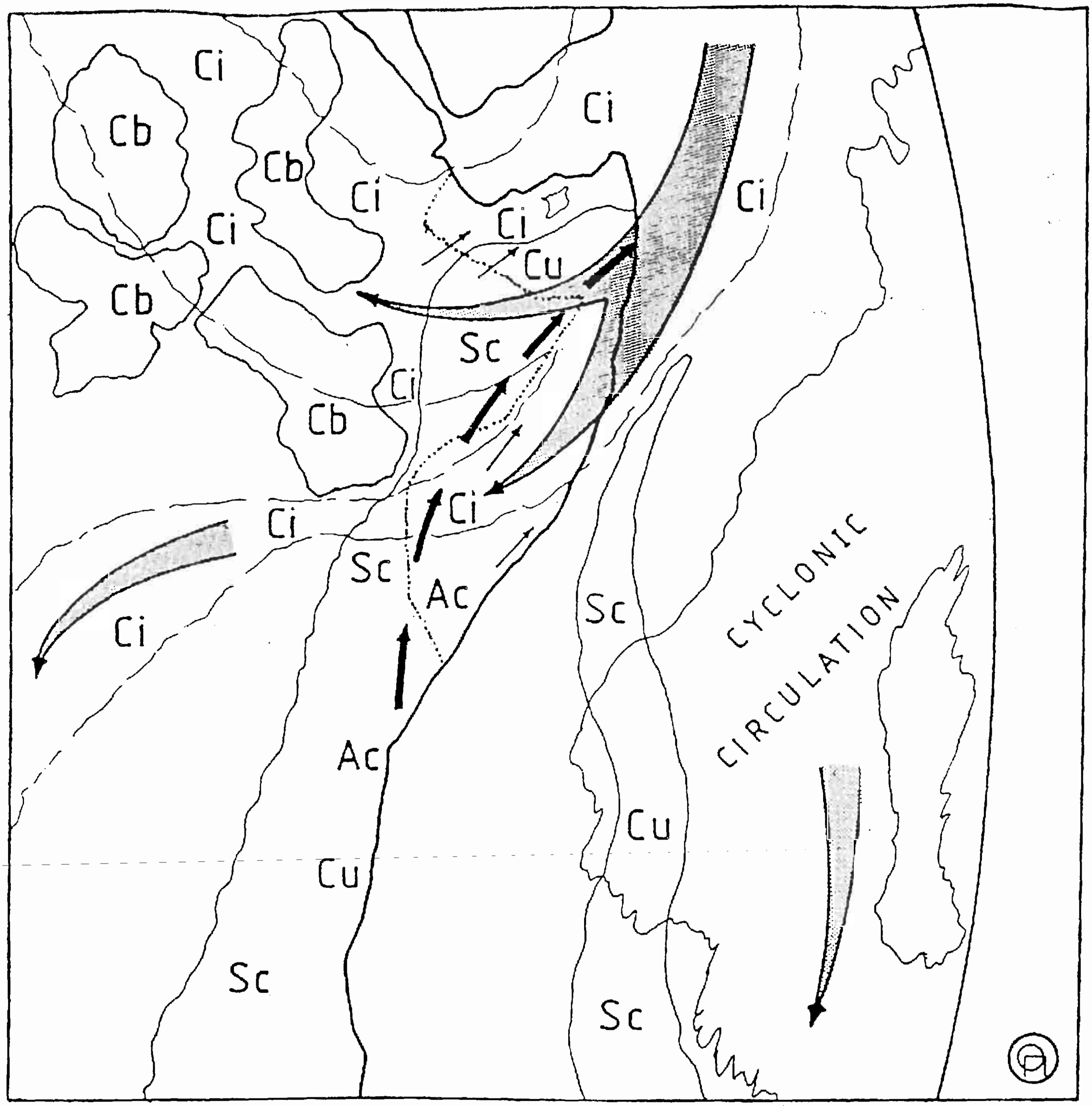


Fig. 12(b)

At the same time, the high level wind flow is from the northeast, from the southeast of the Arabian Peninsula. This can clearly be seen in the Cirrus (Ci) mass of different types lying over northeast Somalia. The flow can be seen to separate, with one branch turning westwards along the I.T.F. and the other following the Somali coast, then curving to the east. This is very clear in the Infra-red image. This flow is essentially dry, so that cumulo-development is restricted to middle and lower levels, with small Cumulonimbus (Cb), Cumulus mediocris (Cu med), Altocumulus (Ac), Altostratus (As), Stratus (St), and even, uncommonly, Nimbostratus (Nb).



SITUATION 11 June 1986 Fig. 12(c)

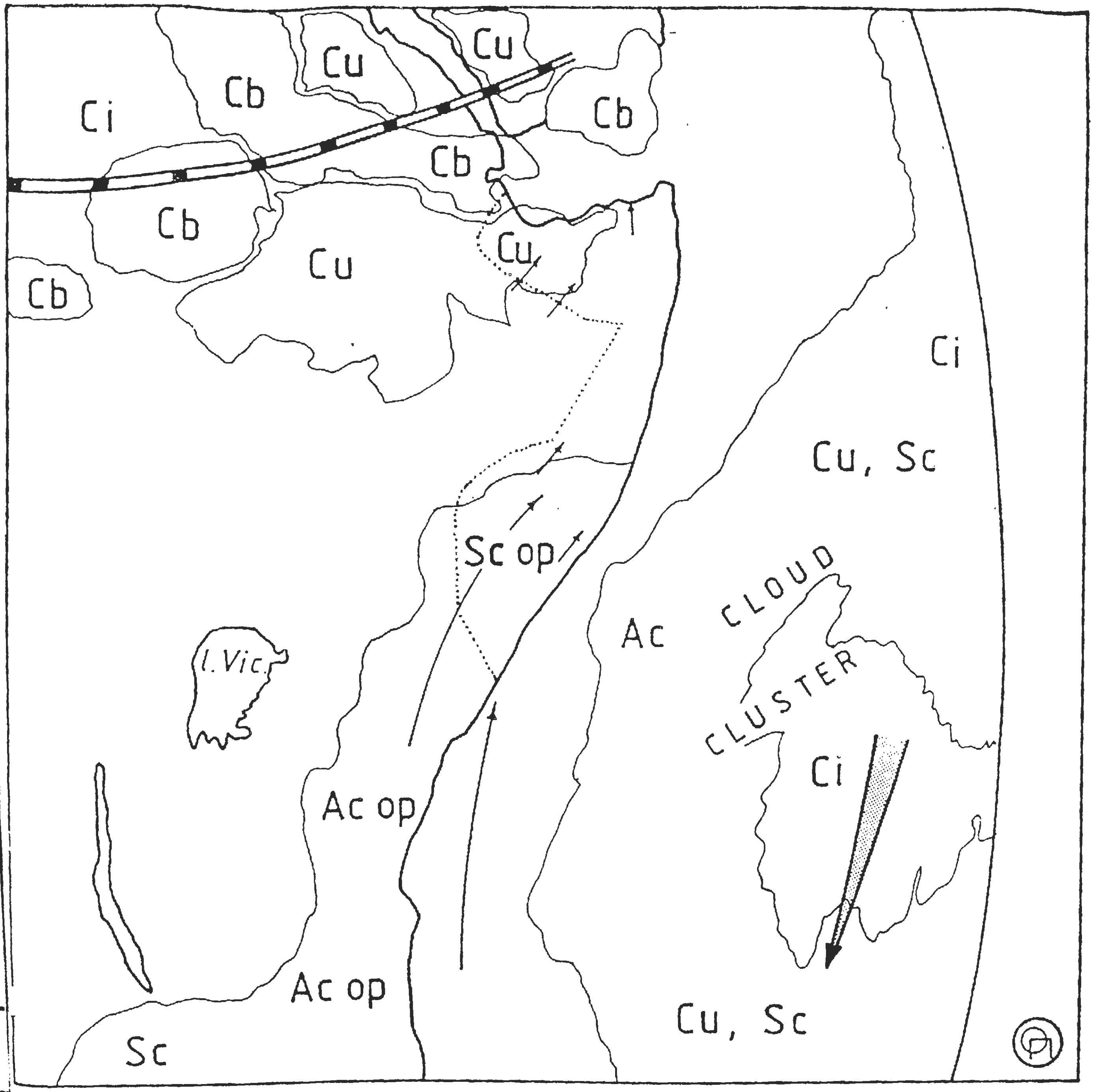
Thus precipitation over Somalia during this season is often weak and of short duration, and the image shows this, with scattered showers occured over Somalia, at Baidoa (1.5mm), Mogadishu (3.5mm), Jowhar (5.6mm), Genale (9.6mm), Modun (19.0mm) and Afgoi (8.8mm).

Fig. 13(a

5 August 1986. Hagai Season.

By the beginning of August, the weather systems are at their northern limit. The ITF is to the north of Somalia, with the main belt of cloud just touching northern coastal areas.

The main Cumulonimbus (Cb) clusters occur in the northern part of Ethiopian Highlands and further westwards. Only a small proportion of the clouds are giving rain on the northern part of Somalia. The middle of the Country is free from cloud cover, including the Indian Ocean coastline.



SITUATION 5 August 1986 Fig. 13(b)

The southern part of Somalia is covered by an extensive sheet of Stratocumulus floccus (Sc flo), which has inadequate moisture content to produce rain.

The Indian Ocean low is towards the northern edge of the image at the horizon. Other cloud over the sea is rather inactive.

Although not in the context of Somalia, the cloud patterns associated with the Rift Valley lakes are of interest.

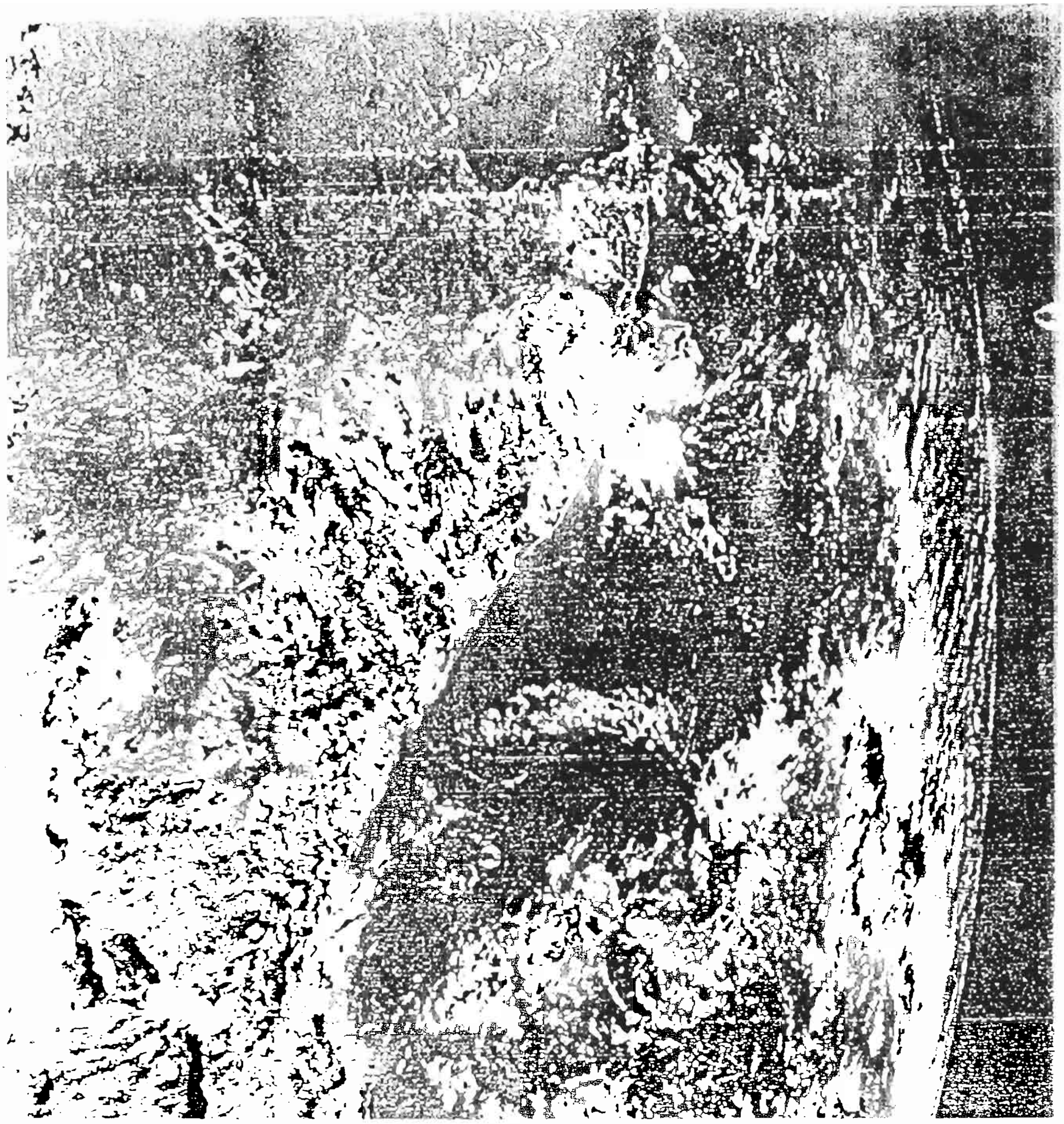
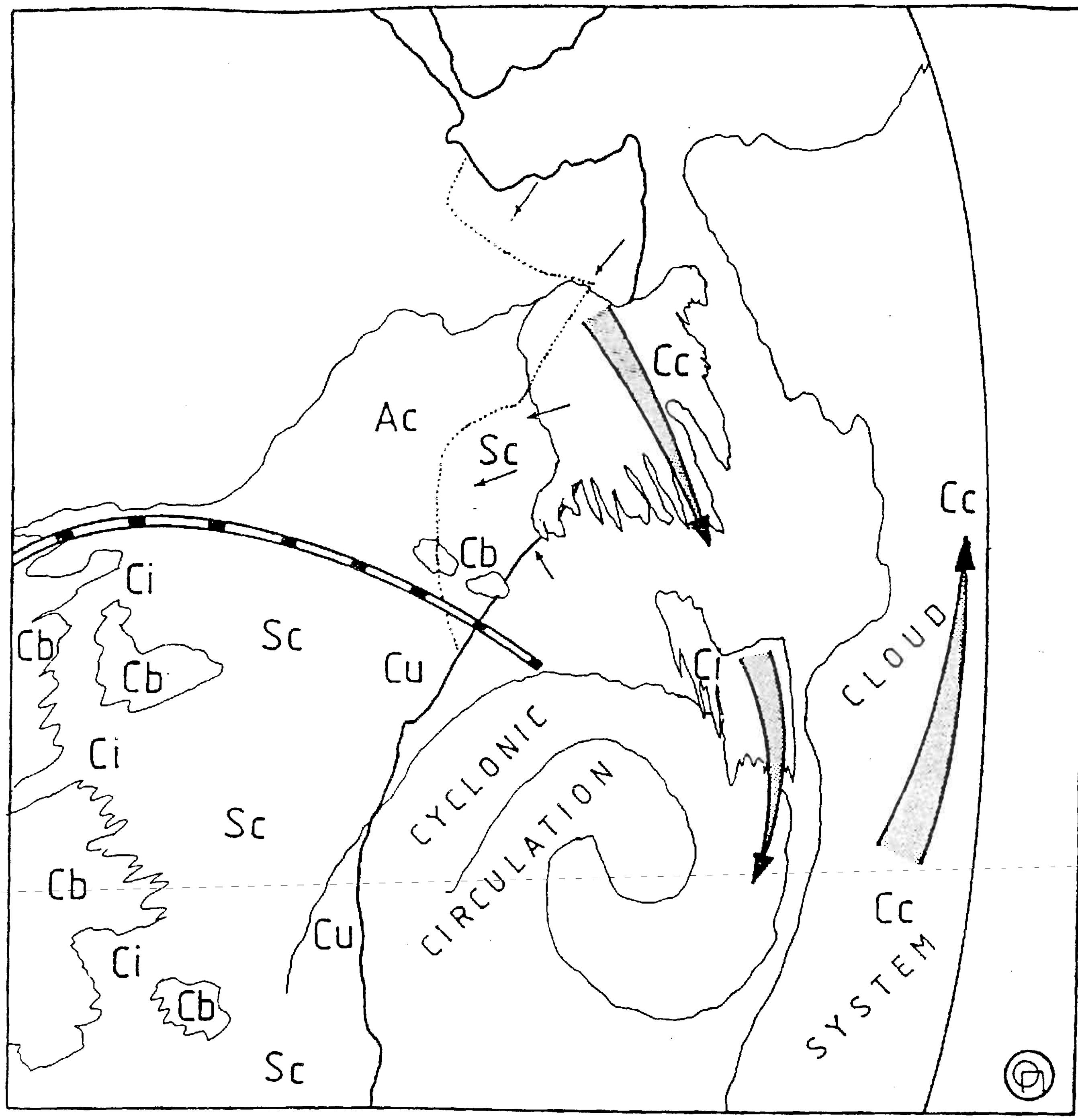


Fig. 14(a)

24 November 1986. Der Season.

During November, the ITF is retreating southwards, with the weak convergence zone lying over the Kenya-Somalia border, at about 0° latitude. In the north of the country, low level winds are northeasterly, while upper level winds, and low level winds further south are more northwesterly. All airstreams from the north are dry, with a consequent clearing of the skies. Further south, there are some clouds, but mainly Cumuloform at all three levels, Stratocumulus (Sc), Altocumulus (Ac) and Cirrocumulus (Cc).



SITUATION 24 November 1986 Fig. 14(b)

An extensive field of Cumulus (Cu) covers from mid-Somalia southwards, though sea areas are relatively clearer, with only the remnants of a cyclonic circulation remaining to the southeast. The actual coastline is clear, and the inland Cumulus (Cu) reaches no great height, except for a few cells which still remain near the south coast and may have developed into Cumulonimbus (Cb) later in the day. Some rainfall occured in southern areas, at Jowhar (17.2mm), Barro Uen (19.0mm), Sablaale (28mm) and Modun (11.3mm).

CHAPTER 2. THE CLIMATOLOGICAL ELEMENTS

1. RADIATION, SUNSHINE & CLOUDINESS.

Radiation.

So far as is known, no direct measurements of Solar Radiation have ever been taken in Somalia. It is possible, however, to determine the solar radiation outside the atmosphere, from Smithsonian Meteorological Tables (List 1966), and, taking a reduction factor of 0.8 for transmission through the atmosphere, arrive at maximum possible radiation for clear skies.

In addition, the Angstrom formula connects solar radiation on the ground with hours of bright sunshine:

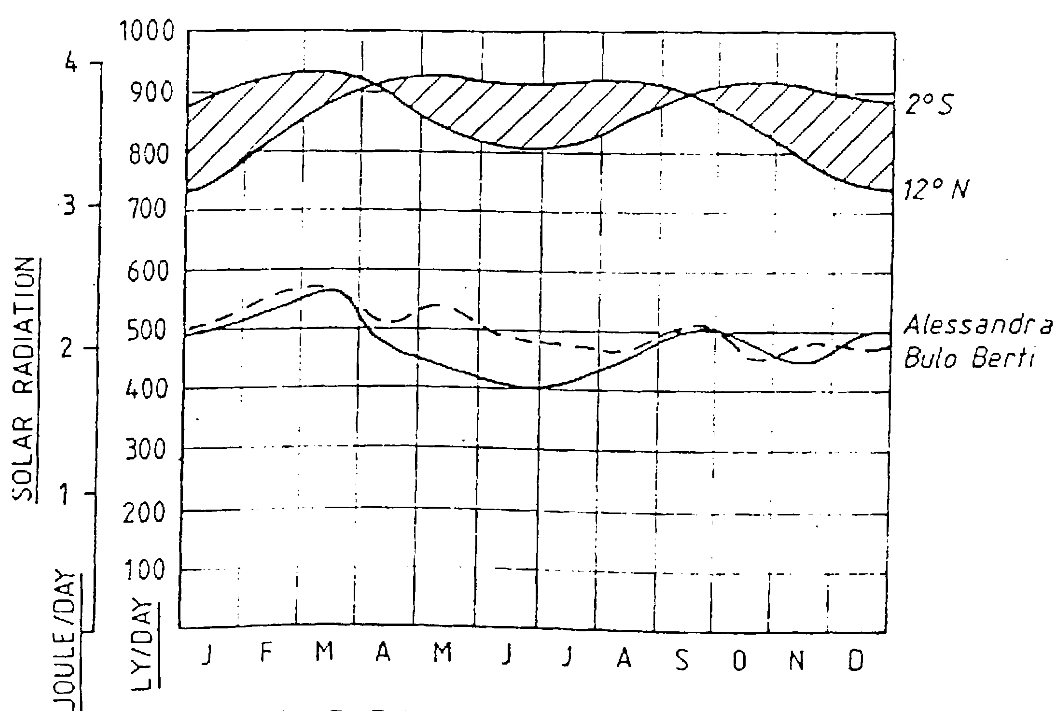
$$R = a + b \frac{n}{N}$$

where R = solar radiation.
a, b are constants.
n = hours of actual sunshine(daily average).
N = hours of maximum possible sunshine.

Although the form of this equation is universal, the values of the constants a and b vary according to locality. However, for dry tropical areas, FAO have adopted values of:

$$a = 0.25$$
$$b = 0.45$$

for those places where direct determinations have not been made.



SOLAR RADIATION ON SOMALIA

Fig 15

Using this information, figure 15 has been constructed. Radiation outside the atmosphere is shown for two latitudes, 2 °S and 12 ° N, which enclose almost all Somalia, so that the relevant radiation figure for any point in Somalia falls between these two lines. The radiation, on the ground, calculated from the sunshine data, is shown for Alessandra, one of the wettest areas in the country, and Bulo Burti, one of the drier parts of the southern area. The radiation does not vary much during the year, mainly because the time of maximum radiation (north of the Equator) co incides with the time of maximum cloudiness.

Sunshine.

Sunshine has been measured at a number of sites in Somalia, using the Campbell-Stokes sunshine recorder, which gives "hours of bright sunshine". Fantoli tabulates nine stations, while the records from the FEWS stations are still too short to provide reliable long term averages.

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi*	8.9	10.2	10.1	8.4	7.2	7.0	8.9	9.1	9.6	8.4	7.6	7.4	8.5
Afmadu	8.8	8.2	8.0	6.1	6.6		6.4	6.4	7.4	6.4	7.6	8.0	
Alessandra	9.2	9.0	10.0	7.6	7.6	6.9	7.0	7.9	8.5	7.5	6.7	8.2	8.0
Baidoa	9.3	9.7	8.9	7.6	7.7	6.9	5.2	6.7	7.3	6.2	7.9	8.9	7.7
Bulo Berti	9.4	10.1	9.5	8.3	9.6	8.7	7.0	7.7	8.7	7.4	8.2	8.6	8.5
Genale	9.3	9.5	9.4	8.2	7.7	6.6	6.3	7.6	8.5	7.6	7.3	8.3	8.0
Jawhar	8.8	9.6	9.2	7.1	7.0	5.9	5.9	7.1	8.1	6.9	8.0	8.3	7.7
Merca	9.0	8.7	9.0	8.3	9.8	8.2	8.1	8.2	8.8	8.9	8.8	9.3	8.8
Mogadisho	8.6	8.9	9.1	8.7	8.8	7.3	7.3	8.2	8.8	8.6	8.7	8.4	8.4

* 2 years of records

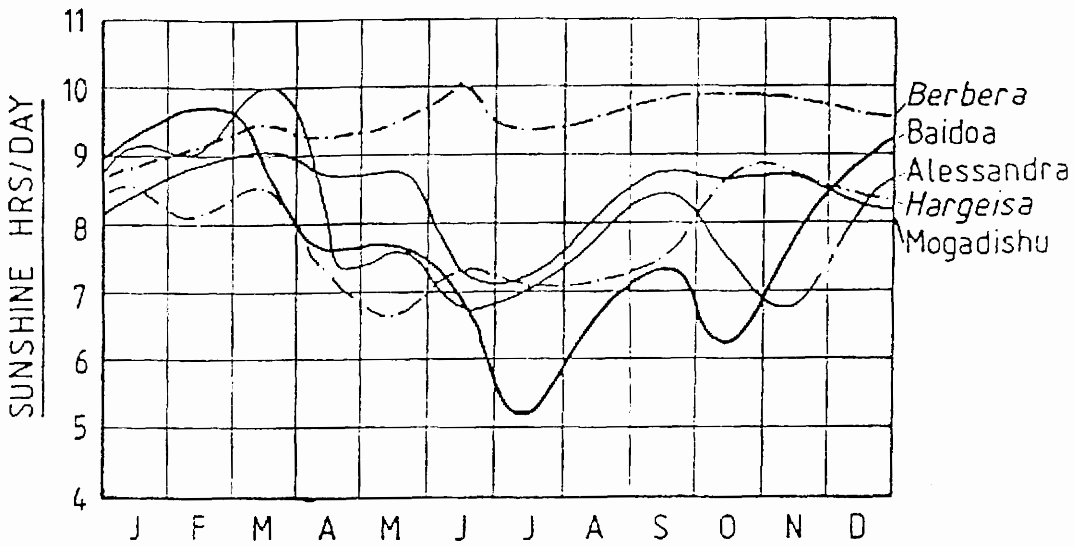
Table 1. SUNSHINE (Hours per Day)

In the south of the country, then one pattern prevails. For the first two or three months the hours of sunshine increase, but as the Intertropical Front enters Somalia moving northward, its associated cloud reduce, quite considerably, the sunshine hours, to a minimum in June or July. Mogadishu shows a fall of nearly 2 hours/day over this period, while Baidoa shows a fall of 4.5 hours/day, from 9.7 to 5.2.

Thereafter the clearer weather behind the Front is indicated by a gradual rise in the sunshine hours, though cloud associated with the retreat of the Intertropical Front interrupts this general rise in October or November (fig.16).

No data is available directly for the north of the country, but, if the relationships between cloudiness and sunshine, obtained from the southern stations can be used for the north, and if the relationship (see appendix 1) can be extrapolated to low cloudiness figures, then the pattern in the north is one of very high sunshine, except in the southern parts of Awdal, West Galbeed and Togdheer, when the sunshine hours are comparable to those in some parts of the south.

Berbera averages 9.6 hours/day, throughout the year, reaching 10.1 hours/day in June. These figures are typical, also of the whole north-east area of the Country, with Alula also averaging 9.6 hours/day, and Faro Dante 9.5. Hargeisa, representing the wetter parts of the north-west averages 7.8 hours/day, throughout the year, about the same as Hoddur and Luuq.



SUNSHINE AMOUNTS

Fig. 16

Cloudiness.

Thirty stations provide records of cloudiness tabulated in table 2 and it is possible to provide maps of this element, that for the annual mean being shown in figure 17.

This data is provided in Oktas, that is, eights of the sky covered. Thus 0 represents a clear sky, 4 a sky half covered, and 8 a completely overcast sky.

For the annual mean, the highest values are to be found in the far south, at Kismayo and in a narrow band stretching between Baidoa and Jalalaqsi, where values are 4 or more over the year.

Northern parts of Gedo and Bakool, as well as almost the entire northern part of the country experience less than 3 oktas, on average, while parts of the northern and north-eastern coastal areas are not covered by more than 2 oktas, on average.

There are, of course variations of cloud amount throughout the year, with higher values occuring during the wet seasons. At Alessandra, the coverage doubles over the first half of the year, from 1.8 oktas in January to 3.5 in July. At Baidoa the coverage trebles, from 1.7 oktas in January

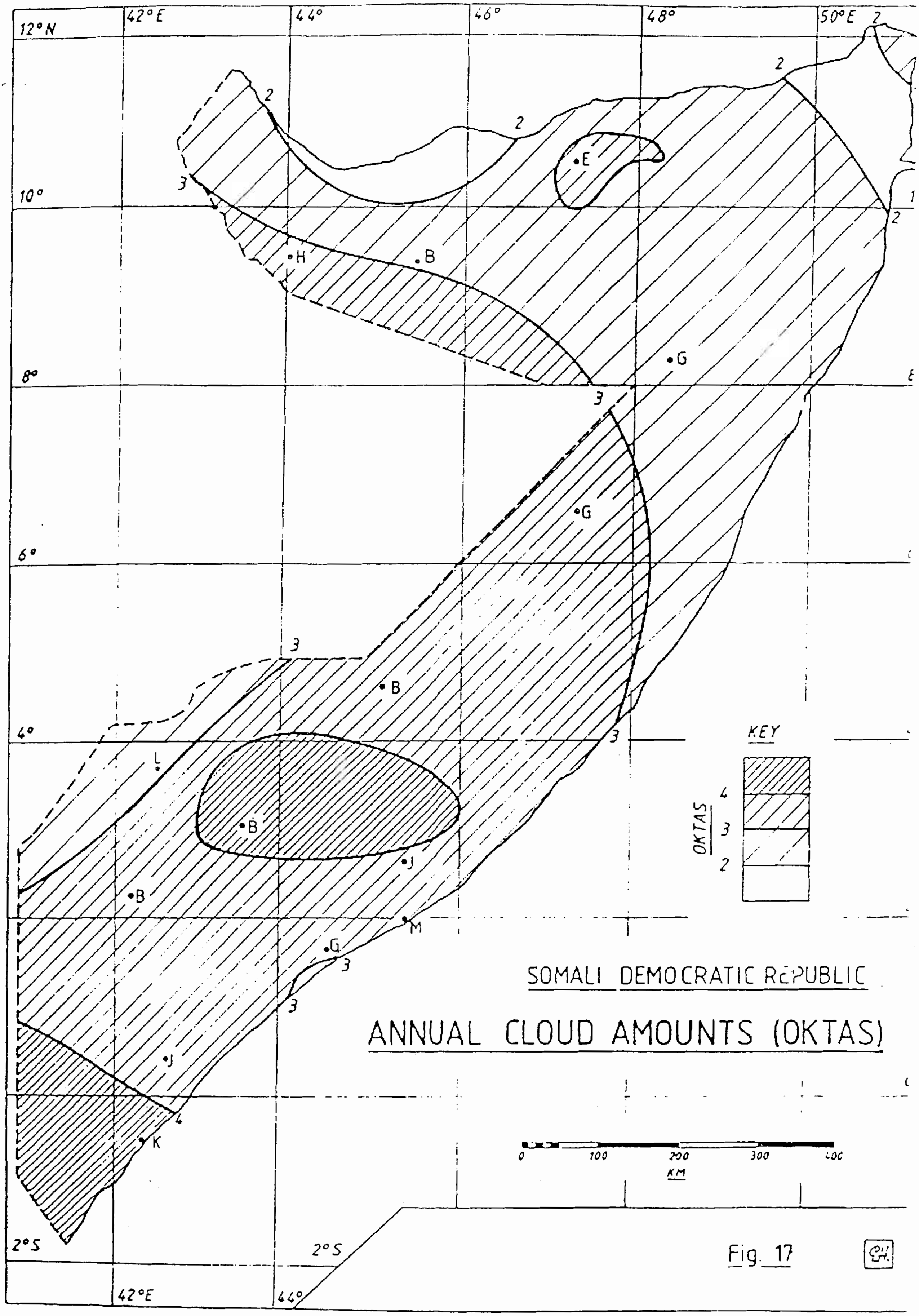

12° N
42° E
44°
46°
48°
50° E
10°
8°
6°
4°
2° S
KEY
OKTAS
4
3
2
0
100
200
300
KM
SOMALI DEMOCRATIC REPUBLIC
ANNUAL CLOUD AMOUNTS (OKTAS)

Fig. 17

to 5.8 in July. These represent typical situations for the southern areas, except for Kismayo, where the variation is much less marked.

In the north, however, this pattern is not so apparent, and coastal influences are stronger. Thus at Cape Guardafui and Alula highest values occur in December and January, the periods with the most persistently onshore winds. Inland, though, this pattern of heavy cloud amount during the wet seasons, if they can be so called, is still somewhat evident.

Cloud amounts do vary throughout the day, though information on this is rather sparse.

In general, cloud amounts are less in the afternoon than in the morning, though the differences are rather small. (see textnote 1), except for Hargeisa, where the afternoon is cloudier than morning and evening time, during the wet season.

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi	2.5	2.2	3.4	4.4	3.8	4.1	4.7	4.1	3.6	3.6	3.8	3.3	3.6
Afmadu	3.4	3.3	4.1	3.8	3.8	3.8	3.7	3.9	3.6	3.9	4.2	4.5	3.8
Alessandra	1.8	1.6	2.0	3.2	3.4	3.4	3.5	3.2	2.6	2.8	2.9	2.5	2.7
Alula	2.2	1.8	0.7	1.0	1.2	1.2	1.8	1.8	1.4	1.3	2.1	2.5	1.5
Baidoa	1.7	1.6	2.9	4.9	5.0	4.7	5.8	5.1	4.6	5.4	4.4	2.7	4.1
Balad	1.4	0.7	0.9	3.7	4.1	4.1	3.1	2.7	2.2	3.2	4.1	1.9	2.7
Bardera	1.8	2.2	3.0	4.5	4.9	4.6	5.0	4.6	4.2	4.6	4.2	3.0	3.4
Belet Uen	2.1	2.2	3.0	4.2	4.2	3.4	4.2	3.4	3.4	3.9	3.8	2.5	3.4
Berbera	2.1	1.9	1.6	1.8	1.6	1.0	1.7	1.5	1.3	1.2	1.3	1.4	1.5
Bosaso	2.2	2.1	1.5	1.7	2.2	2.2	2.4	2.2	1.8	1.7	2.1	2.1	2.6
Brava	2.6	2.9	2.7	3.4	3.5	4.2	4.2	3.5	3.4	3.4	3.2	2.8	3.3
Bulo Berti	2.6	2.3	2.9	4.0	4.0	3.9	4.7	4.4	3.8	4.9	4.4	3.2	3.8
Bur Hakaba	2.3	2.1	3.2	4.2	4.2	4.1	4.7	4.5	4.3	5.4	4.1	2.2	3.8
Cape Guardafui	4.0	2.8	1.9	1.1	1.4	1.5	1.9	1.7	1.0	1.8	[illegible]	3.9	2.2
El Bur	2.5	2.2	2.8	3.8	3.8	3.9	4.4	4.0	3.5	4.2	3.4	2.8	3.4
Faro Dante	2.4	1.7	1.1	1.6	2.6	1.4	2.0	1.5	1.6	0.6	1.4	1.8	1.6
Galcaio	1.8	2.0	2.7	3.7	3.8	3.4	4.2	3.8	3.3	4.1	2.9	2.6	3.2
Genale	1.8	1.8	2.1	3.0	3.5	4.0	4.2	3.4	3.0	3.4	3.1	2.4	3.0
Hargeisa	2.3	2.7	2.4	3.5	4.0	3.4	3.6	3.6	3.4	2.3	2.3	2.5	3.0
Hoddur	1.4	1.4	2.0	3.2	3.5	3.0	3.8	3.4	2.8	4.2	3.6	2.0	2.9
Jawhar	2.1	2.1	2.3	3.3	3.7	3.8	4.1	3.7	3.3	3.7	3.3	2.8	3.2
Jonte	3.7	3.6	3.4	4.1	4.2	4.6	4.4	4.4	4.0	4.3	4.4	4.2	4.1
Kismayo	3.7	3.4	3.6	4.2	4.3	4.6	4.6	4.2	4.0	3.8	3.8	3.8	4.0
Lugh Ganana	1.2	0.9	2.0	3.5	3.2	3.2	4.0	3.5	2.7	3.8	3.2	1.8	2.8
Mahaddei Uen	2.9	3.4	3.2	4.7	4.2	5.0	5.0	5.2	5.0	5.2	5.2	4.0	4.4
Mogadisho	2.7	2.6	2.9	3.8	4.1	4.7	4.8	4.2	3.5	3.3	3.5	3.0	3.6
Obbia	2.7	1.9	2.3	2.8	2.9	2.2	2.6	2.2	2.2	2.8	3.0	2.8	2.6
Qardo	1.6	1.1	1.4	2.9	3.5	2.0	2.9	2.2	2.3	[illegible]	1.7	1.9	2.2
Scushuban	2.4	1.8	1.9	2.6	2.3	1.5	1.8	2.1	2.1	2.1	2.2	2.8	2.2

Table 2. CLOUDINESS (Oktas)

Cloud types have not received much study in Somalia. However a record does exist for Mogadishu (Fantoli), which shows a preponderance of cumuloform cloud, with cumulus (Cu) accounting for 40% of all occurences and cumulonimulus (Nb) a further 12%. Of the other cloud types, then Cirroform account for 14 %, Altoform 5% and low level types 30%, of which stratocumulus (Sc) account for 18%. This data is not broken down by month or season.

Information of the height of the base of cloud in IDCR61 confirm that very little cloud occurs below 600 m, in the North, e.g. in Berbera only 1%, in Bosaso 2%, Hargeisa 5% (mostly in the mornings). In the south significant amounts do occur below 600 m, but little below 300 m, e.g. Bardera 32% and 1%, Mogadishu 24% and 0.5% and Kismayo 12% and 1%.

2. AIR TEMPERATURE.

Mean Temperatures.

Air temperatures are generally high throughout the country, except in the upland areas of the north of Somalia.

Annual mean temperatures (fig.18) vary from over 30 °C in Lugh to 18°C in Erigavo, which is at an altitude of almost 1800 m. In the north, the altitude is the major determining factor with a lapse rate of 6.4°C /1000 m .In Central and southern areas, temperature rises rather gradually away from the coast, despite a gradual rise in altitude.

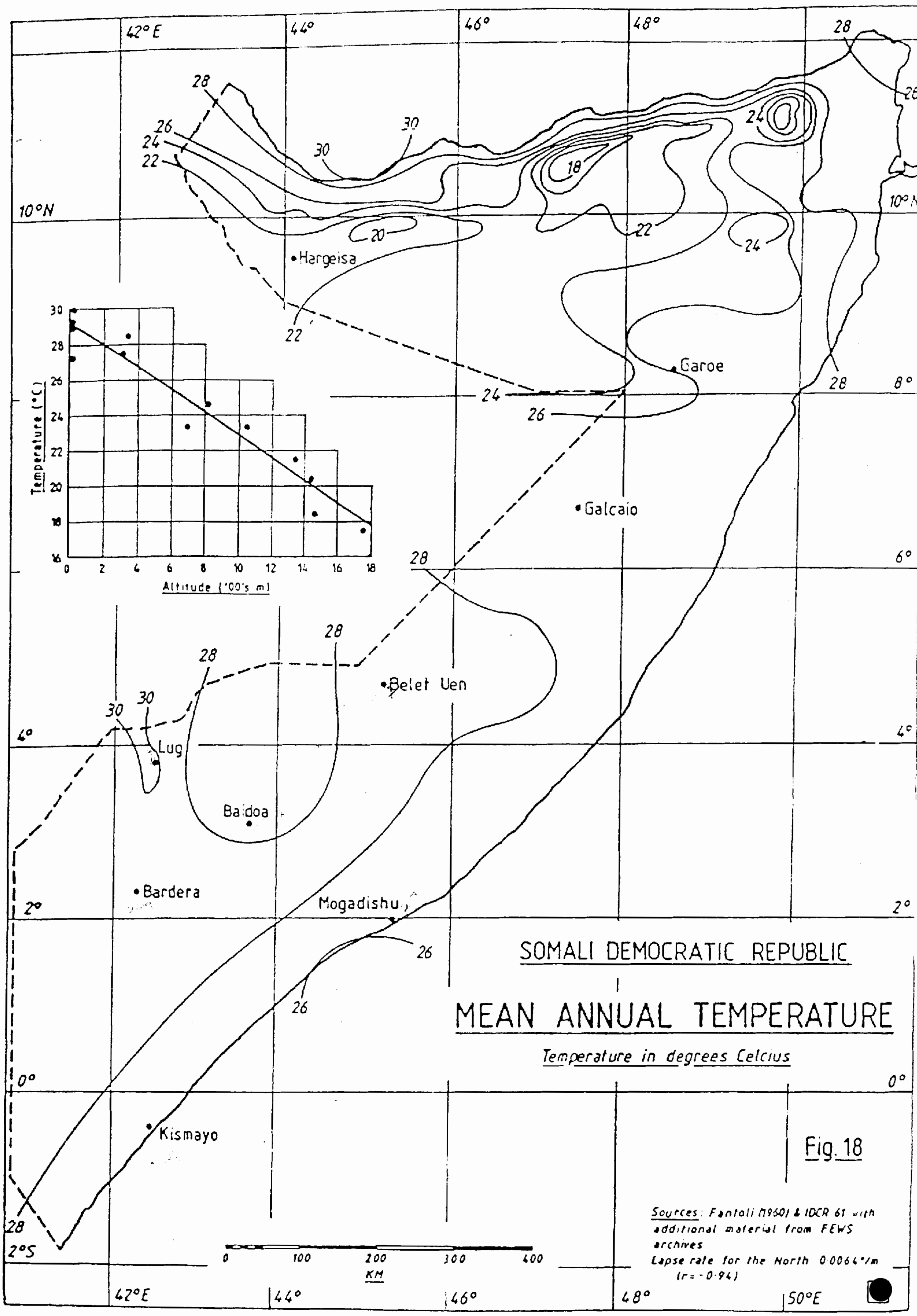
According to Griffiths (1977), Lugh was once thought to be the hottest place on earth, on the basis of the mean annual temperature, but this is now known not be true. Nevertheless, on any world scale, Somalia rates as one of the hottest countries.

Month by month, mean temperatures vary only slightly. Highest monthly temperatures occur in March or April everywhere except north of 8°N, where the highest temperatures occur in May to July. Lugh achieves 33.0 °C in March. Lowest monthly temperatures occur in July, or occasionally in August, south of about 8°N and December or January north of that latitude (table 3).

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi	27.0	27.6	28.4	28.4	27.4	26.1	25.3	25.5	26.3	26.6	26.5	26.8	26.8
Alessandra	28.7	28.7	29.2	29.3	28.2	26.8	25.6	25.8	26.4	27.3	28.0	28.2	27.7
Baidoa	26.6	27.5	28.0	27.1	25.8	24.5	23.8	24.2	25.1	25.3	25.5	26.0	25.8
Balad	28.0	28.9	29.5	29.2	27.7	26.9	26.2	26.5	26.9	27.5	27.5	27.5	27.7
Bardera	29.7	30.6	31.9	30.3	28.2	27.6	26.5	27.0	28.2	29.0	28.7	29.0	28.9
Belet Uen	28.3	28.7	30.1	30.4	29.2	28.4	27.8	27.7	29.0	28.5	28.6	28.4	28.7
Berbera	24.0	25.0	26.1	28.4	31.2	36.1	36.1	36.1	33.9	28.9	26.1	25.0	30.0
Erigavo	15.6	16.6	17.1	18.4	19.2	19.5	19.7	19.7	18.8	16.7	15.6	15.1	17.6
Galcayo	25.4	26.3	27.8	29.6	28.7	28.2	27.3	27.5	28.1	27.8	26.9	26.0	27.4
Genale	26.7	27.2	28.2	28.4	27.4	25.7	25.0	25.1	25.8	26.6	26.6	26.6	26.7
Hargeisa	17.8	19.5	21.7	23.1	24.2	24.5	23.6	23.6	23.9	21.4	19.5	18.1	21.7
Lugh Ganana	31.3	32.2	33.0	31.7	30.5	29.5	28.4	28.3	29.8	30.5	30.7	30.5	30.6
Marere J.S.P.	28.8	29.0	29.1	29.0	27.4	25.6	24.8	24.8	25.6	26.8	27.5	28.0	27.2
Mogadisho	26.5	26.8	27.9	28.8	27.9	26.6	25.8	25.8	26.3	27.1	27.2	27.0	27.0
Kismayo	26.9	27.2	28.2	28.8	27.4	26.1	25.6	25.8	25.9	26.7	27.5	27.4	26.9

Table 3. MEAN DAILY TEMPERATURE (oC)

These variations are due to the balance of wind flow against solar orbit. In the south, the temperature rises after the turn of the year until March/April due to the air streams from the Arabian Peninsula, which is steadily being heated by the northward movement of the sun, but the southwest monsoon brings, not only cooler air from the Indian Ocean, but cooler downdraughts from aloft due to shower activity. In the north, however, the latitude is high enough for the movement of the sun to be the most significant factor in heating of the air.


SOMALI DEMOCRATIC REPUBLIC
MEAN ANNUAL TEMPERATURE
Temperature in degrees Celcius
Fig. 18
Sources: Fantoli (1960) & IDCR 61 with additional material from FEWS archives
Lapse rate for the North 0.0064°/m (r = -0.94)
Temperature (°C)
Altitude ('00's m)
KM
0
100
200
300
400
Hargeisa
Garoe
Galcaio
Belet Uen
Lug
Baidoa
Bardera
Mogadishu
Kismayo
42° E
44°
46°
48°
50°E
10° N
8°
6°
4°
2°
0°
2°S

Mean Maxima and Mean Minima Temperatures.

Mean maximum temperatures (the mean of the highest measured each day) follow a similar pattern to the mean temperatures, with highest monthly values occuring in March or April in southern and central areas, and May or June in the north. Lowest monthly maxima occur in July everywhere except for the north, when it is December or January.

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi	33.6	34.3	34.8	34.4	32.4	30.8	29.9	30.4	31.5	32.0	32.0	32.9	32.4
Alessandra	35.1	35.6	36.0	35.5	33.4	32.1	30.5	31.3	32.4	33.1	33.8	34.5	33.6
Baidoa	34.2	35.6	35.6	33.5	31.2	29.9	28.9	29.7	31.2	31.0	31.3	32.7	32.0
Balad	34.9	36.6	37.1	36.2	33.3	32.5	31.4	31.9	32.5	33.6	33.9	33.8	33.9
Bardera	38.1	39.3	41.0	37.8	34.0	34.0	32.6	33.1	34.9	35.9	35.7	36.5	36.2
Belet Uen	34.5	35.4	36.7	36.9	34.9	34.0	33.0	33.8	35.3	34.4	34.8	34.5	34.9
Berbera	28.9	28.9	30.0	31.8	35.6	41.7	41.7	41.1	39.5	33.5	31.1	29.5	34.1
Erigavo	24.5	25.8	25.8	26.7	26.7	26.1	26.1	26.1	25.8	25.0	23.9	23.4	25.4
Galcayo	32.6	33.7	35.0	37.0	34.9	33.9	32.7	33.2	34.3	33.6	33.5	32.9	33.9
Genale	32.3	32.7	33.5	33.1	31.5	29.6	28.6	28.9	29.5	30.5	31.0	31.6	31.1
Hargeisa	25.0	27.2	29.5	30.0	31.1	31.1	30.0	30.0	30.6	29.5	26.7	25.0	28.8
Hoddur	34.6	36.2	37.5	36.3	33.8	32.9	29.8	32.1	33.8	33.2	33.2	33.7	33.9
Lugh Ganana	38.7	39.7	40.6	38.4	36.1	35.1	33.5	33.9	36.1	37.2	37.5	37.9	37.1
Marere J.S.P.	35.5	36.3	36.3	35.5	32.3	30.7	29.7	30.5	32.0	33.1	33.5	34.3	33.3
Mogadisho	30.1	30.2	31.0	32.1	31.0	29.5	28.5	28.5	29.2	30.0	30.4	30.6	30.1
Kismayo	29.6	29.9	31.0	31.8	30.4	28.6	28.0	28.3	28.6	29.5	30.5	30.5	29.7

Table 4. MEAN DAILY MAXIMUM TEMPERATURE (oC)

The highest monthly value of 41°C occurs in Bardhere in March, closely followed in the same month by Lugh at 40.6°C. The lowest maxima occur in the higher altitudes of the north with 23.1°C at Borama and 23.4°C at Erigavo.

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi	20.4	20.8	22.0	22.6	22.4	21.4	20.6	20.6	21.1	21.2	21.0	20.6	21.2
Alessandra	22.2	21.8	22.4	23.1	23.0	21.4	20.6	20.3	20.4	21.5	22.1	21.9	21.7
Baidoa	18.9	19.3	20.3	20.7	20.3	19.1	18.6	18.7	19.0	19.5	19.7	19.3	19.5
Balad	21.0	21.3	21.8	22.3	22.1	21.5	21.0	21.1	21.3	21.3	21.1	21.1	21.4
Bardera	21.3	21.9	22.8	22.8	22.4	21.2	20.4	20.9	21.5	22.0	21.7	21.5	21.6
Belet Uen	22.0	22.0	23.4	23.9	23.4	22.8	22.6	21.6	22.7	22.6	22.3	22.3	22.6
Berbera	20.0	21.7	21.7	25.0	26.7	30.0	31.1	30.6	28.4	24.5	21.7	20.0	25.0
Erigavo	6.7	7.3	8.3	10.0	11.7	12.8	13.3	13.3	11.7	8.3	7.2	6.7	9.8
Galcayo	18.1	18.8	20.5	22.2	22.5	22.4	21.8	21.7	21.9	21.9	20.3	19.0	20.8
Genale	21.0	21.6	22.9	23.6	23.3	21.8	21.4	21.2	22.1	22.7	22.2	21.6	22.2
Hargeisa	10.6	11.7	13.9	16.1	17.2	17.8	17.2	17.2	17.2	13.3	12.2	11.1	14.6
Lugh Ganana	23.9	24.6	25.4	25.0	24.9	23.9	23.2	22.7	23.5	23.8	23.8	23.1	24.0
Marere J.S.P.	22.0	22.1	21.9	22.5	22.5	20.4	19.9	19.1	19.2	20.5	21.5	21.6	21.1
Mogadisho	22.9	23.3	24.8	25.5	24.7	23.7	23.0	23.0	23.4	24.1	24.0	23.4	23.8
Kismayo	24.2	24.5	25.4	25.8	24.8	23.5	23.1	23.3	23.3	24.0	24.5	24.4	24.2

Table 5. MEAN DAILY MINIMUM TEMPERATURE

Mean minimum temperatures also follow a pattern similar to that of mean temperatures. The lowest monthly values occur in June, or occasionally July, or in December or January. In the north the lowest temperatures occur in December or January. The highest minima occur usually, in April in the south, and July or August north of $8^{O}N$.

Daily Range of Temperature.

The difference between the maximum and minimum temperatures is known as the daily range. Normally, the mean maxima and mean minima are taken for climatological purposes.

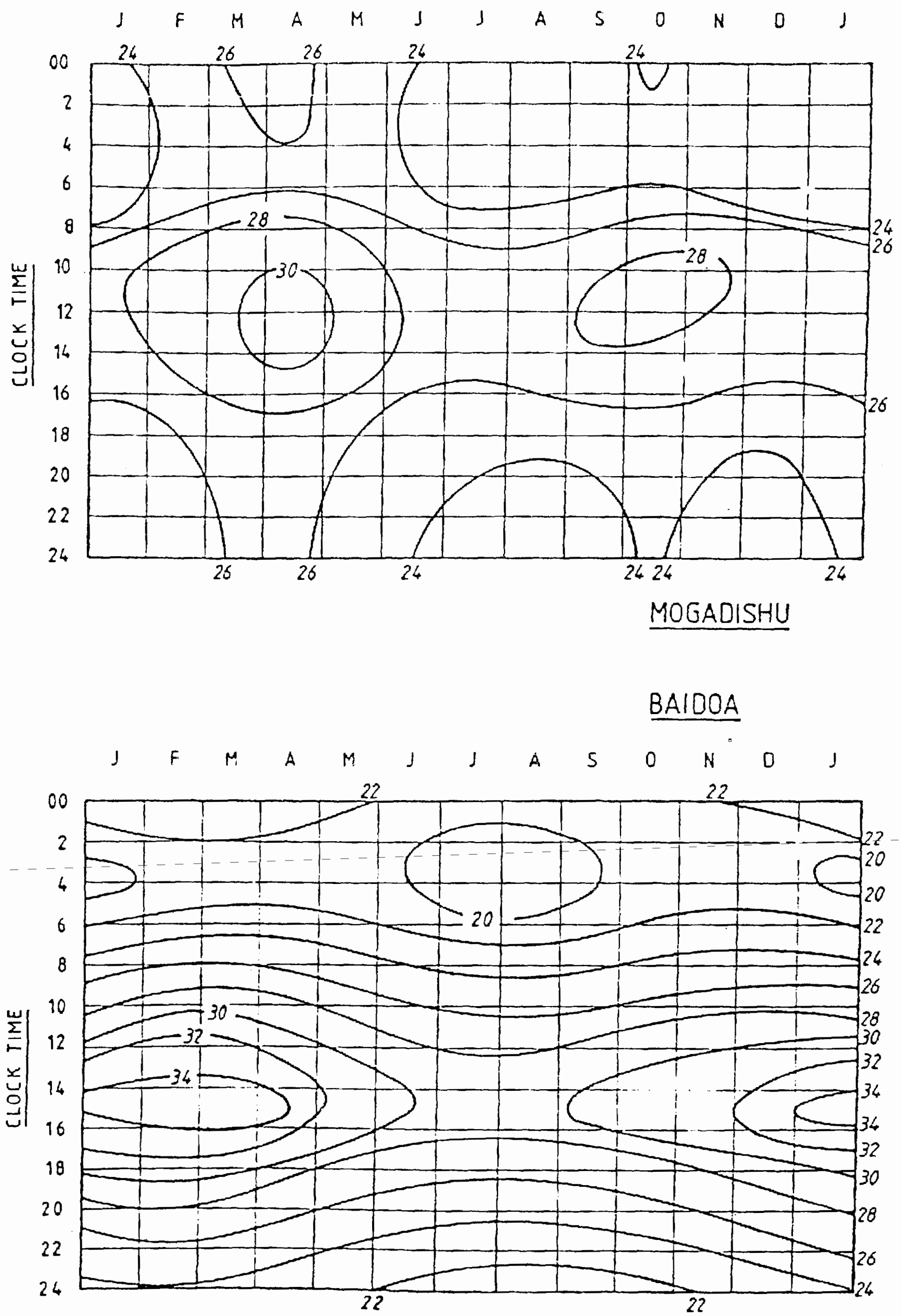
In general, the daily range is rather small. At the coastal stations, because of the alleviating effect of the sea, the range is very small, falling to only 5.5°C at Kismayo in February. Particularly in the semi-arid and arid areas, with little vegetation and low soil moisture levels, one may expect greater ranges, and the reason for it not being so, is the generally high levels of humidity in the air over the country.

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi	13.2	13.5	12.8	11.8	10.0	9.4	9.3	9.8	10.4	10.8	11.0	12.3	11.2
Alessandra	12.9	13.8	13.6	12.4	10.4	10.7	9.9	11.0	12.0	11.6	11.7	12.6	11.9
Baidoa	15.3	16.3	15.3	12.8	10.9	10.8	10.3	11.0	12.2	11.5	11.6	12.4	12.5
Balad	13.9	15.3	15.3	13.9	11.2	11.0	10.4	10.8	11.2	12.3	12.8	12.7	12.5
Bardera	16.8	17.4	18.2	15.0	11.6	12.8	12.2	12.2	13.4	13.9	14.0	15.0	14.6
Belet Uen	12.5	13.4	13.3	13.0	11.5	11.2	10.4	12.2	12.6	11.8	12.5	12.2	12.2
Berbera	8.9	7.2	8.3	6.8	8.9	11.7	10.6	10.5	11.5	9.0	9.4	9.5	9.5
Erigavo	17.8	18.5	17.5	16.7	15.0	13.3	12.8	12.8	14.1	16.7	16.7	16.7	15.6
Galcayo	14.5	14.9	14.5	14.8	12.4	11.5	10.9	11.5	12.4	11.7	13.2	13.9	13.1
Genale	11.3	11.1	10.6	9.5	8.2	7.8	7.2	7.7	7.4	7.8	8.8	10.0	8.9
Hargeisa	14.4	16.5	15.6	13.9	13.9	13.3	12.8	12.8	13.4	16.2	14.5	13.9	14.2
Hoddur	17.5	18.0	17.2	15.3	13.0	13.0	10.6	12.4	14.0	13.2	13.7	15.9	14.4
Lugh Ganana	14.8	15.1	14.1	12.2	11.2	11.2	10.3	11.2	12.6	13.4	13.7	14.8	13.2
Marere J.S.P.	13.5	14.2	14.4	13.0	9.8	10.3	9.8	11.4	12.8	12.6	12.0	12.7	12.2
Mogadisho	7.2	6.9	6.2	6.6	6.3	5.8	5.5	5.5	5.8	5.9	6.4	7.2	6.3
Kismayo	5.4	5.5	5.6	6.0	5.7	[illegible]	5.0	5.0	5.3	5.5	6.0	6.1	5.5

Table 6. MEAN DAILY TEMPERATURE RANGE

The daily variation in temperatures is illustrated in greater detail in figure 19, which shows, for Mogadishu, a coastal station and Baidoa, an inland station, the average temperatures for every hour of the day for every month in the year. In Mogadishu, the highest temperatures occur, on average, at about noon, before the sea breeze effect becames important, while for Baidoa, maxima occur rather later, at about 1500 hours, when the solar heating of the soil has had its greatest effect.

Minima occur a short time before dawn at both stations, though earlier in Baidoa.



HOURLY TEMPERATURES (°C) THROUGHOUT THE YEAR

Fig.19 P.H.

Isotherms are drawn at $2^{o}C$ intervals, and the relative sparsity of lines on the Mogadishu chart indicates the narrow daily range of temperature, while at Baidoa, a greater daily range is evident. On the Baidoa chart, the shape of the isotherms, elongated along the yearly axis, indicates that daily range is greater than the yearly range of temperature.

Extreme Temperatures.

The highest temperature ever recorded was $50.2^{o}C$ on an April day in 1933 at Lugh. No other station has recorded a temperature over 50 ^{o}C, though several stations, Belet Uen, Berbera and Galcaio have recorded $45^{o}C$ or over. The coastal stations of the south generally have had no outstanding maxima, with neither Mogadishu nor Kismayo ever acheiving $40^{o}C$, while the altitude of some of the northern stations have prevented any excessive maxima.

It is these northern upland stations, however which have experienced the coldest temperatures, with both Hargeisa and Erigavo recording freezing temperatures. Erigavo has recorded the lowest, $-3.3^{o}C$ on two occasions, on a December day and a January day.

Also remarkable is the high value of some of the extreme minima. Kismayo has never fallen below 19.0 ^{o}C, and neither Mogadishu nor Alessandra below $16.2^{o}C$. Even the semi-arid and arid stations do not experience the cold nights expected in some similar desert environments.

Station		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Alessandra	a)	40.0	39.0	40.5	40.0	39.0	34.6	35.0	34.5	37.5	37.5	38.0	39.5	40.5
	b)	17.0	18.0	18.8	20.0	18.8	17.4	16.7	16.4	16.2	16.8	19.2	18.5	16.2
Baidoa	a)	44.0	43.0	43.0	43.0	40.3	39.5	37.0	38.0	39.0	40.0	44.0	45.0	45.0
	b)	14.3	15.4	16.0	15.0	14.0	17.0	15.0	10.0	15.0	15.0	16.0	15.5	10.0
Belet Uen	a)	41.5	42.5	43.0	43.0	41.3	39.0	39.0	39.0	40.2	45.0	40.0	42.0	45.0
	b)	16.0	16.5	17.0	16.0	18.0	17.0	17.0	16.3	17.2	17.0	15.0	15.0	15.0
Berbera	a)	34.5	33.4	35.0	43.4	45.6	47.3	46.7	46.7	45.6	41.7	36.7	35.6	47.3
	b)	14.5	15.6	16.7	18.8	20.6	22.2	20.6	20.0	17.0	16.7	16.6	15.0	14.5
Erigavo	a)	30.6	33.4	32.2	33.4	31.7	30.6	30.6	30.0	30.0	29.5	29.5	27.8	33.4
	b)	-3.3	0.5	0.5	2.2	1.7	3.9	5.0	4.4	2.8	0.0	-2.8	-3.3	-3.3
Galcayo	a)	39.0	39.8	42.8	47.2	47.0	40.3	36.5	42.5	40.0	43.0	40.0	37.5	47.2
	b)	11.0	13.0	13.0	17.0	17.0	16.0	18.9	17.0	18.0	15.0	12.0	13.1	11.0
Hargeisa	a)	31.1	33.9	33.4	35.6	36.1	36.1	35.6	35.0	34.5	33.9	32.2	31.7	36.1
	b)	-0.5	0.5	1.7	5.6	10.6	13.9	14.5	14.5	9.5	3.9	1.7	-1.1	-1.1
Kismayo	a)	31.8	33.1	34.0	37.8	34.0	34.0	32.3	32.4	30.3	31.5	32.2	33.0	37.8
	b)	21.0	22.0	23.0	21.3	20.0	21.0	19.0	21.0	22.0	22.4	22.5	22.0	19.0
Lugh	a)	49.2	50.0	50.0	50.2	47.4	42.0	42.0	42.4	49.0	46.2	49.6	49.4	50.2
	b)	15.3	17.8	15.5	16.8	17.3	15.0	19.2	18.9	18.0	17.3	18.2	17.9	15.0
Mogadisho	a)	39.5	39.5	37.3	39.8	34.9	33.0	34.3	36.0	36.0	37.0	39.0	37.3	39.8
	b)	19.0	19.2	20.2	18.0	18.4	19.8	16.8	18.0	18.0	17.5	16.2	16.5	16.2

Table 7. EXTREME MAXIMUM AND MINIMUM TEMPERATURE (oC)

3. ATMOSPHERIC HUMIDITY.

In Somalia, the main source of water vapour in the atmosphere is evaporation from the surface of the Indian Ocean. Secondary sources of water vapour are the Gulf of Aden, the Shabelle and Juba rivers, and some ephemeral rivers in the north of the country, as well as transpiration from the vegetation. The circulation of the water vapour in the atmosphere over the country and the fluctuation of its quantity have a very close relation with the turbulent exchange between the land and the Indian Ocean, Gulf of Aden and the hot dry air from the Arabian Peninsula. The intense vertical convergence zone which lies along the territory between the Ethiopian - Kenyan mountain range and the coast of the Indian Ocean during the Gu and Der seasons is a very important factor influencing the circulation of vapour in Somalia. In addition, the particular circulation of air over the Central and northeastern part of the country (see below, paragraph 4.) creates a humidity regime specific to this area.

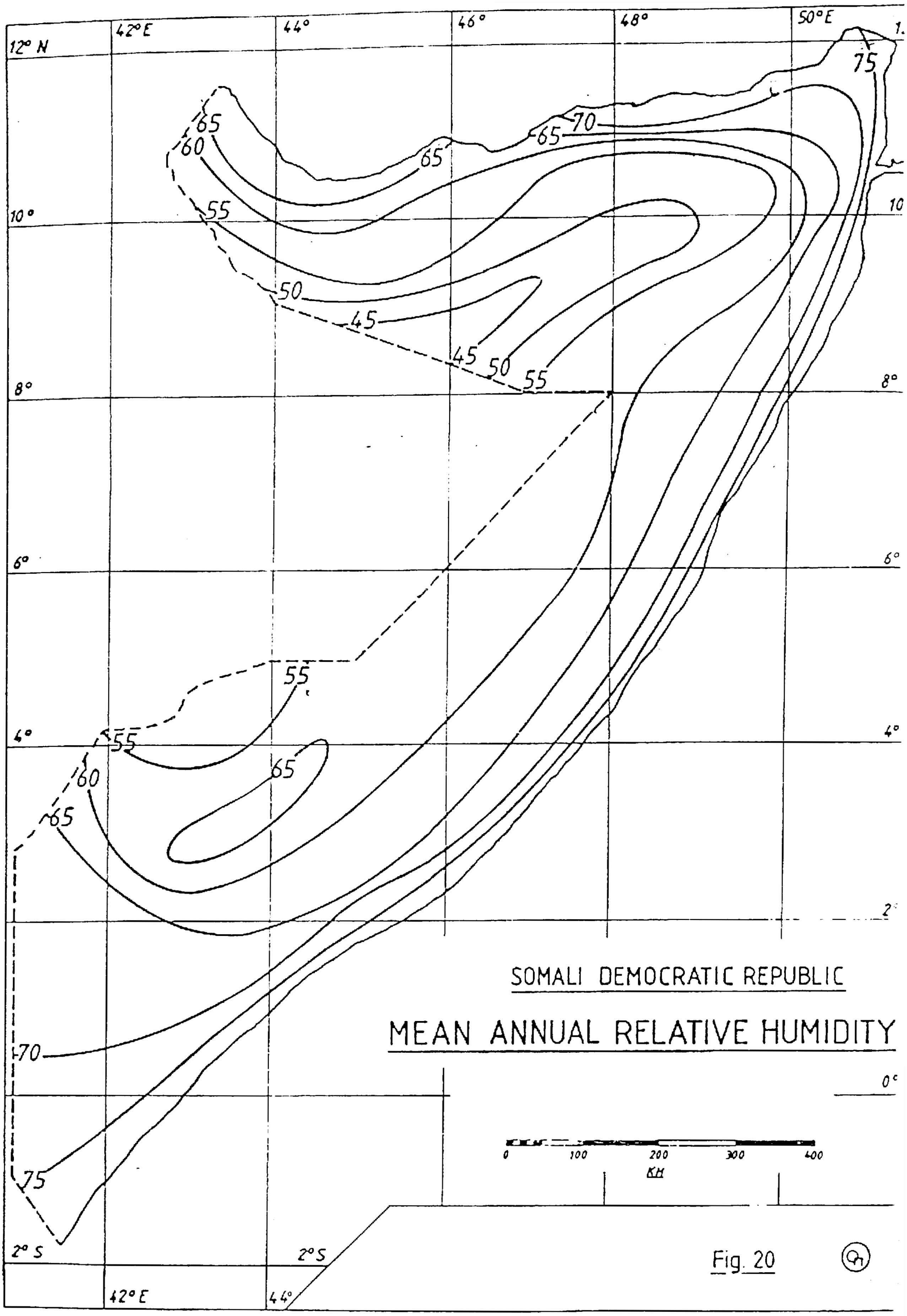
Recording of humidity of the atmosphere in the country started in the second quarter of this century. Observations have mainly been done using wet and dry bulb thermometers, and only at Mogadishu have any recording instruments been used extensively. The observations have included vapour pressure, dew point and relative humidity (see Appendix 2 for definitions of these parameters). There are not so many years of record. At some stations, the data comes from two or more sources and can be quite different, and table 8 shows the different values for relative humidity. The southern and central parts of the country, in general, provide more information than elsewhere. In particular, all inland areas of the northern and northeastern areas have very limited records. At the present time, the Food Early Warning Department are including more instrumental observations of atmospheric humidity, using thermohygrographs.

There is very little known, from instrumental records, about the diurnal fluctuation of atmospheric humidity, except at Mogadishu. Some records do exist in the FEWS Department, but no full analysis has been made. Of course it is known that the relative humidity varies inversely with temperature, and some characteristics of the diurnal fluctuation are discussed below.

Yearly, Seasonal and Daily Fluctuations of Atmospheric Humidity.

As known, Somalia rates as one of the hottest countries, and since saturation vapour pressure increases with increasing temperature, humidity can be very high throughout the two wet seasons of Gu and Der (Table 8), and even high during the dry seasons.

Southern Areas. Along the coast of the Indian Ocean, and near the major rivers, relative humidities are high, averaging about 70-80%, both in the morning and afternoon (Fig. 20). Further inland and away from the rivers, the air is much drier, most particularly in the afternoons. During both rainy Gu and Der seasons, the general level of humidity has a tendency to increase, while at other times, it is lower (Table 8). Daily range in the wet season is up to 25%, and in the dry times rather more, up to 35%. Minimum humidity is observed in the late morning or early afternoons.



SOMALI DEMOCRATIC REPUBLIC

MEAN ANNUAL RELATIVE HUMIDITY

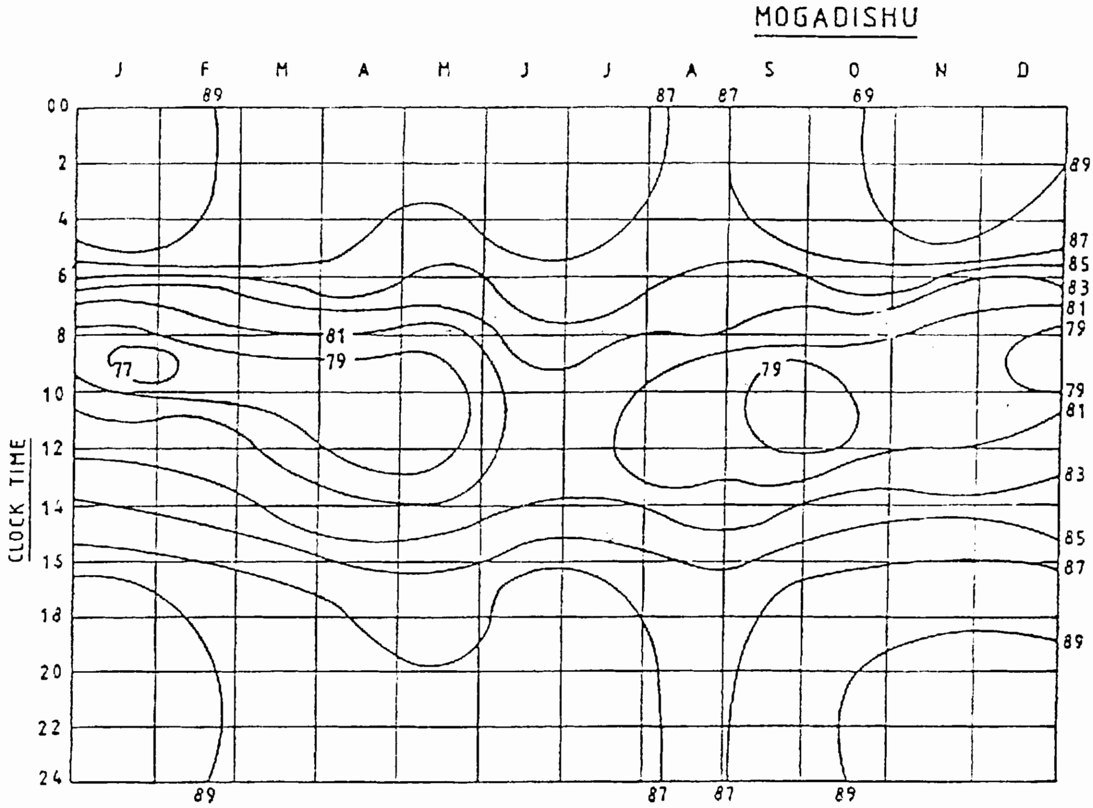
Fig. 20

Station		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi		69	66	66	70	74	75	77	75	72	72	74	71	72
Afmadu		67	64	64	70	75	74	75	73	70	74	73	70	71
Alessandra		68	67	66	72	78	78	77	75	72	73	76	74	73
Alula		74	72	72	73	71	69	66	70	72	70	74	75	71
Baidoa		59	58	60	70	75	70	71	67	64	72	74	67	67
Balad		74	74	66	73	76	71	74	73	72	71	78	76	73
Bardera		63	61	61	69	72	71	69	70	69	73	72	69	68
Belet Uen		58	57	57	60	64	61	65	64	59	64	62	62	61
Berbera	b)	76	77	77	79	71	52	46	45	49	69	73	71	65
	d)	74	76	77	77	73	65	60	69	75	70	73	73	72
Borama		63	64	59	59	53	49	55	57	57	47	52	58	56
Bosaso	c)	70	71	68	66	64	52	47	48	56	69	76	73	63
	d)	77	77	76	72	70	63	61	61	64	73	80	79	71
Brava		77	78	78	76	77	75	76	76	77	78	75	78	77
Bulo Berti		61	57	55	60	63	64	63	59	60	63	63	60	61
Burao	a)	55	53	56	55	50	55	55	56	54	52	57	54	58
	b)	52	54	53	54	52	49	58	46	45	48	47	46	49
Bur Hakaba		51	51	56	62	68	65	66	61	59	62	62	58	60
Cape Guardafui		79	81	77	78	79	75	72	75	77	78	78	77	77
	c) & d)	76	77	78	79	77	58	50	53	67	71	73	77	69
Erigavo	d)	38	45	51	53	59	59	54	57	63	48	36	40	51
	e)	50	54	56	64	64	58	55	56	58	55	48	56	56
El Bur	a)	55	57	60	60	54	61	60	59	58	64	65	64	59
	c)	60	57	56	52	65	63	63	61	58	64	64	63	61
Faro Dante		81	86	85	83	81	82	82	78	79	77	77	80	81
Galcayo		60	60	57	60	63	60	61	60	60	64	64	62	61
Genale		76	74	76	77	81	82	82	82	81	81	82	80	79
Giumbo		74	75	75	72	72	77	75	74	75	75	72	70	74
Gudubi		41	46	46	44	45	42	40	40	37	43	39	46	42
Hargeisa	a)	63	62	58	59	57	54	54	55	55	58	60	61	58
	b)	67	67	57	55	54	55	52	52	54	53	62	66	58
Hoddur		48	45	46	62	65	57	58	54	50	63	57	52	55
Jonte		75	75	76	77	79	81	81	79	78	77	75	76	77
Las Anod		70	78	77	69	71	72	70	67	72	71	73	66	71
Lugh Ganana		51	47	50	62	62	59	60	58	55	58	60	53	56
Mahaddei Uen		66	57	60	61	62	71	72	70	66	67	67	61	65
Marere J.S.P.		68	67	66	72	78	78	77	75	72	73	76	74	73
Mogadisho		78	78	77	77	80	80	81	81	81	80	79	79	79
Kismayo		77	76	76	77	80	80	80	79	78	78	77	77	78
Obbia		76	75	76	76	79	79	79	79	79	81	79	78	78
Scushuban		59	61	56	53	46	47	51	51	50	55	59	61	54
Sheik		70	64	59	64	67	61	67	66	67	67	667	68	65
Qardo	c)	59	59	55	58	59	58	63	62	59	60	63	63	60
	d)	64	61	58	59	59	60	64	65	61	64	66	65	62
Wanle Uen		55	51	52	62	76	71	69	65	62	64	64	62	63

a) - Data from Civil Aviation Department. b) - Data from J.A Hunt
c) - Data from Fantoli d) - Data from Agroclimatological study in the Arab Countries
e) - Food Early Warning Department

Table 8. MEAN RELATIVE HUMIDITY (percent)

At the stations near the Indian Ocean, humidities are very high, with little diurnal (daily) change. Records for Mogadishu, at a station very close to the beach, are available (Fig. 21). From this diagram it may be seen that high humidities of 87% or more exist from 1600 hours until 0500 hours the next day. Throughout the year, the lowest humidity is about 79%, and 77% in January and February, observed between 0800 hours and 1100 hours in the morning.



HOURLY RELATIVE HUMIDITY (%) THROUGHOUT THE YEAR

Fig. 21

However, this is an exceptional case. Inland, it may be expected that the daily and seasonal variation is rather more, with daytime humidities falling below the equivalent values for Mogadishu.

The Western Areas. This big dry territory occupies the west of the southern and central parts of the country, from Lugh to Garoe. The area is located along the leeward side of the Ethiopia - Kenya mountain range, which has been observed as a permanent zone of divergence (Findlater, 1977) to which the the air from the Ocean seldom penetrates. Even at night time the relative humidity is quite low, at 60-70%, observed for short periods at about 0400 to 0500 hours in the morning.

When atmospheric convergence occurs in the country, during the passage of the Intertropical Front, including the Gu and Der seasons, the western areas have a short season, the Gu being about 9 weeks and the Der 5-6. At this time, the atmospheric humidity rises very sharply, (see stations Hoddur, Belet Uen, Baidoa in Table 9). So, for example, in the region of station Hoddur, relative humidity rises from 45 to 65%, and dew point from

13.8°C up to 20.2°C. Such kind of fluctuation of humidity depends on the distance from the mountain range. Over this area the daily range of humidity is very wide, about 60-70%. Sharp falls of 50% can occur over a period of two hours, or in exceptional cases, over one quarter of an hour.

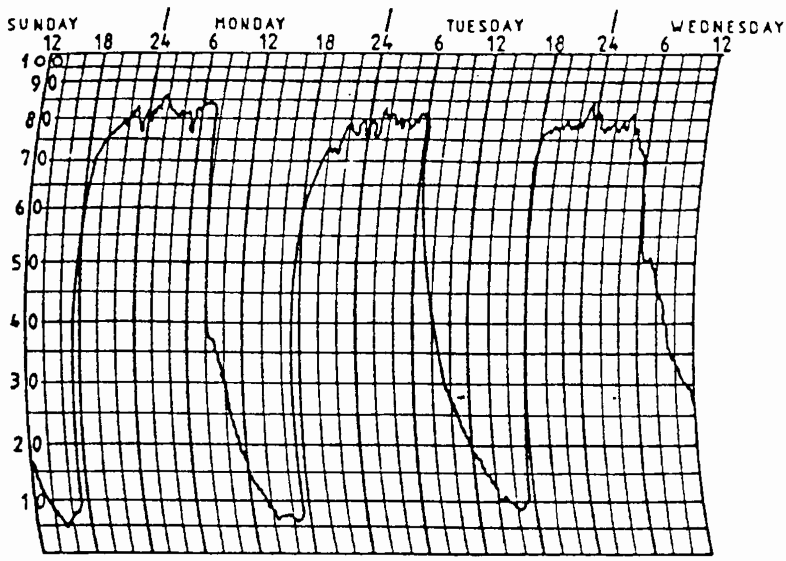
During the dry seasons, the number of days with relative humidities less than 30% can reach 20-25 days in a month, with absolute minima of 10% at the time of lowest humidity at about 1600 to 1700 hours.

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi	20.4	19.9	21.3	21.9	21.8	21.5	20.7	20.8	20.7	20.6	21.2	21.7	21.0
Alessandra	21.6	21.4	21.9	23.4	23.3	21.9	20.9	20.7	20.7	21.7	22.5	22.4	21.9
Alula	20.7	19.9	21.9	23.8	24.6	26.0	26.1	26.4	25.8	22.1	21.1	21.2	23.3
Baidoa	18.7	18.4	21.0	22.8	22.8	21.0	20.2	19.7	19.7	21.1	20.9	19.7	20.5
Balad	21.9	21.9	22.7	23.9	23.6	22.0	21.1	20.8	21.1	22.0	23.1	23.1	22.2
Bardera	22.4	23.1	24.3	24.2	23.8	22.7	23.1	22.2	22.7	23.1	22.9	22.4	23.1
Belet Uen	19.1	18.9	20.2	20.6	20.8	20.3	20.2	19.8	19.8	20.4	20.4	20.0	20.0
Bosaso	20.6	20.7	21.7	23.5	24.6	23.9	23.1	22.3	25.1	23.5	22.1	21.2	22.8
Bur Hakaba	18.7	18.5	19.9	21.0	22.2	20.5	19.6	19.4	19.6	20.1	20.2	20.0	19.9
Cape Guardafui	19.9	?	20.1	21.9	23.6	22.6	20.5	21.9	21.3	21.5	20.8	20.2	21.3
El Bur	18.0	17.9	19.2	21.2	21.5	20.2	18.9	18.8	19.2	20.7	18.7	18.4	19.4
Galcaio	17.9	17.5	18.4	19.8	20.7	20.0	19.4	18.8	19.2	19.9	19.7	18.8	19.2
Genale	21.2	21.2	22.4	23.0	22.9	21.9	20.9	20.7	21.3	21.9	21.8	21.8	21.7
Hoddur	14.7	13.8	16.0	20.2	20.0	17.7	16.6	16.3	16.6	18.9	17.7	16.2	17.0
Jonte	23.8	23.5	24.5	25.4	24.7	23.5	22.9	22.7	23.2	23.8	24.1	22.0	23.8
Kismayo	23.8	23.8	24.7	25.0	24.0	23.1	22.5	22.5	23.1	23.9	24.3	24.3	23.7
Lugh Ganana	16.4	14.6	17.5	20.8	19.9	17.7	17.5	17.8	17.8	18.5	18.1	16.8	17.8
Mogadisho	22.3	22.1	22.6	24.4	24.1	22.6	21.6	21.7	22.0	22.9	23.1	22.7	22.7
Obbia	21.9	22.3	23.1	24.2	24.3	23.2	22.2	22.2	22.1	23.0	23.3	22.8	22.9
Qardo	17.3	17.3	18.4	21.5	22.4	22.6	21.9	22.7	22.5	22.5	20.9	19.8	20.8
Scushuban	17.7	18.4	19.8	21.1	21.3	22.0	21.8	22.0	22.0	20.6	19.0	18.3	20.4
Wanle Uen	19.8	18.9	20.3	22.9	24.0	22.2	20.9	20.8	20.9	21.9	21.6	20.8	21.3

Table 9. DEW POINT (oC)

<u>The Northwest.</u> Another dry part of Somalia is the mountainous northwest, lying at altitudes of 1500 - 2400 metres a.s.l., but falling to sea level at the north coast. The Hydrogeology of the northwest has not so much water resources as to affect the humidity to any degree. Yearly average humidity of air for this area is about 60-65%. A quite small increase of moisture during Gu and Der rainy seasons is observed, just about 3-5%. The daily range of atmospheric humidity is greater, though exact figures are not available.

Due to the proximity of the Gulf of Aden and the altitude, relative humidity is high throughout the night for the entire year, at 80-90%. The permanent strong and dry wind from the Arabian Peninsula exerts the opposite effect during day time. In particular, a very strong and dry wind during June to September, named 'Karif', contains an air mass of very low atmospheric humidity. Permanent high wind activity on the border of these systems create very sharp diurnal fluctuation of humidity, depending on which kind of air mass passes over the territory at the time. The range of relative humidity can reach 70-80%. At the extreme, relative humidity can rise or fall between 10-20% and 70-80%, sometimes during 10-15 minutes, a range of 50-60%, as illustrated in the Hygrograph trace of Aburin (Fig.22).



HUMIDITY RECORD

Aburin, 3-5 July 1988

Fig. 22

The number of days with humidity less than 30% can be up to 25 days in a month, with absolute minima reaching 3-5%, in the late afternoons at 1600 t0 1700 hours. Thus at station Berbera, monthly humidity falls from 79% to 45%, and at Hargeisa from 67-51%. The driest place in this area and, in fact, in the whole of Somalia is station Gudubi in Togdhere Region, where annual mean humidity is only 42%. During the time of the Karif, monthly humidities fall to 37-40%, with the absolute average monthly minimum at 17% for this station.

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Berbera	71	71	74	71	68	48	38	32	39	57	65	61	32
Burao	38	40	37	45	41	38	37	38	33	40	35	33	33
Gudubi	35	41	40	43	38	39	40	30	29	28	17	37	17
Hargeisa	61	58	50	44	49	51	37	37	50	40	53	60	37
Las Anod	67	67	70	59	66	59	63	61	60	65	62	52	52
Sheik	69	53	55	39	60	61	60	59	51	51	56	60	39

Table 10. MONTHLY MINIMUM RELATIVE HUMIDITY (Percent)

The Dry East. The third dry part of Somalia occupies all the northeastern territory of the country. There are three specific circulations of air during some period of the year which form particular characters of the weather. The main influence is the the permanent and strong dry wind from the Arabian Peninsula and the effect of the Karif blowing during June to September. The other strong factor is the Somali Jet over this part of the country. In this case there is a very strong airstream from the dry areas of Galcaio-Gudubi through Garoe to the Eastern corner of Somalia near Cape Guardafui and Faro Dante (see fig 29, below). Because of this circulation the moisture from the Indian Ocean does not reach this area. Therefore, during the entire year, atmospheric humidity is quite low. The yearly average relative humidity remains about 50-60%, except at the coast, where 70-80% is reached (see Table 8). Even the convergent stream of air in the Intertropical Front, which affects the rest of the country during the Gu and Der seasons has little effect in this area. Inland, the fluctuation of air is quite feeble, for example, at station Qardo, the relative humidity varies between 55-63%, only. But on the coastal strips, the range is very high. At station Bosaso, during the Karif, the relative humidity falls from 71 to 47%. At station Berbera, relative humidity falls from 79% to 45%, (see fig 23). Particularly at station Alula, relative humidity fluctuates very little, only 7%.

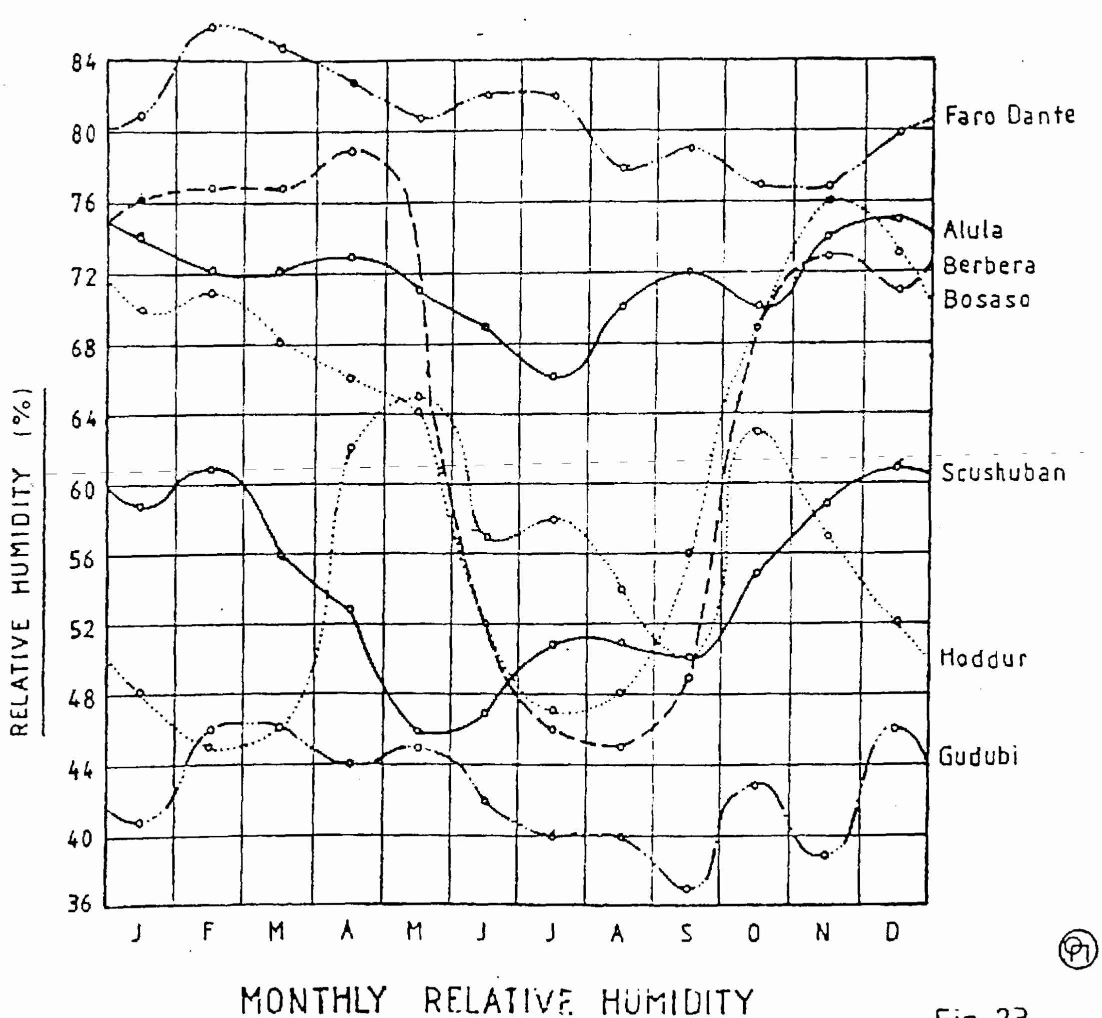
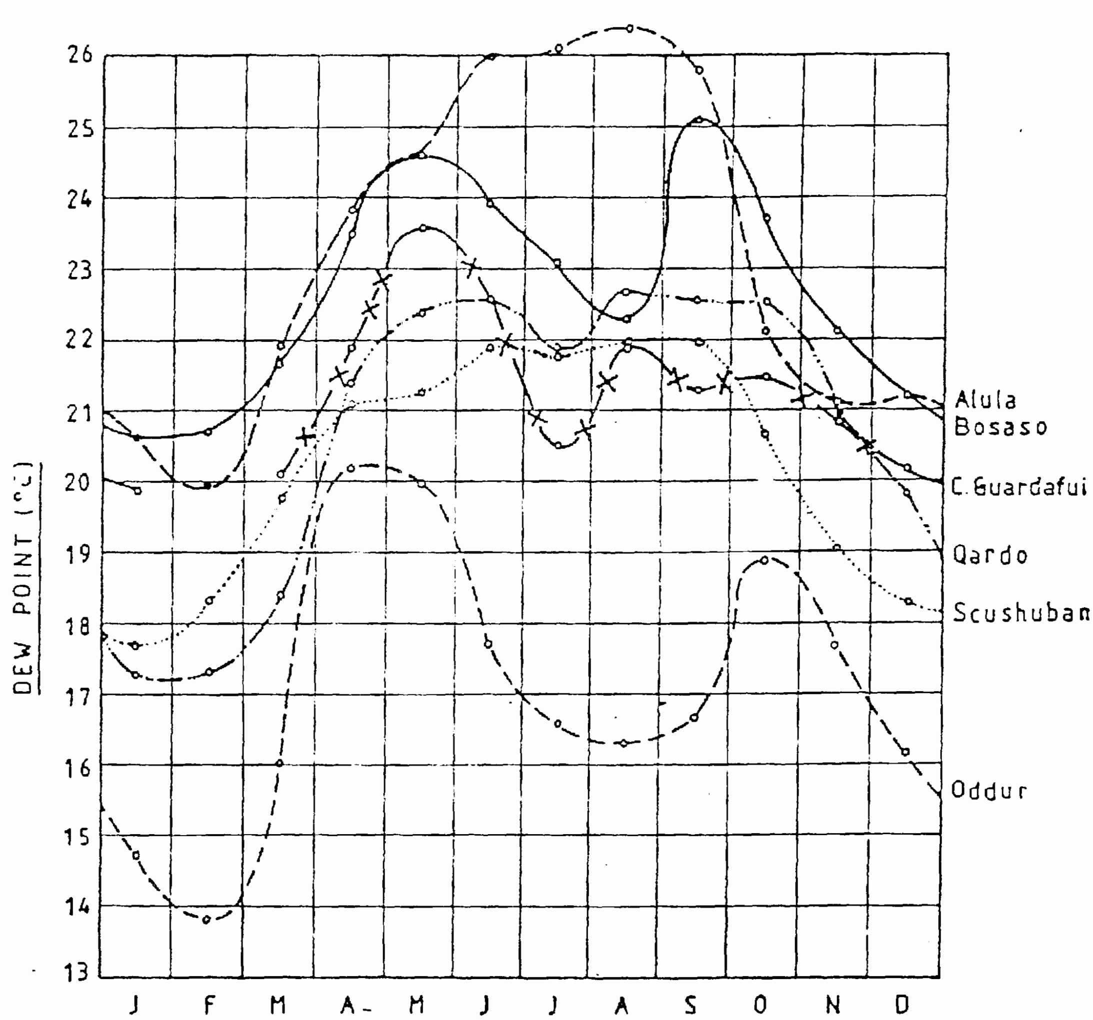


Fig. 23

However, because of temperature variations, relative humidity is not a good indicator of actual moisture in the air. For this, records of dewpoint or vapour pressure are better. For dewpoint, these are displayed in table 9 and figure 24, which immediately clarifies the annual variation. Dewoints rise all over the area during the onset of the Gu season, and fall off with the retreat of the Der. The drier Hagai is evident at some stations during the middle months of the year, but the effect of the Karif, which is an onshore wind, is illustrated by some of the coastal stations, especially Alula.

The influence of the Somali Jet and the Karif form a very specific circulation of air at the Horn of Africa.



MONTHLY DEW POINT AT SOME STATIONS

Fig. 24

4. WIND.

As discussed above, wind in Somalia is a response to the north and south seasonal movement of the Intertropical Convergence Zone, and, in particular the Intertropical Front (ITF). In general, winds blow from the south or southwest south of the ITF, between south and east in the region of the Front and northeast, north of the Front. There are exceptions to this general rule, specially in the north where the land configuration affect both speed and direction, and along the coast, where the sea breeze has an effect varying from slight to dominant.

Wind strengths are, almost everywhere, light to moderate. Only on the north coast are strong winds a significant feature affecting man's activities. However, wind is, in general, not a negligible factor of life, since it affects evapotranspiration, and hence the water balance, as well as providing a potential source of energy, so far almost untapped. Knowledge of the winds is, also a crucial factor in the understanding of the seasons.

Wind Directions.

During January, when the ITF is well to the south of the country, winds blow persistently from the northeast, with some easterlies and northerlies, almost everywhere in Somalia (fig 25(a)). Only in the far south is there some veer towards the east, which is in response to the general circulation pattern of the area.

By March, as the ITF enters the country from the south, so wind directions in the very south begin to veer, from northeast through east to southeast. The process continues throughout April, when all areas south of about 8°N experience south easterlies, while the Lower Juba experiences winds varying from southeast to southwest (fig. 25(b)). At this time, winds north of 8°N are still from the northeast, though local conditions do cause variation in this field. Sheik, for example experiences a local wind, generally southwesterly, while Cape Guardafui is already in the southerly airstream, a local coastal effect.

By June, the ITF has cleared the country, and by July (fig 25(c)) southwesterlies prevail almost everywhere. In the very south, though southerlies, rather than southwesterlies prevail, due to the macroscale flow pattern round the Indian Ocean Low. In the far north, also, there is some deviation in the area of the Horn itself. This is caused by a special combination of circumstances, described below.

The ITF retreats through the north of the country in October, lying between 10° and 11°N at this time (fig. 25(d)). The northern coastal strip thus experiences a return to the northeasterlies, while over the rest of the country the winds tend to back from southwesterly to southerly ahead of the ITF. This process continues throughout November and December, when the ITF finally clears the southern tip of the country, and the return to dry season northeasterly winds is complete.

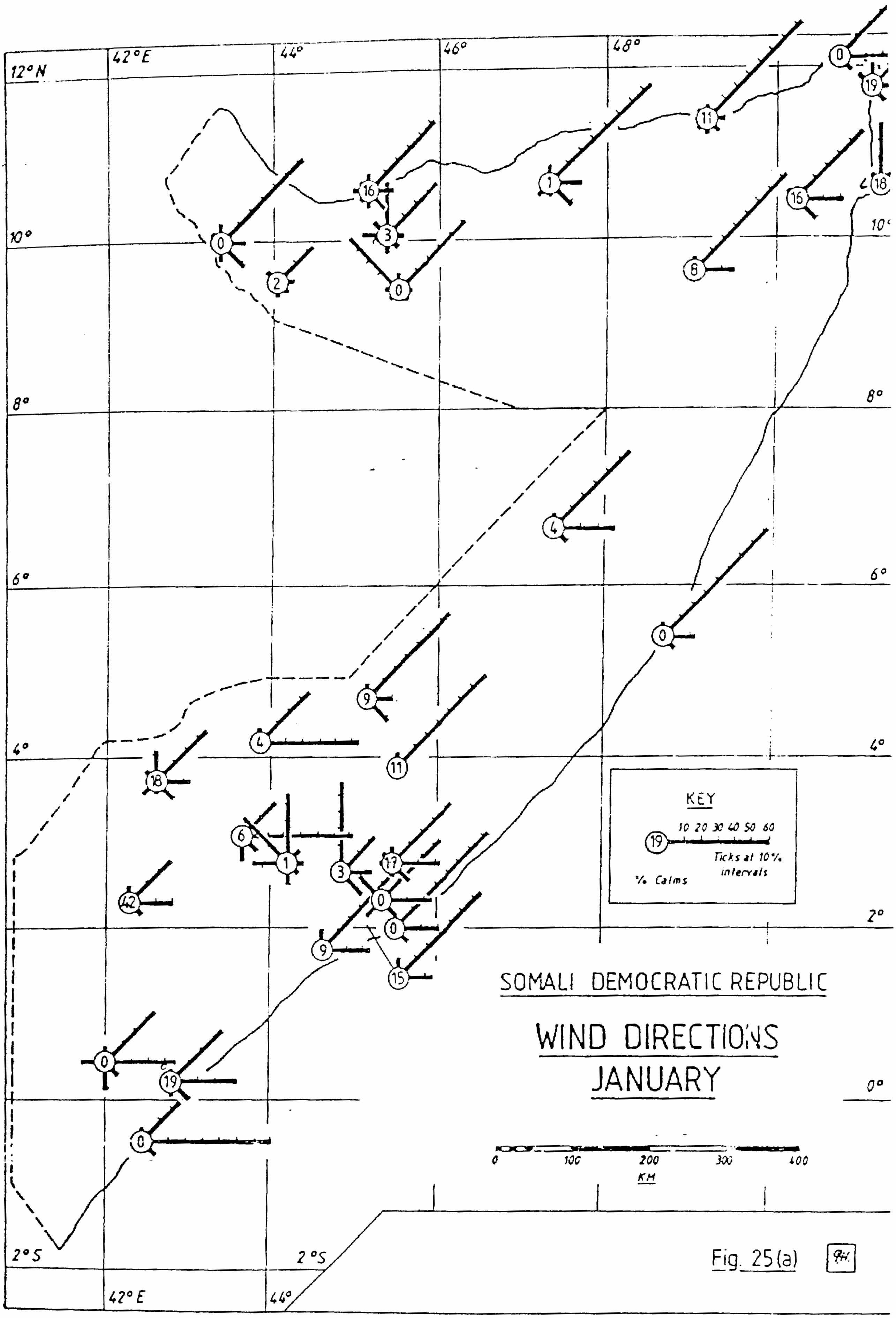
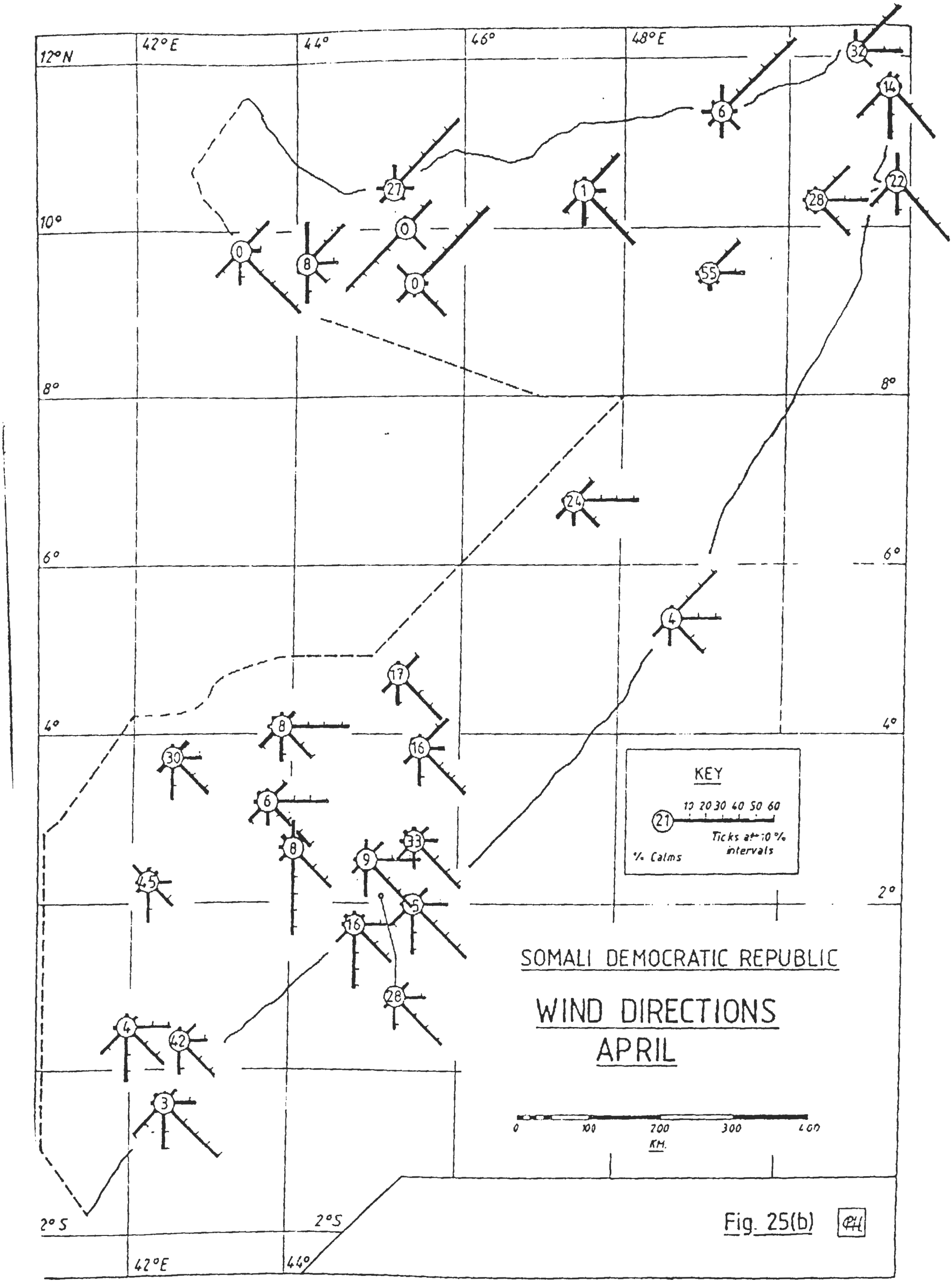

12° N
42° E
44°
46°
48°
10°
8°
6°
4°
2°
0°
2° S
2° S
42° E
44°
KEY
10 20 30 40 50 60
Ticks at 10% intervals
% Calms
0 100 200 300 400
KM
SOMALI DEMOCRATIC REPUBLIC
WIND DIRECTIONS
JANUARY

Fig. 25(a)


12°N
42°E
44°
46°
48°E
10°
8°
6°
4°
2°
2°S
KEY
10 20 30 40 50 60
21
Ticks at 10 % intervals
% Calms
SOMALI DEMOCRATIC REPUBLIC
WIND DIRECTIONS
APRIL
0 100 200 300 400
KM.
Fig. 25(b)
PH

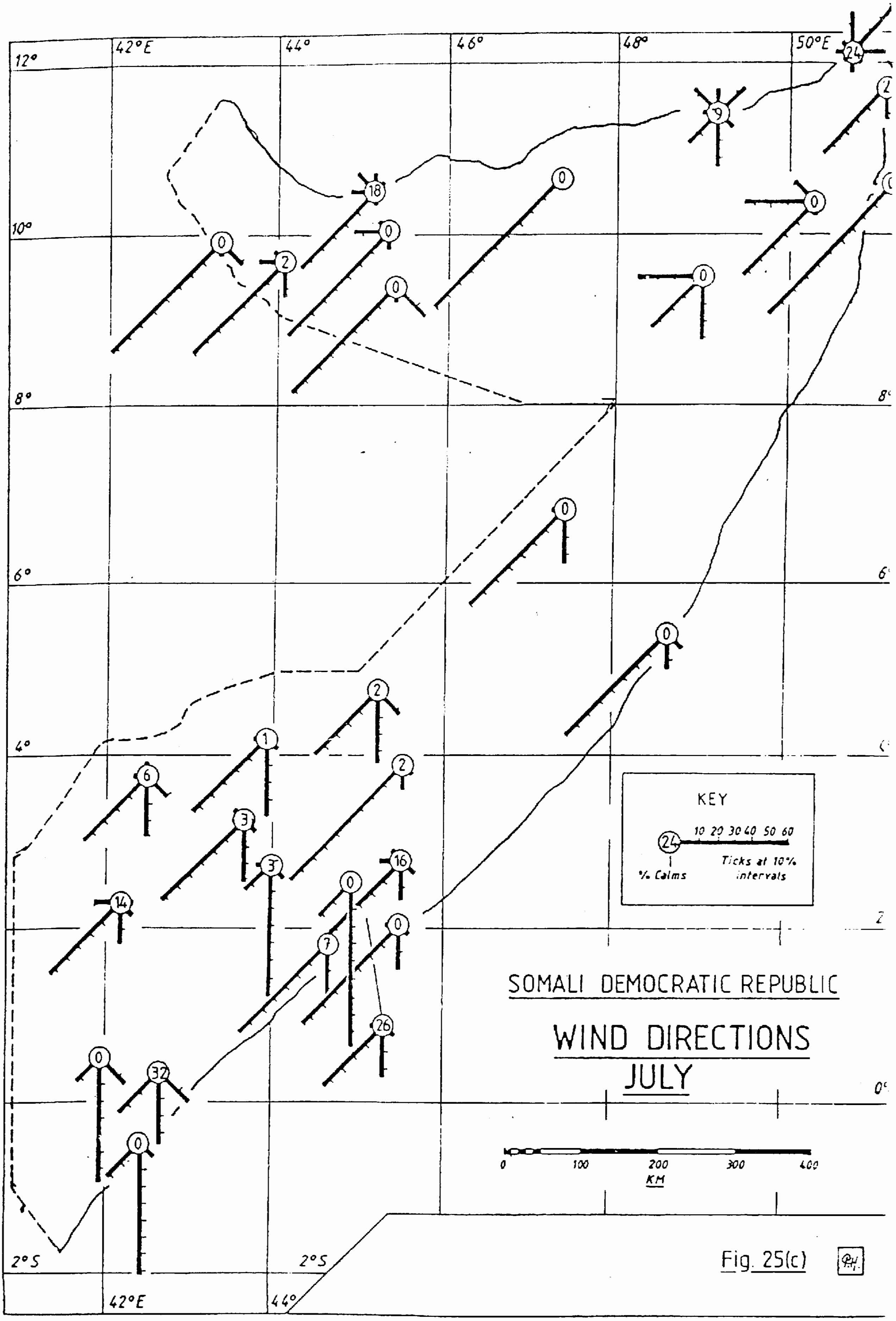

SOMALI DEMOCRATIC REPUBLIC
WIND DIRECTIONS
JULY
KEY
10 20 30 40 50 60
% Calms
Ticks at 10% intervals
0 100 200 300 400
KM
42°E
44°
46°
48°
50°E
12°
10°
8°
6°
4°
2°S

Fig. 25(c)

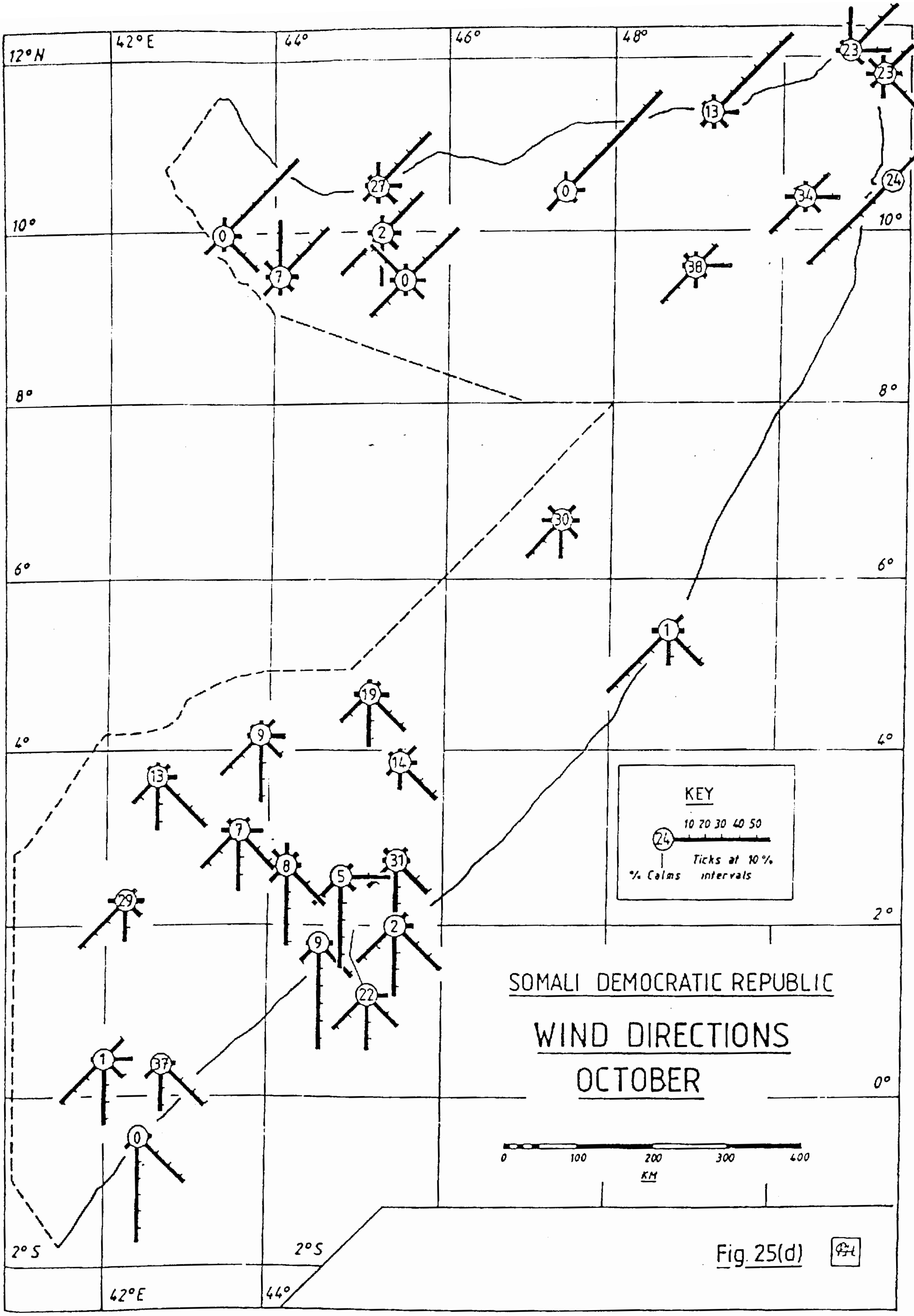

12°N
42°E
44°
46°
48°
10°
8°
6°
4°
2°
0°
2°S
42°E
44°
KEY
10 20 30 40 50
Ticks at 10% intervals
% Calms
SOMALI DEMOCRATIC REPUBLIC
WIND DIRECTIONS
OCTOBER
0 100 200 300 400
KM

Fig. 25(d)

Wind Speeds.

Original wind speed data is rather contradictory (see textnote 2), however, data used here is that derived from the Civil Aviation Archives.

The general pattern of wind speeds throughout the year, is that of moderate winds, averaging between 3 to 11 m/s for the various stations. Winds are generally lighter during the transitional months, that is, during the passage of the ITF, than when the northeast or southwest monsoons are set in (table 11).

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi	5.8	6.0	5.4	3.7	3.5	4.4	4.2	4.5	4.4	3.8	3.0	4.6	4.5
Alula	5.8	5.8	6.6	5.6	3.5	3.0	5.0	3.8	3.1	4.3	4.3	4.6	4.6
Baidoa	4.0	3.8	3.7	3.0	3.1	4.3	4.6	4.3	3.8	2.9	2.6	3.3	3.6
Bardera	4.8	3.5	3.2	2.1	4.3	6.2	6.3	6.8	5.6	4.1	3.4	3.4	4.5
Belet Uen	3.7	3.4	2.7	2.1	2.9	4.6	4.7	4.8	4.1	2.3	2.6	3.2	3.6
Berbera	7.4	6.7	7.6	6.9	7.3	12.6	11.0	12.6	7.5	6.1	5.7	5.3	8.1
Borama	6.6	6.6	7.1	6.4	6.5	7.4	8.0	7.7	6.4	7.0	7.2	6.9	7.0
Bosaso	6.2	6.0	6.5	5.4	5.3	7.5	9.3	8.0	6.3	4.9	5.0	5.8	6.4
Burao	6.8	6.3	6.0	5.8	7.6	10.9	12.1	11.3	7.4	6.0	6.0	6.3	7.7
El Bur	9.7	8.3	6.4	6.7	7.7	10.4	11.0	11.0	9.9	4.9	5.5	7.8	8.2
Erigavo	17.8	8.4	7.0	5.4	6.4	9.5	14.8	12.0	8.3	9.5	10.9	10.4	9.3
Galcayo	4.1	4.2	4.0	3.0	4.2	6.5	7.0	6.6	5.3	2.8	2.9	3.4	4.5
Genale	2.6	3.1	2.0	1.3	2.0	2.6	2.8	2.9	2.9	2.1	1.2	2.1	2.3
Hargeisa	10.4	9.8	9.7	9.8	9.9	14.7	16.6	16.2	11.3	9.2	10.4	10.8	11.6
Kismayo	9.8	8.9	8.2	7.3	8.2	8.6	9.2	9.3	8.7	8.0	7.3	8.7	8.5
Mogadisho	6.8	6.5	5.6	4.2	5.3	6.4	6.7	6.6	6.1	4.8	4.3	6.0	5.8
Qardo	7.6	5.7	5.2	4.1	6.1	10.7	10.4	10.5	9.0	4.4	5.1	6.5	7.1

Table 11. MEAN WIND SPEEDS FOR SELECTED STATIONS (M/S)

Over the year, the winds are strongest round Hargeisa, with an average speed in excess of 10 m/s (fig. 26). Rather less strong winds occur over the rest of the northern areas and the eastern half of the Central Regions. There is a gradient in Central and Southern Regions from east to west, with the lightest winds in the country occuring in Bakool, Gedo and the western parts of Hiraan, Galgadud and Mudug.

Winds are strongest everywhere during the southwesterly monsoon (fig. 27). At Hargeisa, and generally in the northwest, there is a marked increase as as the ITF passes northwards, in May/June, and decrease as it passes southwards, in August/September/October. In other areas, the pattern is more sinusoidal, with more gradual changes. The strongest winds again occur during the southwesterlies, with secondary maxima occuring during January, when the northeasterly monsoon is most established.

Weakest winds, generally having only half the strenth of the maximum winds, occur during the intermonsoonal periods of April/May and October/November. While, in the calmer areas, these weakest winds may reduce to 2.0 m/s, in the windy northwest, average monthly windspeed may not fall below 9.0 m/s, about the same as the strongest winds elsewhere.

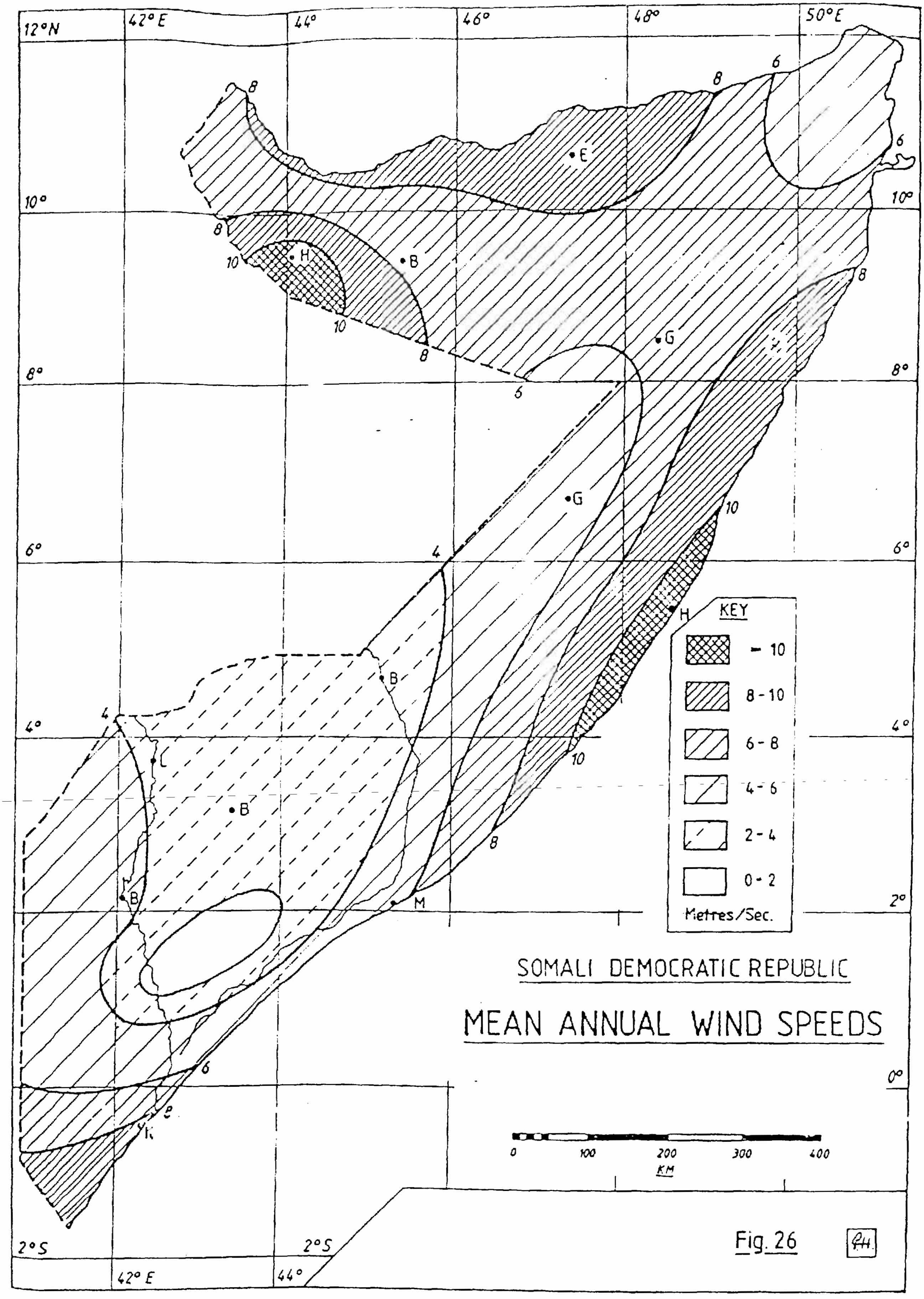
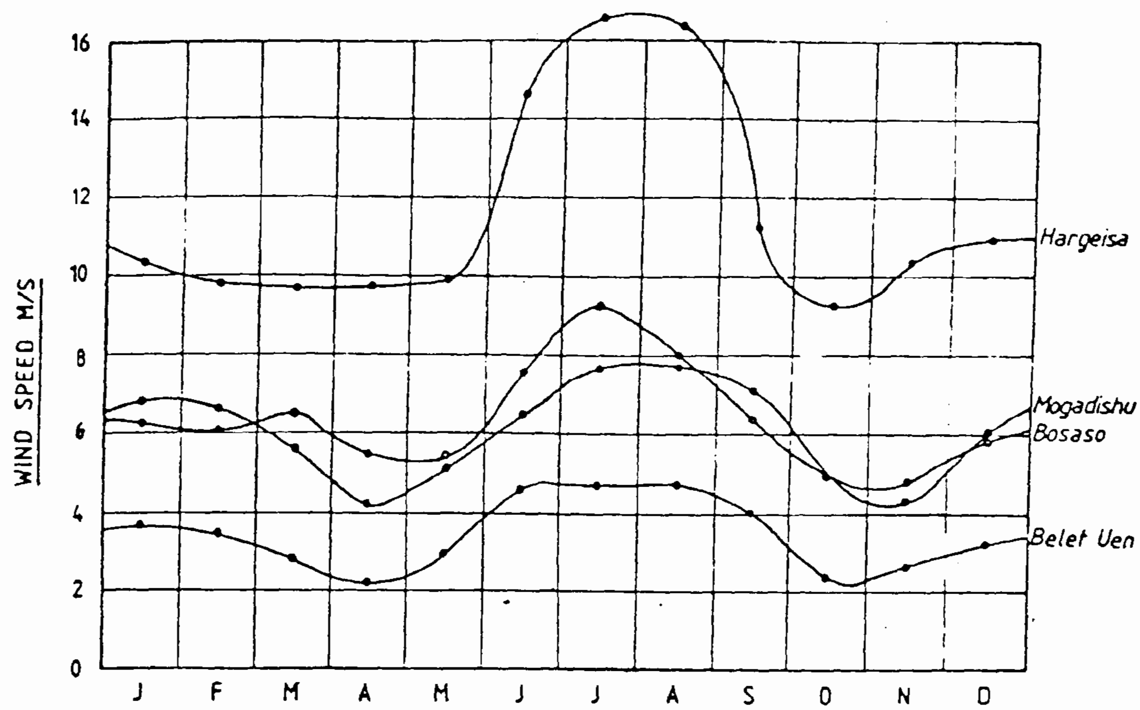

KEY
- 10
8 - 10
6 - 8
4 - 6
2 - 4
0 - 2
Metres/Sec.
SOMALI DEMOCRATIC REPUBLIC
MEAN ANNUAL WIND SPEEDS
0
100
200
300
400
KM
12°N
42°E
44°
46°
48°
50°E
10°
8°
6°
4°
2°
0°
2°S
42°E
44°

Fig. 26



MONTHLY WIND SPEEDS AT FOUR STATIONS

Fig 27 PH

Distributions of Wind Speeds. No data is available which deals with extreme winds, though tables are provided in IDCR61 showing occurences of Force 8 (17.1 m/s) and above, as well as occurences of other wind strengths.

Overall, though calms are relatively rare, except for Berbera, wind strengths are generally light (table 12). The majority of winds everywhere fall within the range of Force 1-3 (0.3-5.4 m/s), with Force 4-5 (5.5-10.7 m/s) accounting for a further 20%. Very few winds attain gale force (Force 8, 17.1 m/s).

	Beaufort Force				
	Calm	1-3	4-5	6-7	>7
Bardera	2.3	76.4	20.2	0.9	0.1
Belet Uen	3.7	83.0	13.1	0.2	0.0
Berbera	23.3	49.1	18.6	6.8	2.7
Bosaso	2.3	65.8	26.9	4.8	0.2
Hargeisa	4.5	68.7	22.7	3.7	0.3
Kismayo	0.5	79.9	18.5	1.1	0.0
Mogadishu	1.0	95.0	-------4.0-------		

Forces: 1-3 = 0.3-5.4 m/s; 4-5 = 5.5-10.7 m/s
6-7 = 10.8-17.1 m/s

Table 12. DISTRIBUTIONS OF WIND STRENGTHS (%)

Almost all gale force winds occur in the vicinity of Berbera, and along the north coast, and these are mostly confined to June, July and August (table 13).

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Bosaso	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	0.0	0.0	0.0	0.0	1.0
Berbera	0.4	0.0	0.0	0.1	0.8	11.0	19.0	17.0	5.0	0.0	0.0	0.0	53.0
Hargeisa	0.0	0.0	0.0	0.0	0.0	0.8	0.5	0.0	0.0	0.0	0.0	0.0	[illegible]

Table 13 NUMBER OF DAYS WITH GALES (Force 8 or more)

Winds of Particular Places.

Wind descriptions are given of Mogadishu in order to illustrate more clearly, the relationships between season, speed and direction.

Mogadishu (fig.28). In January, winds are persistently from the northeast (72% of all occurences), with most of the remainder (20%) from the east, and no calms reported. Average speed is 6.8 m/s, though 61% of all speeds reported are less than 4 m/s, and only a very small percentage greater than 8 m/s (Force 4). By Febuary the northeasterlies are rather less persistent, while the wind rose for March shows a distinct change in the pattern, northeasterlies occount for only 35% of all occurences, with easterlies occounting for 40% and southeasterlies 25%. Wind strengths have decreased, with only a small parcentage exceeding 6 m/s. This wind veer continues through May, when the most persistent winds are southeasterly (40%), though there are significant occurences form northeast, right round to southwest. Little wind exceeds 4 m/s, and calms occount for 5% of all observations.

May to August have very similar regimes, with southwesterlies accounting for 60% to 80% of all occurences, with southerlies accounting for most of the remainder. Calms are almost non-existent, though neither are there many strong winds. 40-50 % of all winds are between 2 and 4m/s, with only a small fraction, about 2-3 % exceeding 6m/s.

During September the wind begins to back, with an increase in southerlies (35%) and decrease in southwesterlies (60%), while October shows a significant proportion of southeasterlies (30%) in addition to the southerlies and southwesterlies. A backing of almost 90^{o} occurs between October and November, with main directions being northeasterly (27%), easterly (32%) and southeasterly (33%). Wind speeds are low, with less than 50 % exceeding 4 m/s.

This significant backing continues until December when the situation returns to the northeasterly pattern evident in January.

The most important features are thus very persistent monsoonal winds, from the southwest during the middle of the year, and the northeast at the turn of the year, with relatively long transitional periods between the monsoons, of about two months each. Though few calms, winds are generally light to moderate, with an almost total lack of gale force winds.

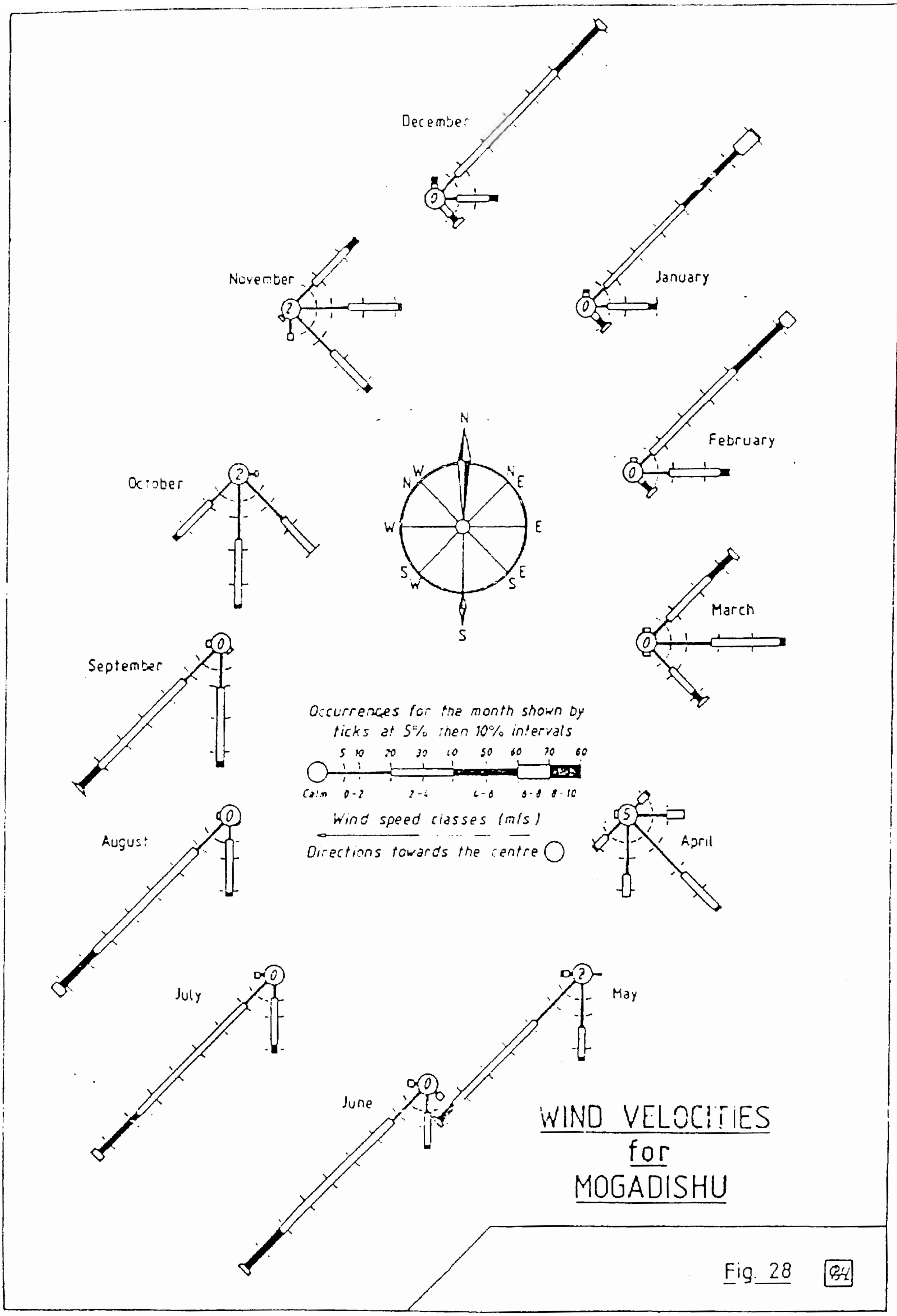

December
January
November
February
October
N
NW
NE
W
E
SW
SE
S
March
September
Occurrences for the month shown by ticks at 5% then 10% intervals
5 10 20 30 40 50 60 70 80
Calm 0-2 2-4 4-6 6-8 8-10
Wind speed classes (m/s)
Directions towards the centre
August
April
July
May
June
WIND VELOCITIES for MOGADISHU

Fig. 28

Particular Winds.

Apart from the general wind patterns described above, there are a number of particular winds, or deviations from the general pattern which are of interest.

Land and Sea Breezes. Land and Sea breeze effects can be noticed all along the coasts, though they are more developed in some areas than others. Because the heating of the land surface during the day, and cooling at night is more pronounced than is the heating of the sea, then air moves inland during the daytime and seaward at night. This is an effect which is vectorially added to the existing wind system. Thus a direct onshore or offshore wind is rather less common than a deflection of the existing winds in one direction or another, with a corresponding increase or decrease in speed. Dobson (1987) reports winds veering through about 40^{o} at Balad (30 km from coast) and at Mahaddei Weyn (80 km from coast) at about 1600 hours during experiments made in January to June.

Unfortunately little data exists to determine variation of wind throughout the 24 hours, available data being mainly provided for daytime observation hours. However, data for Mogadishu shows an increase, for every month of the year from morning (0900L 1200L, 1500L) to afternoon, with a decrease by evening (1800L).

The Kharif. The Kharif is a strong southwesterly wind which blows off the north coast during June, July and August. This is caused by the reinforcement of the southwest monsoon by the night-time land breeze. It thus occurs during the night or early morning blowing from the southwest, weakening and dying out by the middle of the day, when the onshore breeze effect opposes the monsoon. The wind achieves gale force (Force 8, 17.1 m/s) frequently, 34% of occurences in July), and more often than not achieves Force 6 or over (10.8 m/s). Table 14 shows the relevant data for Berbera, where it is most strong. The effect weakens to the east, though Findlater (1971) indicates onshore winds during July between 48^{o} and 52^{o} E.

Time	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0800L a)	0.0	0.0	0.0	0.0	0.6	24.0	34.0	18.0	2.0	0.0	0.0	0.0
b)	0.0	0.0	0.0	0.0	2.0	36.0	52.0	58.0	17.0	2.0	0.0	0.0
1100L b)	3.0	8.0	3.0	3.0	1.0	7.0	8.0	5.0	0.6	0.8	2.0	7.0
2000L b)	8.0	5.0	5.0	2.0	1.0	3.0	8.0	2.0	0.6	1.0	2.0	4.0

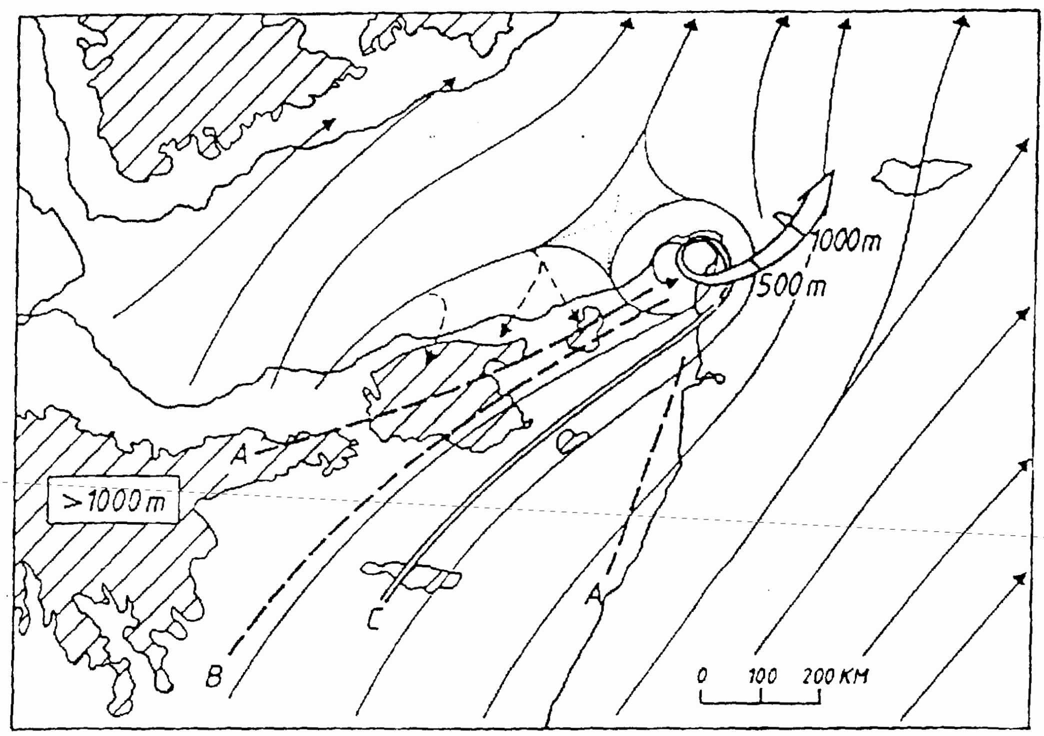
a) - Force 8 or over. b) - force 6-7.

Table 14. THE "KARIF" WIND STRENGTHS at BERBERA (% of Occurrences)

The Winds of Cape Guardafui.

Examination of Fig. 25(c), the wind direction pattern for July, reveals anomolous wind directions in the vicinity of Cape Guardafui (Ras Asir), including Alula. These anomolies include a proportion of southeasterlies at Cape Guardafui itself, predominantly northeasterly flows at Alula, a wind veer i.e. a more westerly component at Scushuban and wind backing in the sea areas to the east of the Cape, including Socotra. These features are most evident in July, the month when the southwesterly monsoon is most developed, but can be detected in June and August.

According to Findlater, this could be due to a large scale eddy round the Cape. The surface wind from the southwest turns eastwards, spiralling on itself, being northeast at Alula, rising over its original track at about 500m above sea level, and eventually returning to southwesterly, having turned a complete circle and rising 1000m (Fig.29). This eddy is



A – Sea breeze front B - Maximum horizontal shear

C – Streamline ——→ Surface streamline - - - -→ Seabreeze

THE CAPE GUARDAFUI EDDY

Fig. 29

PH.

caused by a combination of factors. Firstly, a small range of hills to the south of Alula cause a speed up of the surface wind at the eastern end; secondly the general monsoonal flow is subjected to horizontal shear (changes in wind speed) caused by friction of the air against the higher montains of Kenya, Ethiopia and northern Somalia, shown as the line B in the figure and thirdly, the sea breeze effect on the northern coast, shown as the line A in the figure. The sea breeze on the east coast, though shown in the figure, is not thought to be very significant. Cape Guardafui lies just where the three effects meet, thus causing the eddy.

Fig. 29, redrawn and modified from Findlater shows the general surface flow, in the form of streamlines in the region, the sea breeze fronts (being the lines of convergence), the line of maximum horizontal shear, and the streamline of the eddy.

Although the eddy itself is of a diameter of no more than 200 or 300 km, the effect, in the sense of a deviation of the surface airflow from the southwest monsoon can be observed within a circle of diameter 1000 km, centred on Cape Guardafui.

Sheik. Sheik experiences rather more southerly and southwesterly winds than do the neighboring stations, during those months when these directions are not predominant, i.e. October to April. This shows up most clearly in April (Fig. 25(b)), when, alone in the northwest, the southwesterlies are very persistent. Sheik is on the edge of a north facing escarpment. It is suggested that the differential heating of the lowlands to the north, compared to the uplands to the south, set up an effect similar to a sea breeze, with air being drawn from southwest to northeast to replace air convectively elevated from the lowlands.

Bur Hakaba. Bur Hakaba records show inconsistent directions, compared to nearby stations, particularly in December and January (Fig.25(a)), when the wind is backed by about 90^{o}, i.e North and Northwest, rather than Northeast and East. This is thought to be due only to the local disturbance of the Bur itself.

5. RAINFALL.

Even though high temperatures may be a limiting factor in many aspects of human behaviour, including Agriculture, it is generally considered that Rainfall is the most important Meteorological element affecting life in Somalia. In particular, variations from season to season, and variations within season are what determines the success of agricultural activities.

Origins of the Rainfall.

In Somalia, as mentioned above, the seasons result from the north and south movement of the Intertropical Convergence Zone (ITCZ), and its associated front. In general the Intertropical Front (ITF) is not as well defined as in West Africa and squall lines which are a feature of the wet seasons in the Sahel itself are unknown in Somalia.

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 very 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, on a daily basis, there is very high spatial variability.

Nevertheless, several meso-scale controlling features are in evidence, such as the coastline, the low-level convergence caused by the Kenya-Ethiopia-Northern Somalia Highlands, and the topography of the northern Somali Highlands themselves, and, as a result, distinct patterns are revealed, both on a seasonal and a long term basis.

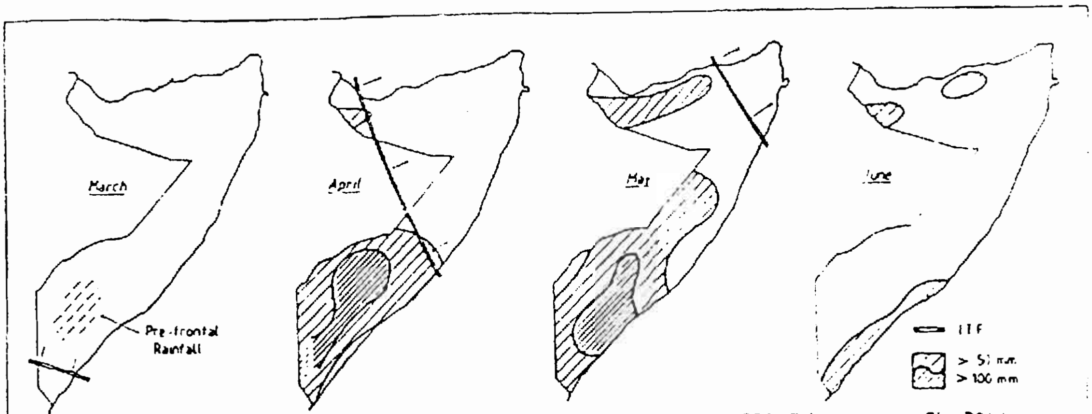
PART 1 AVERAGE CONDITIONS.

Seasonal Patterns.

Rainfall may occur in January or February almost anywhere, but, in general, rainfall first becomes evident in March. Although the ITF can be distinguished entering Somalia from the south in this month, rainfall does not start there, but in the Middle Juba/Bay Regions, and often in the far Northwest. This is a response to the low level windflow being blocked by the Kenya-Ethiopia highlands, thus causing covergence and hence vertical development, in the same way as, later in the year, the Somali jet is controlled by the surface topography.

This effect continues during April, when the ITF lies astride both the Central Regions and the northwest, so that the areas of greatest rainfall are the Bay Region and the northwest. The coastal areas of southern Somalia are relatively less wet, with Kismayo, for example, receiving very little rainfall, even as late as the end of April.

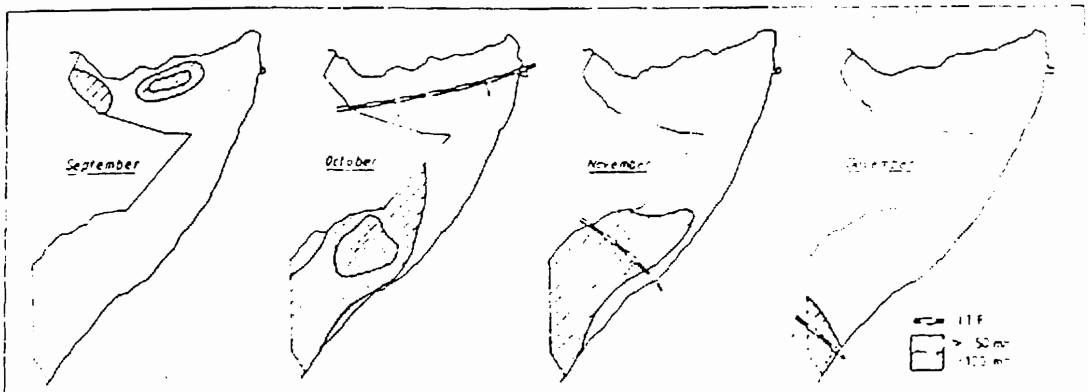
During May, the ITF is clearing off towards the northeast, so that rainfall may occur anywhere behind the Front, including the coastal areas of the south, as showers form in a random manner anywhere within the moist southerly or southwesterly airstreams, though local topographic features, such as the coastline, which encourages the seabreeze and its associated front, and the mountains of the north and northwest, are preferred areas for the formation of cumulo-nimbus rain clouds (Fig 30(a)).



MONTHLY RAINFALL IN RELATION TO THE INTERTROPICAL FRONT (1) Fig 30(a)

These local effects become more important in June and July when significant rain is confined to these areas, the ITF having moved off the country altogether. For the southern coastal areas, June is the best for rainfall, while inland areas of the south experience a rather abrupt end to the Gu rainfall season.

The first intimation of the return of the ITCZ, and the southward movement of the ITF is the intensification of the rainfall in the uplands of the north, during August and September, caused by convergence ahead of the Front. Hargeisa experiences its heaviest rainfall in August, and Erigavo in September (Fig 30(b)).



MONTHLY RAINFALL IN RELATION TO THE INTERTROPICAL FRONT (2) Fig 30(b)

However during October, the ITF crosses the northern areas of Somalia, bringing the dry air mass orginating from the anticyclone resting over Arabia, but covergence ahead of this Front produces the start of the second wet season in the Central and southern Areas. Some of this rain, at least is attributable to the remnants of the Somali Jet lying near north Madagascar (Findlater 1977).

November sees a continuation of this same pattern, with the ITF moving through the Central and Southern Regions, with considerable rain in most of the inland areas of the south, but by December, dry season conditions prevail almost everywhere, though middle Juba and Bay Regions experience, not only the first rains of the year, but also the last.

It is interesting to note that, since rainfall occurs ahead of, during the passage of and behind the ITF, that is, within the convergence zone, rain occurs in association with wind directions, not only of south and southwest, but also in association with the transitional directions, south east and east, and even with the dry season northeasterlies (Table 15). Wind direction, on its own, cannot be taken as an indicator of rainfall conditions.

Station	N	NE	E	SE	S	SW	W	NW	CALM
Alessandra	0.0	6.0	7.0	21.0	18.0	15.0	2.0	0.0	30.0
Baidoa	1.0	6.0	15.0	21.0	19.0	22.0	3.0	2.0	12.0
Galcaio	0.0	7.0	7.0	12.0	13.0	27.0	11.0	3.0	19.0

Table 15. PERCENTAGE OF WIND DIRECTIONS FOR RAINFALL OCCURENCES.

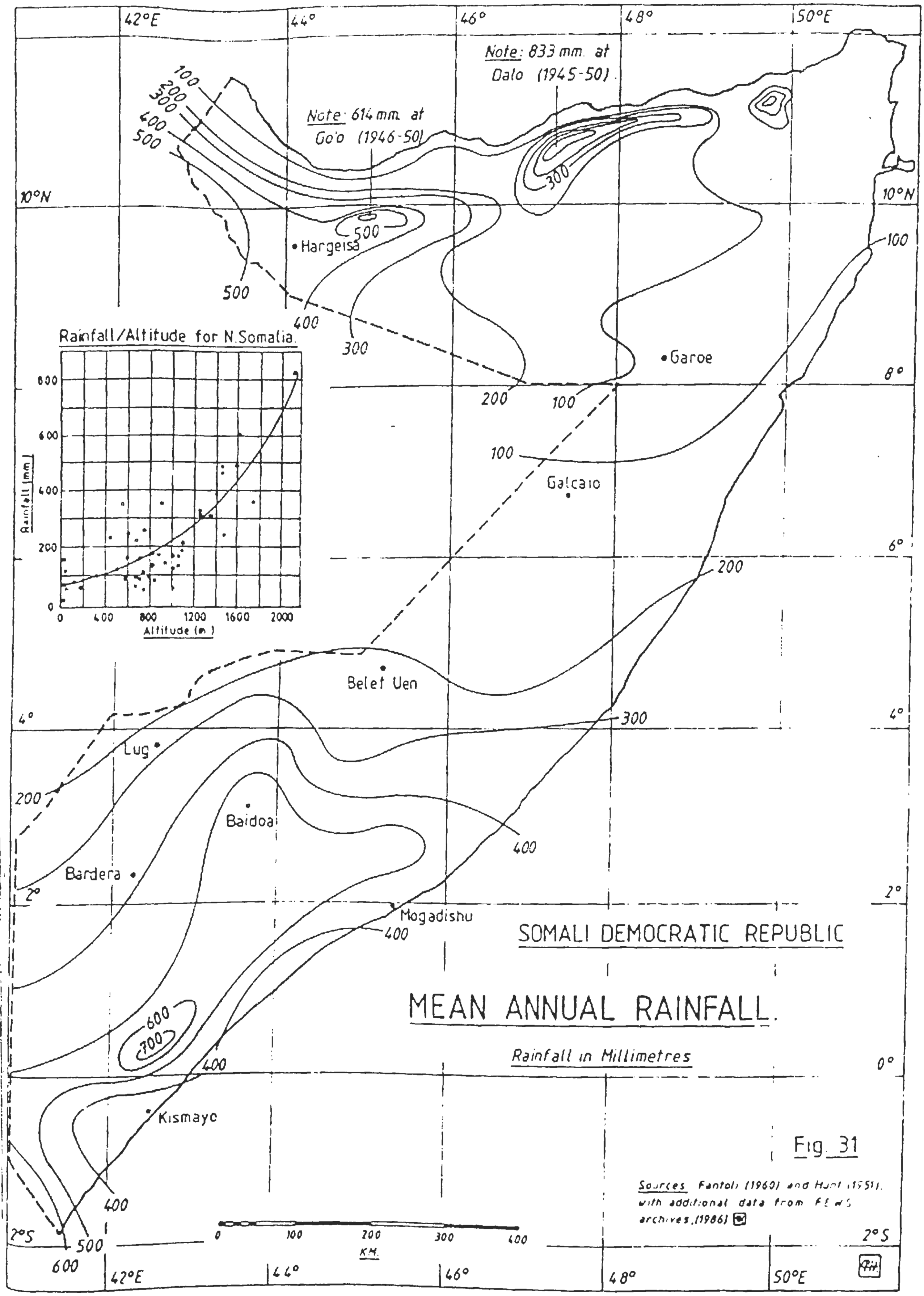
Annual and Seasonal Rainfall Patterns. (See Textnote 5.)

The Mean Annual Rainfall is shown in Fig 31, and reflects the processes described above. High rainfall areas appear round Jilib in the south where over 700 mm may be expected, and, in the north, an area of just over 600 mm east of Hargeisa, and a small area of the escarpment where over 800 mm was recorded by Hunt (1952). Areas with over 500 mm also include Bay Region, part of Middle Shabelle and parts of Lower Juba in the south, and a small slice adjacent to the Ethiopian border in the Northwest.

Elsewhere, rainfall decreases away fron these areas, reaching levels of less than 100 mm in the northeast. The southern coastal strip is less wet than just a few kilometres inland.

In order to fill in the details of rainfall in the varied terrain of the north, the dataset of Hunt has been used to produce a relationship between Rainfall and Altitude, shown, inset in Fig. 31. Rainfall clearly increases with altitude at a rate varying from about 7 mm/100 mm at lower levels, to about 40 mm/100 m at higher levels, with the highest station, Dalo, being in rather special situation on the edge of the escarpment, having a value greater than its altitude would suggest.

Thus, although there is a ridge of high rainfall lying parallel to the north coast, this is not continuous, being dependent on the altitude. The area of rainfall at the eastern end of the ridge has not been measured, but is logical according to the altitude, as well as being evident from the vegetation pattern there.


SOMALI DEMOCRATIC REPUBLIC
MEAN ANNUAL RAINFALL.
Rainfall in Millimetres
Note: 833 mm. at Dalo (1945-50).
Note: 614 mm. at Go'o (1946-50)
Rainfall/Altitude for N.Somalia.
Rainfall (mm)
Altitude (m.)
Hargeisa
Garoe
Galcaio
Belet Uen
Lug
Baidoa
Bardera
Mogadishu
Kismayo
42°E
44°
46°
48°
50°E
10°N
8°
6°
4°
2°
0°
2°S
100
200
300
400
500
600
700
KM.
Sources: Fantoli (1960) and Hunt (1951), with additional data from FEWS archives (1986)
Fig. 31

Gu season Rainfall The "Gu" season has been taken as January to August, though this is not correct usage of the term which should apply only to the months April to July. However, as the rainfall season may start in March, and carry on till August, then this term will be used.

The heaviest rain occurs in a small area parallel to, but inland of, the southern coast, by about 100 km. Within this belt, the most rain occurs at its southwestern end, near Jilib and the Sugar Plantation at Marerey. The belt extends as far north as Mogadishu, which receives just over 300 mm, but peters out further inland. There is another area, shaped as a ellipse, of 300 mm, more or less centred on Baidoa, but stretching southwestwards towards Dinsor, which is not quite obvious on the map. This is the result of the topographic control of the low level air flow, which produces the early rains. Otherwise, the rainfall decreases to the north, reaching very low levels, less than 50 mm in the northeast (Fig 32).

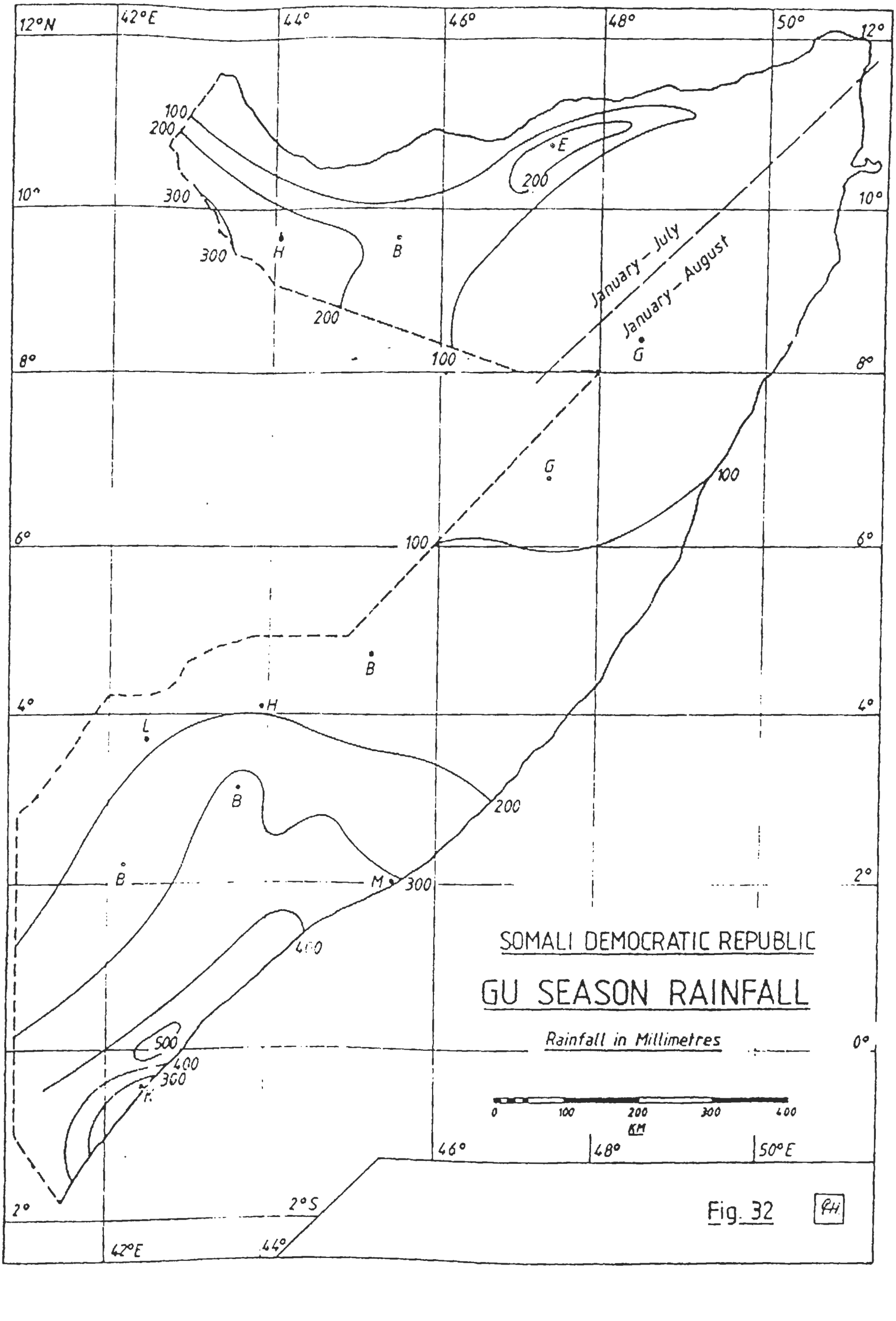
The Gu season in the northwest is taken from January to July, the latter being the month between the two monsoons when the rainfall is least. It should be borne in mind, however, that the season in the north is artificially divided, as in reality, there occurs only one season, which is bimodal. Two main areas of rainfall appear. The smaller area is a pocket centred on Erigavo, and results, mainly, from the topography of the area, the second, and larger area covers the very northwestern part of the country, less the coastal strip, which is in general very dry. Again, the area coincides with the uplands, and there is a sharp gradient near the escarpment.

Der Season Rainfall. The spatial distribution of rainfall during the Der season (here taken as August to December in the north, and September to December in the south, according to the reasoning above) is similar to that of the Gu, although in general, the actual amounts are reduced more because of the shorter length of season than because of less intense rainfall. In the northwest, no 200 mm isohyet appears, though this amount is almost reached in the far west and at Erigavo. The wettest month of the year in the north occurs during the Der, being August at Hargeisa and September at Erigavo (Fig. 33).

The pattern is similar in Central Regions, though with reduced amounts. Galcaio receives only 67 mm in the Der season, this being about 43% of the annual total. The actual amounts are, of course well below that required for rainfed cultivated agriculture.

In the south, the pattern is similar for the two seasons. Baidoa is still favoured with more rainfall than nearby districts, while the belt, inland and parallel to the coast, still exists, though broken and not with the dramatic difference evident in the Gu season. The area round Jilib, extending to the southwest, is still a favoured area.

Comparison of the two seasons shows that, everywhere, the Gu season provides more rain than the Der. The percentage of annual rainfall occuring in the Gu varies from 54 % in Borama, and 55% in Jowhar, to 72% in Genale and 74% in Mogadishu, though most stations report a figure lying between 55% and 68%, thus for the Der, between 32% and 45%.


SOMALI DEMOCRATIC REPUBLIC
GU SEASON RAINFALL
Rainfall in Millimetres
January – July
January – August
0
100
200
300
400
KM
12°N
42°E
44°
46°
48°
50°
12°
10°
8°
6°
4°
2°
0°
2°S
50°E
42°E
100
200
300
400
500
H
B
E
G
L
M
Fig. 32

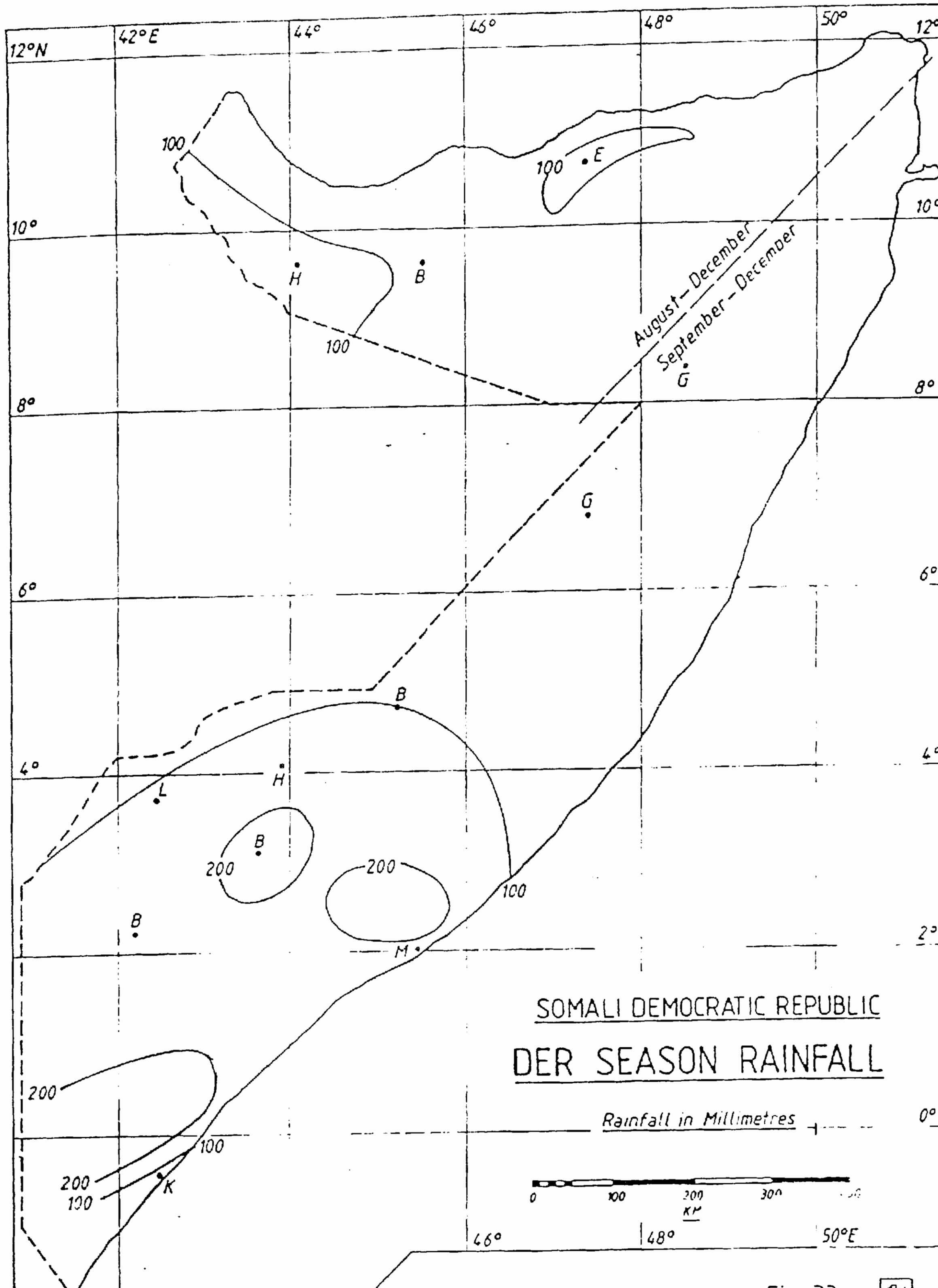

SOMALI DEMOCRATIC REPUBLIC
DER SEASON RAINFALL
Rainfall in Millimetres
August – December
September – December
12°N
10°
8°
6°
4°
2°
0°
2°S
42°E
44°
46°
48°
50°E
100
200
E
H
B
G
L
M
K
0
100
200
300
KM

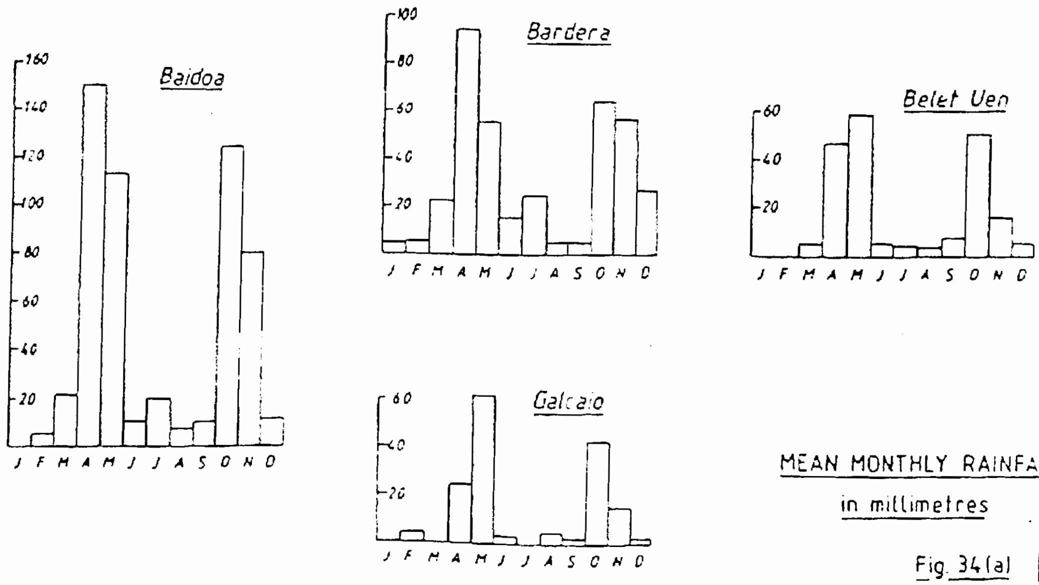
Fig. 33

Seasonal Rainfall at Various Stations.

It is evident from the above that, although the whole country is under the influence of the same macro-scale meteorological conditions, the effects vary from place to place. Thus, although two rainfall seasons are generally evident, in the south there is a marked dry season between them, while in the north, this is not so. Also, the second season in the coastal areas is small compared to the first. Finally the total amounts vary over the country. All this is illustrated in fig 34(a) to fig 34(d) which show monthly rainfall for a number of stations.

Baidoa, Bardera, Belet Uen and Galcayo. The western part of the southern and Central Regions experience a similar rainfall regime, though with different amounts. Apart from pre-seasonal rain, Bardera first receives significant rain, over 20 mm, in March, with Baidoa and Belet Uen receiving less, and Galcaio none.

These early rains continue into April, which is the wettest month for Bardera and Baidoa. By May, rainfall decreases in Bardera and Baidoa, but increases in the two more northerly stations, for which May is the wettest month. Although small amounts of rain do occur, especially in the two southern stations, June effectively signals the end of the Gu season in this part of the country.



MEAN MONTHLY RAINFALL
in millimetres

Fig. 34(a)

The Der season begins very suddenly in October, which is the wettest month of the Der season at all four stations, but by November, the season is already passing by Galcayo and Belet Uen, although they do receive some rainfall (<20 mm). However, November is still a reasonable month in Baidoa, and Bardera. Insignificant amounts occur in December in the three more northerly stations though Bardera does receive more than 20 mm, making December the fifth wettest month at Bardera.

Kismayo and Mogadishu. The Gu season starts later at these two southern coastal stations than further inland. March is generally a dry month, though with rainfall increasing to the north (see Obbia, below). April really sees the start of the season, though it is later at the most southern coastal strip than further north. May and June are both good months, with June being the wettest (compared to April or May further inland). But contrary to the pattern at inland stations, there is no sudden end to the Gu season. Each of the following three months do provide rain, though of decreasing amounts, so that the Der season, which is hardly distenguishable in the far south, is, everywhere on this coastal strip, represented only by a small monthly increase. This increase is for one month only at Kismayo, but rather longer at Mogadishu, while December is almost dry at both stations.

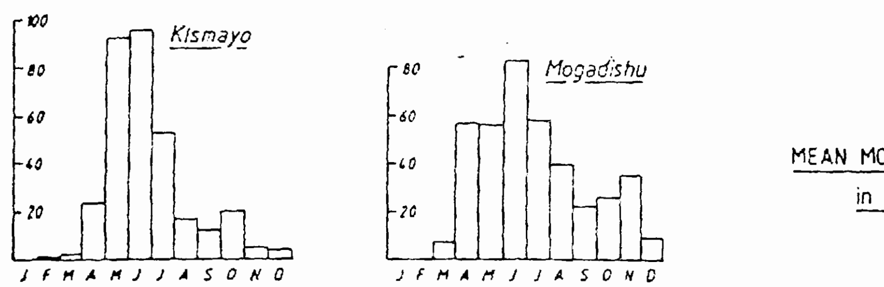


Fig. 34(b)

Obbia, Qardo and Bosaso. One must look carefully to see any rainfall at Bosaso, but, apart from the amounts, the seasonal pattern is similar to the other two eastern stations. The Gu season starts rather gradually, building up from March to May, which is the wettest of the Gu season months. Thereafter occurs a very marked dry season, particularly at Obbia where June, July and August are totally dry, and September experiences only minimal rain. Bosaso is similar, but the inland station of Qardo does experience some dry season rainfall.

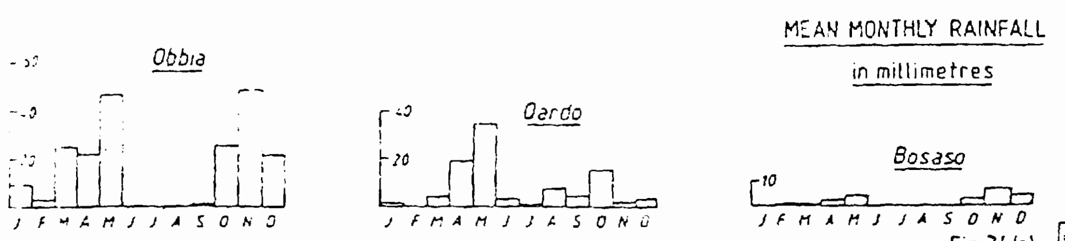


Fig. 34(c)

The Der season returns in October, with November being the wettest month in Obbia, and, for what it is worth, in Bosaso. Also of interest is that the season does carry over into the new year at Obbia, where 10 mm is experienced in January, and at Qardo, where a minimal amount falls. February is dry at both stations.

Erigavo and Hargeisa. In the very north and northwest, rainfall occurs, on average, in 11 or 12 months of the year. The Gu season starts at the same time as at Bardera, that is, as early as anywhere in the country (though in particular years, the rains may start first in either the south or the north). The season builds to a peak in April (Hargeisa) or May (Erigavo). June is still a good month, while July is only slightly less so in the northwest, though rather dry at Erigavo. If July can be considered as the inter-monsoon dry period, then it is very short, but it is better to consider the regime as one bi-modal season.

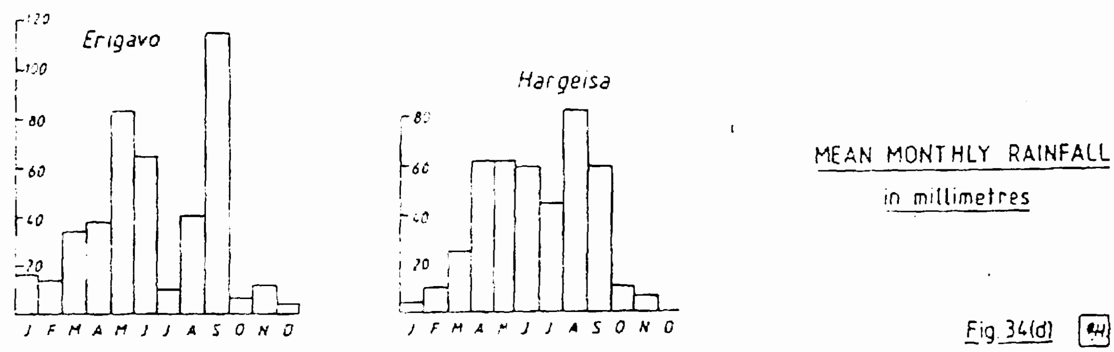


Fig.34(d)

The latter half of the year again sees good rains, with August being the wettest month of the year at Hargeisa, and September the wettest at Erigavo. There is rather an abrupt end in October (compared to the southern and central stations, where October is the start of the Der season), with only small amounts falling in November and December.

Ten-day (Decadal) Rainfall. For all stations, data is available in ten-day intervals in the Technical Reports 1-10. This gives the facility to be rather more accurate in the descriptions of the seasons, which are here given for four representative stations.

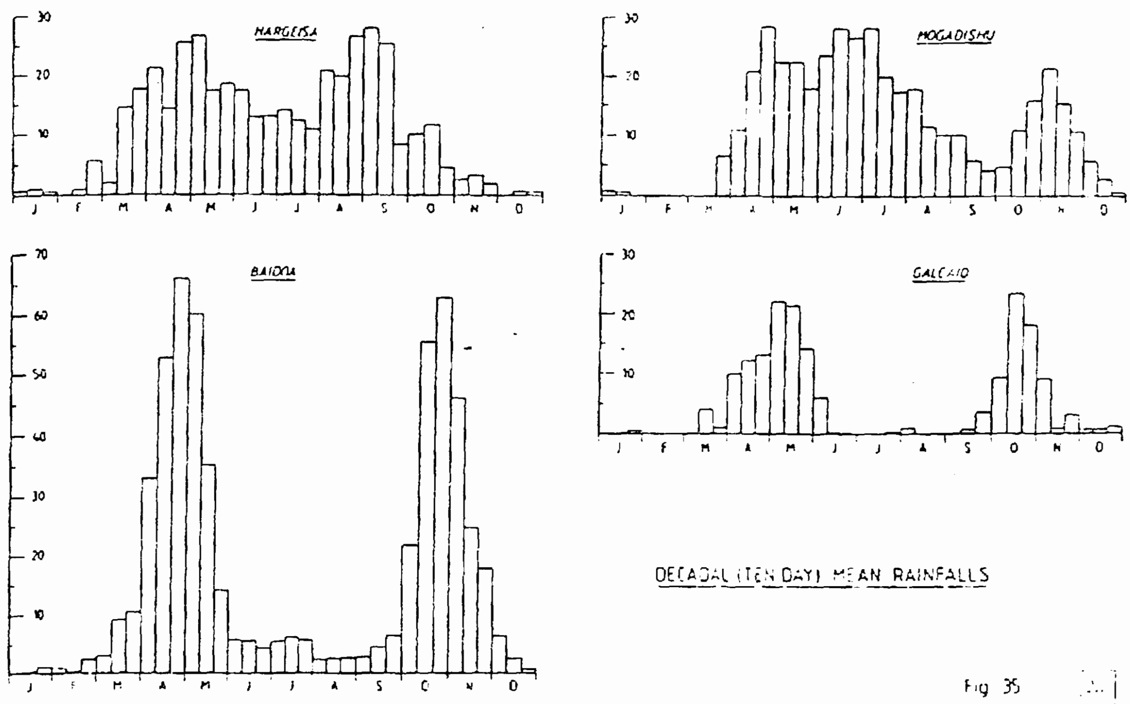
Mogadishu Though the decadal pattern follows that of the monthly pattern a few additional features do emerge. Firstly the season does build up rather more evenly than appears with the monthly data. From a rainfall of zero in the second decade of March (all rainfall in March falls in the third decade), rainfall climbs steadily to a maximum value of almost 30 mm in the last decade of April. The rainfall thereafter is less, for four decades, until another peak which lasts from the middle of June to the first decade in July. Thus on average, there are two wettest periods-the last decade in April and the three decades from the middle of June to the begining of July. Thereafter, the rain falls off rather steadily reaching as minimum at the end of September and first decade of October. The first decade of November is the wettest of the Der season.

Baidoa. At Baidoa, the ten-day histogram does mirror the monthly. The season does start suddenly at the begining of April and reaches it's peak by the end of the same month. Rainfall declines steeply during May, and there is no period of sustained rainfall, though at Baidoa the highest ten-day values do exceed, by about twice, those of most other stations, with 60-70 mm as against 30 mm elsewhere. By the end of May, the Gu season is vitually over, though occasional rain may occur during any decade of the dry season. The Der season is a replica of the Gu, with sharply rising values during October, sharply falling during November, and effectively zero by the end of December.

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi	2.7	1.4	7.6	87.8	92.9	57.6	53.8	22.9	11.9	55.2	106.9	36.7	537.4
Afmadu	4.9	12.3	32.3	101.8	80.9	22.7	29.5	13.0	17.5	83.8	97.2	53.4	549.2
Alessandra	1.8	2.6	6.3	136.1	140.2	73.3	54.2	19.4	21.1	67.1	69.7	45.4	637.2
Baidoa	2.4	4.7	23.4	152.9	110.8	15.2	16.9	7.4	13.0	141.1	85.8	11.4	584.8
Balad	6.9	1.9	7.9	88.8	87.1	50.7	21.1	14.7	14.9	61.0	87.6	33.5	476.1
Bardera	5.4	6.1	23.0	97.8	61.0	12.3	20.0	6.4	7.8	74.4	80.0	24.3	418.7
Belet Uen	0.1	0.4	6.2	61.4	71.5	9.6	1.8	2.0	9.6	66.5	30.5	6.3	266.1
Berbera	5.2	5.2	10.9	10.9	8.5	0.6	1.6	2.3	2.1	2.2	3.5	3.7	56.7
Borama	5.1	12.7	33.0	78.7	76.2	38.1	33.0	53.3	73.7	71.1	25.4	15.2	516.0
Bosaso	0.3	0.0	0.5	5.2	2.8	0.0	0.0	0.0	0.0	2.1	5.2	2.0	18.1
Brava	0.4	0.0	2.8	49.8	83.3	95.9	66.4	22.5	17.3	14.3	20.1	10.0	382.8
Bulo Berti	2.5	2.4	15.9	73.1	66.4	3.9	4.3	2.8	12.1	87.6	62.0	5.7	338.7
Burao	1.3	0.6	8.4	35.1	56.9	14.6	10.9	12.8	25.2	20.7	11.6	1.7	199.8
Bur Hakaba	3.0	0.2	11.7	129.2	84.3	15.1	21.0	3.6	9.7	106.1	56.4	10.0	450.2
El Bur	4.7	1.2	13.8	52.4	49.2	1.5	3.4	1.1	6.6	49.0	20.0	6.7	209.7
Erigavo	12.1	9.6	23.2	29.6	58.3	45.1	6.5	30.3	80.3	4.9	8.6	1.2	309.7
Galcayo	0.2	1.4	3.0	29.2	53.3	4.3	0.4	1.5	3.2	46.5	14.5	1.3	158.7
Gebiley	2.9	3.9	22.5	53.3	49.3	49.5	74.3	89.3	67.7	13.4	9.4	2.2	429.8
Genale	1.0	0.1	5.7	109.9	82.3	78.1	61.3	48.4	18.3	27.0	54.4	21.1	507.6
Hargeisa	5.7	19.9	38.9	61.4	67.5	46.3	43.5	70.9	60.8	25.3	13.7	3.6	457.5
Hoddur	1.9	0.6	10.9	109.2	67.2	1.6	4.7	0.8	15.5	97.3	46.2	4.5	360.3
Jamaame	1.5	3.7	7.4	70.0	101.5	83.9	62.5	24.4	36.5	27.6	38.5	19.6	382.9
Jowhar	4.8	1.2	21.3	94.0	88.2	25.4	25.8	15.7	10.9	105.9	79.9	21.4	494.5
Jowhar(HTS)	8.1	4.0	23.3	86.5	113.7	30.2	29.3	19.9	6.0	111.6	87.3	21.6	541.4
Kismayo	0.5	0.8	3.1	39.6	103.3	106.0	57.6	24.7	22.5	14.3	16.3	4.8	393.5
Las Anod	1.0	0.8	3.7	14.1	51.8	1.3	0.0	0.0	14.8	29.7	10.1	2.3	171.6
Lugh Ganane	1.5	3.2	26.7	102.0	40.8	0.8	2.6	0.2	1.2	46.3	57.1	15.7	298.2
Mogadishu	0.5	0.9	7.3	60.1	61.5	79.8	66.3	40.8	20.1	30.3	49.4	9.2	426.1
Obbia	10.3	1.8	16.9	29.0	45.2	3.6	0.3	0.1	2.6	28.9	45.7	19.1	203.5
Qardo	0.2	0.9	6.7	24.7	31.6	3.4	0.5	3.1	7.2	18.7	3.8	1.3	102.0
Sheik	5.5	5.8	24.8	82.1	71.9	35.0	30.7	57.5	74.0	68.6	28.1	14.0	499.9
Wanle Uen	5.1	4.3	8.1	165.0	87.5	29.8	33.1	18.1	14.4	95.2	71.2	26.9	558.7
Zeila	11.5	4.3	8.0	17.2	7.1	0.0	2.1	4.2	1.2	7.1	24.2	13.3	99.9

Table 16. MONTHLY & ANNUAL RAINFALL AT VARIOUS STATIONS.

Galcaio. A steady build up, over about six decades, of the Gu season is indicated by the histogram of Galcaio, with a rather sudden end, over no more than two decades. The Der season, such as it is, is begun and finished in four decades, little more than a month. Rainfall exceeds 20 mm in only three decades of the entire rainfall year.



DECADAL (TEN DAY) MEAN RAINFALLS

Fig 35

Hargeisa. Though the Gu season monthly rainfalls at Hargeisa (April to July) are fairly uniform, in fact, the ten-day histogram does reveal a build up, starting in the second decade of March, and reaching its peak at the beginning of May, thereafter falling off only rather steadily, and with no dry decade at all. Although August, as a whole, is wetter than September, the wettest decade of the year is the first in September. There is a rather sharp drop between the second and third decade of the same month, with the effective end of the season occuring at the end of October. Though, over the year, Hargeisa is one of the wetter stations in the country, no decade, on average, exceeds 30 mm.

PART II VARIABILITY.

Rainfall varies from year to year, whether it is the annual, monthly or tenday intervals which are being considered. The annual rainfall for Mogadishu, for example, has varied between a minimum of 56.7 mm in 1915 to 997.2 mm in 1923, with a mean value of 426.1 mm over the seventy years record. It is important that these variations are known and understood, since low variability allows the accurate matching of crops to their water requirements and a happy farmer, while high variability means droughts, and loss of harvest, at one end of the scale, and floods with their attendant dangers at the other. For statistical analysis, the data can be considered either as a sample of unordered data, or as a sequence of data (time series). In this section, the data is considered as an unordered sample.

Sample statistics are used to describe, with a few numbers, the original data. The most used statistics, the mean, maximum and minimum have already been mentioned, but other statistics are of importance including median, quantiles and standard deviation. In addition the distribution of the data, that is, that it falls into some easily describable pattern is also an essential descriptor of the data, as well as being a necessary tool for further analysis.

Annual Rainfall.

Standard Deviation and Coefficient of Variability. The standard deviation is the most common measure of variability. When divided by the mean of the data, then converted to a percentage, this measure is the Coefficient of Variation.

For annual rainfall, the meaning of the standard deviation (s.d.) is that the rainfall value will be, in about two years out of every three within one standard deviation of the mean. For Jowhar, the mean is 496.0 mm and s.d. 170.4, thus rainfall will be within 496.0 ± 170.4 mm two years out of three or between 326 and 666 mm, quite a wide range. For Bosaso, the mean is 16.9 mm and s.d. 19.2 mm, giving equivalent figures of 0 and 36.1 mm, an actually smaller range, but much wider relative to the mean. For these two stations the coefficient of variation is 34% and 115%, thus indicating the higher relative variability for Bosaso.

In general, the coefficient of variability (C.V.) increases as the annual rainfall (R) decreases. Thus drier stations are relatively more variable. This is indicated in fig. 36 for Somalia, in which stations with a longish record are included. This relationship can be described by the equation:

$$C.V. = 0.94 - 0.00136 \times R,$$

shown drawn on the map.

We have used all the data to derive the equation, but it does seem that the stations in the northwest, shown by the solid circles (•) do have lower variability compared to stations elsewhere with the same mean. Compared to other tropical areas with similar rainfall regimes, the range of coefficients of variation found in Somalia is high. Those in the Sahel for example, hover round 20%, and approaches 30% only when rainfall is less than about 250 mm annually (Cocheme & Franquin, 1967).

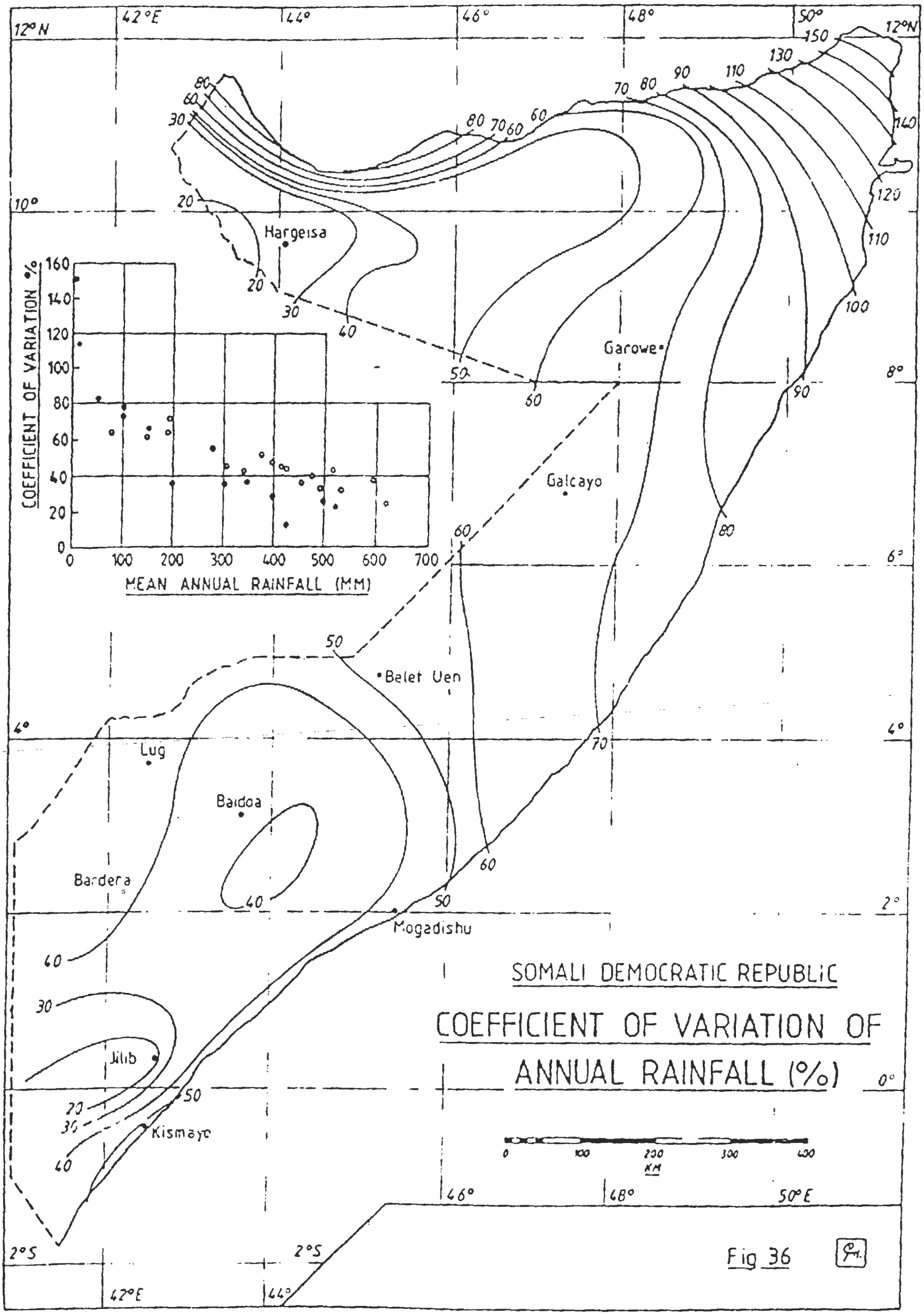

COEFFICIENT OF VARIATION %
MEAN ANNUAL RAINFALL (MM)
Hargeisa
Garowe
Galcayo
Belet Uen
Lug
Baidoa
Bardera
Mogadishu
Jilib
Kismayo
SOMALI DEMOCRATIC REPUBLIC
COEFFICIENT OF VARIATION OF ANNUAL RAINFALL (%)
KM

Fig 36

The coefficient of variation over the country is shown in fig. 36. The lowest values, thus the most reliable rain, occur in two small areas, round Jilib and along the southwest border of the northwest, i.e. Borama to Tog Wajale. In the case of Jilib, the low C.V. is a result of the high rainfall. In the northwest, however, the rainfall conditions are slightly different, and the C.V. is lower there compared to an area in the south with the same annual rainfall. The highest appear in the dry areas of the north east, where the C.V. is greater than 100%, indicating very unreliable rains. In the crop growing areas of the south, the C.V. is 30-40%, which is rather higher than any farmer likes.

Cumulative Distribution and Percentiles. The variability may also be shown in the form of cumulative distribution (graphically) or as percentiles (tabular), though both of these methods show the same data. Each method shows the percentage of occurences (years of rainfall) which exceed (or do not exceed) the values of rainfall given, or shows the values of rainfall which are exceeded (or not exceeded) by the percentage of occurences.

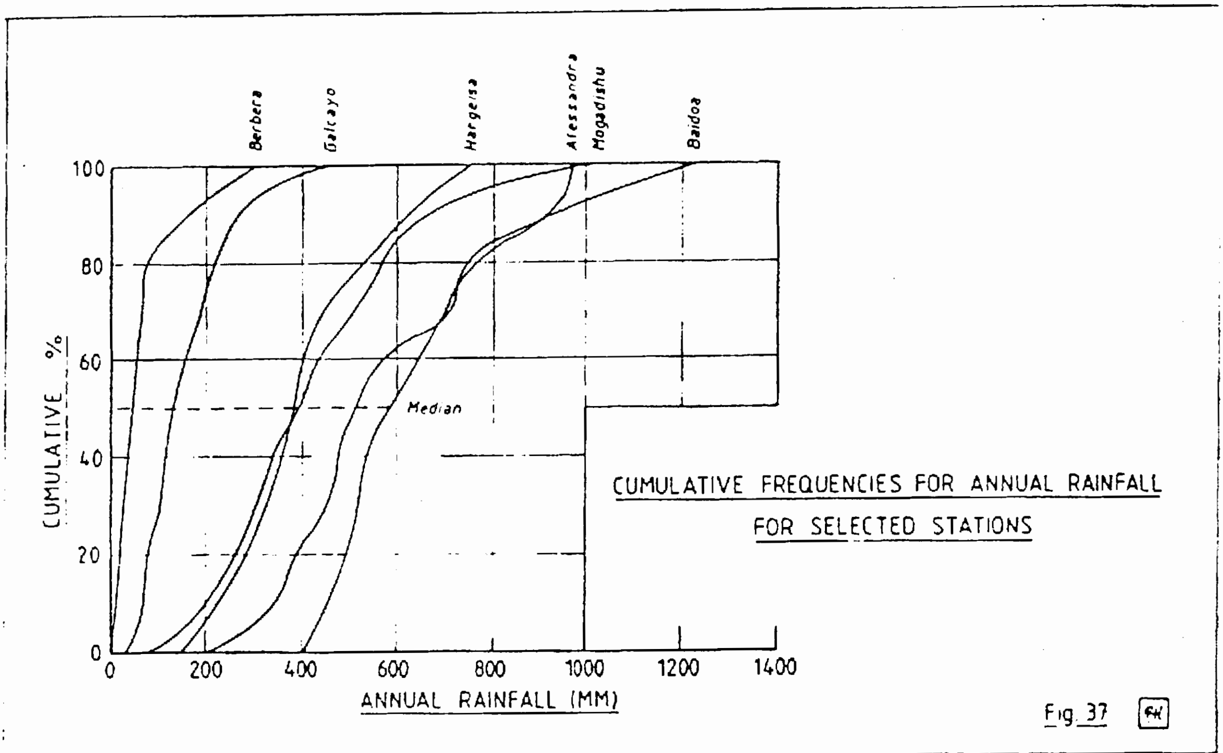


Fig. 37 shows the cumulative distribution for a number of the most important stations. The graph shows the percentages of the total years when rainfall is less than (or equal to) the given rainfall value. All the curves are "S" shaped, with the upper arm stretching out to the right, indicating the few very high values. Thus for Baidoa, the maximum annual value is 1217 mm, and is shown as the end point of the curve. The minimum value is 205, which is shown as the start of the curve. 50% of all occurences are less than 513 mm (this is also the median). The percentage, thus the probability of rainfall being less than, (or more than) a particular value can be read off the chart.

The table of percentiles (table 17) is arranged to give cumulative percentages not exceeded for the given rainfall values. Being tabular, it is more accurate than the graph though revealing less information. The table includes stations having twenty years or more of rainfall.

		% Exceedences										
Station	Minimum	90	80	70	60	50	40	30	20	10	Maximum	C.V. %
Afgoi	191.6	300.2	399.3	430.4	447.2	501.2	550.9	653.8	693.8	808.8	913.0	33
Alessandra	415.1	461.6	497.8	510.6	530.4	593.8	649.6	706.7	749.6	942.1	954.5	27
Baidoa	205.9	263.0	380.3	456.0	475.9	522.0	564.3	718.0	736.3	961.3	1217.5	39
Balad	276.0	286.2	307.7	338.9	363.7	457.8	493.6	519.2	651.2	823.0	899.0	40
Bardera	86.7	232.9	267.4	302.5	338.9	365.9	391.1	511.4	565.6	686.1	877.9	45
Belet Uen	44.5	99.1	155.8	179.7	197.1	263.5	281.4	302.5	362.6	534.7	650.7	57
Berbera	1.8	13.7	21.1	27.3	34.8	47.2	57.8	68.8	73.5	160.3	297.9	82
Brava	129.6	158.9	221.7	323.4	364.8	393.9	416.6	485.0	520.3	611.4	899.0	44
Bulo Berti	96.0	171.3	191.5	218.2	285.5	337.0	382.7	430.2	508.9	519.0	711.0	45
Bur Hakaba	247.0	280.7	337.4	360.9	387.1	408.8	532.0	668.3	751.7	980.8	1048.0	44
El Bur	8.0	39.9	78.7	104.4	153.8	177.6	196.2	248.4	303.0	388.3	541.4	64
Galcayo	33.0	70.0	75.4	104.8	113.9	124.5	165.2	191.9	217.3	259.3	448.0	61
Genale	148.9	300.6	330.4	391.2	410.9	435.9	499.4	537.8	578.4	718.6	1045.4	38
Hargeisa	156.7	224.2	280.8	318.2	364.8	382.1	403.3	443.5	535.9	630.1	749.1	29
Hoddur	163.4	219.4	230.6	254.0	313.0	324.1	336.1	419.0	483.4	548.7	751.5	36
Jowhar	236.2	318.2	352.9	376.6	402.3	439.3	5.4	567.3	612.9	740.5	1089.5	34
Jowhar (HTS	200.0	355.2	426.4	455.6	536.2	566.0	590.4	609.8	718.4	844.6	854.6	36
Kismayo	77.7	181.3	243.2	275.4	328.1	369.5	402.6	453.1	495.4	638.8	970.0	52
Lugh	58.6	141.1	189.3	216.4	229.0	255.5	330.9	392.7	460.5	509.1	552.5	45
Obbia	33.4	62.6	80.5	104.0	117.0	185.7	199.4	228.2	269.2	365.0	596.5	71
Mogadishu	56.7	222.5	269.6	303.9	338.7	397.1	428.1	519.4	566.9	657.6	997.2	45

Table 17. ANNUAL RAINFALL PERCENTAGE EXCEEDENCES

The Normal and Gamma Distributions. The selection of a distribution which best fits the sets of annual rainfall data will be dealt with in detail in a later publication. However, we present here histograms of annual data from a few stations (Fig.38.). Examination of these histograms reveals that they are not symmetrical about the mean value but that the maximum frequency occurs to the left (low value) of the histogram, which itself tails off (extends) to the right (high values). This is more evident at the drier stations. Thus, the distribution cannot be taken as a Normal one, which is a common phenomenon in semi-arid and arid areas (Gibbs, 1987).

The distribution which best fits rainfall values is the Gamma distribution. According to its parameters, it may take the form of a skewed 'bell' shape, or a reversed J shape. It corresponds to reality in that it is zero-bounded (i.e. no negative values), and it tails to the right. Although useful for annual values, it becomes more and more applicable as the interval of measurement is reduced, and is usually an excellent descriptor of daily rainfall distributions, (see appendix 4 for more information on the Gamma Distribution).

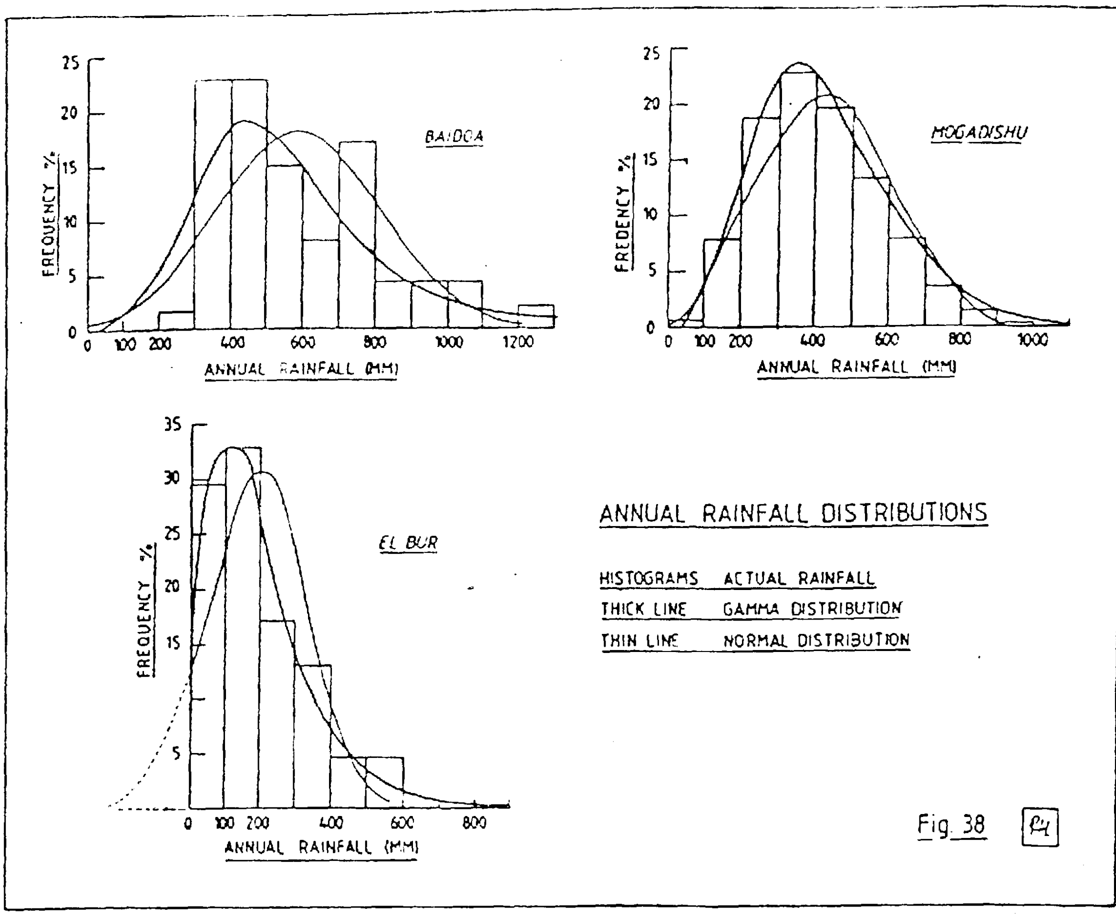


Fig. 38

However, even for annual values, the Gamma distribution is a better fit than the Normal. For the higher rainfall stations, the improvement is not great, though noticeable. For Baidoa, for example, the Gamma distribution (Mean = 583 mm, shape factor k = 6.7) peaks at a lower rainfall value than the normal at about 425 compared to 600 mm, and the peak is higher. The difference is greater for the low rainfall stations. The lower the annual rainfall, the more the distribution departs from the normal, with the peak moving to the left, and the tail extending to the right. For El Bur, the Gamma distribution (mean = 198mm, k = 1.8) fit is very different to the normal, and clearly represents the data better. In particular, the Normal distribution extends to negative values, a practical impossibility, whereas the Gamma provides an excellent fit in the low value region. From Fig. 39 it may be seen that these examples represent a general relation, in which the shape factor is proportional to the annual rainfall, thus the fit provided by the Gammma distribution, though an improvement on the Normal distribution over the whole range of annual values, is particularly suitable for the dry areas.

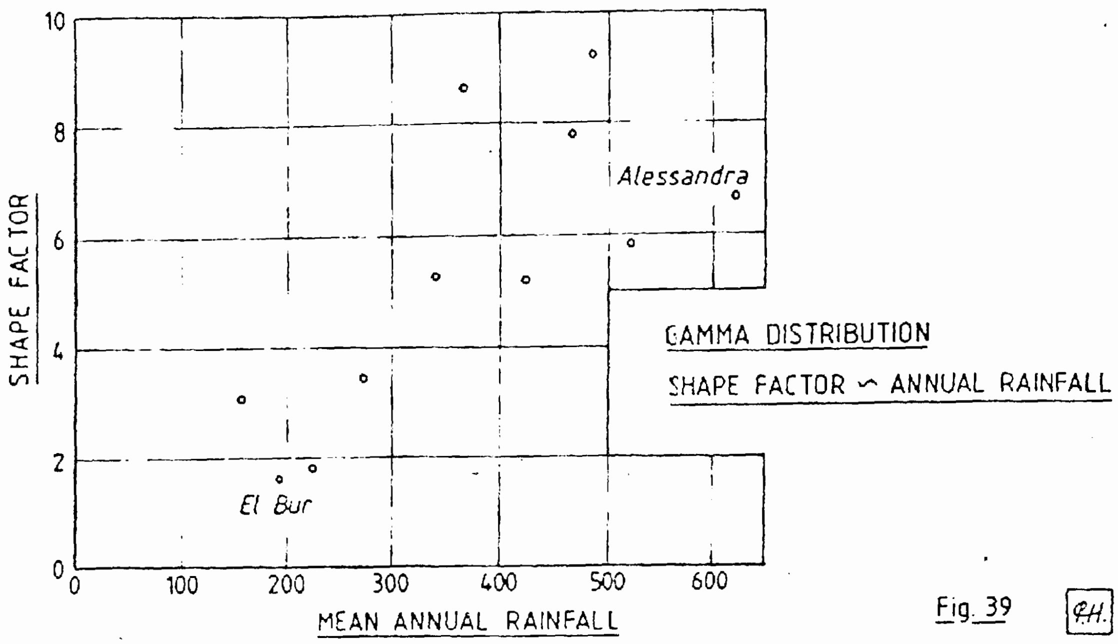


Fig. 39 PH.

Monthly Rainfall.

Standard Deviation and Coefficient of Variability. Table 18 shows the means, standard deviations and coefficients of variation for a selection of stations, including one of the wettest, Alessandra, and one of the driest, Berbera. Many of the calculations are trivial, in a practical sense, because of the very low mean values, including those for January, February, March, September and December for most stations, and for the whole year for Berbera.

Even for the wet months, the coefficients of variation are rather high, with only 1 month in the entire table, April at Alessandra, being less than 50%. Most wet months have C.V.s lying between 50% and 100%, though this is exceeded for the dry stations of Berbera and Galcayo.

Apart from indicating the very high variability of monthly rainfall data in Somalia, the coefficient of variability is of limited value in any meaningful analysis.

Station		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Alessandra													
	a)	1.8	2.6	6.3	136.1	140.2	73.3	54.2	19.4	21.1	67.1	69.7	45.4
	b)	3.4	8.5	15.5	67.2	80.9	63.6	36.6	15.1	36.9	73.6	43.6	36.5
	c)	188.0	327.0	246.0	49.0	58.0	87.0	67.0	78.0	175.0	110.0	63.0	80.0
Baidoa													
	a)	2.4	4.7	23.4	152.9	110.8	15.2	16.9	7.4	13.0	141.1	85.8	11.4
	b)	5.2	11.3	39.9	82.2	77.8	17.4	14.8	10.0	20.4	89.8	105.9	16.0
	c)	217.0	240.0	171.0	54.0	70.0	114.0	88.0	135.0	157.0	64.0	123.0	140.0
Berbera													
	a)	6.1	4.8	10.9	9.6	13.7	0.8	2.0	4.1	1.7	2.2	3.7	3.7
	b)	16.0	12.8	29.0	18.4	35.7	3.7	4.9	10.2	4.2	6.8	10.4	11.7
	c)	262.0	267.0	266.0	192.0	261.0	463.0	245.0	248.0	247.0	309.0	281.0	316.0
Afgoi													
	a)	2.7	1.4	7.6	87.8	92.9	57.6	53.7	22.9	11.9	55.2	106.9	36.6
	b)	6.7	5.4	18.0	61.0	65.6	52.7	40.0	24.8	27.8	57.0	84.4	38.6
	c)	248.0	386.0	237.0	69.0	71.0	91.0	74.0	108.0	234.0	103.0	79.0	105.0
Galcayo													
	a)	0.2	1.4	3.0	29.2	53.3	4.3	0.4	1.5	3.2	46.5	14.5	1.3
	b)	1.0	6.5	14.8	39.1	66.8	12.8	1.4	5.8	7.6	54.9	28.5	4.3
	c)	500.0	464.0	493.0	114.0	125.0	298.0	350.0	387.0	238.0	118.0	196.0	330.0
Hargeisa													
	a)	1.3	6.6	28.4	66.2	62.9	43.2	38.0	64.6	58.0	26.9	8.3	1.2
	b)	5.2	22.9	50.3	59.6	54.3	35.8	26.5	38.4	34.1	35.3	20.0	3.2
	c)	400.0	347.0	177.0	90.0	86.0	83.0	70.0	59.0	59.0	131.0	241.0	267.0
Kismayo													
	a)	0.5	0.8	3.1	39.6	103.3	105.9	57.6	24.7	22.5	14.3	16.3	4.8
	b)	1.9	3.0	13.6	48.6	87.8	78.1	52.9	26.9	44.1	31.4	33.9	12.8
	c)	380.0	375.0	439.0	123.0	85.0	74.0	92.0	109.0	196.0	219.0	208.0	267.0
Mogadishu													
	a)	0.5	0.9	7.3	60.1	61.5	79.8	66.3	40.8	20.1	30.3	49.4	9.2
	b)	1.7	6.7	32.3	56.9	62.4	63.6	49.9	51.8	33.5	43.5	55.8	16.6
	c)	340.0	744.0	442.0	95.0	101.0	80.0	75.0	127.0	167.0	144.0	113.0	180.0

Row a) is the Mean; b) is the Standard Deviation and; c) is the Coefficient of Variation

Table 18. MEANS, STANDARD DEVIATIONS AND COEFFICIENTS OF VARIATION FOR MONTHLY RAINFALL

Cumulative Distribution and Percentiles. On the other hand, frequency distributions, of various kinds are very useful for showing the variability of such highly scattered data as monthly rainfall. However, as the available data is twelve times greater than for annual data, then only a limited selection of stations is discussed here, and a full analysis will be available in a future publication.

Three tables of percentiles are shown, for Alessandra, one of the wettest stations, for Berbera, one of the driest, and for Mogadishu, which has the longest record. In these tables are shown the maximum, minimum and mean of the monthly data, as well as the percentiles. A dot (.) against a percentile indicates zero.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Minimum	.	.	.	.	.	.	.	.	.	.	.	.	1.8
10	.	.	.	.	.	.	.	.	.	.	.	.	13.7
20	.	.	.	.	.	.	.	.	.	.	.	.	21.1
30	.	.	.	.	.	.	.	.	.	.	.	.	27.3
40	.	.	.	.	.	.	.	.	.	.	.	.	34.8
50	.	.	.	.	1.3	.	.	0.5	.	.	.	.	47.2
60	0.5	0.5	0.7	1.7	3.2	.	.	1.2	.	.	.	0.3	57.8
70	1.5	1.9	1.8	8.5	5.2	.	.	1.9	.	.	0.5	1.5	68.8
80	5.1	2.8	5.0	15.7	13.6	.	1.4	5.3	2.5	.	1.7	4.0	73.5
90	21.7	20.4	48.5	35.2	50.9	1.1	11.0	11.9	7.8	8.7	12.1	9.1	160.3
Maximum	65.3	57.2	146.8	88.4	195.6	21.8	19.6	58.4	17.3	30.5	47.5	67.8	297.9
Mean	21.7	4.8	10.9	9.7	13.8	0.8	2.0	4.1	1.8	2.2	3.7	3.7	62.2

Station BERBERA 9531 (37 Years)

Table 19(a). FREQUENCY DISTRIBUTIONS, MONTHLY AND ANNUAL RAINFALL

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Minimum	.	.	.	24.5	41.0	.	.	.	.	.	.	.	415.1
10	.	.	.	46.7	45.0	21.6	5.2	.	.	.	9.5	.	461.6
20	.	.	.	62.9	73.1	25.2	22.8	5.3	.	4.0	27.5	13.1	497.8
30	.	.	.	83.2	87.7	32.3	32.6	7.9	1.1	16.2	42.7	16.5	510.6
40	.	.	.	121.6	100.0	44.2	40.6	11.3	2.8	27.5	52.4	21.5	530.4
50	.	.	.	141.1	137.6	53.8	49.0	14.1	6.1	45.1	69.0	42.4	593.8
60	.	.	0.2	149.6	152.7	69.8	58.5	20.5	10.5	71.3	80.8	56.8	649.6
70	1.2	.	3.6	168.4	159.4	77.1	66.8	32.4	18.2	94.7	98.2	67.4	706.7
80	2.9	.	6.1	189.4	181.6	106.9	92.7	36.9	44.0	108.1	109.9	80.5	749.6
90	8.6	10.6	26.3	233.2	271.7	170.0	108.5	52.4	67.7	175.2	136.1	95.3	942.1
Maximum	11.1	41.5	65.5	286.1	383.5	285.5	136.3	46.0	162.1	299.2	157.4	132.8	954.5
Mean	1.8	2.6	6.3	136.1	140.2	73.3	54.2	19.4	21.1	67.1	69.7	45.4	624.4

Station ALESSANDRA 0223 (25 Years)

Table 19(b). FREQUENCY DISTRIBUTIONS, MONTHLY AND ANNUAL RAINFALL

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Minimum	.	.	.	.	1.0	.	.	.	.	.	.	.	56.7
10	.	.	.	0.5	6.1	13.0	16.4	3.3	0.2	.	.	.	222.5
20	.	.	.	7.7	14.6	23.0	27.3	9.6	2.2	1.2	4.1	.	269.6
30	.	.	.	23.3	22.4	34.7	37.6	13.8	4.3	3.0	7.8	.	303.9
40	.	.	.	35.9	34.8	53.5	44.8	16.2	5.5	5.3	14.9	.	338.7
50	.	.	.	41.6	43.7	72.3	51.5	20.5	10.5	13.7	26.0	0.2	397.1
60	.	.	.	57.4	55.0	82.6	63.8	31.1	13.3	19.8	36.6	2.6	428.1
70	.	.	0.5	87.5	75.0	[illegible]	81.5	47.5	16.9	30.3	[illegible]	[illegible]	519.4
80		.	3.0	105.9	92.5	121.0	98.5	[illegible]	[illegible]	50.9	[illegible]	[illegible]	566.9
90	1.2	.	10.7	125.1	140.4	154.6	128.4	93.1	60.7	90.5	132.9	33.4	657.6
Maximum	8.7	.	257.0	256.8	324.0	348.8	240.0	289.0	239.4	192.0	228.3	76.0	997.2
Mean	0.5	.	7.2	60.1	61.5	79.8	66.3	40.8	20.1	30.3	49.4	9.2	425.8

Station MOGADISHU 2531 (77 Years)

Table 19(c). FREQUENCY DISTRIBUTIONS, MONTHLY AND ANNUAL RAINFALL

For the driest station, Berbera, the median (50% percentile)) is zero for 10 months, and with only small amounts for the remaining two months. This indicates that fifty percent or more of nearly all months are dry, that is, the expectancy is for no rain. In June and October, almost 90% of all months are dry. The months which are dry are not crammed into particular years, thus no year has actually been dry, though 50% of all years experience 47.2 mm. or less.

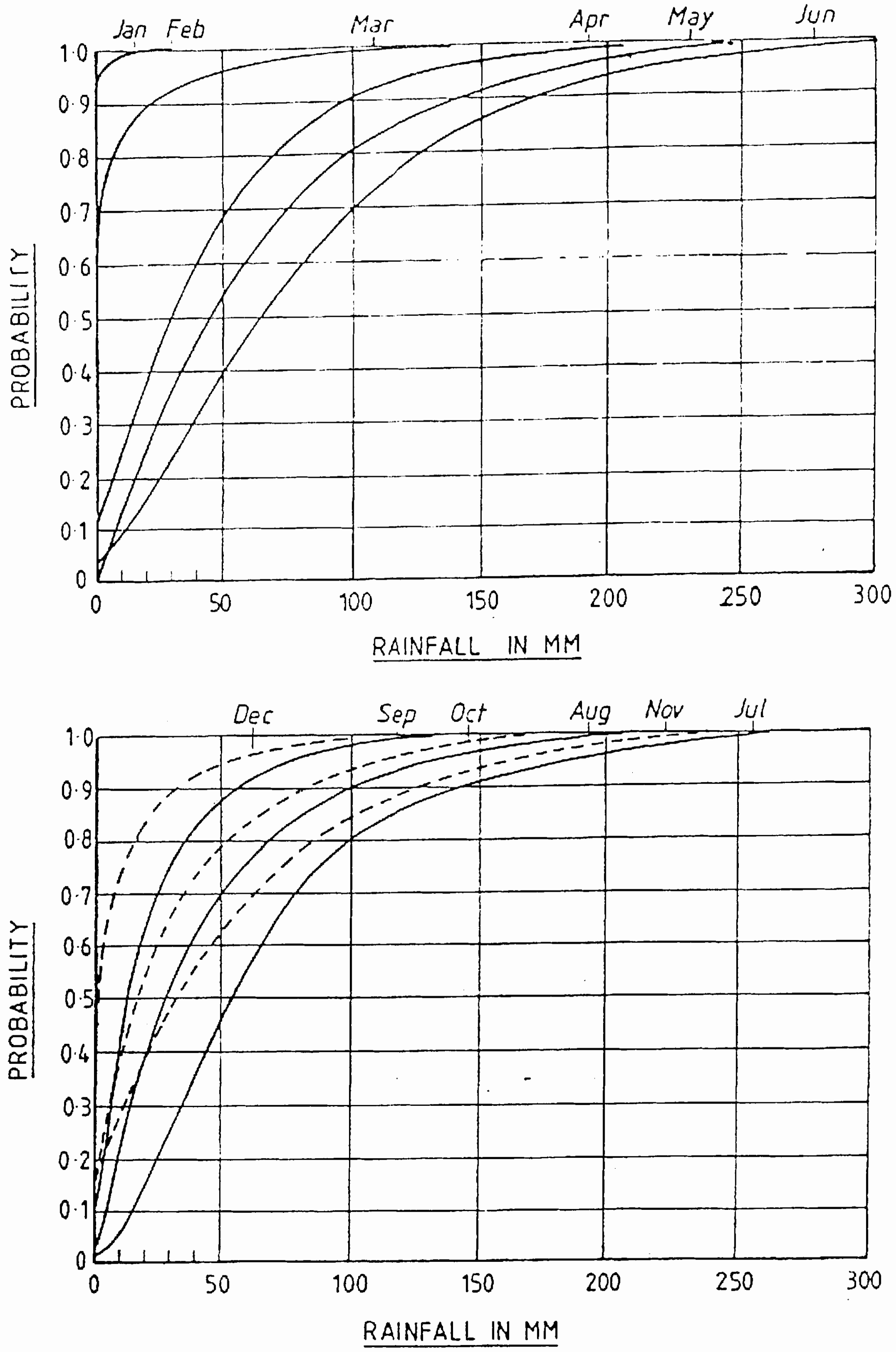
For the wettest station, Alessandra, neither April nor May have ever produced a dry month, and for three other months the occurence of dry months is less than 10%. Only at the beginning of the year are there months with high dry percentages. Median values are quite close to mean values, particularly in the wetter months.

For Mogadishu, which is included because of its long record, only one month, May, has not had a zero value. February has never recorded rainfall. Fig. 40 shows the same information, on two graphs for clarity, and corresponds to figure 37 for annual rainfall. We have shown the vertical axis as "probability" from 0 to 1, but this corresponds to "frequencies %" from 0 to 100 in the previous figure. January is only just visible in the top left hand corner, while February, being all zeros, cannot be represented. Otherwise, as the year progresses to July, so the curves for each month stretch out to the right, thereafter falling back again, with the exception of the Der season months of October and November. From these graphs can be obtained both the expected frequency or probability of any particular rainfall value being exceeded or not, and the rainfall expected for any particular probability.

An alternative method of displaying the information, which indicates clearly the seasonal variation, though with some loss of information is shown in fig. 41 (lower graph). Here the several probabilities, including the median (50% probability) are shown as they vary throughout the year. Both Gu and Der season provide peaks, though the inter-season dry spell is shown only as a reduction of probabilities rather than an actual dry spell.There is less than a 30% frequency of dry months in the Hagai season.

Whichever method is used to display the data, tables or graphs, provides simple methods of indicating the probabilities, and underlines the point that the mean value of monthly rainfall provides only a part description of the rainfall amounts.

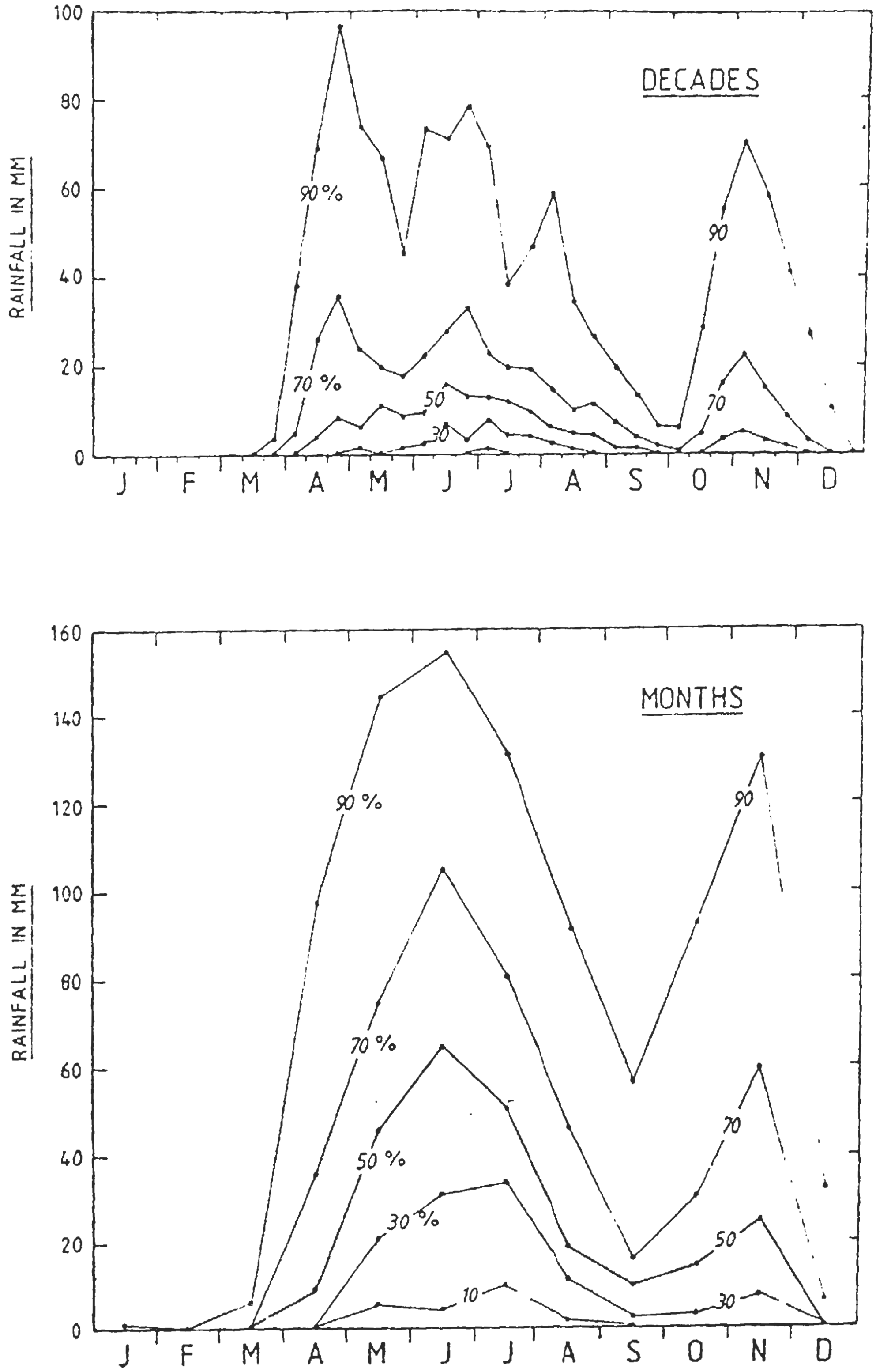
Normal and Gamma Distribution. We have not attempted a full analysis of monthly data using the Normal and Gamma Distributions, as this will appear in a later publication. However, we do present information for Mogadishu station. Clearly, the Normal distribution does not describe the monthly data at all well. Nor can the Gamma Distribution be used directly, since a proportion of the occurrences are zeros. We have therefore adopted the method of Stern and others (1982). In this method, a two part model is formulated. In this, the occurences of zero values are first separated out in a simple binomial distribution. That is, we calculate the proportion of zero values, and the proportion of non-zero values. To the non-zero values



MOGADISHU

PROBABILITIES OF MONTHLY TOTALS BEING LESS THAN THE RAINFALL SPECIFIED.

Fig. 40



MOGADISHU MONTHLY & DECADAL RAINFALL PROBABILITIES

NOTE: The points show, for each month and decade, the value of rainfall which will not be exceeded for the given % probabilities.

Fig. 41 PH

we then fit the Gamma distribution. As we know, the Gamma distribution can be described by two parameters, thus the monthly rainfall distribution can be described by three parameters:

The proportion of dry months.
The mean of the non-zero data, and
The shape factor, k, of the Gamma distribution.

The analysis of the Mogadishu data using this method is shown in table 20. The number of months in each case is 73, except for May (74). Then is shown the number of dry months, ranging from 0 in May to 68 in February. This allows the calculation of the proportional of dry months and of wet months. For the non-zero data, the Gamma distributions have been calculated, and the mean and shape factors given.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
No. of Years	73	73	73	73	74	73	73	73	73	73	73	73	73
Dry Months	59	68	47	7	0	2	1	3	7	11	12	33	0
P (wet)	0.19	0.07	0.36	0.90	1.00	0.97	0.99	0.96	0.90	0.85	0.84	0.55	1.00
P (dry)	0.81	0.93	0.64	0.10	0.00	0.03	0.01	0.04	0.10	0.15	0.16	0.45	0.00
Gamma Distribution													
Mean	2.59	12.44	20.41	46.43	61.70	82.10	67.20	42.50	22.60	35.70	59.10	16.80	425.80
'k'	0.75	0.33	0.30	1.17	1.07	1.58	1.72	1.02	0.86	0.71	1.02	0.61	5.15

Table 20. TWO PART FREQUENCY DISTRIBUTIONS FOR MOGADISHU MONTHLY RAINFALL

The shape factor is substantially greater than one for only two months, June and July, and is only substantially less than one for February and March. The former is a trivial case, since only 5 months are used in the analysis. Thus the exponential distribution, which is a special case of the Gamma when k=1 is a fair descriptor of the data in most cases. In all cases, the shape of the distribution is represented by a reversed j, except for June and July, both of which peak very close to zero. We have not illustrated these, but reference to appendix 4 gives the idea of the shape of these curves.

Tenday (Decadal) Rainfall.

The analysis of tenday rainfall periods (decades) is substantially the same as that for monthly intervals. What is revealed is more detailed information rather than new ideas. Therefore, though analysis of tenday rainfall is important, it is left to a future publication, and only a brief mention of one station, Mogadishu is made here.

Table 21 shows the frequency distributions of the tenday rainfalls, as well as the minima, maxima, mean and standard deviation. In general the median (50% frequency) is considerably less than the mean, indicating a highly skewed distribution, even on the wettest days.

The frequencies also appear in figure 41 above as rainfall probabilities. In this figure, the smooth annual progression of the monthly probabilities conceals considerable intra-monthly variation. The rainfall build up at the beginning and fall off at the end of each season is clearly shown. It is also quite interesting that the 90% probability peaks at the end of April, compared to June for the monthly data, though

Month Decade	Min.	Max.	Mean Normal	S.D.	Percentiles 10	20	30	40	50	60	70	80	90
JAN.													
I	0	8.7	0.3	1.27	0	0	0	0	0	0	0	0	0.8
II	0	6.0	0.2	0.83	0	0	0	0	0	0	0	0	0
III	0	0.9	0	0.13	0	0	0	0	0	0	0	0	0
FEB.													
I	0	0	0	0	0	0	0	0	0	0	0	0	0
II	0	1.6	0	0.19	0	0	0	0	0	0	0	0	0
III	0	57.0	0.9	6.81	0	0	0	0	0	0	0	0	0
MAR.													
I	0	26.2	0.4	3.13	0	0	0	0	0	0	0	0	0
II	0	6.7	0.3	1.15	0	0	0	0	0	0	0	0	0
III	0	257.5	6.4	32.09	0	0	0	0	0	0	0	0.6	4.0
APR.													
I	0	133.5	10.7	23.36	0	0	0	0	0.3	1.4	5.9	12.4	38.7
II	0	148.5	20.1	30.24	0	0	0	0.2	4.9	14.0	26.0	36.8	69.2
III	0	181.4	28.7	41.39	0	0	0	3.1	8.8	17.4	36.0	50.9	97.3
MAY													
I	0	176.0	22.3	34.71	0	0	2.0	3.1	6.8	12.4	24.2	36.5	74.1
II	0	148.0	22.3	33.10	0	0	1.2	5.8	11.7	14.8	20.2	31.9	66.3
III	0	251.9	17.9	33.56	0	0.9	2.1	5.0	9.0	13.4	18.5	25.9	45.8
JUN.													
I	0	146.0	23.4	34.64	0	0	2.9	4.0	9.6	13.6	23.3	43.3	73.5
II	0	198.9	27.8	36.86	0	3.1	7.7	11.7	16.6	21.4	28.8	39.6	71.9
III	0	171.6	26.7	35.07	0	0.8	3.5	8.4	14.0	22.7	32.6	42.3	77.9
JUL.													
I	0	208.0	28.3	39.64	0.6	6.5	9.6	11.4	14.4	18.8	23.3	35.3	70.1
II	0	126.0	19.4	24.15	0	1.1	4.9	10.1	14.2	17.6	20.2	28.1	38.6
III	0	107.1	17.6	21.09	0	1.0	4.4	6.7	10.3	14.0	19.6	28.6	47.9
AUG.													
I	0	149.8	17.9	30.02	0	1.1	3.4	4.9	6.9	9.2	14.6	21.9	58.9
II	0	122.8	11.5	19.27	0	0	1.5	4.1	5.5	7.8	10.9	14.0	34.8
III	0	82.2	[illegible]	16.06	0	0	0.3	1.7	4.6	7.0	11.6	13.9	27.4
SEP.													
I	0	197.4	10.1	26.55	0	0	0	0.5	1.4	4.2	7.6	10.9	19.1
II	0	65.7	5.2	10.48	0	0	0	0.7	1.8	3.0	3.7	6.0	13.8
III	0	75.9	4.1	11.81	0	0	0	0	0.3	1.2	2.2	3.6	6.9
OCT.													
I	0	105.0	4.8	16.08	0	0	0	0	0	0	1.5	3.1	6.9
II	0	123.9	10.9	24.22	0	0	0	0	1.0	2.5	5.0	17.0	29.1
III	0	110.0	15.7	23.43	0	0	0	0.6	4.0	10.0	17.0	23.7	55.8
NOV.													
I	0	161.9	21.6	34.03	0	0	0	0	5.0	10.6	23.1	38.4	70.6
II	0	125.8	15.2	26.87	0	0	0	0.4	2.5	8.2	15.7	21.8	58.6
III	0	87.2	10.7	18.52	0	0	0	0	1.8	5.0	8.4	17.0	42.0
DEC.													
I	0	46.0	5.3	10.62	0	0	0	0	0	0.5	2.7	6.8	27.5
II	0	52.6	2.8	8.86	0	0	0	0	0	0	0	0.3	10.8
III	0	14.5	0.5	2.17	0	0	0	0	0	0	0	0	0.2

Notes: 73 years of data used. Values in mm.

Table 21. DECADAL RAINFALL FREQUENCIES FOR MOGADISHU.

the median is relatively low, indicating the greater frequency of occurence of heavy rainfalls at the end of April.

Daily Rainfall

The analysis of daily rainfall is usually tackled in a rather different way to that of monthly and annual rainfall, since the nature of the data is rather different. The proportions of zeros is very high, and there is generally little interest in average daily rainfall, whereas, when grouped into longer intervals of ten days, months or years, frequency analyses become important and extreme daily rainfalls very interesting.

Frequency Analysis. An important quantity for further analysis is the number, or proportion of rain days. In table 22 are shown the proportions of wet days, month by month and station by station. In all cases the proportion is rather low, and, of course, very low in the dry seasons, though it is rather rare for no rain to have fallen in any month for the period of record. The highest proportion of raindays occurs in July in Mogadishu, with 40% of the days being wet, and a few other station-months experience more than one wet day in three, including Alessandra in May, Baidoa in April, Kismayo in May, and Mogadishu in June and July.

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi	1	1	3	24	26	28	31	15	5	12	26	8	15
Alessandra	1	1	2	31	35	30	31	18	7	13	23	15	17
Baidoa	2	2	8	34	23	12	14	7	5	32	23	5	14
Belet Uen	0	0	2	17	19	3	1	1	3	19	11	3	7
Berbera	4	4	4	3	3	0	1	3	1	1	1	2	2
Dinsor	0	0	6	21	13	13	2	2	3	14	18	3	8
Galcayo	0	0	1	7	12	1	0	0	1	12	5	1	3
Gerale	1	0	2	24	29	33	29	15	5	10	17	5	14
Hargeisa	1	2	7	17	22	22	20	28	31	11	3	1	14
Jowhar	3	0	4	25	23	19	21	14	6	26	23	9	14
Kismayo	1	1	2	31	35	30	31	18	7	13	23	15	17
Mogadishu	1	0	2	16	21	38	40	28	15	12	15	5	1
Obbia	4	0	3	9	10	2	2	1	1	10	8	4	5

Table 22. PROPORTION (%) OF RAINDAYS FOR EACH MONTH -

Distribution of rainfall intensities. The frequency analysis of rainfall on those days when it did rain does provide some interesting information. The distributions vary from station to station, but there does not appear to be any geographical variation, nor does the shape of the distribution appear to depend on the mean annual rainfall. Mogadishu has more light rainfalls (<10mm) than any station, but Berbera shows a very similar distribution. Although Dinsor has the lowest proportion of light rainfalls, its neighbour Baidoa has considerably more. Dinsor is quite similar to Obbia which experiences a different rainfall regime and is geographically differently located. The implication is that what makes a difference to the annual rainfalls over the country is not the type or intensity of the rainfalls, but the number of raindays.

Station	>0-9.9	10-19.9	20-29.9	30-39.9	40-49.9	50-59.9	60-69.9	70-79.9	80-89.9	90-99.9	100+
Afgoi	71	16	5	3	2	1	1	0	0	0	0
Alessandra	71	15	7	3	2	1	1	0	0	0	0
Baidoa	67	16	6	5	2	1	1	1	0	0	1
Belet Uen	64	18	8	4	2	1	1	1	0	0	1
Berbera	79	10	5	4	1	1	0	0	0	0	1
Dinsor	54	18	12	6	5	2	1	0	3	0	0
Galcayo	60	20	7	6	3	2	1	0	0	0	1
Genale	72	16	5	3	2	1	0	1	0	0	0
Hargeisa	74	15	6	3	1	1	0	0	0	0	0
Jowhar	70	14	7	4	2	2	1	0	0	0	0
Kismayo	71	15	7	3	2	1	1	0	0	0	0
Mogadishu	81	10	4	2	1	1	1	0	0	0	0
Obbia	61	19	6	6	3	2	0	2	0	1	1

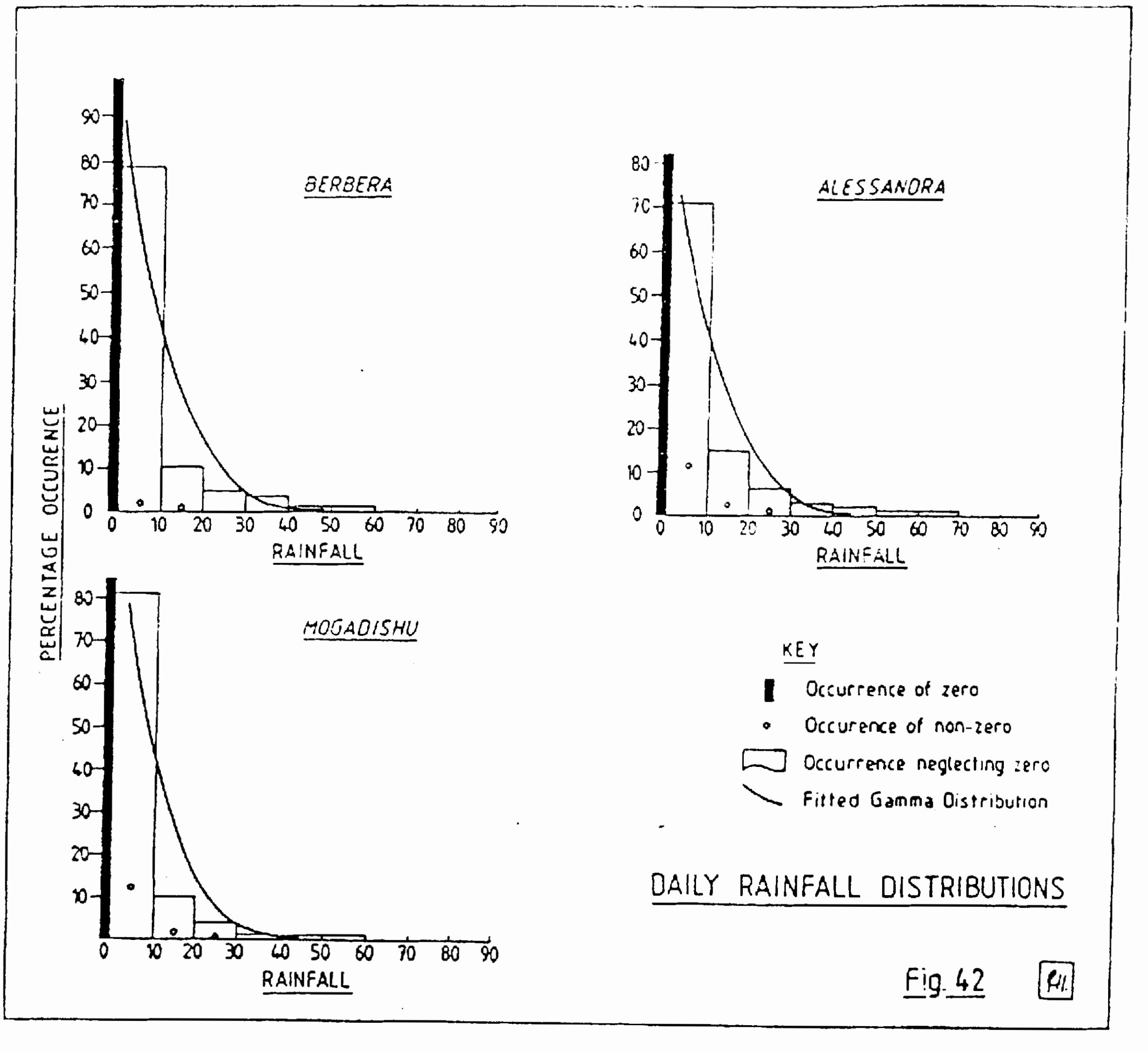
Table 23. DISTRIBUTION (%) OF DAILY INTENSITIES FOR THOSE DAYS WHEN RAIN OCCURRED

The same type of data, but month by month for three stations is set out in table 24. Again one of the wettest, one of the driest, and the longest records are chosen. There is some tendency for the rainfalls, when they occur, to be heavier in the wet seasons, at least at Alessandra. But at Mogadishu, June and July are the wettest months, but April, May, October and November have the higher proportion of rainfalls greater than 10.0 mm; therefore there is no general rule.

Rainfall	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNU
Alessandra													
>0-9.9	100	71	71	55	62	78	87	90	80	54	67	69	[illegible]
10-19.9	0	14	21	18	16	12	8	8	2	24	20	21	[illegible]
20-29.9	0	0	7	11	10	4	2	2	10	13	7	6	
30-39.9	0	14	0	7	5	2	2	0	2	4	2	1	
40-49.9	0	0	0	3	3	1	0	0	4	1	3	2	
50-59.9	0	0	0	2	1	1	0	0	0	1	1	1	
60-69.9	0	0	0	3	1	0	0	0	0	1	0	0	
70-79.9	0	0	0	1	1	0	0	0	0	0	0	0	
80-89.9	0	0	0	0	0	0	0	0	0	1	0	0	
90-99.9	0	0	0	0	0	0	0	0	2	0	0	0	
100 +	0	0	0	0	1	0	0	0	0	0	0	0	
Berbera													
>0-9.9	86	90	79	63	67	75	77	83	80	63	81	83	[illegible]
10-19.9	7	3	12	13	12	0	23	10	20	13	6	8	[illegible]
20-29.9	2	5	0	10	9	25	0	7	0	25	0	4	[illegible]
30-39.9	2	3	5	10	6	0	0	0	0	0	6	4	[illegible]
40-49.9	2	0	0	0	0	0	0	0	0	0	6	0	[illegible]
50-59.9	0	0	2	3	0	0	0	0	0	0	0	0	[illegible]
60-69.9	0	0	0	0	3	0	0	0	0	0	0	0	[illegible]
70-79.9	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]
80-89.9	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]
90-99.9	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]
100 +	0	0	2	0	3	0	0	0	0	0	0	0	1
Mogadishu													
>0-9.9	100	75	69	64	77	83	88	89	90	71	64	80	[illegible]
10-19.9	0	0	6	15	11	9	7	7	6	18	20	14	10
20-29.9	0	0	8	9	5	3	3	2	1	5	7	2	4
30-39.9	0	0	3	4	2	2	1	1	1	2	5	2	[illegible]
40-49.9	0	0	0	3	2	1	1	1	1	2	2	2	1
50-59.9	0	25	6	2	1	0	0	0	1	1	1	0	1
60-69.9	0	0	8	0	1	1	0	0	0	1	1	0	1
70-79.9	0	0	0	2	0	1	0	1	0	0	0	0	0
80-89.9	0	0	0	0	0	0	0	0	0	0	0	0	0
90-99.9	0	0	0	0	0	0	0	0	0	0	0	0	0
100 +	0	0	0	0	1	0	0	0	0	0	1	0	0

Table 24. DISTRIBUTION (%) OF DAILY INTENSITIES FOR THOSE DAYS WHEN RAIN OCCURRED

The Gamma Distribution. We have mentioned above that the Gamma distribution is very suitable for daily rainfalls, though the dry days should first be excluded - one of the applications of determining the proportion of dry days. For daily data taken on an annual basis (i.e. the entire record), the Gamma distribution gives means of values generally a little under ten, and shape factor k rather more than 1.0, which would be the exponential distribution. In any case, the distribution is nearly always a reversed 'j' shape. Fig 42 shows the actual histogram and the fitted Gamma distribution. Also shown is the distribution including the zeros.



Extreme Rainfalls. Very heavy rainfalls are of interest in various Agrometeorological studies, including soil erosion, flooding etc. We have not yet, at the time of writing completed our collection of rainfall for the entire country (see Technical Reports in the References), but have not found any very heavy rainfalls, if the questionable record for Mogadishu on 22/6/1967 is omitted. This particular record is discussed in Technical Report No.1 by the present authors. Otherwise no daily record has even approached 200 mm, except for one record at Kismayo. The heaviest rainfalls we have found from 13 of the largest records are:

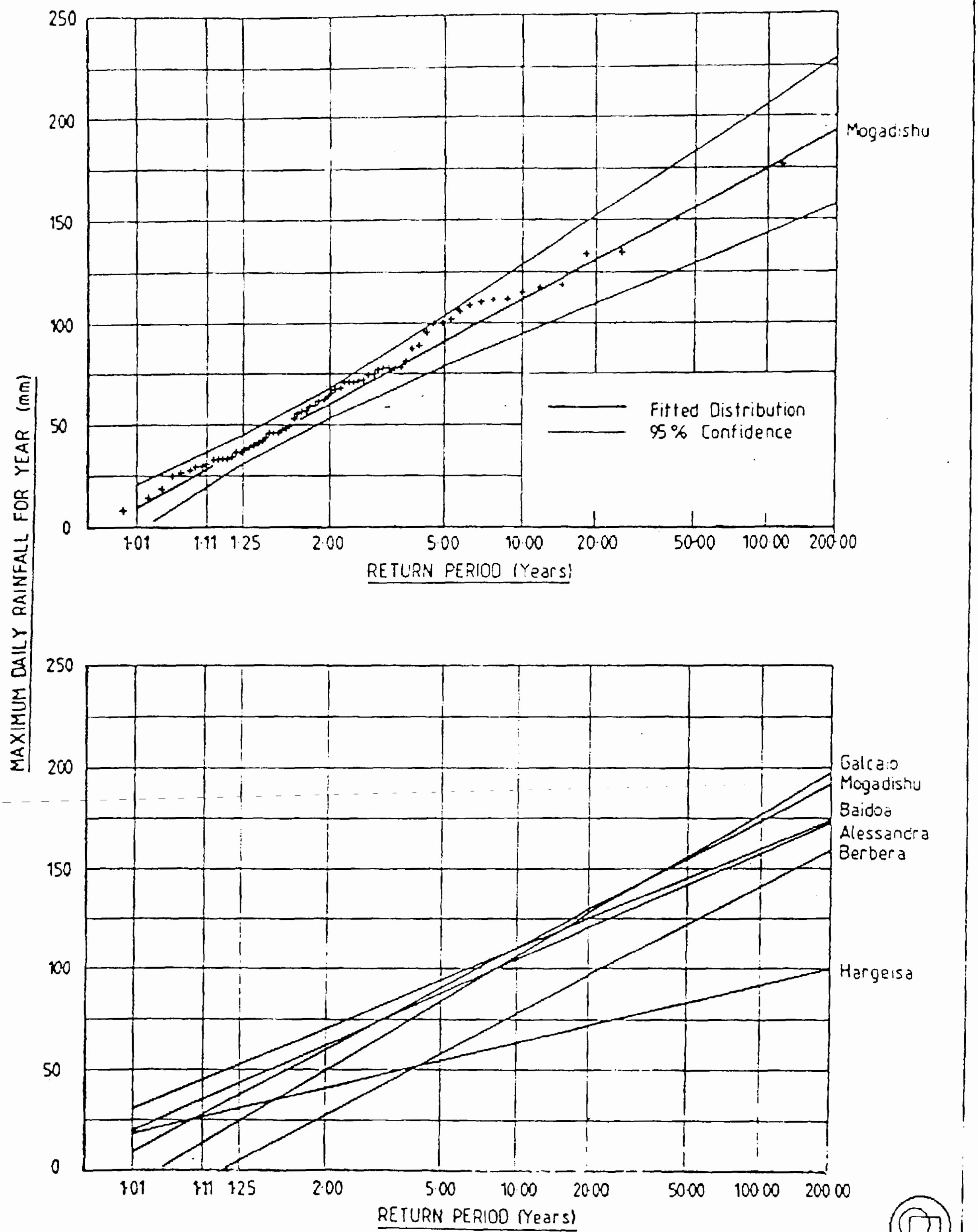
Station	Year	Month	Day	Rainfall	Return Period (years)
Kismayo	1899	4	24	214.9	
Mogadishu	1980	6	19	176	105
Berbera	1945	5	8	168	71
Galcaio	1965	10	12	167	68
Galcaio	1973	4	10	166	
Afgoi	1980	6	19	157	
Kismayo	1900	5	24	151.6	
Baidoa	1981	4	16	150	59
Mogadishu	1923	5	6	150	
Kismayo	1984	6	16	149	
Alessandra	1984	6	16	149	61

These falls are spread fairly evenly throughout the country, with the drier stations being well represented, with Berbera, in particular, recording the third highest daily rainfall in this record.

Extreme Rainfall Distributions. Though the actual extreme values are interesting, more valuable information is obtained by considering extreme rainfalls as statistical distributions. The most popular of these is the Gumbel Extremal Probability, which is described in any texbook on rainfall or Hydrology (e.g. Wilson, 1983 or Shaw 1983). In this distribution, the highest daily rainfall each year is taken and fitted to the distribution. The result is a table, or graph of **return periods**, or its converse, which is the amount of rainfall which may be received once in so many years. Some of these return periods are shown below. Another way in which the distribution can be described is the probability that a particular value of rainfall will be exceeded in any one year.

Probab. Exceed.	Return Period	MAXIMUM RAINFALL Baidoa	Galcaio	Alessandra	Hargeisa	Berbera	Mogadishu
0.990	1.01	30.91	-	21.78	19.25	-	9.78
0.980	1.02	34.37	-	25.46	21.23	-	14.17
0.950	1.05	40.02	6.41	31.46	24.47	-	21.35
0.900	1.11	45.59	14.28	37.39	27.66	-	28.42
0.800	1.25	53.17	25.00	45.45	32.01	3.94	38.06
0.500	2.00	71.01	50.21	55.82	42.24	26.66	60.71
0.200	5.00	95.00	84.12	64.42	56.00	57.23	91.20
0.100	10.00	110.89	106.58	89.94	65.11	77.47	111.38
0.050	20.00	126.13	128.12	106.83	73.85	96.88	130.74
0.020	50.00	145.86	156.00	123.04	85.16	122.01	155.80
0.010	100.00	160.64	176.89	[illegible]	93.53	160.07	174.57
0.005	200.00	175.37	197.71	159.74	102.08	185.18	193.28
0.001	1000.00	209.49	245.93	175.40	121.64	210.24	236.62
PMP		562.5	755.8	576.5	356.5	615.9	693.8

Table 25. GUMBEL PROBABILITIES FOR MAXIMUM DAILY RAINFALL & PROBABLE MAXIMUM PRECIPITATION



GUMBEL DISTRIBUTION FOR DAILY RAINFALL

Fig. 43

The values for a number of stations are shown in table 25. The first column lists the probability of exceedance and the second, the return period in years, therefore the rainfalls are listed station by station. Thus for Baidoa, the amount of rainfall to be expected or exceeded for a return period of two years, is 71.0 mm. The probability of 71.0 mm being exceeded every year is 0.50. Engineering design, roads, bridges, etc may work on a return period of 50 years, more or less depending on the structure, which for Baidoa represents a rainfall of 145.9 mm. In Agriculture, the design of field drains, irrigation and run off canals find this information useful, as would any matter to do with soil erosion.

The distribution may also be presented graphically, using so-called Gumbel paper, which is scaled so that the Gumbel distribution plots as a straight line (fig. 43).

We find that, for the stations presented, the values of the distributions are all quite similar, except for Hargeisa. Whatever the mean annual rainfall, the values for long return periods, 50 100, 200 and 1000 years are very close, though for the shorter return periods, the values for the drier stations diverge, and become negative. This latter is because of the years when the maximum daily rainfall was quite small, Hargeisa is a special case, in which there are no very high daily rainfalls, the maximum measured being only 85.0 mm. This is explained by the altitude of Hargeisa. The amount of moisture in the atmosphere which is available to become rainfall is dependent upon the thickness of the column of air above any one place. The column above Hargeisa, which is at 1500 mm asl is that much shorter than that above Mogadishu at sea level, and so on. Therefore the maximum rainfalls will be less.

This raises the question of what the probable maximum daily rainfall could be. This can be determined through a meteorological approach, in which all meteorological conditions of temperature, humidity, etc are considered as most suitable, and thus calculating, using physical laws, the maximum possible rainfall, or through a statistical approach based on Hershfield (1961). In the latter case, the result is known as the Probable Maximum Precipitation (PMP), which is also shown in table 25. Readers are refered to standard textbooks, e.g. Weisner (1970), for further information. Whereas for the other stations listed the PMP's lie between 560 and 750 mm, that for Hargeisa is 356.5 mm.

6. EVAPORATION, EVAPOTRANSPIRATION AND SIMPLE WATER BALANCE

Very few measurements have been made of evaporation in Somalia. A few stations have records from American Class 'A' pans, but these records are broken and uncertain. Since 1980, FEWS stations have been installed with Piche evaporimeters, but no attempt has been made to correlate these with pan measurements. On the other hand, calculations of potential evaporation and potential evapotranspiration, using the Penman formula have been done by a number of agencies, though the most comprehensive is that done by FAO as part of the Agro-Ecological Zones Project (FAO, 1977) and published also separately.

Direct Measurements

Five records of direct measurement using the class 'A' pan have been found (Table 26). The Afgoi data is recent (1973-1986), and is taken from FEWS records and old handwritten data found at Afgoi. The data for Marere is from 1978 to 1987. The other three stations are from the Arab study (1977), which are also mentioned in Fantoli. Of this data, that for Genale is clearly too low.

Station		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi	a)	8.8	9.9	10.1	8.0	6.5	6.7	[illegible]	6.8	8.1	7.5	6.6	7.3	7.7
	b)	273	287	313	240	202	201	[illegible]	211	243	233	198	217	2810
Genale	a)	2.7	3.0	3.1	2.7	2.3	2.6	2.1	2.0	2.8	2.8	2.3	2.3	2.6
	b)	84	87	96	81	71	80	65	62	84	87	69	71	937
Jowhar	a)	7.0	8.4	9.7	7.5	5.4	5.2	4.9	5.8	6.4	4.3	4.4	5.3	6.2
	b)	217	244	301	225	167	156	152	180	192	133	132	164	2263
Mogadisho	a)	5.7	5.3	5.4	5.0	4.5	4.4	4.6	4.2	4.6	4.2	4.5	5.0	4.8
	b)	177	154	167	150	140	132	143	130	138	130	135	155	1751

a) is mean daily evaporation and b) is mean monthly evaporation in millimetres

Table 26. DAILY AND MONTHLY PAN EVAPORATION

Estimations of Evapotranspiration

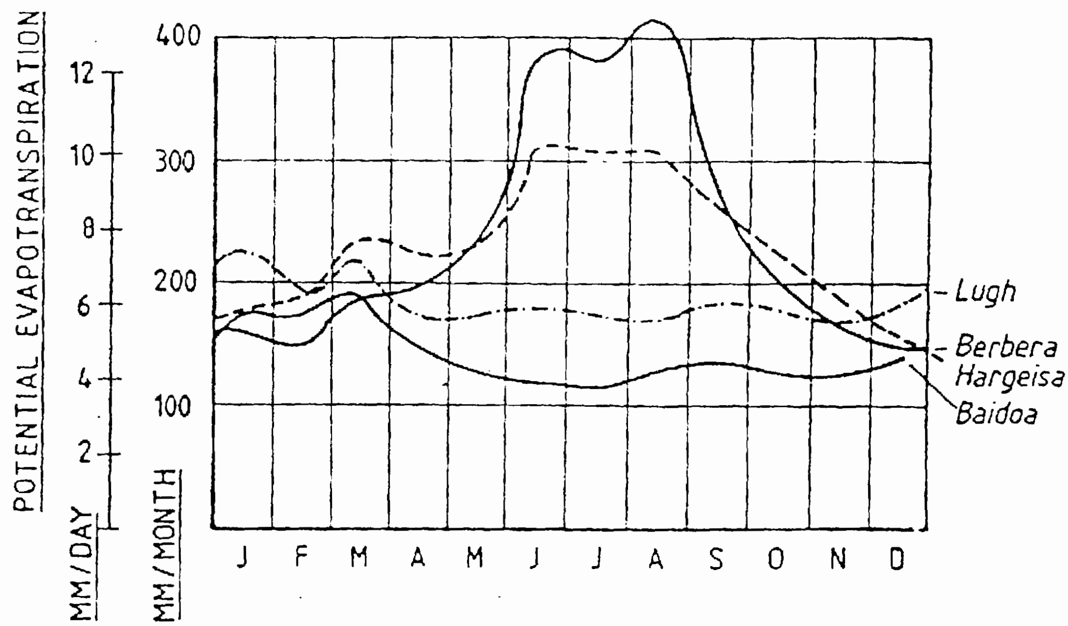
For purposes of standardisation, the FAO calculations of potential evapotranspiration are taken as correct. Independent calculations within the FEWS Department have shown small differences on a monthly basis, but not enough to alter significantly the sense of what is described below.

Annual Potential Evapotranspiration. On an annual basis, the highest potential evapotranspiration occurs along the northern coastline, with Berbera showing the maximum value of 2886 mm/yr, equivalent to nearly 8 mm/day, while the lowest is in the far south with Jonte achieving only 1460 mm/yr, or 4 mm each day (Fig 45). The main contributory factor in these generally high figures is the high air temperature, while high humidities do act to temper the effect of the air temperatures. Wind is locally important, for example in Hargeisa, where, despite rather cooler temperatures, and relatively high cloud cover, potential evapotranspiration is not far short of the values achieved in the hot coastal strip. Geographically, there is a reduction in potential evapotranspiration from north to south, though the northern areas of Gedo and Bakool suffer rather more potential evapotranspiration than their latitude might indicate.

Elsewhere, potential evapotranspiration is more uniform throughout the year. Rather than an increase in April, potential evapotranspiration is reduced, with minimum values occuring in the middle of the year with, generally, a small rise at the end of the year.

Thus (fig. 45), the maximum monthly values vary from place to place from 150 mm/month on the southern coastal strip to over 400 mm/month on parts of the north coast, while the time of these maximum values is divided between the middle of the year (June to August) in the north and the beginning of the year (January to March) in the Central and Southern Regions. Minimum monthly values vary from place to place from under 100 mm/month in parts of the southern coastal strip to over 150 mm/month at various locations - the upper Juba valley, round El Bur, and the agricultural zone of the northwest. Minimum monthly values occur at the end of the year (November and December), except for the eastern parts of the south.

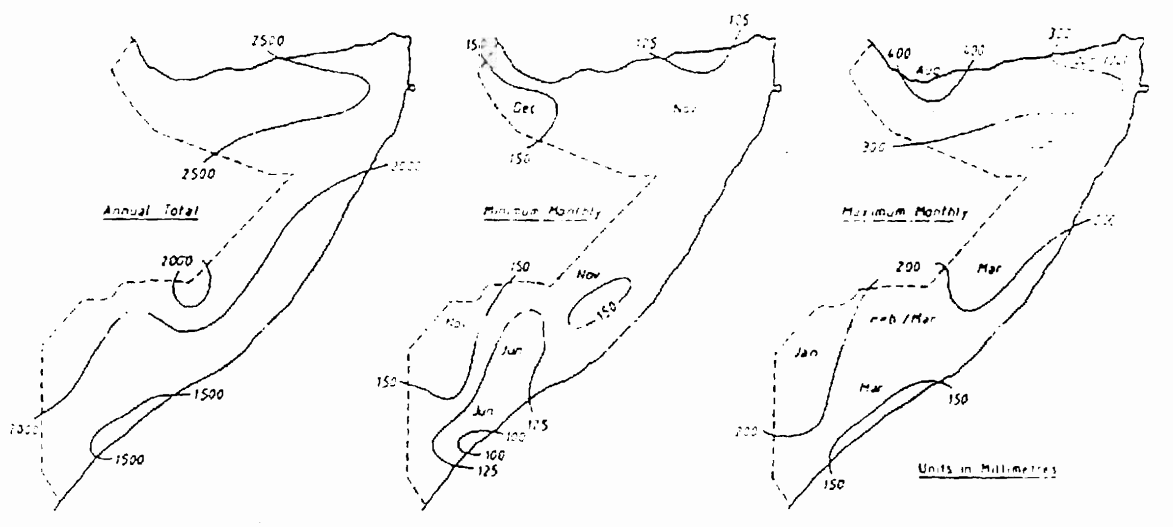
Seasonal Variations. The highest estimated potential evapotranspiration occurs at Berbera in August, with 413 mm, or more than 13 mm/day, and the lowest at Jonte in June with 98 mm, only just over 3 mm/day.



POTENTIAL EVAPOTRANSPIRATION

Fig. 44

In the north, potential evapotranspiration, after fluctuating in January to April, increases rather steeply in May and June, remaining very high for three months. Berbera plateaus at about 400 mm/month, while Hargeisa plateaus at 300mm/month. From September to the end of the year, there is a general decline to the year's lowest figures in December.



ANNUAL & MONTHLY POTENTIAL EVAPOTRANSPIRATION

FIG 45

Water Balance.

Nowhere, on an annual basis does rainfall even approach potential evapotranspiration. Whereas the range of annual rainfalls lies between almost zero and 700 mm, potential evapotranspiration ranges between 1500 mm/year to nearly 3000 mm/year. Everywhere, there is a large water deficit. The area closest to a balance is Alessandra/Jilib, where potential evapotranspiration at about 1600 mm/year is a little more than twice the annual rainfall.

On a monthly basis, the situation is a little better (Fig. 26). In a few areas, round Baidoa and Alessandra/Jilib, then some months do have a water surplus. At Baidoa, these are April and October - the start of the Gu and Der seasons, while round Alessandra/Jilib a few months do have a surplus or near surplus.

In terms of agriculture, then water needs of crops (see below) vary from 0.3 to 1.3 times the potential evapotranspiration. Taking the values of half potential evapotranspiration (as do FAO, 1977, see below), then some agricultural areas do have water to sustain agriculture. This will be discussed below but figure 46, in a nutshell, demonstrates the most important feature of Somali agriculture - the imbalance between water need, and its provision by rainfall.

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi	176	177	194	158	141	125	143	151	161	157	138	155	1876
Afmadu	194	176	194	146	131	125	128	146	167	154	138	148	1847
Alessandra	160	158	182	138	126	105	108	121	132	137	125	139	1631
Baidoa	177	174	187	144	130	123	115	130	136	125	125	143	1709
Bardera	234	198	217	158	162	165	169	182	195	167	161	177	2185
Belet Uen	165	166	174	148	143	150	150	167	173	144	138	152	1870
Berbera	162	149	188	191	233	385	380	413	281	200	160	144	2886
Bosaso	129	132	170	172	197	253	291	271	224	150	105	116	2210
Brava	139	124	148	139	132	114	119	128	129	133	129	135	1569
Bulo Berti	184	197	197	183	154	150	149	160	170	164	160	166	2034
El Bur	206	199	221	176	174	164	171	196	215	163	153	176	2214
Galcayo	163	158	196	174	179	198	195	199	190	144	138	158	2092
Gardo	180	143	186	178	210	251	208	246	243	179	138	148	2310
Genale	141	139	149	135	126	107	108	124	134	132	116	127	1538
Hargeisa	178	189	234	222	229	312	309	307	269	227	190	158	2824
Hoddur	186	187	202	188	152	166	164	181	184	149	139	158	2056
Jonte	132	122	146	131	120	98	102	110	120	132	117	130	1460
Jowhar	154	161	181	146	133	114	116	128	139	144	136	147	1699
Kismayo	172	162	176	165	145	133	139	153	158	168	158	166	1895
Lugh Ganana	221	194	217	172	174	180	173	170	187	179	168	181	2216
Merca	148	134	157	136	131	117	120	126	135	1?2	127	138	1611
Mogadisho	155	149	172	159	156	133	139	148	150	157	148	152	1818
Obbia	149	150	185	181	165	167	162	169	160	[illegible]	[illegible]	148	1945
Scusciuban	[illegible]	[illegible]	194	195	278	333	295	[illegible]	[illegible]	198	[illegible]	[illegible]	2724

Table 27. MEAN MONTHLY AND ANNUAL EVAPOTRANSPIRATION IN MILLIMETRES

1. AGRO-CLIMATIC CLASSIFICATIONS.

Climatic Classifications are a method of reducing the many sets of tables associated with climatic data to a few, simply understood parameters, and thus describe climates of particular areas, and identify areas having similar climates. Classifications may be based only on climatological considerations, though more often they are used as a tool in some application involving the climate, such as for agro-ecology or forestry.

Koppen Classification.

The classification of Koppen is included here because it was the first of the universally recognised classifications. Koppen worked at this from 1900 to 1953. It uses climatological factors, but attempts to match the climatology to the variations in natural vegetation. Five natural vegetation groups are recognised, and the corresponding climates are classified according to temperature and rainfall.

Climatic classes. A,C,D and E are defined according to the mean temperature of the coldest month, type A being above 18°C, type C being between 0°C and 18°C and types D and E below 0°C, these last two being separated according to whether the temperature of the warmest month is above 10oC (Type D) or below (Type E). Type A is designated "Tropical Rainy", type C, "Warm Temperate"or "Mesothermal Forest", type D, "Boreal", or "Microthermal Snow Forest" and type E as "Polar". However, none of these climates appear in Somali, which experiences only type B, known as Arid.

The definition of B-type climates is rather more complicated. It is first assumed that rainfall is less than potential evapotranspiration.

In the simplest form of the classification, Type BW (Desert) occurs if annual rainfall is less than 250 mm and BS (Steppe) if more than 250 mm but less than potential evaptranspiration.

Type BS can be further described, firstly according to the mean temperature of the coldest month, thus if the temperature is greater than 18°C, then it is hot (BSh) and if less than 18°C, then it is cold (BSk). Further if the mean temperature of the warmest month is less than 18°C then it is very cold (BSk').

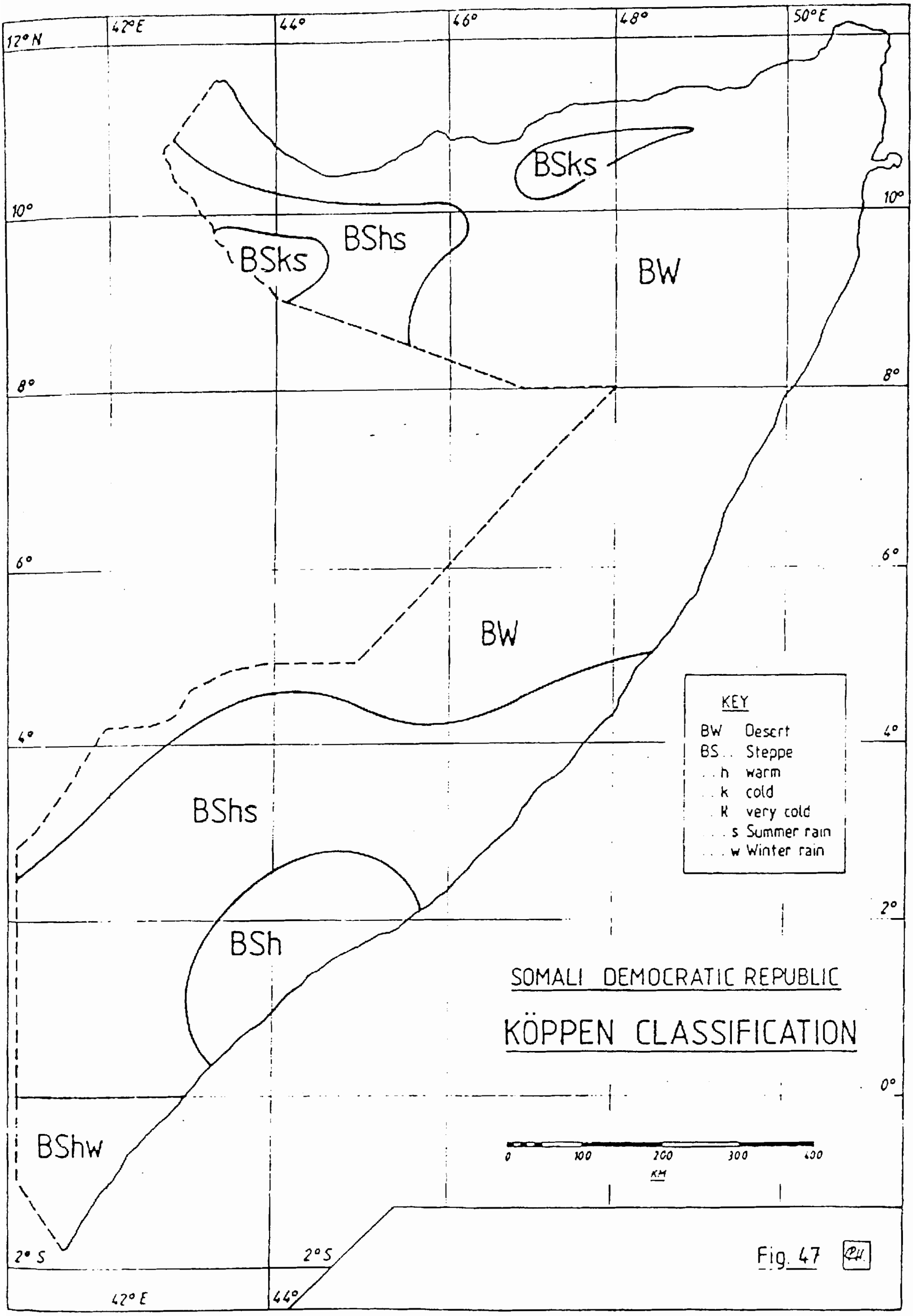
Secondly, a descriptor can be added, depending on whether there is summer rainfall, winter rainfall, or indifferent rainfall. Winter rainfall, or summer rainfall regimes are specified only if the wetter season exceeds the dryer season by a factor of 1.25.

Classification for Somalia. In Somalia, rainfall is less than potential evapotranspiration everywhere, hence the entire country experiences a dry (B) climate.

Desert climates (BW) occur in areas with less than 250 mm rainfall per year. These include Central Regions, north of about 5°N and all Northern Regions except the area round Erigavo and the southern parts of the Northwest region. (Fig. 47). All other areas are steppe (BS).

All steppe areas are hot (BSk) except for the small area round Erigavo and the higher parts of the Northwest Region, including Hargeisa, where they are cold (BSk).

The final descriptor, of summer or winter rainfall is hardly applicable to the southern areas, which are close to the Equator.. In the north, and central areas, summer rainfall predominates everywhere (BShs), (BSks). In the south, however, Bay Region, part of Middle Shabelle, and parts of adjacent areas have indifferent rainfall regimes. Nowhere does winter rainfall predominate, except that the areas south of the Equator experience rainfall from April to September, technically "Winter: south of the Equator" (BShw).



12° N
42° E
44°
46°
48°
50° E
10°
8°
6°
4°
2°
0°
2° S
BSks
BSks
BShs
BW
BW
BShs
BSh
BShw
KEY
BW Desert
BS . . Steppe
. . h warm
. . k cold
. K very cold
. . . s Summer rain
. . . w Winter rain
SOMALI DEMOCRATIC REPUBLIC
KÖPPEN CLASSIFICATION
0 100 200 300 400
KM

Fig. 47

FAO Eco-Climatic Classification.

The FAO Eco-climatic classification (Le Houerou, U,N, & Popov G.F., 1981) is intended to

> "take into consideration the whole body of information (climatic, biological, agronomic) available today and which would present to the ecologist and the agriculturalist a simple but accurate means to understand better the complex features of a developing continent".

The classification is for Intertropical Africa.The main criteria used are:

a) Rainfall distribution patterns (monomodal or bimodal).
b) Precipitation: annual amount (mm).
c) Annual distribution of rainfall (numbers of dry & rainy months).
d) Temperatures (occurence of frost).
e) Land use (pastures, crops, forest).
f) Nature of crops.
g) Livestock species and breeds.
h) Distribution of Tsetse flies.

According to the Rainfall distribution, four classes are possible.

a) a simple rainy season/one dry season (Tropical).
b) two rainy seasons/two dry seasons (Equatorial).
c) no rainy season/permanent drought.
d) no dry season/permanent rains.

In Somalia, only classes (b) and (c) occur.

The actual lengths of the rainy seasons are calculated according to the water requirements of crops. A month is "rainy" if monthly rainfall (R) exceeds one third of potential evapotranspiration (0.35 PET), which corresponds to the water requirement of a newly sown crop.

The zonation is shown in Table 28, in which the zone is defined by the number of rainy months, with the rainfall in column 4 being indicative only. In this zonation, No. 7 corresponds to "(c) no rainy season/permanent drought" and Nos. 1-6 to the Equatorial type of rainfall distribution.

The criterion of Temperature is included only in respect of the occurence of frost, though it is also implicit in the 'Montane' climates element, described below. Apart from some very small areas in the north, notably round Erigavo, frost is not a factor in Somalia, and is general only in uplands, which therefore become a factor in the classification.

Criteria (e) to (g) are included as descriptions attached to the various zones (Table 29).

Criterion (h), "Distribution of Tsetse flies" is implicit in the Rainfall (mm) criterion, in that the flies are usually confined to areas with rainfall exceeding 800 mm, and, incidentally, to areas below 1500 m a.s.l. There are exceptions to this, particularly in wet depressions adjacent to rivers in drier areas, such as the Juba and Shabelle river valleys.

Although not mentioned in their list of criteria, Le Houerou and Popov also discuss 'Montane' Climates. Since the vegetation of highland zones is usually different to lowland zones, even with the same classification, it is thought necessary to show this differential in the form of special zones. This differential is as true for agricultural crops as it is for natural vegetation.

The 'Montane' climates are divided into two, named "Highland" and "Montane". Highland zones are those where the daily mimimum temperature of the coldest month lies between 7°C and 10°C, and Montane, those with the equivalent temperatures lying between 0° and 7°C.

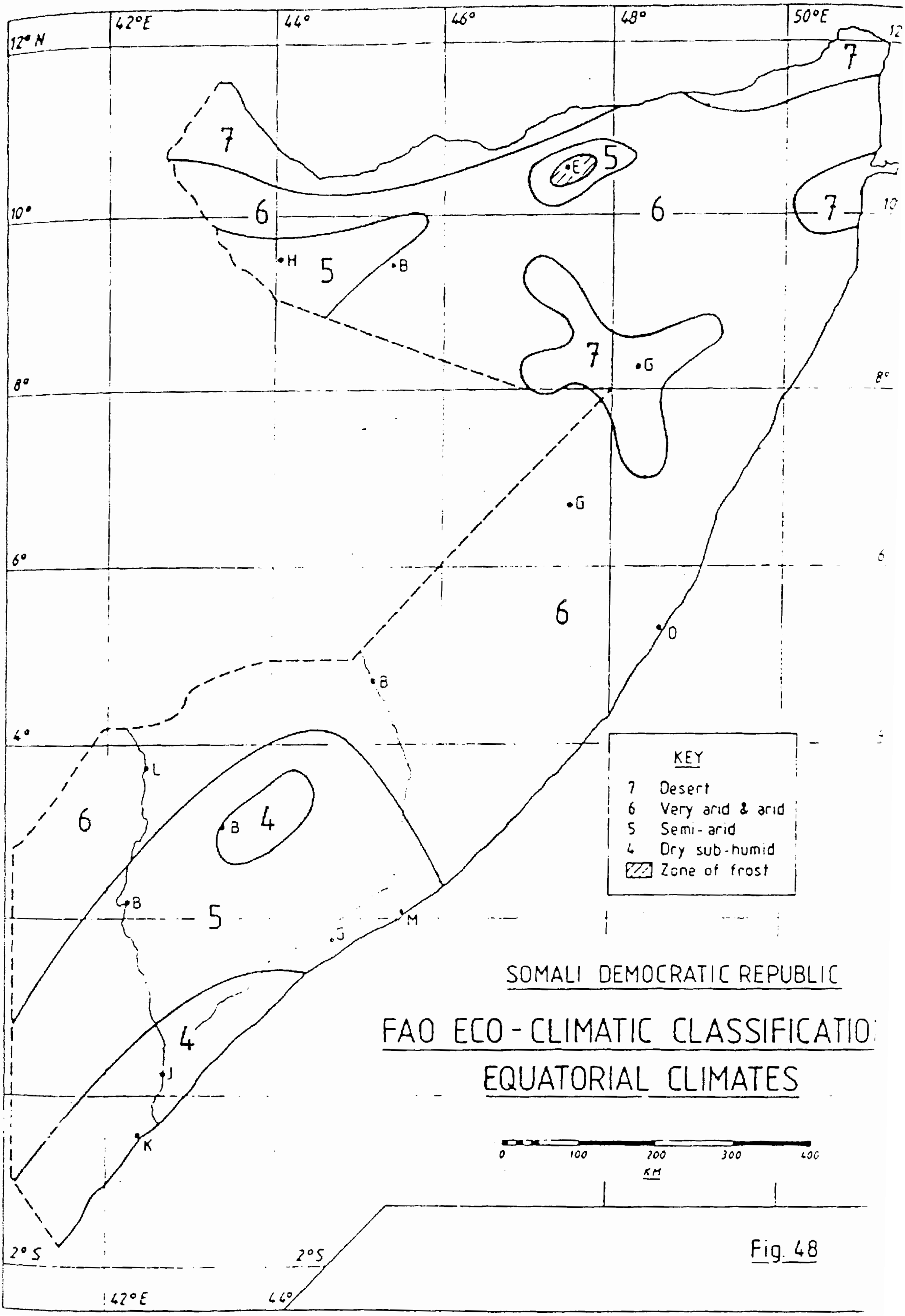
Zone No.	Climates	Ecological Zones	Rainfall mm	Duration of rainy seasons, in "humid months"
7	Desert	Desert thorn dwarf dwarf scrub	R<100	RS = 0
6	Very arid and arid	Acacia, Commiphora woodland	100<400	RS = 1 - 3
5	Semi-arid	Acacia,-Commiphora woodland	400<R<600	RS = 4 - 5
4	Dry,sub-humid	Combretum, Acacia, Woodland	600<R<800	RS = 5 - 6
3	Sub-humid	Brachystegia, Terminalia woodland	800<R<1200	RS = 6 - 7
2	Humid	Evergreen forest	1200<R<1500	RS = 8 - 10
1	Hyper-humid	Rain forest	R>1500	RS>10.

Table 28 Equatorial Climates.

Classification for Somalia. For Somalia, the full classification is shown in figures 48 and 49.

The whole country falls into zones 4 (Dry, subhumid), 5 (semi-arid), 6 (Very arid and arid) and 7 (Desert). Zone 4 includes the coastal strip from Mogadishu southwards including the Lower Juba, and an area of the Bay Region. Here are woodlands, savanna and grasslands, settled animal husbandry, and farming, including sorghum, cowpea and groundnuts.

Zone 5 includes much of the rest of the southern region, excluding the northern parts of Gedo and Bakool, the uplands of the northwest, and a small area round Erigavo. This is semi-arid land, with bushland and open woodland. Land use includes a combination of grazing, nomadism and settled pastoralists with some farming of sorghum.



SOMALI DEMOCRATIC REPUBLIC

FAO ECO-CLIMATIC CLASSIFICATIO[N]

EQUATORIAL CLIMATES

Fig. 48

Zone No.	Sub-Climates	Vegetation types/ Livestock	Land Use patterns.
7	Desert	Contracted. Camels, goats, some sheep, rare cattle	Grazing, nomadism, no cultivation without irrigation.
6	Very arid	Diffuse shrubland and open bushland-perennial grasses, camels, goats, sheep, some cattle (zebu)	Grazing, nomadism, virtually no rainfed cultivation
5	Semi-arid	Bushland and open woodland, perennial grasses, cattle,sheep, goats, rare camels	Grazing nomadism and settled pastoralists, some farming (millet, sorghum, cowpeas)
4	Dry, sub-humid	Woodland, savanna, grassland, crop land, light tsetse infestation, cattle (zebu), sheep, goats	Settled animal husbandry farming, millet, sorghum cowpea, groundnuts, sweet potatoes, pigeon pea, sown pasture and range reseeding possible
3	Sub-humid	Woodland, savanna, grassland, crop land, heavy tsetse infestation in woodland and savanna (G. morsitans)	Limited animal husbandry, sorghum maize, sugarcane, banana, rice, yam, cassava, cotton, tobacco, sown pasture and range reseeding
2	Humid	Forest, woodland, savanna, crop land, Taurine cattle and dwarf goats Perennial tsetse riverine infestation	Restricted animal husbandry farming as above. Timber production
1	Hyper-humid	Rainforest. Taurine cattle and dwarf goats permanent, heavy tsetse infestation	Restricted animal husbandry Oil palm, cocao, coffee, coconut, hevea, timber production

Table 29 Equatorial Climates (lowland), Vegetation and Land Use Patterns

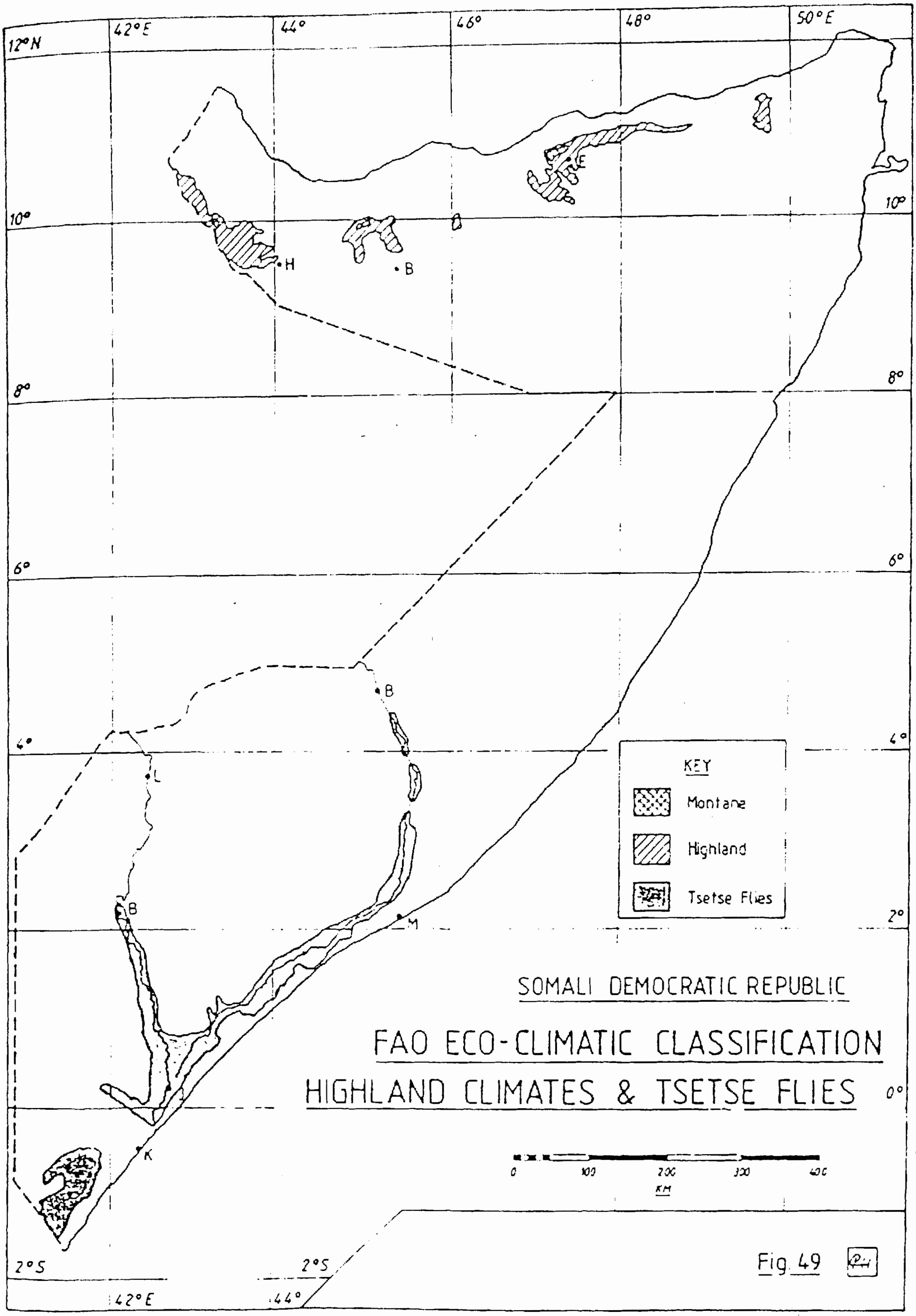
Zone 6 occupies much of the rest of the land area. Diffuse shrubland, open bushland and perennial grasses predominate, with land use being confined to grazing and nomadism.

Zone 7 exists along the northern coastal strip, inland from Faro Dante and an area round Garowe. Relatively little vegetation exists. Land use is confined to grazing and nomadism, though camels, rather than cattle are the most important type of animal.

Although rainfall nowhere reaches the figure of 800 mm/year which is the lowest amount for Tsetse flies, the "desheks" and other low lying areas alongside the Juba and Shabelle rivers do encourage the presence of Tsetse flies. These areas are shown in fig 49, but taken from the ODA Report (Hendy 1985), rather than the FAO paper. Since that report, however, an ODA Tsetse Eradication Project has been instituted, but the results are not yet published.

Highland areas, as discussed above, are designated those with daily minimum temperatures between 7^{o} and $10^{o}C$ for the coldest month, and Montane areas are those with corresponding temperatures between $0^{o}C$ and $7^{o}C$ for the coldest month. Although over a wide area these temperature limits occur at differing altitudes, for Somalia the limits can be taken to co-incide with the 1500 m and 2000 m contours, since these only occur in northern areas, between $9^{o}N$ and $11^{o}N$. Fig 49 shows the zones, the "Highland" consisting only of a few small areas, though these areas are locally important, particularly round Erigavo and northwest of Hargeisa. "Montane" zones are minute, and generally of no economic significance.

It may be seen that this classification, designed for the whole of inter-tropical Africa, does fit Somali conditions without modification, and does provide an adequate description of the link between Climate and Land Use Patterns over the entire country.



12°N
42°E
44°
46°
48°
50°E
10°
8°
6°
4°
2°
0°
2°S
H
B
E
L
M
K
KEY
Montane
Highland
Tsetse Flies
SOMALI DEMOCRATIC REPUBLIC
FAO ECO-CLIMATIC CLASSIFICATION
HIGHLAND CLIMATES & TSETSE FLIES
KM

Fig. 49

Agro-Forestry Climatic Zoning.

As an example of a classification for a specific purpose, an Agroforestry climatic zonation is given.

This system is intended to provide a classification, based on those aspects of climates which affect tree growth, which can be used to identify, for particular areas, tree species which would grow satisfactorily, based on comparisons with those areas where the species are actually growing. Conversely, the classification identifies those areas suitable for particular species. But it does not take into account other factors, such as soils, economic and farming conditions which may provide obstacles to successful growth.

Climatic Classification. The method is based on the work of Webb and Wood (1984), who selected Annual Mean Temperature and Annual Mean Rainfall as the two most significant factors of climate affecting tree growth. In addition, altitude above sea level, with which both the above are usually correlated is also considered.

For Kenya, Teel (1984) used this method, with some modification, mainly in the class boundaries, and a further modification by Hutchinson (1987) has tailored the method specifically for Somalia. For Somalia, the number of classes needed to be extended, i.e. an extra hot class and an extra dry class.

The method simply classifies areas according to the annual mean temperature and the annual mean rainfall according to the table shown in fig.50. Any zone is described according to its rainfall and temperature class, e.g. V-1 for Baidoa.

Thus Teel's class boundaries for rainfall are:

	<325 mm	class VII	
<500 mm	>325 mm	class VI	
<800 mm	>500 mm	class V,	etc.

to which a class;

<150 mm	class VIII	has been added

For temperature, the class boundaries are:

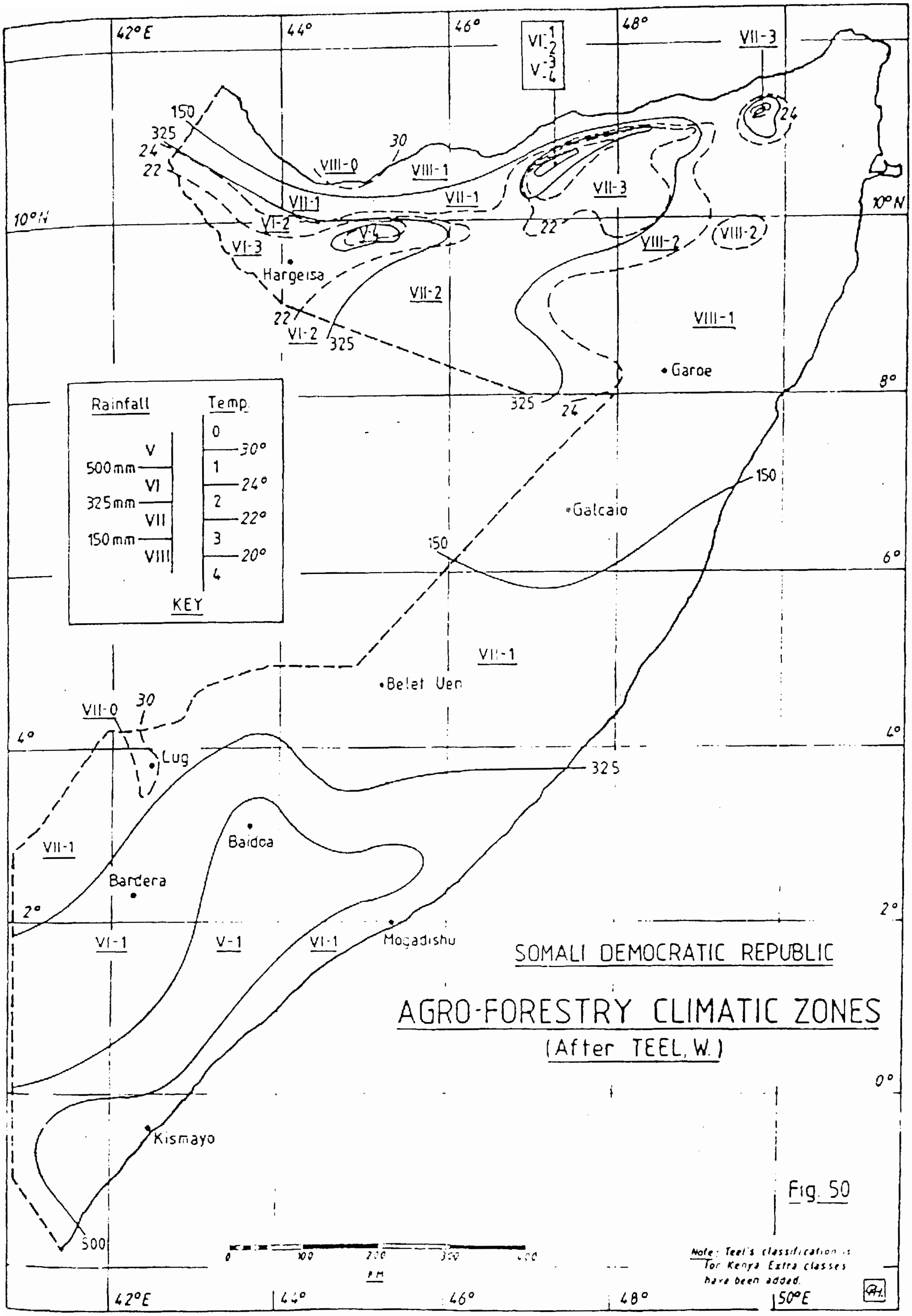
	<20°C	class 4
<22°C	>20°C	class 3
<24°C	>22°C	class 2
	>24°C	class 1

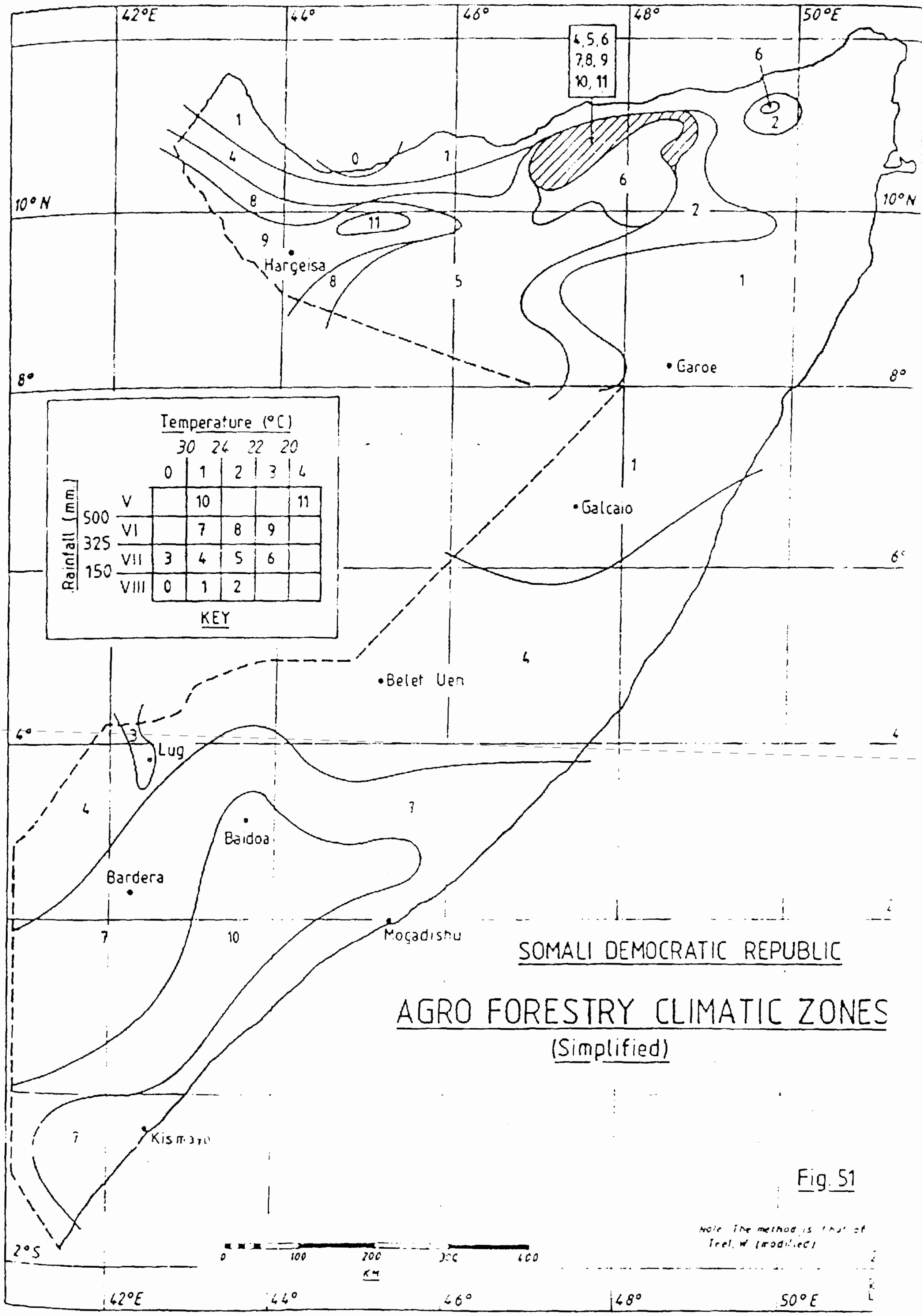
to which a class;

>30°C	class 0	has been added.

In order to interpolate between actual stations, then the relationship between rainfall, temperature and altitude were investigated, and the maps (figs 50 and 51) drawn accordingly. The relationships are shown on these figures.

Zonation for Somalia. The resultant zonation, using the Teel nomenclature is shown in fig 51. Almost all the southern and central areas fall into temperature class 1 (24°C-30°C), so the zonation of these areas is mainly based on the variations of rainfall, except the small area round Lugh, which is in temperature class 0.


SOMALI DEMOCRATIC REPUBLIC
AGRO-FORESTRY CLIMATIC ZONES
(After TEEL, W.)
Fig. 50
Rainfall
Temp.
V
500mm
VI
325mm
VII
150mm
VIII
0
30°
1
24°
2
22°
3
20°
4
KEY
Hargeisa
Garoe
Galcaio
Belet Uen
Lug
Baidoa
Bardera
Mogadishu
Kismayo
42°E
44°
46°
48°
50°E
10°N
8°
6°
4°
2°
0°
Note: Teel's classification is for Kenya. Extra classes have been added.



SOMALI DEMOCRATIC REPUBLIC

AGRO FORESTRY CLIMATIC ZONES
(Simplified)

Fig. 51

Note: The method is that of Teel, W (modified)

Parkinsonia Aculeatia (Tugar), is an introduced species, though it is found everywhere except in the driest areas of the north Central Regions and eastern areas, that is in all zones except 0,1 and 2. It is drought-tolerant, responding by dropping the leaves to reduce transpiration need. Its uses include fuelwood, fodder and for live fencing.

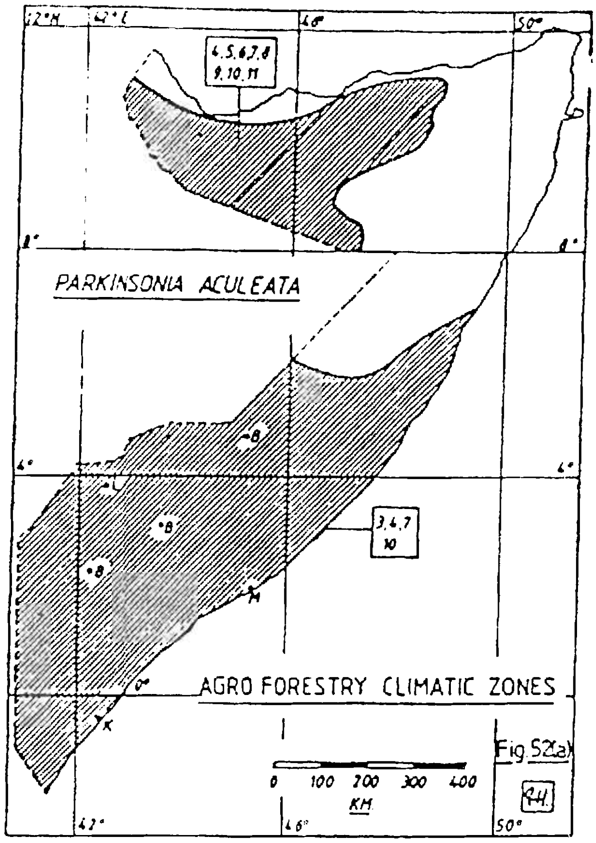


Fig 52(a)

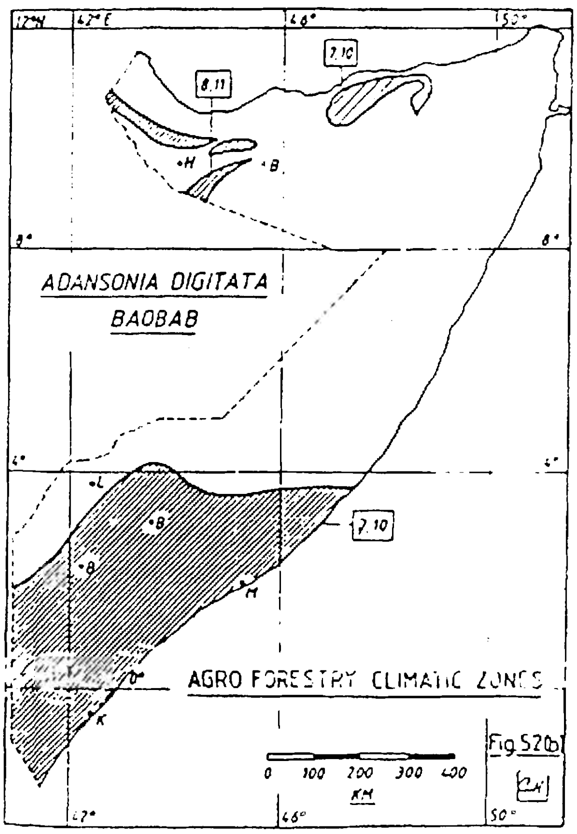


Fig 52(b)

Adansonia Digitata (Baobab) is confined to the wetter areas of the country, (zones 8,10,11) Only in the very wettest areas, where rainfall exceeds 600 mm/year is it widespread, so it is common in certain areas of the lower Shabelle and lower Juba. Elsewhere it may be found where water can be concentrated, for example, as the runoff from Burs. It has many uses, though fuelwood is not one of them, including water storage, paper making, for canoes, fibre for baskets and even strings for musical instruments.

In the north, however, the varied topography produces a complicated pattern of classes, in both rainfall and temperature dimensions. In particular the areas round Erigavo, Burao and Sheik provide a very complex zonation.

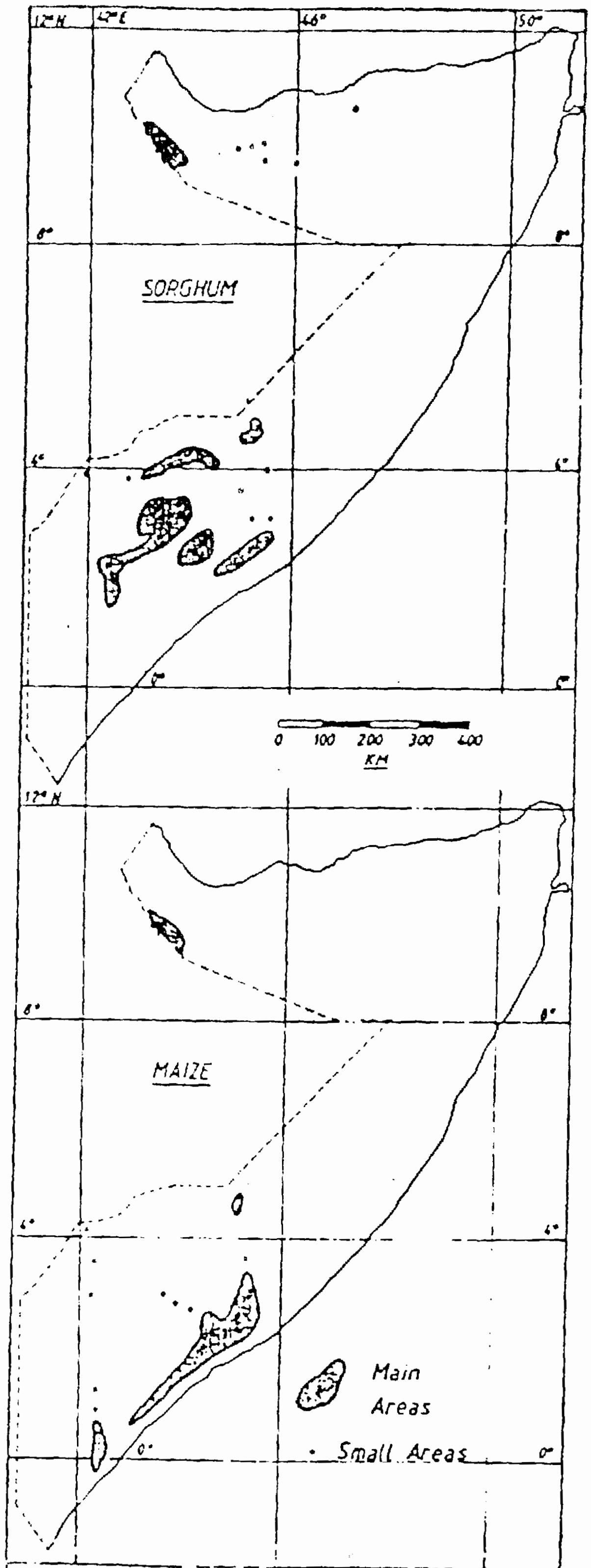
For this reason, and because not all of Teel's classes appear in Somalia, further simplifications have been made, both in the nomenclature and in the areal delimitation of the zones. Instead of a two number classification, a single numbering system is used, though the class boundaries are unchanged. Also, modification of some actual boundaries on the ground have been made to provide a simpler map. In theory, some inaccuracy is thus produced, but in practice little adverse effect would be noticed. These simplifications appear in fig 51, in which the simpler nomenclature is also tabulated. Only those of Teel's classes which actually appear in Somalia have been given a class number. The net effect is a system of 11 classes, and a much simplified map. Only in the mountainous area round Erigavo there remains a complex pattern,which is too detailed to map at the scale used.

Most of the southern areas fall into the modified class numbers 4,7 and 10, corresponding to temperatures of $24^{\circ}C$ to $30^{\circ}C$ and a range of rainfall greater than 150 mm. In the north, a more varied pattern emerges, mainly related to the land relief. In particular, there is a very marked change between Sheik and the north coast, with the zonation changing from 11, the coolest and wettest to 0, the hottest and driest.

<u>Distribution of four Species</u>. Of course, climate is not the only determinant of species distribution. Soil type is important, as is the availability of groundwater, apart from rainfall. However, in figures 52(a) to 52(d) the distribution of four species are given, even though some areas within these designated zones may be unsuitable for reasons unconnected with climate.

Sorghum. In terms of area planted, though not in production, sorghum is Somalia's most important crop. It is widely grown in the inter-riverine area, and in the northwest, though in the Lower Shabelle and Lower Juba areas, maize is prefered. Isolated areas also occur in the northern areas between Hargeisa and Erigavo, in the wetter areas of the highlands and along the Escarpment. Restrictions to growth in the inter-riverine area lie in the nature of the soil, as the entire area, except for the outer fringes of Hiran, Bakool and Gedo receive adequate rainfall. In total, about one quarter of a million tons of sorghum is produced.

Maize. Maize is second to sorghum in terms of area planted, but because of higher yields, is the most important crop in terms of production (336,000 tons). Over half of the production comes from the Lower Shabelle, particularly Afgoi, and one quarter from Middle Shabelle, especially Balad in the Gu season and Jowhar in the Der. Middle and Lower Juba, provide 10% of production, where concentration is in the Jilib and Jamame Districts. The northwest provides a further 5%, with Gedo, Hiran and Bay Regions providing the remainder.



CROP GROWING AREAS

Fig. 53(b)

Cowpeas. Cowpeas are the fourth largest crop, with about 26,000 tons. About half the production comes from the Jowhar and Balad Regions of Middle Shabelle and from Lower Shabelle, including the districts of Afgoi, Merca and Brava, where it largely grown intercropped. The northwest and Bay Region each provide about 20%, with the remainder from areas scattered over the southern half of the country, including Galgadud and Mudug.

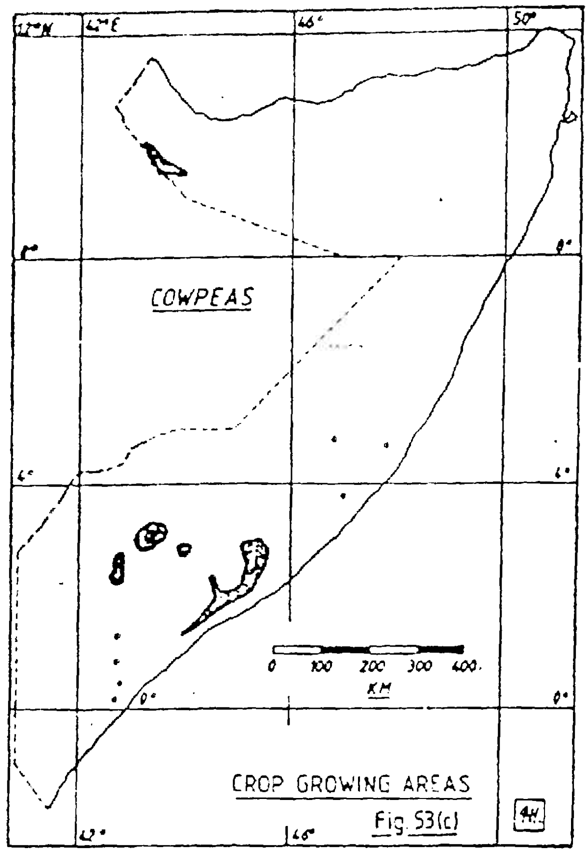


Fig. 53(c)

Crop Calendar. Because of the two wet seasons, and the variation in time of their occurence across the country, the crop calendar in Somalia is rather complicated.

In the north, long duration varieties of sorghum and maize (including the composite Somtox) are grown, these varying from 120-150 days duration. Planting takes place in the middle of April, which is relatively well into the wet season, which starts (Hargeisa) in the middle of March. Flowering takes place in June, when soil moisture storage should be high. Harvesting takes place in August. The long duration, particularly after flowering, allows for good grain development and high yield. In some years cowpeas are grown in northern districts along with the maize and sorghum; in others, it is planted later in the year, in August for harvesting in November, to take advantage of the second rainfall peak (the Kareen).

In the Central Regions, both seasons are short, thus short-duration sorghum (90 days) and cowpeas (75 days) are planted. Gu season plantings take place in mid-April, more or less co-inciding with the start of the rains. In this region, the rainfall season effectively ends by the end of June, thus the sorghum is flowering at a time alrady dry. Since average rainfall does not exceed 2 mm per day, little soil moisture storage can be built up during the season, thus yields are expected to be low. Cowpeas, with an even shorter duration do rather better, and are harvested only just after the end of the wet season. The Der season plantings are in mid-October, with sorghum lasting over till January, but cowpeas are harvested in December, to forestall the onset of insect damage in late December and January.

2. GROWING SEASONS.

Growing Areas and Crop Calendar.

Growing Areas. The distribution of the main crops in Somalia is governed by two factors - the availability of water, either directly from rainfall or from irrigation, and the suitability of the soils. For rainfed agricultural crops little cultivation takes place where rainfall does not exceed 300 mm per year, or 200 mm per season. Thus, the entire country north of about 4°N, with the exception of the high rainfall areas of the north, supports virtually no cropping. South of 4°N, large areas are unsuitable because of the poor soils.

Thus the main agricultural areas are along the two main rivers, the Shabelle and the Juba, and the inter-riverine area, including Bay Region, and, in the north, in the area stretching west from Hargeisa, and a small area round Erigavo.

Sesame. Sesame is grown, either under direct irrigation or in flood recession areas, desheks, and the like, this latter being known as 'Dhay'. The growing areas are therefore close to the rivers (Fig. 53(a)). The Middle and Lower Shabelle Regions are the most important growing areas, each accounting for about 43% of the total production of 45,000 tons. Otherwise the areas round Lugh and Boale plant 1000 ha. or more, each contributing to Gedo's 3% of total production and Middle Juba's 1%.

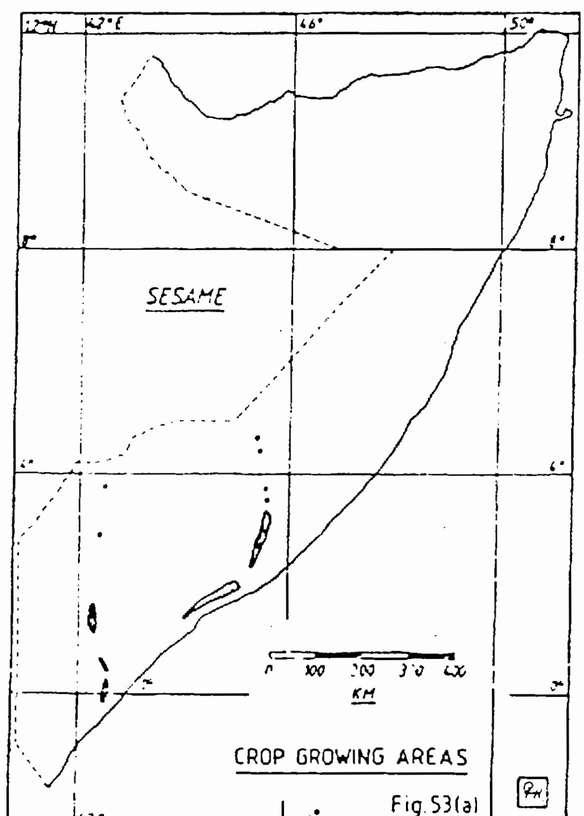


Fig.53(a)

Juniperus Procera (Pencil Cedar) is confined to a small area of the northern Highlands (Friis,1983), since it requires moisture and is intolerant of high temperatures (Zone 11). Rainfall should exceed 600 mm/year, and temperatures be less than 22°C (mean annual), these conditions being met only in a small area round Erigavo and the edge of the escarpment further west. It is used in those applications which require split wood, e.g. fence posts, and it is termite resistant. It can also be used for making matches.

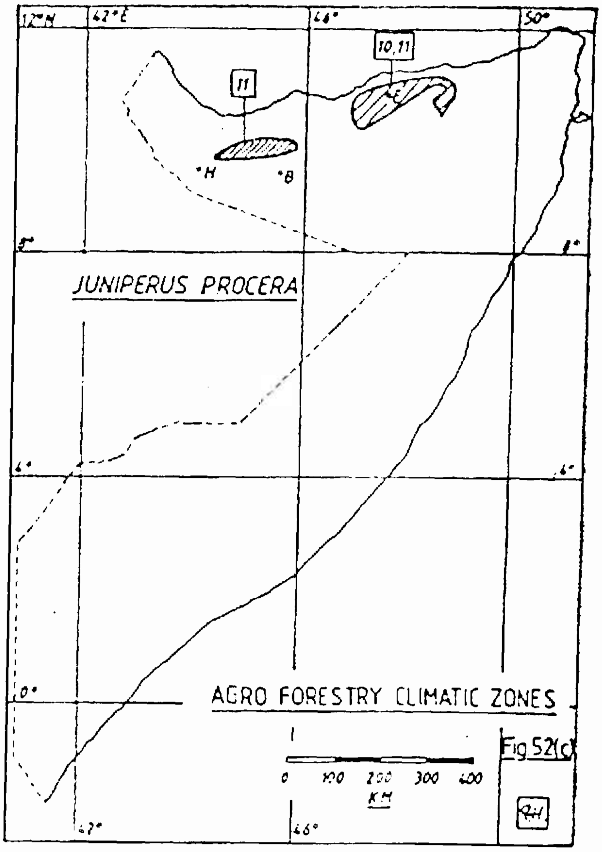


Fig 52(c)

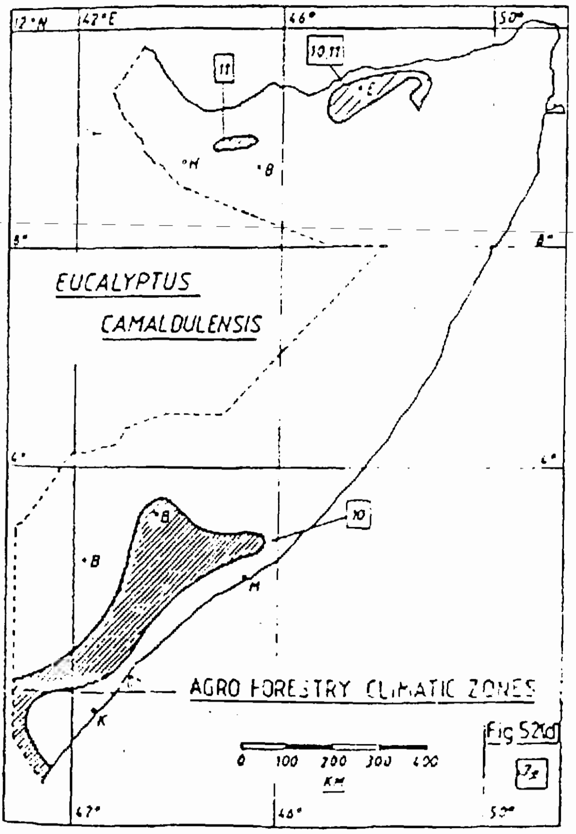
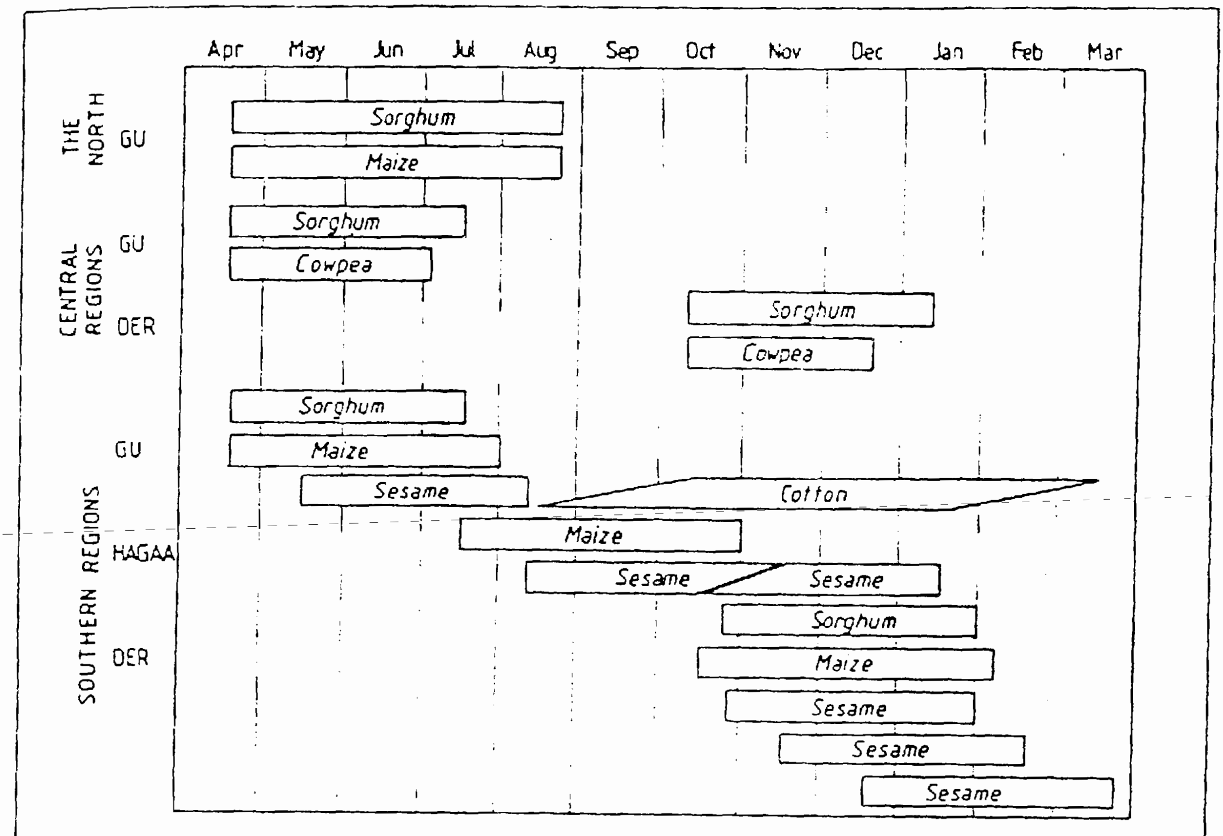


Fig 52(d)

Eucalyptus Camaldulensis (Baxarsaaf) is an introduced species. It requires 500 mm/year of rainfall and prefers warmer climates. Thus it is found in zone 10, which includes the wetter parts of the south, except the coast, and a few isolated spots in the north round Erigavo and Burao. It grows quickly and is useful for fuelwood. The leaves have medicinal properties, either chewed directly or boiled and the juice drunk. It is used as a natural anti-biotic for the treatment against streptococcus, staphylococcus, paratyphoid A and B, and against Dysentery. Parasitic worms in the stomach can also be treated. Used in the bath it eases muscles and calms the nervous sytem.

The southern regions present a much more varied picture, not only because of the rainfall variations over the area - particularly the unique season along the coast, but also because the two great rivers provide the facility for irrigated as well as flood recession agriculture.

Away from the coast, then short to medium duration sorghum and maize provide the major crops. Planting in April follows the early season rain in some areas, e.g. Bay Region. Although the rainfall season is virtually finished by the end of June, soil moisture reserves should be available to provide the water necessary for the last 30-60 days growth. Sesame is planted rather later, since it relies on irrigation, and farmers are required to wait for the first flush of the flood flow to clear away the salty waters. Harvesting occurs later in August, overlapping with the start of the cotton growing cycle. Cotton is grown under irrigation, starting during the Hagai dry season, so as to avoid both high atmospheric humidity and diseases, but has an 150 day duration, so the cotton season extends into January.



CROP CALENDAR

Fig. 54

Inland, the Der season starts in mid or end October, with Middle duration maize and short duration sorghum, both of which being harvested in January. Sesame is again grown under irrigation or in recession areas, and thus may be planted at any time from October onwards.

In the coastal areas, where the rainfall season starts later, and with little or no intermediate dry season, plantings do not occur till July or August, with short duration maize, and sesame under irrigation. Cotton, also grown under irrigation is planted in mid to late October for harvest the following March. Rice is grown entirely under irrigation, thus availability of water becomes less important compared to other problems. One such is the avoidance of bird damage, which reaches its potential maximum in September with weaver birds. Thus plantings take place in March, for harvest before September, and in August, so that the rice is at an early stage of growth in September.

The FAO Agroecological Zones Project.

The FAO Agroecological Zones Project was intended to make a complete inventory of the World's agricultural production potential. The project first assessed the World's climatic and soil resources, then considered their use by 11 of the most important crops, of which Phaseolus bean, paddy rice, cotton, sorghum and maize are grown in any quantity in Somalia, in relation to their technological requirements.

The climatological (or Agroclimatological) component consisted of carrying out soil moisture balances for a large number of stations (730 in Africa, 24 in Somalia), and arriving at the concept of the growing period, thereafter matching the duration of the various crops to this growing period. Four types of water balance regime are recognised,

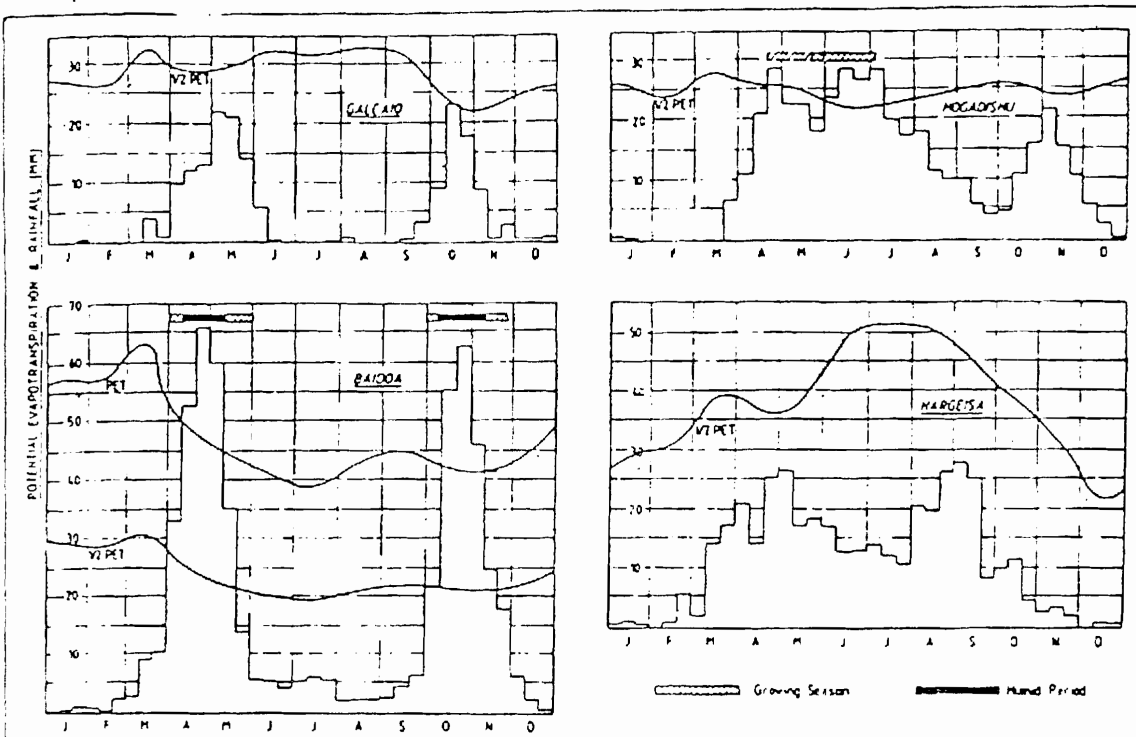
a) Normal, when rainfall exceeds Potential Evapotranspiration (PET). for some of the year
b) Intermediate; when rainfall exceeds half PET for some of the year.
c) All year round humid; when rainfall exceeds PET for the entire year.
d) All year round dry, when rainfall is less then half PET for the entire year.

In Somalia, types a), b) and d) occur.

Derivation of the Soil Moisture Balance. In order to derive a general quantitative assessment of the water balance, and thus the growing period, two assumptions were made, one, that the growing period occurs when rainfall exceeds half (0.5) PET, and two, that maximum useful soil moisture storage equals 100 mm water.

Thus, see figure 55, rainfall exceeds half PET at Baidoa, on average, on 30th March, which thus marks the start of the Gu growing season, and again on 29th September for the Der season. When rainfall exceeds PET, then the humid period begins. In this time, not only is there adequate moisture for crop growth, but there is surplus which is added to soil moisture. For Baidoa, the relevant dates are 10th April and 5th October. As the rainfall decreases, so it falls below PET, thus marking the end of the humid period, which for Baidoa occurs on 11th May and 31st October, and again below 0.5 PET, marking the end of the rains or rainy season. However, the growing season continues as long as soil moisture is available to the plants. Depletion of this soil moisture begins as soon as rainfall falls below PET, thus, if there is only a little soil moisture stored, then the end of the rainy season is also the end of the growing season. If there is enough soil moisture, then the growing season (when the plant utilises soil moisture) extends beyond the end of the rainy season. This does not, according to FAO happen in Somalia. Everywhere, any soil moisture stored during the humid period is used up by the end of the rainy season.

As well as Baidoa, we have shown three other stations. At Hargeisa, rainfall never reaches 0.5 PET, thus no growing season exists at this station. This rather demonstrates the generality of the approach. For particular crops, the crop coefficient varies throughout the season, beginning, possibly, around 0.3 or 0.4, which would indicate that there are first planting conditions. However, the figure does illustrate why water conservation and concentration techniques, such as planting in Wadis (ephemeral river beds), and water retention bunds, are practiced in the north-west.



FAO GROWING SEASONS

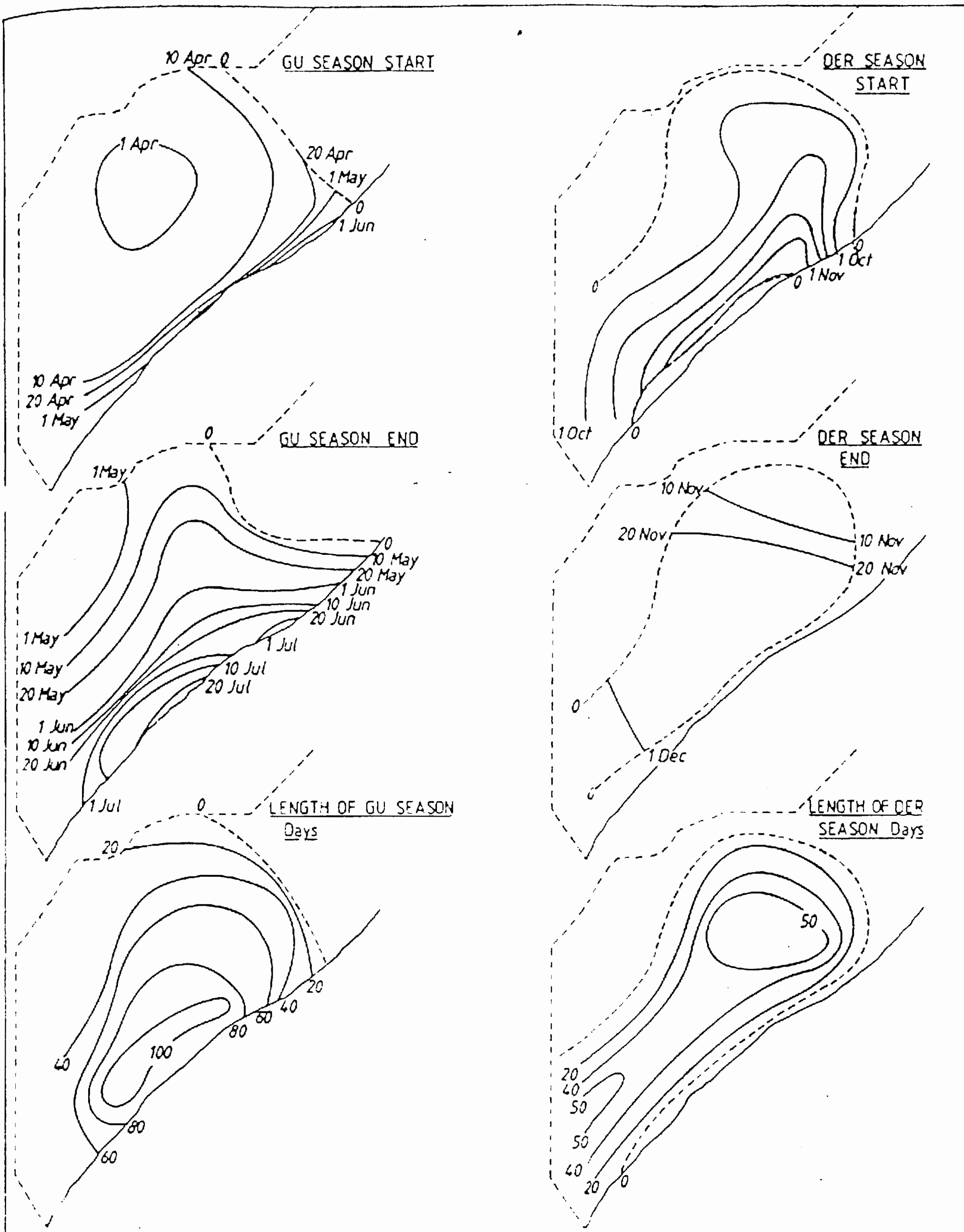
Fig 55

In the case of Galcaio, than the same situation applies, in that rainfall does not exceed 0.5 PET at any time of the year, but with the additional burden that the rainfall seasons (as distinct from the FAO 'rainy' season) are so much shorter. Thus sedentary agriculture, as known in the wetter parts of the country, is very limited in the Central Regions.

For Mogadishu (though not an agricultural area), FAO compute (using monthly values) only one growing season of 32 days, though using ten-day mean values, rainfall and 0.5 PET are almost the same for a period from the middle /end of April to the beginning of July.

Growing seasons. Using the data from all 18 stations provided by FAO, the figure 56 has been drawn up. The most important result is that no growing season, in the sense used by FAO, exists north of about 5°N.

Gu season. The growing season first starts in the Bay Region round Baidoa on the 30th March. Thereafter it spreads very quickly to other southern areas by the 10th April, with the exception of the coastal strip, Afgoi, Balad and northeastern parts of Hiran. By the 20th April, only the coastal strip has not been reached, and this area has to wait till the start of May, or even late May in Mogadishu for successful start. This accords well with the movement of the ITF and the distribution of rainfall described in chapters 1 and 2, which shows early rains in the Bay Region and a late start to the rains on the coastal strip.



START, END AND LENGTH OF GROWING SEASONS BY FAO METHOD

Fig.56

P.H.

The season ends first in Bakool at the end of April, with, inland, the end occuring in May, finally clearing Jowhar on 30th May. At the coast, however, and for a distance of 50-100 km inland, the end is delayed through June until the middle of July at some areas, such as round Jilib in a strip both eastwards to Genale and Afgoi.

As a result of these effects, the season is longest, at 100 days or slightly more along a belt from Jilib to Genale and Afgoi, but excluding the immediate coastal strip. The length of the season falls off in all directions, with most of the Bay Region experiencing 60 days or more. The important agricultural area of the Middle and Lower Juba experiences 80-100 days, but Gedo, Bakool and most of Hiran have 20 days or less.

Der Season. The Der season starts very late in September (Baidoa) and early October, or not at all, as in Bakool and the coastal strip.

The season ends in November or early December, the data being well correlated with the southwards movement of the ITCZ. Thus the northern parts of the south (Hiran, Gedo) see an end in early November, with Middle Shabelle and Bay Regions ending around 20 November. Lower Juba and the Jilib area, however, remain in season until the end of November or start of December.

As a result, the season is longest in Bay Region (east) and Jowhar, at 50 days or more, falling off in all directions, except to the southwest, where in Lower Juba and Jilib area the season is as long. Afmadu has a season of 56 days, the same as Jowhar.

Start and End of the Rains.

The FAO Agroecological zones project was concerned with average conditions, though the method can be applied to individual seasons. There is usefulness, however, inlooking at the year to year variation in the length and timing (particularly the start) of the seasons. A suitable approach to this task is that of Dale and Stern (1984), which identifies the start of the rains, the end of the rains, and thus the length of the season by specific rainfall and soil moisture criteria. Note that in this case, it is the rainy season which is being derived, not the growing season, although the criteria used may be chosen to provide the facility that the rainy season and the growing season are identical. A variety of criteria for the start and end are available. Firstly a time limit can be chosen, so that any rain before a specific date is discarded, i.e. to ignore pre-season rain. Then the start is chosen on the day when the subsequent so many days provide such an amount of rain, i.e. the day such that the following 10 days yield 20 mm rain. This could be the criterion for the start of the season. It is possible to guard against a false start by specifying that no dry spell of such a length occurs in the next so many days, e.g. no dry spell of length 10 days in the next 30 days. If such a dry spell occurs, then the start is a false start and is rejected.

After some experiementation, we provide here for Baidoa, as an example, the start with the following definition:

> "First day from dry 61 (April 1) with more
> than 20 mm over 10 days, with no dry spell
> of 10 days or more in the next 30 days".

Similar criteria can be used for the end of the rains, with the additional facility that soil moisture content does not rise above a certain value. Thus we have chosen the end to be defined as:

> "First day from day 12 (May 1) with less than
> 10 mm over the next 10 days and with soil
> moisture remaining less than 60 mm".

Definitions for the second, 'Der' season are the same except that the season cannot start before day 260 (September 1) and cannot end before day 305 (October 15).

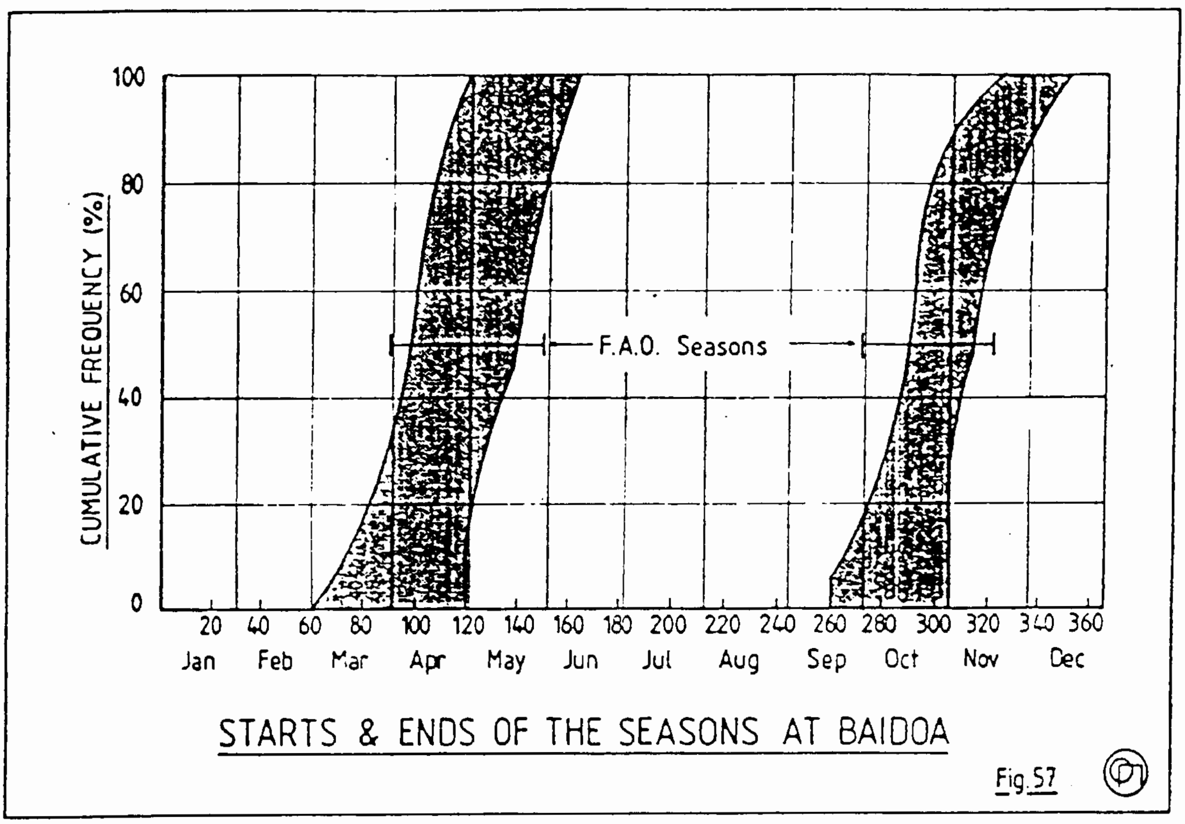
Such definitions give starts and ends for each season, thus for a long record, there is provided a distribution of starts and ends. This is illustrated in fig 57, which shows the starts and ends for Baidoa

Ignoring the seasons when no starts occured, then for example, at Baidoa, the earliest start was March 1, and the latest April 30, a spread of two months with the median occuring on April, 10. The earliest end on record is May 1 (by definition), and the latest on June 10 with the median on May 18. This gives an average season length of 42 days. Equivalent figures for the Der season are:

Start,	earliest,	day 260	(September 15) (by definition)
	latest,	day 324	(November 20)
	median	day 288	(October 18)

End,	earliest	day 305	(October 31) (by definition)
	latest	day 351	(December 16)
	median	day 314	(November 19)

The median lengths for the two seasons are 42 days and 25 days respectively. These figures are comparable to the humid period of the FAO system, at 31 and 27 days respectively for Baidoa, though there is no comparison to the FAO growing period of 60 and 55 days.



The question arises as to whether there is any relationship between the start, end and length of season, and even the inter-season dry period. Unfortunately no useful correlation is apparent, (see table yy). Although correlations do exist, they can not be used in any predictive capacity. Thus though the length of the Gu is highly correlated with the start of the Gu, the end of the Gu is not, thus the correlation indicates that the later the start, the shorter the season but with the finish estimated only as the mean end.

Start of the Gu	1.000						
End of the Gu	-0.143	1.000					
Length of the Gu	-0.931	0.490	1.000				
Length of Hagai	0.090	-0.702	-0.338	1.000			
Start of the Der	-0.017	0.011	0.931	0.704	1.000		
End of the Der	0.161	0.219	-0.060	-0.702	-0.198	1.000	
Length of the Der	0.115	0.134	-0.051	-0.647	-0.775	0.773	1.000

Table 30. CORRELATION ON START, END AND LENGTH OF THE SEASONS

3. CROP POTENTIAL AND POSSIBLE YIELDS.

In this section we consider what are the maximum yields, under ideal farming conditions, possible under the existing climatic environment, based on theoretical and practical considerations. We then examine how the existing rainfall regime would reduce these maximum possible yields, and compare these results with actual or assumed production. (See Textnote 6).

Crop Potential.

According to FAO (Doorenbos and Kassan, 1979), "the upper limit of crop production is set by the climatic conditions and the genetic potential of the crop".

It is interesting to identify what the upper limit of crop production would be, and how it varies over Somalia, not because this limit could be reached, but to indicate by how much actuality falls short of this upper limit, thus indicating the best possible choices for methods of increasing production, including the use of irrigation.

Measured Maximum Yields. One approach to identifying maximum possible yields is obtain data from elsewhere in the world where the crops are grown, giving the best yields which have been obtained. The same reference gives, for semi-arid and arid tropics the following; Maize, 6-8 t/ha; sorghum 3.5-5 t/ha; Groundnut 3-4 t/ha. These figures represent yield under the best conditions, including the provision of optimum amounts of water, and could only be achieved in Somalia under irrigated conditions.

Calculated Maximum Yields. Another approach is based on physical and biological relationships, firstly to produce a theoretical maximum independent of the actual crop, thereafter tailoring the relationships to particular crops and conditions. Several methods are available to do this, but we include here only one, that of FAO Agro-ecological Zones Project.

The calculation of the maximum "dry matter production of a standard crop" is based on a method of de Witt (1965), which relates dry matter production (de Witt uses the word 'production' here in the sense that we are using the word 'yield') to radiation falling on the crop, according to the equation:

$$Y_o = F \cdot y_o + (1-F)\, y_c$$

Where;

Y_o is the production.
F is the cloudinesss as a fraction.
y_o is the dry matter production on cloudy days (from tables).
y_c is the dry matter production on clear days. (from tables).

As well as cloudiness, Yo depends on latitude and month. Table 31 shows the calculations for some stations. Evidently Yo varies very little over the country and over the year, everywhere the values falling between little under 300 Kg/ha/day to a little over 400. This production really is a measure of the solar radiation which is available to the plant for conversion into dry matter. The factors Yo and Ye represent the highest possible biomass production.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Afgoi	352	370	344	317	324	311	298	321	339	337	325	330
Alessandra	369	384	379	347	333	328	328	343	364	357	347	349
Baidoa	355	375	353	308	304	308	282	303	315	293	298	328
Balad	360	402	403	338	326	323	349	363	375	345	305	347
Bardera	369	369	354	314	297	297	291	309	324	313	315	337
Belet Uen	346	361	351	326	324	341	322	345	345	329	312	333
Bosaso	327	351	385	394	384	384	379	383	386	370	337	323
C. Guardafui	286	335	375	409	404	402	392	396	406	368	312	284
El Bur	337	361	356	336	334	328	317	330	342	322	322	326
Faro Dante	322	361	395	396	374	404	389	401	391	396	353	330
Galcaio	353	365	358	338	334	341	322	335	348	324	334	331
Genale	369	379	377	352	331	327	311	338	354	342	359	352
Hargeisa	325	337	295	348	338	353	348	347	346	356	333	315
Kismayo	322	340	339	322	312	297	301	319	329	332	325	318
Lugh	367	392	375	343	349	346	327	342	363	331	326	349
Mogadishu	347	360	357	332	317	295	296	319	342	345	332	337
Qardo	340	375	388	363	351	388	366	383	374	351	346	330

Table 31. REFERENCE PRODUCTION (YIELD) KG/HA/DAY

This reference yield is then subjected to corrections for effect of climate, crop species, temperature length of growing period and harvest index, (harvested fraction).

The effect of climate is said to be reflected in the potential evapotranspiration, and saturation deficit, actually as a ratio of the two. (Bierhuizen and Slatyer, 1965). This ratio turns out to lie between 0.26 (Lugh in February) and 0.77 (Mogadishu in January and August). In general Mogadishu has the highest, because of the low saturation deficit while Lugh has the lowest.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Afgoi	180	211	196	165	191	215	200	231	197	189	143	149
Alessandra	137	138	152	118	130	121	138	144	153	143	135	133
Baidoa	163	165	155	163	152	197	175	179	157	179	197	187
Balad	108	121	109	196	173	107	147	145	146	110	159	139
Bardera	140	114	110	104	151	128	131	142	136	[illegible]	139	135
Belet Uen	[illegible]	123	173	104	133	147	155	173	[illegible]	[illegible]	115	[illegible]
Galcaio	145	[illegible]	129	101	127	130	135	141	143	130	140	136
Genale	207	190	196	183	218	199	199	220	216	202	212	215
Kismayo	138	136	142	109	119	119	129	140	138	136	120	121
Lugh	121	102	101	110	129	131	128	133	123	109	104	105
Mogadishu	267	230	236	193	212	198	210	246	280	214	216	222

Table 32. METEOROLOGICAL FACTORS (YIELD) KG/HA/DAY

Combining the previous result with the effect of climate gives an index for the growth potential of an area according to its climate (solar radiation, potential evapotranspiration and saturation deficit) and assuming an adequate supply of water. Thus it is a kind of irrigated potential index. Unfortunately the data is not available for all stations, but in Table 32 are given the available values, in Kg/ha/day. These values range between 101 (Galcaio in April and Lugh in March) and 280 (Mogadishu in September).

To bring the matter closer to reality, it is then necessary to correct for various crop factors. The first of these is the effect of temperature, since specified crops are adapted to particular range of temperature. For the range of temperatures experienced in Somali, the correction for temperature to 0.6 for both maize and sorghum.

It is also necessary to correct for crop species (k). For maize this is 1.9 and sorghum 1.6.

Then there is the correction for the harvested part, in the case of maize and sorghum, the weight of grain as a fraction of total weight. For maize the factor is 0.4 and for sorghum 0.35.

Finally, there is a correction for the length of the growing season. This must be matched, of course, with the locality, the actual crop, and the time of the year when planted.

			Gu Season		Der Season	
		Crop	Duration Days	Production Tons	Duration Days	Production Tons
Afgoi	a)	Maize	110	10.8	110	8.4
	b)	Sorghum	100	6.7	100	5.3
Alessandra	a)	Maize	110	6.5	110	6.9
	b)	Sorghum	-	-	-	-
Baidoa	a)	Maize	-	-	-	-
	b)	Sorghum	100	5.9	100	6.2
Balad	a)	Maize	110	8.3	110	6.7
	b)	Sorghum	100	5.1	100	4.6
Bardera	a)	Maize	-	-	-	-
	b)	Sorghum	100	4.5	100	4.8
Belet Uen	a)	Maize	-	-	-	-
	b)	Sorghum	90	4.4	-	-
Galcaio	a)	Maize	-	-	-	-
	b)	Sorghum	90	4.3	-	-
Genale	a)	Maize	110	10.2	110	10.6
	b)	Sorghum	100	6.9	100	7.1
Kismayo	a)	Maize	110	5.5	110	[illegible]
	b)	Sorghum	-	-	-	-
Lugh	a)	Maize	110	6.4	110	5.6
	b)	Sorghum	100	4.3	100	3.7
Mogadishu	a)	Maize	110	11.3	110	11.7
	b)	Sorghum	100	6.9	100	7.7

Table 33. MAXIMUM POSSIBLE YIELD (Tons/Season)

The resulting calculation provides, for the season, locality and crop, a yield, which is the maximum possible, provided that there is adequate water, and provided that the agronomic factors are perfect - good soil, correct fertilizers, suitable cultivation, and absence of pests and diseases. All these are never achieved in reality, therefore the calculated yields are above any possible achievement. However, they are useful as comparative figures -comparing areas and crops, to assist in the planning of new developments, especially irrigation, as well as for setting targets for existing systems.

The results of our calculations are shown in table 33. It appears that the highest yields are possible round Mogadishu at over 11 tons/ha, for maize, compared with the 6-8 tons/ha quoted above. Afgoi and Genale are other potential high yielding areas. This is a result of the high humidity at these stations near the coast, with consequent low saturation deficit. At the other end of the scale, then low yielding areas provide figures of just over 4 tons/ha. For sorghum the figures are proportionately lower, though with the same pattern.

In the next section, the effect of water shortage on these theoretical yields is discussed, and it will be seen that the calculated yields approach nearer to reality and do provide some sort of realistic target for the efficient farmer.

Yield Response to Rainfall.

In the previous section we discussed the maximum possible yield according to crop and location, assuming water supply was optimum. In rainfed areas, the yield would be reduced according to any moisture shortage which the crop experiences. Methods are available for estimating yield of crops based on rainfall and other meteorological variables. Most such methods are based, in some form or other, on the water balance. One method, which includes response to inadequate water supply is that of Doorenbos and Kassam (1979).

In this method, as with the Frere and Popov, predicted yield is reduced from a theoretical maximum, according to the shortage of water. The advantage of the Doorenbos and Kassam method is that the rate of reduction varies according to the stage of development of the crop.

The basic equation is:

$$\left(1 - \frac{Ya}{Ym}\right) = ky\left(1 - \frac{ETa}{ETm}\right)$$

Where;

Ya is actual yield.
Ym is theoretical maximum yield.
ky is yield reduction factor.
ETa is actual evapotranspiration.
ETm is the crop required evapotranspiration.

Actual evapotranspiration is the rainfall plus any soil moisture storage, up to the crop required evapotranspiration, which is the potential evapotranspiration multiplied by the crop coefficient Kc.

The equation can be applied to the growing season as a whole, or to the various growing periods, usually taken as, (for maize and sorghum):

0 Establishment, from planting to head initiation.
1 Vegetative, from head initiation to head emergence.
2 Flowering, from head emergence to seed set.
3 Yield Formation, from seed set to physiological maturity.
4 Ripening, from physiological maturity to harvest.

Method of Calculation. To estimate yield, five steps are necessary.

Step 1. Determine to maximum possible yield of the variety, (Ym) based on the climate, assuming adequate water supply and assuming no limitations due cultural practices. It is possible to do this by a few methods, outlined in Doorenbos and Kassam, but we have taken the figures provided by the Agronomical Section of the FEWS Project.

Step 2. Calculate the maximum evapotranspiration (ETm) (Col.7) when crop water requirements are fully met. This calculation is potential evapotranspiration (PET) (Col.6) multiplied by the crop coefficient (Kc) (Col.4). Potential Evapotranspiration may be taken from direct measurement, or calculated indirectly from the Penman or other formula. We have taken the FAO data directly (see previous chapter). The Crop Coefficient represents the fraction of potential evapotranspiration which the crop requires, at the various stages of growth. The values of the coefficient are based on concensus over many years of experimentation and estimation, and, for maize and sorghum are shown in table 34.

Step 3. Determine the actual crop evapotranspiration (actual water use). This is concerned with the availability of water in the soil. In areas which are generally short of water, such as Somalia, it is assumed that all rainfall goes into the soil, and the crop takes what it requires, up to what is available. If any surplus exists at the end of a ten day period, then it may be used in the next ten day period. (Col.5 + soil storage).

Step 4. Resolve the equation, either on a seasonal basis, or by each growing period. In each case a yield response factor (Kg.) (Col.9) is chosen for the season or each growing period, allowing the equation to be solved.

Results for Sorghum. We have taken four stations for sorghum, all in the main sorghum regions of Bay and Hiran. Baidoa, the heart of the region is well suited to sorghum growing, with, on average, no moisture deficit at any period, thus yield should be close to the maximum possible. Away from the higher rainfall area, then potential yield falls off. At Hoddur, there is no moisture deficit until stage 2; (Flowering), but because of the high water need, and sparse rainfall, only 40% of the water need is fulfilled, eventually resulting in a 29% reduction in yield for the stage. It is in stage 3; (Yield Formation), however, where most yield is lost, since only 10% of the water need can be met, resulting in a 59% reduction in yield. The final yield at Hoddur is thus only 34% of possible. This pattern is repeated at Bardera, where there is a slight deficit even at stage 1; (Vegetative), and Belet Uen, where the eventual yields are as low as 31%(3.6 t/ha) and 37%(1.6 t/ha) respectively of the maximum possible.

There is also some sorghum grown in the northwest, where, although rainfall is reasonable, potential evapotranspiration is very high, due to the strong winds and low vapour pressure. There is a water deficit here throughout the season, with yield reductions at every stage of growth, with the result that the final yield estimate is only 26% of the maximum possible.

Results for Maize. We have chosen three stations in the main maize growing belt, Afgoi, Genale and Alessandra. In these places, the crops get off to a reasonable start, except for some slight difficulty during stage 2;(Vegetative) at Genale, but the exceptionally high crop response coefficient of 1.5. for stage 3;(Flowering), means that the moisture deficit at this stage is very important in terms of lost yield. Maize is very sensitive to moisture shortage during flowering. Only Alessandra escapes a serious reduction in yield; Afgoi loses a massive 78% and Genale 55%. Further losses occur at all three stations in the remaining 2 stages, with the final yield estimates being 15%(1.6 t/ha), 37%(3.8 t/ha) and 54%(3.6 t/ha) at Afgoi, Genale and Alessandra respectively.

At Hargeisa, where longer duration maize is grown the situation is worse. The crops suffer a complete failure due to shortage of moisture during flowering.

In practice, of course, the situation is not as gloomy. In Middle and Lower Shabelle, then irrigation of maize is widely practiced, while in the northwest, water conservation and concentration techniques, such as bunding or planting in wadis is common. This method of calculation demonstrates why.

The above method of estimation is based on theoretical considerations, and assumes optimum input of fertilisers, good soil, good farming practices and perfect crop protection. The differences between the estimations and the figures presented below are a measure of the effect of the less than perfect conditions and practices, and indicate the gap which may go some way to being filled by improvements in farming practices.

(1) Crop Stage	(2) Days	(3) Decades	(4) Kc	(5) Rainfall	(6) PET	(7) ETm	(8) 1-ETa/ETm	(9) Ky	(10) 1-Ya/Ym	(11) Ya/Ym
0 Establishment	20	Apr 1,2	0.4	85.7	96	38	0	-	0	1
1 Vegetative	20	Apr 3,May 1	0.7	126.5	91	64	0	0.2	0	1
2 Flowering	15	May 2,3	1.1	55.1	65	72	0	0.55	0	1
3 Yield Formation	35	Jun 1,2,3	0.8	36.1	138	110	0	0.45	0	1
4 Ripening	10	Jul 1	0.5	5.2	38	19	0	0.2	0	1
	100		BAIDOA		SORGHUM			Reduction to:		100%

Table 34(a). YIELD REDUCTION DUE TO WATER SHORTAGE

(1) Crop Stage	(2) Days	(3) Decades	(4) Kc	(5) Rainfall	(6) PET	(7) ETm	(8) 1-ETa/ETm	(9) Ky	(10) 1-Ya/Ym	(11) Ya/Ym
0 Establishment	20	Apr 1,2	0.4	68.4	125	50	0	-	0	1
1 Vegetative	20	Apr 3,May 1	0.7	67.9	114	80	0	0.2	0	1
2 Flowering	15	May 2,3	1.1	32.4	76	84	0.53	0.55	0.29	0.71
3 Yield Formation	35	Jun 1,2,3	0.8	15.2	191	153	0.90	0.45	0.41	0.59
4 Ripening	10	Jul 1	0.5	0.8	49	25	0.97	0.2	0.19	0.81
	100		HODDUR		SORGHUM			Reduction to:		34%

Table 34(b). YIELD REDUCTION DUE TO WATER SHORTAGE

(1) Crop Stage	(2) Days	(3) Decades	(4) Kc	(5) Rainfall	(6) PET	(7) ETm	(8) 1-ETa/ETm	(9) Ky	(10) 1-Ya/Ym	(11) Ya/Ym
0 Establishment	20	Apr 1,2	0.4	59.7	106	42	0	-	-	1
1 Vegetative	20	Apr 3,May 1	0.7	56.1	106	74	0.01	0.2	0	1
2 Flowering	15	May 2,3	1.1	26.2	81	89	0.71	0.55	0.39	0.61
3 Yield Formation	35	Jun 1,2,3	0.8	21.4	192	154	0.86	0.45	0.39	0.61
4 Ripening	10	Jul 1	0.5	6.1	56	28	0.78	0.2	0.16	0.84
	100		BARDERA		SORGHUM			Reduction to:		31%

Table 34(c). YIELD REDUCTION DUE TO WATER SHORTAGE

(1) Crop Stage	(2) Days	(3) Decades	(4) Kc	(5) Rainfall	(6) PET	(7) ETm	(8) 1-ETa/ETm	(9) Ky	(10) 1-Ya/Ym	(11) Ya/Ym
0 Establishment	20	Apr 1,2	0.4	44.4	99	40	0	-	0	1
1 Vegetative	20	Apr 3,May 1	0.7	68.7	97	68	0	0.2	0	1
2 Flowering	15	May 2,3	1.1	36.7	71	78	0.45	0.55	0.25	0.75
3 Yield Formation	35	Jun 1,2,3	0.8	20.8	174	139	0.85	0.45	0.38	0.62
4 Ripening	10	Jul 1	0.5	0.2	50	25	0.99	0.2	0.20	0.80

	100	BELET UEN		SORGHUM				Reduction to:		37%

Table 34(d). YIELD REDUCTION DUE TO WATER SHORTAGE

(1) Crop Stage	(2) Days	(3) Decades	(4) Kc	(5) Rainfall	(6) PET	(7) ETm	(8) 1-ETa/ETm	(9) Ky	(10) 1-Ya/Ym	(11) Ya/Ym
0 Establishment	20	Apr 1,2	0.4	36.1	148	59	0	-	0	1
1 Vegetative	30	Apr3,May1,2	0.7	70.2	227	159	0.56	0.2	0.11	0.89
2 Flowering	20	May 3,Jun 1	1.1	36.1	180	198	0.81	0.55	0.45	0.55
3 Yield Formation	40	Jun2,3Jl1,2	0.8	70.3	414	331	0.83	0.45	0.38	0.62
4 Ripening	15	Jul 3,Aug 1	0.5	22.9	154	77	0.70	0.2	0.14	0.86

	125	HARGEISA		SORGHUM				Reduction to:		26%

Table 34(e). YIELD REDUCTION DUE TO WATER SHORTAGE

(1) Crop Stage	(2) Days	(3) Decades	(4) Kc	(5) Rainfall	(6) PET	(7) ETm	(8) 1-ETa/ETm	(9) Ky	(10) 1-Ya/Ym	(11) Ya/Ym
0 Establishment	20	Apr 1,2	0.4	66.4	125	50	0	-	0	1
1 Vegetative	25	Apr 3,May12	0.7	67.9	114	80	0	0.2	0	1
2 Flowering	20	May 2,3Jun1	1.1	32.4	76	84	0.53	0.55	0.29	0.71
3 Yield Formation	35	Jun1,2,3Jul	0.8	15.2	191	153	0.90	0.45	0.41	0.59
4 Ripening	10	Jul 2	0.5	0.8	49	25	0.97	0.2	0.19	0.81

	110	ALESSANDRA		MAIZE				Reduction to:		34%

Table 34(f). YIELD REDUCTION DUE TO WATER SHORTAGE

(1) Crop Stage	(2) Days	(3) Decades	(4) Kc	(5) Rainfall	(6) PET	(7) ETm	(8) 1-ETa/ETm	(9) Ky	(10) 1-Ya/Ym	(11) Ya/Ym
0 Establishment	20	Apr 1,2	0.4	59.7	106	42	0	-	0	1
1 Vegetative	25	Apr 3,May12	0.7	56.1	106	74	0.01	0.2	0	1
2 Flowering	20	May 2,3Jun1	1.1	26.2	81	89	0.71	0.55	0.39	0.61
3 Yield Formation	35	Jun123Jul1	0.8	21.4	192	88	0.86	0.45	0.39	0.61
4 Ripening	10	Jul 2	0.5	6.1	56	10	0.78	0.2	0.16	0.84

	110	AFGOI		MAIZE				Reduction to:		34%

Table 34(g). YIELD REDUCTION DUE TO WATER SHORTAGE

(1) Crop Stage	(2) Days	(3) Decades	(4) Kc	(5) Rainfall	(6) PET	(7) ETm	(8) 1-ETa/ETm	(9) Ky	(10) 1-Ya/Ym	(11) Ya/Ym
0 Establishment	20	Apr 1,2	0.4	44.4	99	40	0	-	0	1
1 Vegetative	25	Apr 3,May12	0.7	68.7	97	68	0	0.2	0	1
2 Flowering	20	May 2,3Jun1	1.1	36.7	71	78	0.45	0.55	0.25	0.75
3 Yield Formation	35	Jun123Jul1	0.8	20.8	174	139	0.85	0.45	0.38	0.62
4 Ripening	10	Jul 2	0.5	0.2	50	25	0.99	0.2	0.20	0.80

	110	GENALE		MAIZE				Reduction to:		37%

Table 34(h). YIELD REDUCTION DUE TO WATER SHORTAGE

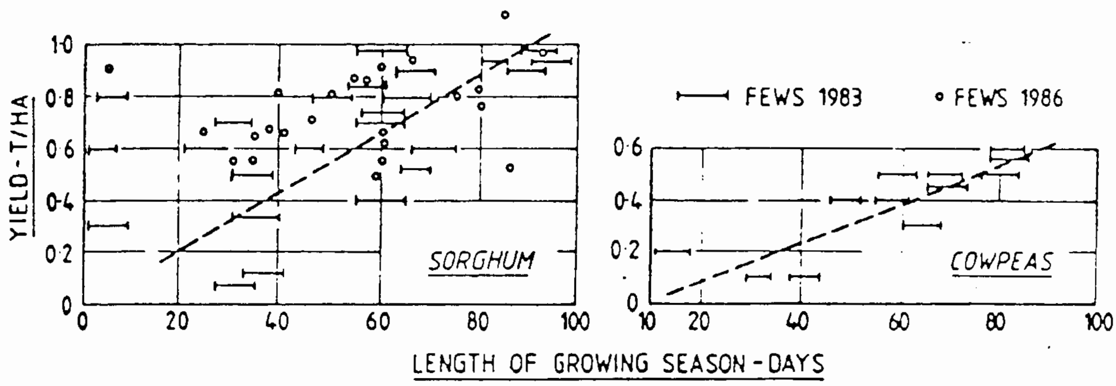
(1) Crop Stage	(2) Days	(3) Decades	(4) Kc	(5) Rainfall	(6) PET	(7) ETm	(8) 1-ETa/ETm	(9) Ky	(10) 1-Ya/Ym	(11) Ya/Ym
0 Establishment	20	Apr 1,2	0.4	36.1	148	59	0	-	0	1
1 Vegetative	30	Apr3,May1,2	0.7	70.2	227	159	0.56	0.2	0.11	0.89
2 Flowering	20	May 3,Jun 1	1.1	36.1	180	198	0.81	0.55	0.45	0.55
3 Yield Formation	40	Jun2,3Jl1,2	0.8	70.3	414	331	0.83	0.45	0.38	0.62
4 Ripening	15	Jul 3,Aug 1	0.5	22.9	154	77	0.70	0.2	0.14	0.86

	125	HARGEISA		MAIZE				Reduction to:		26%

Table 34(i). YIELD REDUCTION DUE TO WATER SHORTAGE

Actual Yields.

Table 35 is part of the suitability classification of the FAO Agroecological Project. For beans and sorghum, any area with a season less than 90 days is unsuitable, and for maize, the equivalent figure is 105 days. Thus, out of the whole of Somalia, only a small strip from Jilib to Genale provides what FAO calls "Marginally suitable" lands for these crops, with yields, no more than 30% of the maximum possible with no constraints,



YIELDS OF SORGHUM & COWPEAS

Fig 58

being at most 0.3/0.4 t/ha sorghum, 2.0/2.3 t/ha maize and 0.2/0.5 t/ha beans. These correspond to actual yields of 0.1/0.8 t/ha sorghum, 0.6/1.5 t/ha maize and 0.2/0.5 t/ha cowpeas. No comprehensive study or even measurement of crop yields has ever been done, though various projects have carried out some crop cutting trials. Thus any relationship between length of growing season and yield is rather speculative. However, fig 58 shows data from two sources (FEWS, 1983, and FEWS 1986) for sorghum and cowpeas. Apart from a few outliers, some slight association can be detected. We have not subjected such uncertain data to statistical analysis, but it appears that sorghum yield may increase by approximatly 0.1 t/ha for each 10 days increase in length of growing season, and rather less, by 0.07 t/ha for cowpeas.

Days		75-89	90-119	120-149
	a)	0.1-0.2	0.3-0.5	0.5-0.7
Sorghum	b)	7 19	27 39	40 56
	c)	¦----NS---¦	----MS---¦	----S---¦
	a)	0.5-1.2	1.9-2.7	3.7-5.4
Maize	b)	7 17	27 38	52 76
	c)	¦----NS-------	---¦-MS-¦	----S---¦
	a)	0.1-0.1	0.2-0.3	0.5-0.6
Beans	b)	10 18	28 38	56 75
	c)	¦----NS---¦	----MS---¦	----S---¦

a) Estimated crop yields

b) Percent of maximum possible

c) Suitability

NS = Not Suitable

MS = Marginally Suitable

S = Suitable

Table 35. SUITABILITY CLASSIFICATION AND YIELD IN T/HA BY LENGTHS OF GROWING PERIOD (Low input level)

Forage Production.

Drawing on a previous publication by one of the present authors (Hutchinson 1986), it is possible to relate the Climate to production of forage, which is an even increasingly important topic in view of pressures on the utilisation of rangeland. By means of the methodology used by the FAO in their study of Water Use in Irrigated Agriculture, a reference production, similar to that above is first calculated according to the formula:

$$Yo = (15.3 + 10.6 \frac{n}{N}) Ra . \frac{ETa}{ETo}$$

Where Yo = reference production in Kg/ha/day.
n = actual sunshine hours.
N = maximum possible sunshine hours.
Ra = extra-terrestrial radiation.
ETa = actual crop evapotranspiration.
ETo = reference crop evapotranspiration (Water need)

This equation is similar, but not identical to that used above. It uses similar meteorological parameters, though with sunshine hours instead of cloud amount, but with no reference to saturation deficit, but the parameters are differently arranged, and the constants are different.

We included this equation to indicate that there is no one definitive method of estimating yield, rather a selection from which a choice may intelligently be made, and applied with cautions professionalism.

But to get back to the calculation:

To convert this reference producion to predicted actual production, then a number of factors need to be included:

$$K = a . C_t . e . K_f . \frac{1}{1-m} \; 0.0305$$

Where:

a = Photosynthetic efficiency of the crop,
C_t = Correction for actual temperature against optimum temperature for maximum growth of the crop.
e = Cultural efficiency.
K_f = Fraction of plant which can be harvested.
m = Moisture percentage of harvest.
0.0305 = Conversion from Kg/ha/day to T/ha/month.

For want of better information, we have taken the following values for rangeland:

a = 0.2, since, for alfalfa a = 0.3.
c = 0.9, since it is assumed that rangeland plants will exist in near optimum temperature conditions.

e = 0.5, since, for favourable agricultural practices e = 0.7.

Kf = 0.6, taking into account roots and woody material.

m is ignored, giving dry matter directly.

Finally, we have taken ETa as monthly rainfall, and ETo as Potential Evapotranspiration, and performed calculations on a monthly basis, cumulating to give annual production, and using the FAO data.

K is thus 0.54, and the actual equation used is:

$$Ydm = \sum_{1}^{12} 0.54 \left(15.3 + 10.6 \frac{n}{N}\right) Ra. \frac{P}{PET}$$

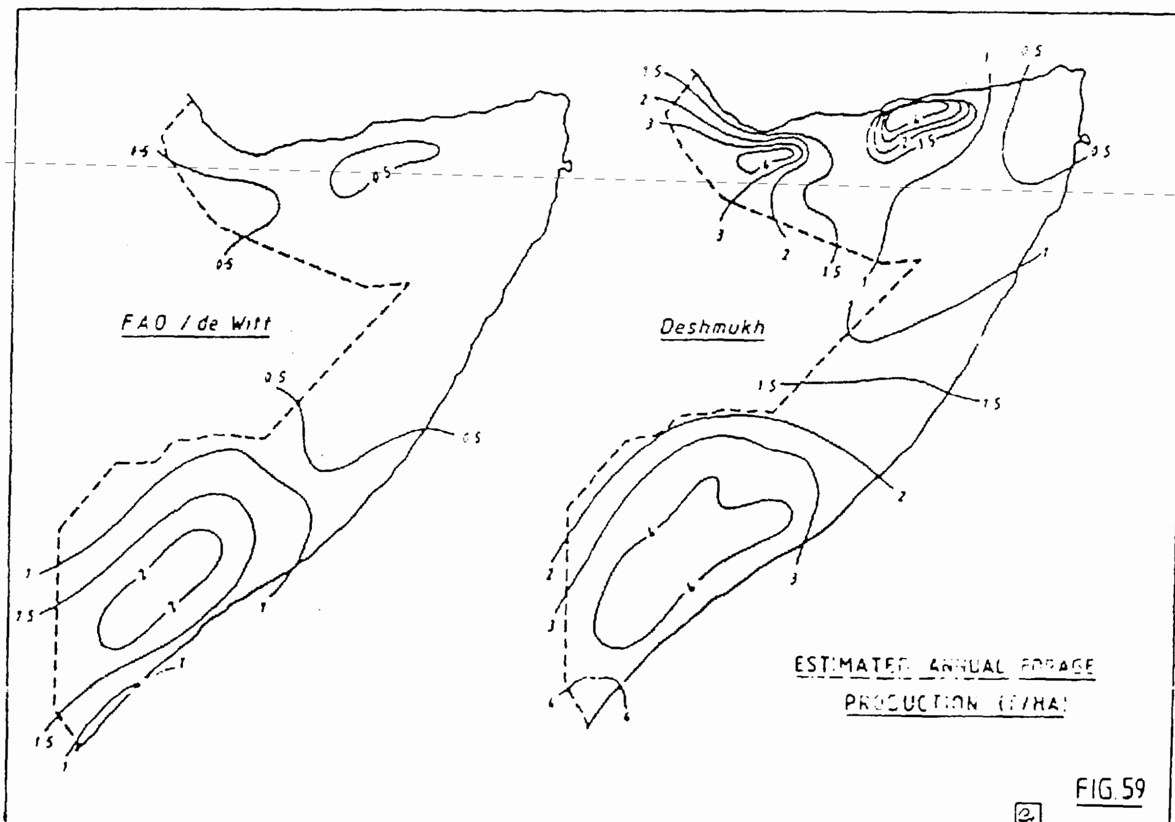
Where Ydm = annual dry matter production in t/ha

P = Monthly rainfall.

PET = Monthly potential evapotranspiration.

This equation is most effected by the ratio P/PET, since both $(15.3 + 10.6 \frac{n}{N})$ and R_a vary rather little over the country and the year.

PET varies from a monthly minimum of 98 mm (at Jonte, June) and a maximum of 413 mm (at Berbera, August) and thus has some effect, but it is the variations in rainfall which has most effect on the variations of Ydm, both in time and space.



ESTIMATED ANNUAL FORAGE PRODUCTION (T/HA)

FIG.59

The results of these calculations are shown in the figure 59. Forage production is highest in the agricultural areas of the south, reaching a maximum of 2 tons/hectare. In the traditional nomadic areas, production falls off to values of under half a ton per hectare, and to almost zero in the far northeast.

A simpler method, based on actual field measurements (and thus comparable to the figures for recorded maximum yields quoted above), is that for grasslands by Deshmukh (1984) which is derived from a number of independent trials, relating peak biomass above ground for grassland with annual rainfall. The trials were carried out by several observers in Africa, covering an area stretching from southern Africa (the Namib) to Kenya, and including sites in Tanzania and Uganda.

The equation is:

(Peak biomass (Kg/ha) = 8.488 x precipitation (mm) - 195.768.

Since biomass is directly related to the annual rainfall, then the geographical distribution also follows the map of annual rainfall (see figure 31). The predicted peak biomass biomass varies from less than 0.5 t/ha in the far north-east to over 4.0 t/ha in the two high rainfall areas of the northwest and over the Bay and Middle Juba areas, (see fig. 59). In this derivation, no account has been taken of soil and other variables, thus actual biomass production is likely to be less than the peak values shown.

Comparing the two methods, it is seen that the peak biomass method of Deshmukh produces higher values than the estimates of actual production by the de Witt method. In the south it is higher by a factor of 2, but in the north the factor increases, even up to a value of 5.

However, so many assumptions have been made here that the actual results need to be supported by field trials, results of which are not available at the time of writing.

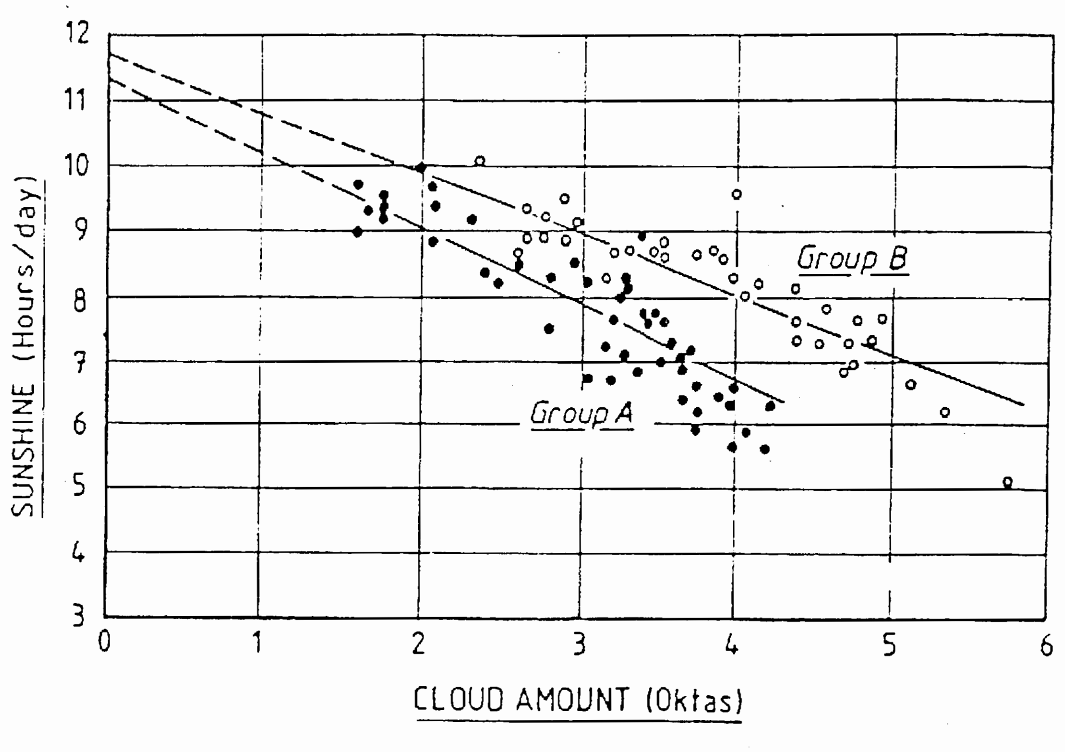
APPENDICES.

APPENDIX 1 Estimation of Sunshine Hours

Records from nine stations for duration of bright sunshine exist, while for cloud amount, there are records from 30 stations. In this analysis, seven sunshine station records are used, since one has been dropped because there is no equivalent cloudiness record and one because of its short record.

Cloud amounts are recorded in Fantoli in tenths, but these have been converted to eighths (Oktas) for this analysis.

The estimations of sunshine hours is based on linear regressions between measured sunshine hours and cloud amounts, using monthly values without reference to the time of the year. Preliminary analysis showed that there appeared to be two rather different groups of stations, with Alessandra, Genale, Jowhar and Afmadu providing one data set (A) and Baidoa, Bulo Berti and Mogadishu the other. The reason for this is not clear, except that group (B) contains the more cloudy stations, but the distinction is evident in the scattergraph.



CLOUD AMOUNT ~ SUNSHINE

Fig.60

The linear regressions fitted to these two groups of data provided the following:

	A	B
Correlation Coefficient	-0.803	-0.868

Regression Coefficients Group A

Parameter	Estimate	St.Error	t
Constant	11.38	0.41	27.73
Oktas	-1.15	0.13	-9.15

Regression Coefficients Group B

Parameter	Estimate	St.Error	t
Constant	11.62	0.34	33.8
Oktas	-0.89	0.09	-10.17

The regressions thus explain 64% and 75% of the variance of the dependent variable (Sunshine Hours).

Using the simple form of the standard error of estimate;

$$S_y = s\sqrt{1-r^2}\ ,$$ where s is the standard deviation,

gives S_y = 0.636 and 0.525 for Group (A) and Group (B). Thus any estimate of monthly sunshine from the cloud amount is likely to fall within a range of + 2 S_y, or 2.5 and 2.1, which are rather large amounts on actual values lying between 4 and 10.

Station		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Berbera	a)	2.1	1.9	1.6	1.8	1.6	1.0	1.7	1.5	1.3	1.2	1.3	1.4	1.5
	b)	8.9	9.1	9.5	9.3	9.5	10.1	9.4	9.6	9.9	9.9	9.9	9.7	9.6
Hargeisa	a)	2.3	2.7	2.4	3.5	4.0	3.4	3.6	3.6	3.4	2.3	2.3	2.5	3.0
	b)	8.7	8.2	8.6	7.3	6.7	7.4	7.2	7.2	7.5	8.7	8.7	8.4	7.8

a) is Cloud Amount in Oktas. b) is Sunshine Hours per Day

Table 36. DERIVATION OF SUNSHINE FROM CLOUD AMOUNT

However for Hargeisa and Berbera, shown in fig. 60, the Group (A) equation has been used, mainly because they experience low cloudiness. The results of these calculations are shown in table 36, and the figures appear to be reasonable, though the uncertaincy is quite high. The January estimate for Berbera, given as 8.9 could, however, with 95% probability fall within the range 7.6 to 10.2 hours per day. In addition, Statisticians may well shudder at the idea of deriving the Berbera data largely by extrapolating the relationship beyond the limits of the actual data, as may also Geographers for going beyond the geographical limits of the actual data.

APPENDIX 2 The Parameters of Atmospheric Humidity.

Meteorological observations in Somalia include those of Vapour Pressure, Dew Point and Relative Humidity.

Dew Point is the temperature when the water vapour in the air becomes saturated and therefore condenses as dew on a suitable surface.

Relative Humidity is the ratio between vapour pressure of the air and the saturated vapour pressure at the same temperature, and is usually given as a percentage. It may be thought of as the quantity of moisture the air actually contains compared to the maximum it could contain at the same temperature.

Vapour pressure (e) is the pressure exerted by the moisture in the atmosphere on a horizontal surface, in the same manner in which air also exerts a pressure on a horizontal surface e.g. the surface of the Earth. Saturated Vapour Pressure is the maximum pressure which the air can exert at any temperature when the air is saturated, i.e. contains as much vapour as it can.

Absolute Humidity (q) is defined as the mass of water vapour in $1m^3$ of air.

The relation between these two quantities, e and q can be shown as:

$$q = g \cdot \frac{1293}{1+at} \cdot \frac{e}{760}$$, where;

q is the mass of $1\ m^3$ of dry air, which exerts a pressure of 760 mb when the temperature is 0^oC.

a is the coefficient of expansion of air (0.00366)

The specific gravity (g) of a vapour related to air is 0.623, thus:

$$q = 0.623 \cdot \frac{1293}{760(1+at)} \cdot e$$

$$= \frac{1.06}{(1+at)} \cdot e$$

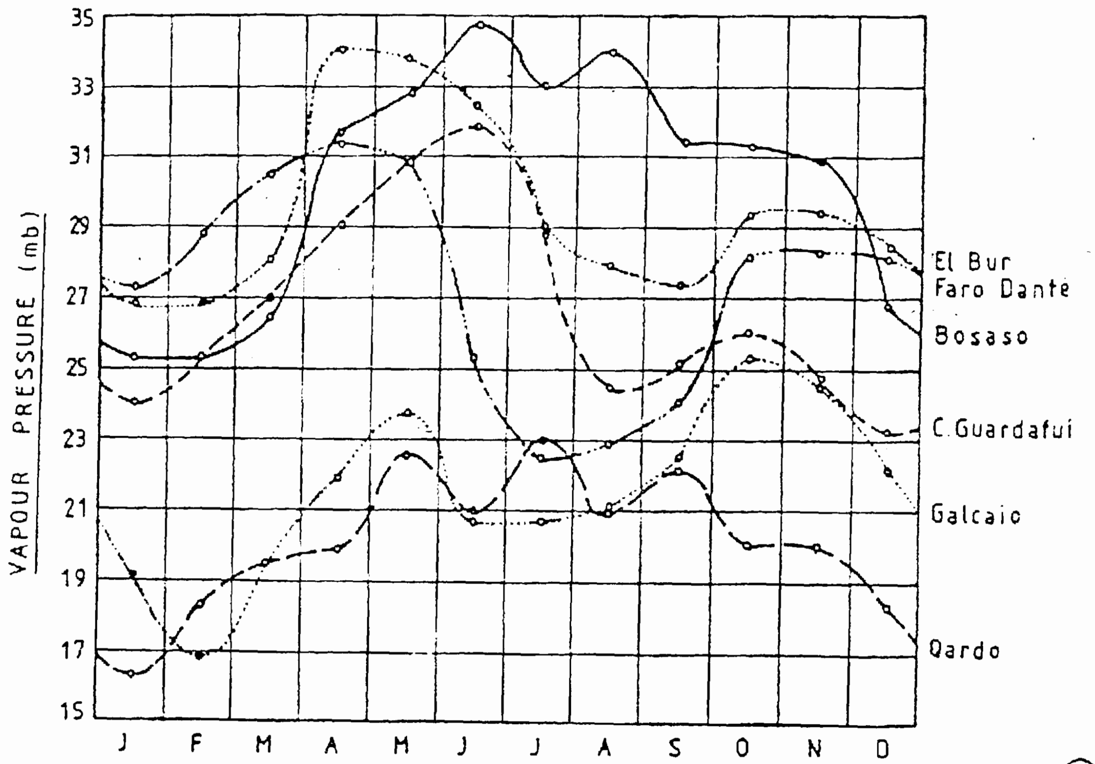
Since a is very small, then $1+at \approx 1$, therefore, approximately,

$q = e$.

Each of the various methods of describing humidity has its application, for example, relative humidity is the closest to what the human body can perceive and is the easiest to measure, whereas vapour pressure is a more useful parameter in scientific applications.

However, relative humidity is very dependent on air temperature, so that variations in actual water content of the atmosphere may be masked by variations in air temperature. For this reason, either dewpoint or vapour pressure is used more in scientific applications and weather forecasting.

Compare the tables and figures for relative humidity and dewpoint given in chapter two (Figs. 20 23 & 24) and vapour pressure (Fig. 61) shown in this appendix. In these cases, the atmospheric situation is more clearly demonstrated using vapour pressure or dewpoint, than by using relative humidity, for which fig. 23 represents a rather disorderly situation. In particular, the onset of the two wet seasons and the effect of the Karif are quite clearly demonstrated.



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MONTHLY VAPOUR PRESSURE AT FEW STATIONS

Fig. 61

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi	24.1	26.7	27.3	28.6	28.6	27.8	25.2	25.7	25.0	25.5	24.1	23.9	26.0
Alessandra	24.9	24.8	25.6	27.4	27.8	25.9	24.3	23.6	23.9	24.9	27.2	26.1	25.6
Baidoa	22.0	23.6	23.7	26.8	26.7	24.1	23.3	22.8	22.8	25.5	26.4	25.3	24.1
Balad	20.9	24.4	19.7	26.9	28.2	23.1	24.0	23.3	23.2	21.2	27.7	24.4	24.1
Bardera	22.3	22.5	24.3	27.3	27.8	24.3	22.0	22.4	23.1	27.8	27.3	25.2	24.7
Belet Uen	24.9	22.9	26.1	28.2	28.9	27.0	27.0	26.1	25.1	26.7	26.9	26.1	26.4
Bosaso	25.3	25.3	26.5	31.7	32.8	34.8	33.0	34.0	31.4	31.3	30.9	36.8	30.2
Cape Guardafui	24.0	25.2	27.0	29.0	31.8	28.8	24.5	25.2	25.7	26.0	24.7	23.1	26.3
El Bur	26.8	26.9	28.0	34.0	33.7	32.4	29.0	27.8	27.3	29.3	29.3	28.4	29.3
Faro Dante	27.2	28.8	30.5	31.3	30.8	25.3	22.5	22.9	24.0	28.0	28.2	28.0	27.3
Galcalo	19.1	16.9	19.5	21.9	23.7	20.7	20.7	21.1	22.5	25.3	24.5	?	21.5
Genale	26.7	26.9	28.8	30.1	30.1	27.2	26.1	25.5	25.9	27.4	28.4	28.0	27.6
Kismayo	28.1	28.8	31.0	31.0	30.8	28.1	27.0	27.0	26.8	27.7	29.4	29.2	28.8
Lugh Ganana	23.5	23.5	23.5	28.8	28.0	25.3	24.0	24.0	23.5	25.6	26.7	23.9	24.9
Mogadisho	27.9	27.6	28.9	30.5	29.9	28.3	26.7	26.8	28.1	28.5	28.5	28.0	28.3
Qardo	16.3	18.3	19.5	19.9	22.5	19.9	22.9	20.9	22.1	20.1	20.0	18.3	20.0

Table 37. MONTHLY VAPOUR PRESSURE (Mb.)