The environment of the Ethiopian Rift Valley compared to other areas of Africa*

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**Summary of the ILCA Internal Document `The environment of the Ethiopian Rift Valley in relation to other areas of Africa'.*

SUMMARY

THE CLIMATES, *soils and vegetation of the Ethiopian Rift Valley were compared with those of other areas of Africa with reference to the screening of forage species.*

The climates of the Rift Valley are diverse and range from hot and arid to cool (subtropical) and humid. In general most of the Ethiopian Rift Valley is similar to the semiarid and subhumid regions of East Africa with their bimodal rainfall. There is also an area in the north of the valley with a climate similar to that of the Sahel region of West Africa.

The soils of the Rift Valley are largely derived from recent volcanic rocks and, by comparison with many areas of Africa, their base status is generally good. Constraints to forage production include low phosphorus levels, micronutrient imbalances and in some cases poor physical structure. The areas with soils most similar to those of the Rift Valley of Ethiopia are the equivalent rifts in Kenya, Tanzania and Zambia.

Three major vegetation zones are found in the Rift Valley: the subhumid zone, the semi-arid zone and the arid zone.

The grass floras from 20 areas in West and East Africa, including three from the Ethiopian Rift Valley, were compared using Hartley's agrostological index. Classification based on cluster analysis of these sites showed that the semi-arid and arid areas at the northern and southern ends of the Rift Valley were closest to areas in the Sahel region of West Africa, while an area at a higher altitude in the central Rift Valley was close to an area in the Rift Valley of Kenya and to two sites in Sudan.

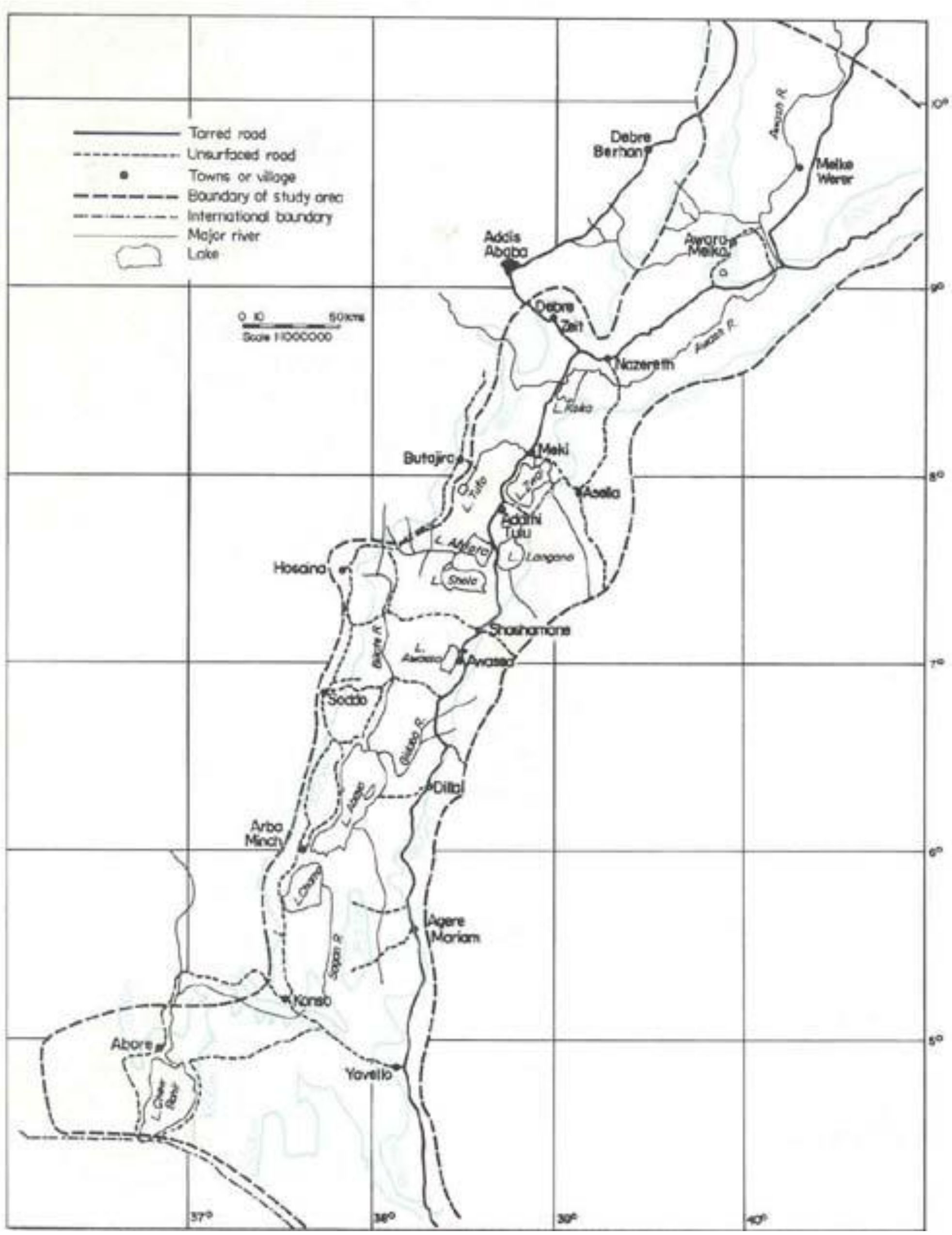
Introduction

ILCA's Forage Legume Agronomy Group aims to evaluate tropical forage and pasture species for potential use throughout Africa. Although the Ethiopian Rift Valley seems attractive as a location for such evaluation, because of its ease of access and range of climates and soils, it was first necessary to establish of which areas of Africa it is representative in terms of plant environments.

The aim of this study was to briefly review the climates, soils and vegetation of the Rift Valley and to relate these to other areas of Africa. Clearly the conclusions reached depend in part on the level of detail at which comparisons were made. For this initial assessment broad-scale comparisons were made; more detailed studies of individual regions within the Rift Valley will have to await the availability of more data.

The limits of the Rift Valley for the purposes of this study are shown in Figure 1. The limits of the study area along the escarpments of the valley correspond to the 1800 m contour. Above this altitude the vegetation is quite different from the semiarid steppe and savanna woodland communities of the Rift Valley floor, and below 1800 m frosts are of infrequent occurrence and of negligible importance in determining the nature of the vegetation.

Figure 1. *Map of the Ethiopian Rift Valley showing units of the study area and 1000 m and 1800 m contours.*



The Rift Valley of Ethiopia, like its extension in East and central Africa, was formed by extensive downfaulting of the earth's crust at the end of the Tertiary and at the beginning of the Pleistocene period. It forms part of a series of fractures in the earth's crust extending from the Dead Sea in the north, via the Red Sea and the rifts of East and central Africa, to Mozambique in the south. In Ethiopia it has a general northeast to southwest trend and extends over approximately 750 km. South of Nazareth (lat. 8°20') it takes the form of a relatively narrow corridor (35–80 km wide) demarcated by faults at the edges of both the Ethiopian and the Somalian plateau.

Since the end of the Tertiary period the Ethiopian Rift Valley has been the scene of intense volcanic activity and further minor faulting. Consequently the geological formations are almost entirely volcanic in origin and include both alkaline (basalts) and acidic (rhyolites, ignimbrites, pumices and ash) rock types.

One consequence of the volcanic origin of the bedrock of the Rift Valley is the extensive and serious erosion in certain areas. This is particularly noticeable where the soils overlie ignimbrite—rock types deposited from incandescent volcanic clouds escaping from cracks in the crust, which opened after the formation of the rift. These young volcanic rocks are generally rich in base elements but in many cases are deficient in phosphorus.

Climate

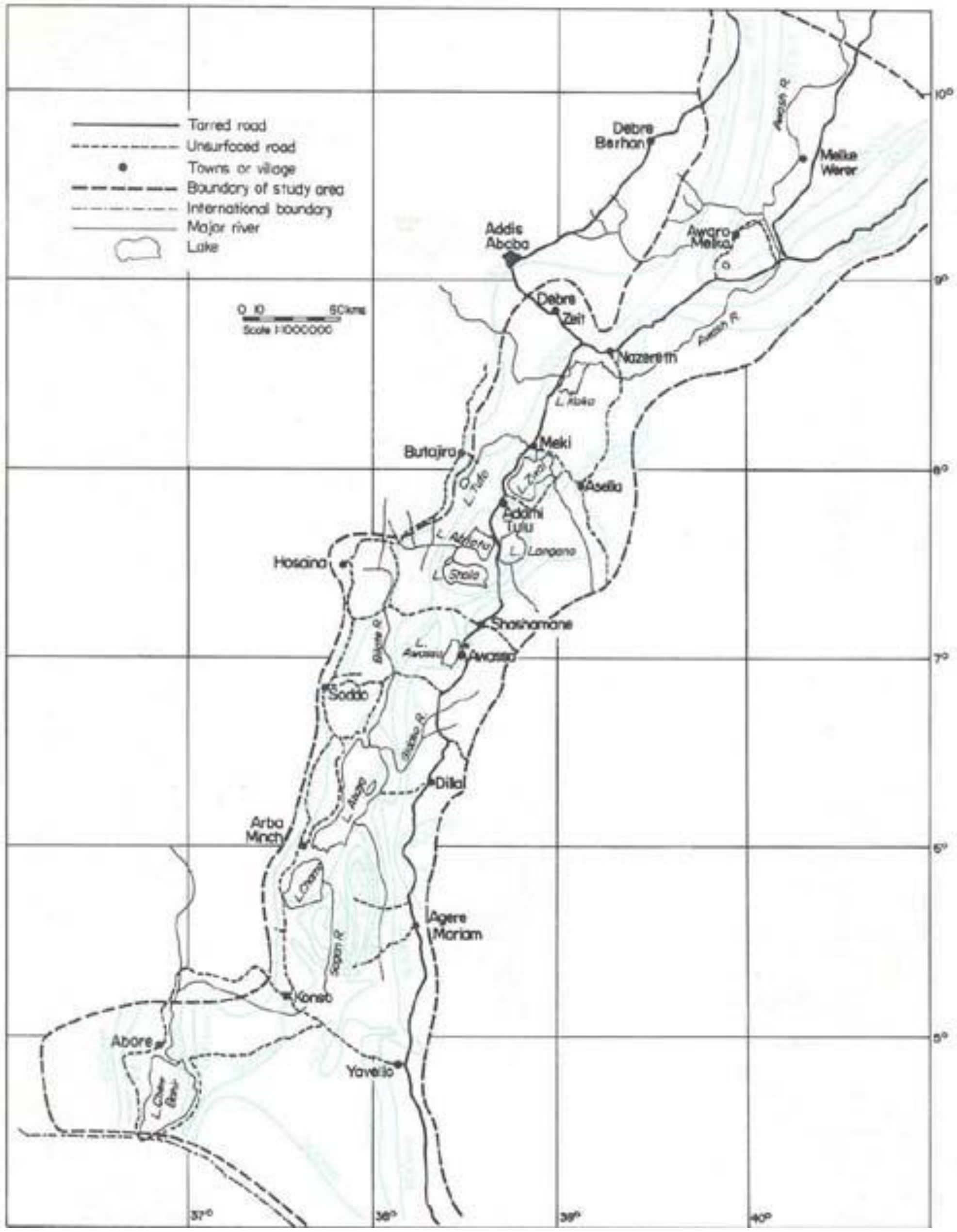
The climate of the Ethiopian Rift Valley

Rainfall

From November to February northeast winds prevail, giving settled dry weather throughout most of the valley. During this period there is little cloud, diurnal temperatures are high and relative humidities low. Between March and May more unsettled weather is experienced due to the convergence of moist southeast winds from the Indian Ocean with the northeast airstream. This brings heavy rains south of latitude 6°30' (Lake Abaya), but north of this latitude rainfall is normally light and very unreliable. From July to October the main rains come to the northern Rift Valley with the wet winds from the Indian and Atlantic oceans converging over the highlands. Intense rainfalls associated with convective thunderstorms are frequently experienced at the beginning of this period. In the southern part of the valley, however, there is little rainfall between June and August and a secondary peak in September and October. There are thus two rainfall regions within the valley.

The average annual rainfall for all stations in the Rift Valley below the 1700 m altitude is 754 mm (n = 29). All such locations can be considered to be on the floor of the valley. This estimate is probably high due to the location of most stations in the highest rainfall areas. Figure 2 shows isohyets of mean annual rainfall for the Rift Valley. These suggest that a value between 600 and 700 mm annually is a reasonable average value for most of the floor of the valley.

Figure 2. *Isohyets of mean annual rainfall in the Ethiopian Rift Valley.*



Rainfall increases with altitude along the Rift Valley escarpment to an approximate annual average of 1600 mm at the 3000 m contour. However above about 1800 m the correlation of rainfall with altitude is particularly poor due to oreographic effects.

From the viewpoint of climatic classification the area of the Rift Valley includes four zones:

1. Arid zone: median annual rainfall less than 400 mm.

2. Semi-arid zone: median annual rainfall between 400 and 700 mm.

3. Subhumid zone: median annual rainfall between 700 and 1000 mm.

4. Humid zone: median annual rainfall above 1000 mm.

Approximate estimates for the overall areas of the semi-arid and subhumid zones within the Rift Valley are 35% and 55% respectively.

Temperature

Records for temperatures from stations in the Rift Valley are even fewer and more fragmentary than those for rainfall, and to date data have been obtained for only 13 stations. These data are summarised in Table 1. There is a reasonable correlation between temperature and altitude: on average mean annual temperatures decrease by approximately 1.55°C for every 100 m increase in altitude.

Table 1. *Mean annual temperatures for some stations in the Rift Valley*.

Station	Altitude (m)	No. of years	Ann. mean (Min.°C)	Ann. mean (Max.°C)	Ann. mean (°C)
Asela	1700	10	12.7	28.4	20.6
Alaba Colito	1800	10	11.5	26.4	18.9
Awassa	1680	12	11.5	26.8	19.1
Bekewle (Conso)	1380	6	16.9	27.3	22.1
Gato	1320	3	18.6	31.1	24.9
Mega	1700	6	14.2	23.1	18.6
Melka Guba	not known	3	18.6	32.0	25.3
Miereb Abaya	1290	4	17.1	31.2	24.1
Moyale	1200	2	19.1	29.8	24.5
Neghelli	1480	20	12.7	25.7	19.2
Tertele	1460	2	16.9	26.9	21.9
Wondo Chabicha	1800	11	11.3	26.3	18.9
Yavello	1740	13	13.1	25.2	19.1

Highest monthly temperatures are normally recorded in the dry season between November and March. Lowest monthly minimum temperatures are also recorded during the dry season when night skies are clear.

The incidence of low temperatures may influence the growth of plants at altitudes above 1400 m. It is known that many tropical legumes cease to grow at temperatures between 10 and 12°C (Fitzpatrick and Nix, 1970) and that some show considerable limitation in growth at around 15°C.

Length of growing season

The Ethiopian Mapping Agency has recently published a length-of-growing-season map for the whole of Ethiopia on a 1:2 000 000 scale (EMA,1983). The length of growing season is calculated in days for which rainfall exceeds 50% of the potential evapotranspiration calculated from Penman's formula. Very approximate estimates can be made for the proportion of the total area of the Rift Valley with different lengths of growing season as follows:

< 60 days 10%

60–75 days 5%

75–90 days 5%

90–120 days 10%

120–150 days 15%

150–80 days 25%

180–210 days 20%

210–240 days 10%

It is remarkable that, according to these estimates, over 50% of the area of the valley has a growing season in excess of 150 days. The shortest growing seasons (60 days) are found at the northern and southern extremities of the valley. The longest growing seasons (over 210 days) are found around the lakes Abaya and Chamo where the eastern and western escarpments of the Rift Valley most closely approach one another.

The climates of the Rift Valley and other areas of Africa

The important climatic zones in the Rift Valley are the semi-arid zone (400–700 mm rainfall) and the subhumid zone (700–1000 mm rainfall).

Since rainfall is of overriding importance in determining plant growth, the main basis of comparison has been the annual quantity and duration of rainfall. Seasonal distribution has also been taken into account. Temperatures have been considered, but only where extreme temperatures are likely to influence the distribution of tropical or subtropical plant species.

The Sahel

The Sabel comprises a vast area of semiarid and arid land. The climatic limits of the region are normally taken to lie between the 600 mm rainfall isohyet in the south and the 100 mm isohyet in the north. The most obvious feature of rainfall in the Sahel is its restriction to a period in summer of 2 to 4 months, with little or no rainfall during the rest of the year. The actual duration of the growing season varies from an average of 120 days at the southern edge of the region to about 45 days in the north (FAO,1978).

The areas of the Rift Valley which are likely to be most similar to the Sahel would therefore have a mean annual rainfall between 100 and 600 mm, with a unimodal distribution centred sharply on July and August and mean annual temperatures between 27.5 and 29.0°C. The most similar area is the extreme northern part of the Rift Valley in the Middle Awash valley. It is not argued that this area represents an exact climatic homologue to anywhere in the Sahel region— indeed the seasonal distribution of rainfall is broader than for most areas of the Sahel. However it does appear more similar than other areas of the valley, a conclusion supported by the data on vegetation.

The northern Sudanian savanna

The Sudanian savanna is a band of tree or shrub savannas stretching across West Africa between the Sahel to the north and the zone of dense tropical forest in the south. We are concerned here only with the northern portion of the region having an annual rainfall between 650 and 1000 mm and corresponding approximately with the subhumid zone as defined above. The dry season lasts for 6 to 8 months and mean annual temperatures vary between 26.0 and 29.5°C.

Although a large part of the Ethiopian Rift Valley has rainfall between 650 and 1000 mm annually, much of this area lies in the southern portion of the valley with a bimodal distribution pattern.

Furthermore most of the areas with a subhumid climate lie at altitudes above 1300 m with average annual temperatures below 25°C and average minimum temperatures below 17.5°C. These areas are relatively cool compared to the northern Sudanian region of West Africa. However, much of the northern Rift Valley has mean temperatures for this period between 17.5 and 22.5°C. While these figures are 5 to 7°C lower than the corresponding values for the northern Sudanian zone, they are probably not limiting to the growth of many tropical legumes.

East Africa

The climate of East Africa is extremely complex. Griffiths (1972) describes 52 climatic regions for the area covering 30 different rainfall seasons. This complex pattern can be somewhat simplified by dividing the area into a part with unimodal rainfall and a part with bimodal rainfall. The region as a whole, and particularly Kenya, is also well known for the unreliability of its rainfall.

Stations in the Rift Valley of Kenya, like those in the southern Rift Valley of Ethiopia, have a bimodal rainfall distribution.

Although no temperature data are available for stations in Kenya, the relationship between temperature and altitude for the Kenyan Rift Valley should be similar to that for the Ethiopian Rift Valley. If this is the case there should be a reasonable similarity between areas at the same altitude in the Ethiopian and Kenyan portions of the Rift Valley. There are also other parts of the semi-arid and subhumid zones of East Africa, particularly in Tanzania, that may be climatically similar to the Rift Valley of Ethiopia.

Other areas

Although there are large areas of central and southern Africa that have semi-arid or subhumid climates, they differ from the Ethiopian Rift Valley in two important aspects:

1. South of approximately 7°S the rains fall between November and April, precisely the reverse of the case in Ethiopia.

2. Over much of this area low temperatures are experienced, at least for short periods, during the dry months when cold air penetrates the region from the south. Consequently night frosts can be experienced at this time of the year at altitudes as low as 1000 m.

Conclusions

The climate of much of the Ethiopian Rift Valley can be described as cool, semi-arid or subhumid with either bimodal or unimodal rainfall distribution. Only below an altitude of about 1100 m are hot conditions found. Much of the southern Ethiopian Rift Valley is climatically similar to the Rift Valley in Kenya and, possibly to that of Tanzania. There may be more general similarities between this part of the valley and other semi-arid and subhumid parts of East Africa as a whole. In the extreme north, below 1100 m, there is an area in the Middle Awash valley which shows some climatic similarities to the Sahel region of West Africa.

Soils

Soils of the Ethiopian Rift Valley

The information on soils was drawn from the maps in Makin et al (1975) and FAO (1965). Areas for major soil units within the southern Rift Valley were computed from King and Birchall (1975) and for the northern portion they were derived from planimetric measurements on the soils map of the Awash River basin in FAO (1965). The legend of the latter map was interpreted in terms of the approximate equivalent units in the FAO classification system. The FAO system of classification was used (and adapted) because it permits comparisons between the Rift Valley and other parts of Africa, based on the FAO/UNESCO Soil Map of Africa (1977).

Major soil types

Thirteen major units and a further six subunits in the FAO/UNESCO soil classification are of importance in the Rift Valley.

Table 2 shows the estimated extent of each of the major soil units within the Rift Valley and the proportion of the total area occupied by these units. For our purposes, histosols and gleysols can be ignored as being permanently flooded or waterlogged. Saline soils (solonchaks and solonetz), while used for grazing to some extent, are of sufficiently small area to be of little importance overall. The most important groupings in terms of total area covered are thus: vertisols (19.2%), cambisols (17.9%), fluvisols (16.2%), regosols (15.8%), lithosols (9.5%), andosols (7.1%) and acrisols (6.1%). All remaining soil units taken together account for less than 10% of the total area.

Table 2. *Estimated extent of FAO soil units within the Ethiopian Rift Valley and the proportion of the whole area covered by each unit.*

FAO soil unit	Total area (km^2)	% of whole area
Ferric acrisols	3 367	6.1
Chromic cambisols	3 671	6.7
Eutric cambisols	6166	11.2
Eutric fluvisols	8 529	15.2
Calcaricfluvisols	391	0.7
Histosols	200	0.4
Eutric gleysols	262	0.5
Eutric nitosols	436	0.8
Vitric andosols	3 888	7.1
Pellic vertisols	6 229	11.3
Chromic vertisols	4 330	7.9
Eutric regosols	8 669	15.8
Lithosols	5 210	9.5
Luvic xerosols	1780	3.2
Haplic xerosols	940	1.7
Orthic solonchaks	647	1.2
Orthic solonetz	253	0.4
Total	54 968	

Source: FAO (1977).

The soils of the Rift Valley and other areas of Africa

The soils of the Rift Valley of Ethiopia are quite diverse. Seventeen out of 106 FAO suborders are important in the region, a reasonable proportion for a small area in African terms. However, there are certain peculiar features of the Rift Valley soils that distinguish the valley from many other areas of the continent. Firstly, the soils are for the most part derived from young rocks of volcanic origin. The result is that many of the soils are of good nutrient status since leaching has not proceeded to a very marked degree. Approximate estimates based on the figures in Table 2 would suggest that 46% of the area has soils of excellent base status, 31 % of the area has a moderate base status while only 23% of the area has soils of poor base status. Such a high proportion of `good' soils must be relatively unusual for other African regions. Overall the most frequent limitation to plant growth in the Rift Valley is likely to be availability of water rather than soil fertility.

The other important feature of the soils of the area is the absence of certain major soil units (e.g. arenosols, luvisols and ferrasols) which are of widespread occurrence in other areas of Africa.

The total area and proportion of sub-Saharan Africa occupied by various soil units is shown in Table 3. This reveals some interesting features of these units as regards their importance in tropical Africa as a whole. Firstly, the 17 units listed together only account for 27% of the total area of tropical Africa. Secondly, if one divides the soil units into those of `high', `medium' and `low' base status one finds that `high' base status units account for 6.6% of the total area of tropical Africa, `medium' for 7.3% and `low' for 12.9% of the total area. This is exactly the reverse order to that for the Ethiopian Rift Valley. Thirdly, 11 of the 17 soil units are proportionally better represented in the Rift Valley than in sub-Saharan Africa as a whole.

Table 3. *Total area in km' and proportion of sub-Saharan Africa occupied by some soil units of importance in the Rift Valley of Ethiopia.*

FAO soil unit	Total area (km^2)	% of sub-Saharan Africa
Ferric acrisols	589 290	2.7
Chromic cambisols	226 370	1.0
Eutric cambisols	245 920	1.1
Eutric fluvisols	332 270	1.5
Calcaric fluvisols	85 790	0.4
Histosols	17 450	0.08
Eutric gleysols	237 380	1.1
Eutric nitosols	404 290	1.9
Vitric andosols	1 440	0.006
Pellic vertisols	344 810	1.6
Chromic vertisols	597 080	2.8
Eutric regosols	524 590	2.4
Lithosols	1 646 310	7.6
Luvic xerosols	17 630	0.08
Haplic xerosols	398 330	1.8
Orthic solonchaks	72 950	0.3
Orthic solonetz	93 190	0.4

Source: FAO *(1977).*

Vegetation

Vegetation of the Ethiopian Rift Valley

No complete vegetation survey exists for the Rift Valley as a whole and general descriptions are vague and concentrate almost entirely on woody vegetation. The following general description of the vegetation of the region must thus be regarded as provisional. The diversity of vegetation types in the area is however apparent.

General description

Makin et al (1975) divide the southern Rift Valley into the following four ecoclimatic zones:

Zone 1: Humid to dry-humid lands, now mostly under coffee or other intensive agricultural use; formerly forest or montane grassland.

Zone 2: Dry subhumid or semi-arid lands characterised by evergreen shrubs, Combretum or allied vegetation.

Zone 3: Semi-arid lands with relatively low or erratic rainfall, characterised by dryland acacias with some broad-leaved trees and shrubs.

Zone 4: Arid lands, mostly dry thorn bushland unsuitable for rainfed agriculture.

Zone 1 lies almost entirely above 1800 m altitude and therefore is not considered in this study. Zones 2 to 4 correspond in a very general way to the subhumid, semiarid and arid climatic zones defined above, but the exact limits of each zone in tenors of rainfall are not clearly defined.

Table 4 shows the approximate area and proportion of the southern Rift Valley occupied by each ecoclimatic zone and also the relationship of these zones to those defined by Pratt et al (1966) for East Africa.

Table 4. *Areas for the major ecoclimatic zones of the southern Rift Valley and corresponding zones in Pratt et al (1966)'s classification.*

Eco-climatic zone	Total area (km^2)	%	Pratt[a] zonal equivalent
2	11 200	34	III
3	13 760	41	IV
4	8 220	25	V & VI

[a]From Pratt et al (1966).

Zone 2 or the subhumid zone has a tree cover characterised by the presence of broad-leaved *Combretum* and *Terminalia* species. Important species include *Acacia hockii, A. abyssinica, Albizia gummifera, A. schimperiana, Combretum aculeatum, C. molle, Croton macrostachyus, Cordia abyssinica, Erythrina abyssinica, Ficus sycamores, Heeria reticulata, Terminalia brownii, T. schweinfurthii* and *Vernonia abyssinica.* At lower altitudes (1300 to 1500 m) evergreen thicket is common and is dominated by *Carissa edulis, Dodonaea viscosa, Euclea schimperi, Rhus natalensis*and *Olea africana.* The dominant grasses include *Eragrostis superba, Heteropogon contortus, Hyparrhenia hirta, H. rufa, Themeda triandra* and *Andropogon* spp*.*

Zone 3 or the semi-arid zone is characterised by the presence of acacias as the dominant species of the tree and shrub layers. Physiognomically there are vegetation types ranging from closed acacia woodland to scattered and open acacia bushland. The most common *Acacia* species are *A. brevispica, A. mellifera, A. nilotica, A. nubica, A. reficiens, A. seyal* and *A. tortilis.* They are accompanied by many broad-leaved trees and semi-evergreen shrubs such as *Acokanthera brownii, Balanites aegyptium, Cadaba farinosa, Capparis tomentosa, Commiphora africana, Croton macrostachyus, Dichrostachys cinerea, Euphorbia tirucalli, E. candelabra, Harrisonia abyssinica, Sclerocaryea birrea* and *Terminalia brownii.* Dominant grasses include *Aristida kenyensis, Chloris pycnothrix, Hyparrhenia anthistirioides, Panicum atrosanguineum* and *Pennisetum schimperi.*

Zone 4 or the arid zone, with less than 450 mm annual rainfall, is characterised by dry thorn bnshland. The common shrub species include *Acacia etbaica, A. horrida, A. mellifera, A. nilotica, A. nubica, A. reficiens, A. senegal, A. seyal,* and *A. tortilis.* Trees and shrubs commonly associated with these include *Boscia coriacea, Cadaba farinosa, C. rotundifolia, Commiphora* spp.*, Dobera glabra, Grewia* spp.*, Sansevieria ehrenbergii, Salvadora persica* and *Sterculia africana.*

The grass cover is discontinuous, with up to 60% bare ground in very dry or heavily grazed areas. In all areas other than those that are seasonally waterlogged or saline, *Chrysopogon plumulosus* is the dominant grass accounting for up to 65% of the herbaceous cover. Ephemeral annual grasses are abundant, particularly species of the genera *Aristida* and *Eragrostis.*

Vegetation of the Rift Valley and other areas of Africa

Phytogeographic relationships

According to Ibrahim (1978), Ethiopia lies within the Sudano-Zambezian phytogeographic region of Africa which comprises the largest formation of the continent and can be characterised as tropical, with an annual dry season of 4 to 9 months, annual rainfall between 300 and 1500 mm and vegetation which includes steppe, savanna and dry to subhumid woodland and forest. More specifically it comes within the Sudanian subregion with a dry tropical climate and rainfall up to 1000 mm. The highlands of Ethiopia are, of course, excluded, forming part of the Afro-montane region. At a third level of organisation Ibrahim includes Ethiopia in the Afro-Oriental domain which covers the lowlands of Tanzania, Kenya, Somalia and Ethiopia. Vegetation ranges from steppe to thorn woodland. Ibrahim sets an attitudinal limit of 1100 m for this domain but it probably extends considerably higher than this in the Ethiopian Rift Valley.

In plant geographic terms the lowlands of Ethiopia belong with the rest of East Africa, with most of Uganda excluded. However, they have more general connections throughout the Sudano-Zambezian region. In particular White (1965) suggests that the Sahel region, which can be characterised as wooded steppe with *Acacia* and *Commiphora* spp., represents a floristically impoverished western extension of the rich Afro-Oriental domain.

Of the tree species found in the Ethiopian Rift Valley, *Acacia nilotica, A. seyal, A. senegal,* and *A. sieberiana* occur throughout much of the Sudanian subregion, including the Sahel, while *A. nubica*and *A. mellifera* have an Afro-Oriental and eastern Sudanian distribution. The grass *Schoenfeldia gracilis* is a more strictly Sahelian species but is also known from the lowlands of Ethiopia (Froman and Persson, 1974). Other important grass species from the

Ethiopian Rift Valley which have a general Sudano-Zambezian distribution pattern include, *Andropogon gayanus, Aristida* spp*., Bothriochloa insculpta, Cenchrus ciliaris, Chloris gayana, C. pycnothrix, Cymbopogon giganteus, Eragrostis cylindrifiora, Hyparrhenia filipendula, H. rufa, Imperata cylindrica, Panicum maximum, Pennisetum ramosum, Setarui sphacelata, Sporobolus pyramidalis* and many others (Wickens, 1976).

Application of Hartley's agrostological index

Hartley (1963) has devised a technique for comparing grass floras on the basis of the proportion of different tribes of grasses in the flora of a given area. Using a previous analysis of the climatic relationships of some of the more important tribes of tropical grasses, he was able to show that the proportions of these tribes within the flora of a given area provided a reasonable indication of the prevailing environmental conditions.

The first step in using this analysis to compare Ethiopian and other grass floras was to try to quantify the relationship between the proportion of different grass tribes in the floras considered with climatic factors. This was possible for annual rainfall even though in some cases the figures used were taken from rather vague references or, in the cases of some of the larger areas, were the mean figure from a wide range.

Figures 3 and 4 show the relationship between mean annual rainfall and the proportion of different grass tribes in the floras of 15 localities in West Africa, Sudan and Ethiopia. It can be seen that there is a good positive correlation ($r = 0.88$) between annual rainfall and percent Andropogoneae in a grass flora, while Aristideae show a good negative correlation ($r = –0.81$) with rainfall. The proportion of Eragrostideae is negatively correlated with rainfall but the correlation is poor ($r = –0.64$), while the proportion of Paniceae does not appear to be correlated with rainfall at all. It should be noted that the majority of observations were from the semi-arid and arid zones and that the relationships determined here do not necessarily extend to wetter climatic zones.

Figure 3. *Relationship between rainfall and proportion of (A)* Andropogoneae *and (B)* Aristideae *in different grass floras.*

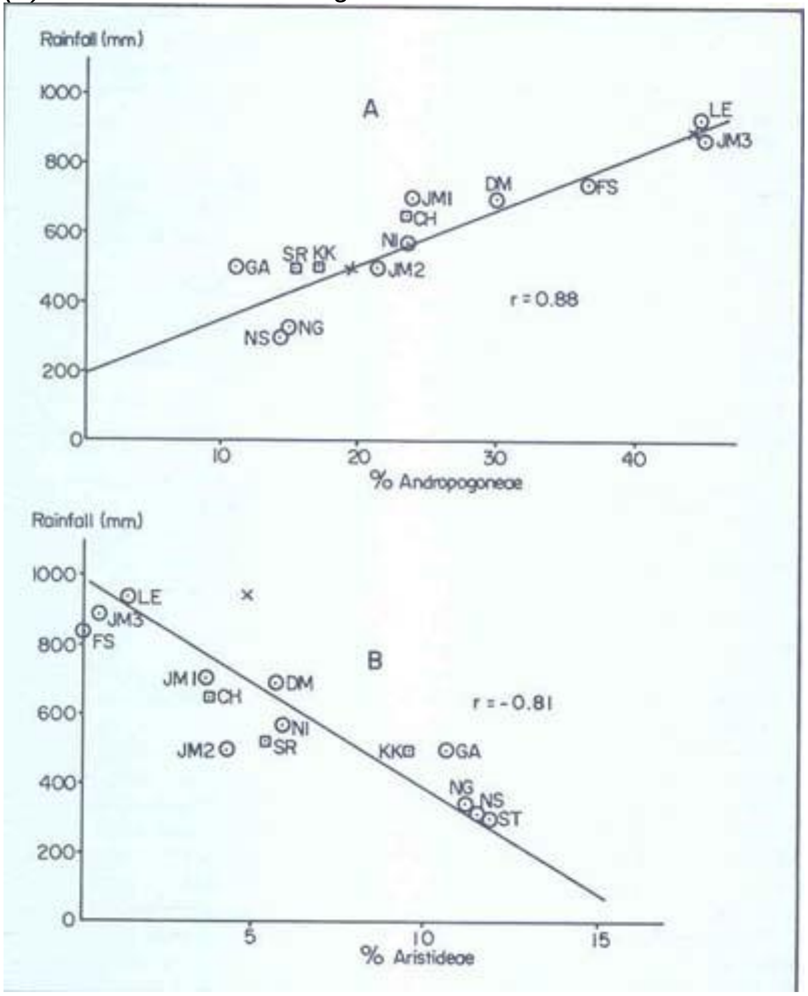
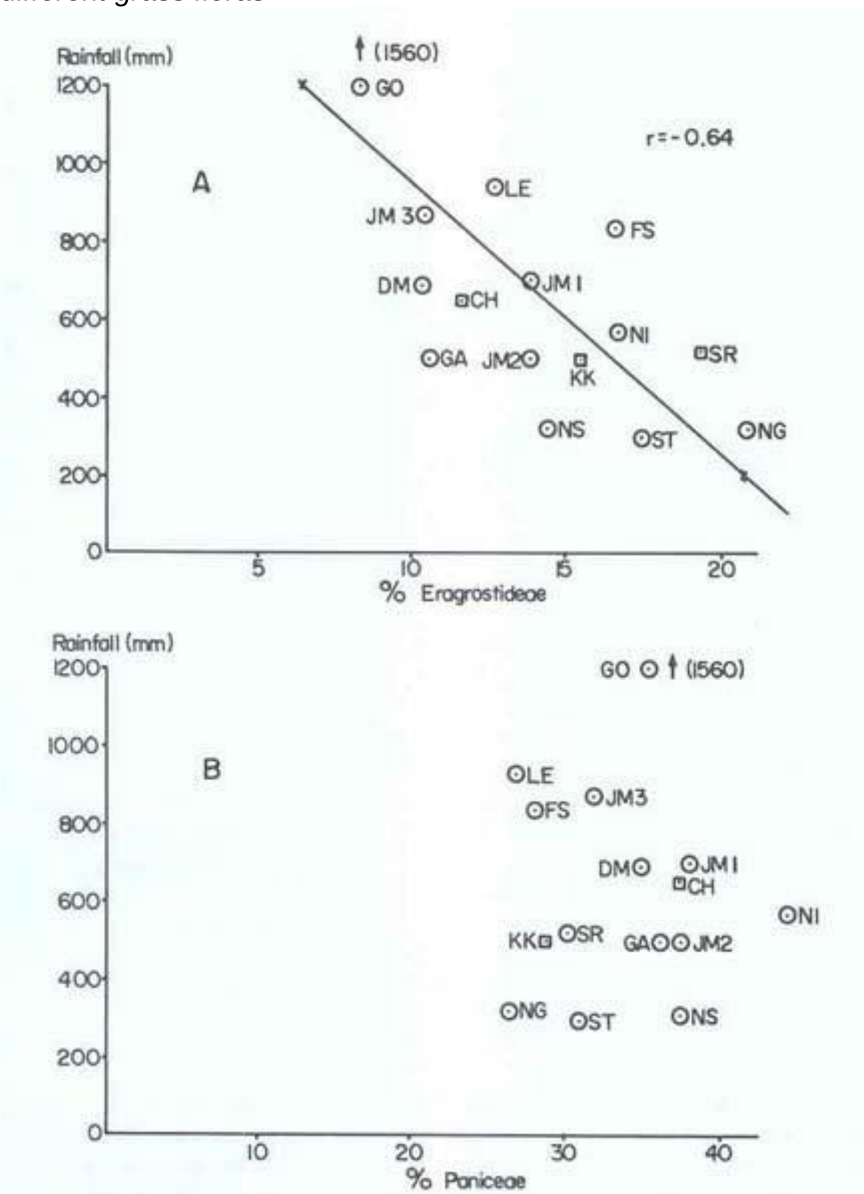


Figure 4. *Relationship between rainfall and proportion of (A)* Eragrostideae *and (B)* Paniceae *in different grass floras*



Key to abbreviations used in Figures 3 and 4.

CH	Chilalo, Ethiopia
DM	Dalliol-Maouri, Niger
FS	Ferlo-Sud, Senegal
GA	Gallayel, Senegal
GO	Gomoko, Central African Republic
JM 1	Jebel-Marra 1, Sudan
JM 2	Jebel-Marra 2, Sudan
JM 3	Jebel-Marra 3, Sudan
KK	Kessem Kabana, Ethiopia

LE	Leo, Upper Volta
NG	Nord-Gouré, Niger
NI	Niono, Mali
NS	Nord-Sanam, Niger
SR	Southern Rangelands, Ethiopia
ST	Sud-Tamesna, Niger

The data on tribal composition of the 20 grass floras considered in this study are shown in Table 5. Only the proportion of the larger tribes is included, together with annual rainfall (where known) and the approximate latitude for each site. The method used in classifying these grass floras was cluster analysis. In this method clusters of observations are formed based on the Euclidean distance (i.e. the square root of the sum of squares of differences between values of observations for two sites). The Euclidean distance between 2 sets of clusters (j and 1) is:

$$d_{jl} = \left[\sum_i \left(x_{ij} - x_{il}\right)^2\right]^{\frac{1}{2}}$$

Table 5. *Proportion of major tribes in the grass floras of 20 African locations together with rainfall and latitude (where known).*

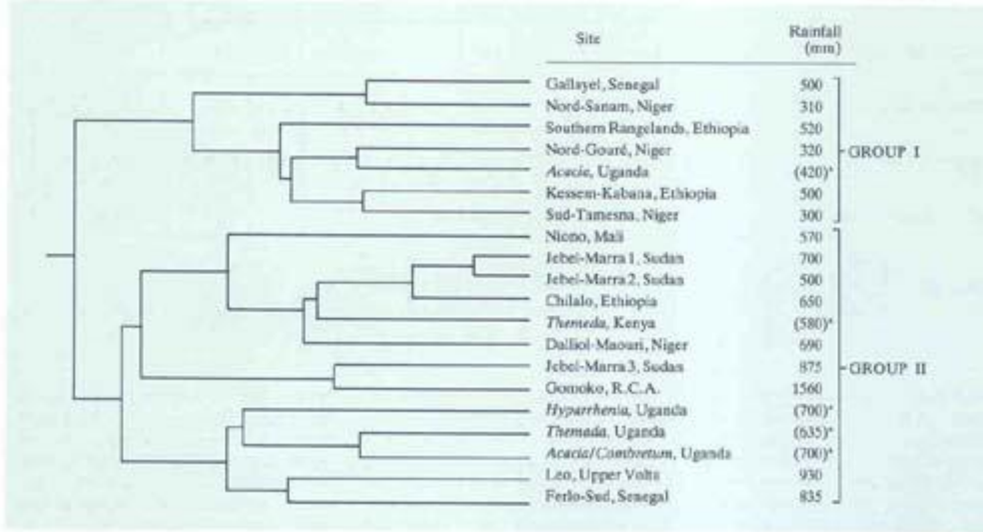
Tribes location		Andropo-goneae	Eragros-tideae	Paniceae	Aristideae	Others	Total species	Rainfall (mm)	Latitude
1	Gallayel Senegal	10.6	17.0	36.2	10.6	25.6	47.0	500	15040
2	Ferlo-Sud Senegal	7.2	16.7	28.2	0.0	17.9	48.0	835	13°40
3	Niono, Mali	23.8	16.7	41.7	11.9	11.9	84.0	570	14°20
4	Leo Upper Volta	42.3	12.8	26.9	1.4	16.6	78.0	930	11°20
5	Nord-Sanam Niger	14.5	14.5	37.7	11.6	21.7	69.0	310	15°25
6	Sud-Tamesna Niger	19.3	17.4	31.1	11.9	20.3	100.0	300	16°00
7	Dalliol-Maouri Niger	30.1	10.4	34.9	5.7	18.9	106.0	690	13°00
8	Nord-Goure Niger	15.2	20.9	26.7	1.4	25.8	105.0	320	15°00
9	Gomoko R.C.A	35.5	9.2	35.5	0.0	19.8	76.0	1560	4°50
10	Jebel-Marra 1 Sudan	24.1	13.9	37.9	3.7	20.4	108.0	700	12°30
11	Jebel-Marra 2 Sudan	21.5	14.0	37.6	4.3	22.6	93.0	500	12°30
12	Jebel-Marra 3 Sudan	42.6	10.6	31.9	0.0	14.9	94.0	870	12°30
13	Kessem-Kabana Ethiopia	17.3	15.4	28.8	9.6	28.9	52.0	590	9°15
14	Chilalo Ethiopia	23.5	11.8	37.3	3.9	23.5	51.0	650	8°00
15	S. Rangelands Ethiopia	15.5	19.4	30.2	5.4	29.5	124.0	520	4°30
16	Themeda Kenya	19.1	12.8	31.9	4.3	31.9	47.0	–	–

17	Hyparrhenia Uganda	26.5	20.4	24.5	2.1	26.5	49.0	–	–
18	Acacia Uganda	12.8	19.1	25.5	8.5	34.1	47.0	–	–
19	Acacia/Combretum Uganda	27.3	14.8	28.4	2.3	27.2	88.0	–	–
20	Themeda Uganda	25.0	15.9	25.0	4.5	29.6	44:0	–	–

Source: 1. Mosnier(1967)
2. Diallo (1968)
3. Boudet and Leclercq (1970)
4. Toutain (1974)
5. Peyre de FabrBgues(1963)
6. Peyre de Fabregues(1970)
7. Boudet(1969)
8. Peyre de Fabregues(1965)
9. Audru and Boudet (1964)
10. Wickens (1976)
11. Wickens (1976)
12. Wickens (1976)
13. Corra(1981)
14. Mengistu (1974)
15. Agrotech/CRG/SEDES (1974)
16. Lind and Morrison (1974)
17 Langdale-Brown et al (1964)
18. Langdale-Brown et al (1964)
19. Langdale-Brown et al (1964)
20. Langdale-Brown et al (1964)

Initially each site is considered to be in a cluster of its own. At each step the two clusters with the shortest Euclidean distance between them are amalgamated and treated as one cluster. This process of combining clusters continues until all sites are combined into one cluster. This algorithm is known as the average distance or average linkage. A tree diagram of the clusters is then constructed to describe the sequence of clusters formed. This is shown in Figure 5.

Figure 5. *Dendrogram derived from cluster analysis of sites listed in Table 5.*



* Estimated from regressions in Figure 3.

A particularly interesting feature of the classification is that the Kessem-Kabana and southern rangelands of the Ethiopian Rift Valley are closer in tribal composition to a number of localities in the Sahel of West Africa than to the Chilalo area of the Rift Valley or to most East African sites. By contrast the Chilalo area of the Rift Valley is closest to two of the Jebel-Marra sites in Sudan and also quite close to the *Themeda* grasslands of Kenya. Given the inadequacy of some of the floristic data and the problems of estimation of rainfall, the classification correlates reasonably with climatic conditions.

Comparison by shared species

A second method of comparing vegetation of different areas is to use shared species to group related, areas. For this purpose a very simple index, Soroensen's quotient of similarity, was adopted:

$$Q = \frac{2_j}{a + b}$$

where
j = species shared between two areas;
a = total number of species in area a; and
b = total number of species in area b.

In this index, shared species are weighted by a factor of 2 to stress their importance. When the quotient is calculated for all combinations of the areas considered, they can be arranged in the form of a Trellis diagram where individual sites are ranked in an order that brings together those with close quotients of similarity. The areas can then be divided on a subjective basis into `communities' with similar indices.

Because computation of shared species by hand is highly time-consuming, only 12 of the 20 sites listed in Table 5 have been included in the analysis. These have been selected to include the full range of geographic locations and of annual rainfall covered by all the sites. They also include all three locations from the Ethiopian Rift Valley.

The Trellis diagram for the sites analysed is shown in Figure 6. The shading in the upper quadrant has been added to assist interpretation and shows values for the index between 0.00 and 0.20, 0.21 and 0.40, 0.41 and 0.60 respectively. Firstly, the values are generally low with only 4 out of 66 exceeding 0.40. Secondly, it is clear that there is a group of West African sites (Gallayel, Niono; Sud-Tamesna and Leo) with a high proportion of shared species.

Figure 6. *Trellis diagram showing relationships between 12 grass floras from Africa using Soroensen's index of similarity to group floras according to shared species.*

	Rainfall (mm)	Gallayel, Senegal	Niono, Mali	Sud-Tamesna, Niger	Leo, Upper Volta	Gomoko, R.C.A.	Jebel-Marra, Sudan	Kessem-Kabana, Ethiopia	Chilalo, Ethiopia	S. Rangelands, Ethiopia	*Themeda*, Kenya	*Acacia*, Uganda	*Hyparrhenia*, Uganda
Gallayel, Senegal	500												
Niono, Mali	570	0.46											
Sud-Tamesna, Niger	300	0.49	0.59										
Leo, Upper Volta	430	0.16	0.41	0.34									
Gomoko, R.C.A.	1560	0.13	0.19	0.15	0.32								
Jebel-Marra, Sudan	500	0.36	0.36	0.28	0.34	0.25							
Kessem-Kabana, Ethiopia	500	0.16	0.10	0.11	0.03	0.05	0.29						
Chilalo, Ethiopia	650	0.06	0.04	0.09	0.03	0.05	0.18	0.33					
S. Rangelands, Ethiopia	520	0.14	0.18	0.24	0.09	0.05	0.32	0.34	0.28				
Themeda, Kenya	(580)	0.17	0.11	0.12	0.05	0.08	0.26	0.22	0.33	0.26			
Acacia, Uganda	(420)	0.19	0.12	0.23	0.06	0.10	0.24	0.28	0.24	0.29	0.36		
Hyparrhenia, Uganda	(400)	0.12	0.12	0.13	0.14	0.13	0.32	0.18	0.14	0.21	0.31	0.29	

Index value: 0.00 – 0.20; 0.21 – 0.40; 0.41 – 0.60

A major grouping of sites includes those in the Ethiopian Rift Valley with those from East Africa. Here the value of the index is lower (0.21–0.40), with the highest values occurring within the subregions, i.e. the East African sites are most similar to each other as are the Ethiopian sites.

The two types of analysis of the grass floras carried out here clearly provide different types of information concerning the similarity ,of the areas studied. Hartley's agrostological index tells us about the general environmental conditions, and more particularly about the degree of aridity or otherwise of an area. Analyses based on shared species provide information on present-day pathways of dispersal of species and on the phytogeographic history of the areas concerned.

Conclusions

Climatically much of the Ethiopian Rift Valley is very similar to the Rift Valley of Kenya, and possibly to parts of Tanzania. However the region is clearly diverse, with climates ranging from hot and arid to cool (subtropical) and humid. Both temperatures and rainfall vary with altitudes, although in the latter case the relationship is only approximate due to oreographic effects. While frosts are probably of little importance within the Rift Valley as defined above, it is concluded that low temperatures may well affect the growth and distribution of tropical legumes at altitudes above 1400 m. In the extreme north of the Rift Valley there is an area of hot, lowlying country with unimodal rainfall centred on July and August, which has some similarities to the climate of the Sahel region of West Africa. The climatic comparisons have been limited by lack of suitable data for other areas of Africa.

The soils of the Rift Valley, mainly derived from young volcanic rocks, are generally of good base status. In this they differ markedly from soils of many other areas of Africa, where a combination of poor parent materials and intensive weathering has produced soils impoverished in mineral nutrients. Constraints to forage or crop production in the Rift Valley relate to the low phosphorus status of many soils, micronutrient imbalances and, in the case of vertisols and saline soils, difficult physical conditions. It is possible that for the purposes of screening forage species in the Rift Valley, soil types (e.g. acrisols and nitosols) of low fertility can be located that have a range of constraints for plant growth similar to the highly weathered arenosols and luvisols characteristic of many other parts of Africa. The importance attached to locating such impoverished soils will depend on the relative weight given to screening for climatic or edaphic adaptation of forage species.

In phytogeographic terms the Rift Valley belongs to the Sudano-Zambezian region of Africa, with rainfall between 300 and 1500 mm annually and 4 to 9 months of annual dry season. In areas with annual rainfall between 300 and 700 mm the dominant woody species are acacias, but above 700 mm broad-leaned trees and shrubs are dominant. Many of the common acacia species are very widely distributed and are also dominant in the Sahelian domain of West Africa which is extremely similar, in physiognomic terms, to many areas of the Rift Valley of East Africa and Ethiopia, although floristically impoverished.

The use of Hartley's agrostological index also suggests that there is a clear relationship between some of the lower-lying areas of the Ethiopian Rift Valley and the Sahel region of West Africa, while the areas at higher altitudes appear more similar to other areas in East Africa.

The other method of floristic comparison used here, based on the proportion of shared species in different grass floras, is probably of less value for establishing agronomically similar areas. It is probably influenced by historical factors in the evolution of the floras concerned, and certainly by the ease of dispersal of species between different areas. Many of the shared species between two or more sites will have either pantropical or palaeotropical distribution patterns which contribute little relative information about the areas concerned.

Attempting to use soils as a means of comparing areas has many drawbacks. Soils are normally of secondary importance to climate (in particular rainfall) in determining where plant species will grow. Also the soil units used for mapping purposes often do not reflect the problems faced by the plant in growing in those soil types. Many of the major soil, units are of such widespread distribution that they are of little use for the purposes of classifying different areas.

The use of climatic information for comparing different areas avoids many of these drawbacks and has been tried with some success in the past (e.g. Russell and Moore, 1970). However Williams and Burt (1982) highlight two difficulties with this approach. The first is the theoretical one that plants respond to more than just climate. The second is the difficulty in obtaining reliable and comparable climatic data for many areas in the tropics.

On theoretical grounds plants themselves should act as the best indicators of all the factors that influence their ability to survive in a particular area. For the grass floras examined in this study there does seem to be a reasonable correlation between the proportion of certain families and rainfall at least in the semi-arid and subhumid areas of Africa.

In screening forage species, the range of adaptability of species already in use, especially those in commercial production, is of particular importance. In Table 6 the adaptability of some of the important tropical genera is shown with respect to water stress, temperature stress and poor soils.

Table 6. *Adaptability*[a] *of some genera of tropical forage legumes in commercial use to water stress, heat stress and poor soil.*

Genus	Water stress	Thermal stress	Poor soils
Stylosanthes	+++	+	+++
Gentrosena	–	–	++
Desmodiurm	–	+	++
Macroptilium	++	++	+++
Neonotonia	+	++	–
Lotononis	–	+++	++
Leucaena	++	+	++
Acacia	+++	+++	+++

Sources: Humphreys (1980), Skerman (1977) and Summerfield and Bunting (1978).
[a] – low adaptability
+ moderate adaptability
++ good adaptability
+++ very good adaptability

The widest range of adaptability is shown by *Acacia* spp. This genus of some 800 species of trees and shrubs has worldwide distribution and in Africa alone is found at altitudes from sea level to almost 3000 m and on a wide variety of soils. The much smaller genus *Macroptilium* also has reasonable adaptability to these conditions.

Adaptation to temperature stress, particularly low temperatures, appears more widespread than adaptation to water stress amongst these genera.

Adaptation to poor soils is widespread among all but one of the genera considered.

If these genera are representative both of those in commercial use and those likely to come into commercial use, it suggests that the most critical parameter in the screening process is water stress. In other words so long as it is possible to locate areas with a range of different rainfall regimes in which to carry out screening, soils and temperature regimes are of secondary importance. The conclusions drawn from the table are in fact supported by the screening currently taking place with new lines of existing commercial species both in Australia and South America. This work suggests that there is a much greater range of genetic adaptability available in these species than is currently being exploited in commercially available cultivars (B. Grof, pers. comm.).

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