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A contribution to the concept and the classification of the bioclimatic unit in Sub-Saharan Africa

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ABSTRACT

A bioclimatic unit is an integration of climatic factors (e.g. radiation, humidity complexes) and features modified by physiography and vegetation (biotic communities and associated habitats, i.e. wherever possible, ecosystems).

Unit implies an entity irrespective of ecological status and dimensions: these are otherwise differentiated.

It often must suffice to use vegetation communities, because information regarding biotic communities or ecosystems is unavailable.

Increasingly, disturbance of 'natural' conditions makes it imperative to involve man in the classification, demarcation and policy for the development of bioclimatic units.

Ignorance regarding the nature and distribution of a climax necessitates using pro- (pre- or post-) climaxes.

This is based upon the differentiation in these criteria: climatic (radiation and humidity complexes); vegetation (physiognomy and ecological status) . . . and as these are further modified by physiography and edaphic features (physiognomic differentiation ranges from specific faciations of forest or thicket); wooded savanna (facies of woodland, shrubland); facies or faciations of grassland; climatic differentiation ranges from highly humid to arid . . . and further to subdesert and desert.

Recommendations respecting policy and practice in pastoral, crop production and forestry development based on this concept have been used in various sectors of Africa, South East Asia and Latin America. Detailed experience has been gained in Natal and elsewhere.

Several maps illustrate the application of the concept.

RÉSUMÉ

CONTRIBUTION AU CONCEPT ET À LA CLASSIFICATION DE L'UNITÉ BIOCLIMATIQUE DE L'AFRIQUE AU SUD DU SAHARA

Une unité bioclimatique est un complexe de facteurs climatiques (par exemple radiation, humidité) et de données modifiées par la physiographie et la végétation (les biocénoses et leur milieu, c'est à dire, chaque fois que c'est possible les écosystèmes).

L'unité bioclimatique est une entité indépendante de tout status écologique et de toute de dimensions; ceux-ci sont différenciés d'une autre manière.

Souvent on doit se limiter aux formations végétales faute d'informations sur les biocénoses ou les écosystèmes.

De plus en plus, la perturbation des conditions 'naturelles' nous oblige tenir compte de l'homme dans la classification, la délimitation et le plan de développement d'unités bioclimatiques.

L'ignorance en ce qui concerne la nature et le répartition d'un climax nécessite l'emploi de pro- (pre- ou post-) climax.

La différenciation des critères du climat et de la végétation ont servi de base à la définition des unités bioclimatiques.

Les recommendations quant à la politique et à la procédure pour le développement des pâturages, de l'agriculture et de la foresterie, basées sur ce concept, ont été appliquées dans divers secteurs d'Afrique, du Sud-Est asiatique et d'Amérique latine. Une expérience approfondie a été acquise au Natal et ailleurs.

Plusieurs cartes illustrent l'application de ce concept.

DEFINITION OF A BIOCLIMATIC UNIT

It is impracticable to discuss the history of the concept of bioclimatic units here. Even the UNESCO-FAO Working Party (1963), responsible for a series of bioclimatic maps of the Mediterranean Zone, did not attempt this. Space-consuming without being gainworthy in practice, this must await a wider opportunity.

Because this Working Party achieved a noteworthy success in producing a series of scientifically sound and practical maps, it is fitting to record its concept that the purpose of a bioclimatic map is to exhibit, for a particular region, a synopsis of the climatic factors of special importance for living creatures. In practice, the Working Party was essentially concerned with the interreplay of climatic factors and vegetation.

My concept of a bioclimatic unit is that of a natural region wherein influent climatic factors, as modified by physiographic features and edaphic conditions, control the growth and welfare of vegetation so as to permit its development to a stage where this is in dynamic equilibrium with the climate.

A more satisfactory ecological definition would introduce *biotic* communities rather than vegetation

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but, because of the preponderant emphasis in practice, on vegetation, I have perforce acquiesced. Although the climatic climax is inherently involved in this definition, in practice it may be expedient to work with proclimaxes or other penultimate communites.

OBJECT

What is the purpose of presenting a summary of the concept and classification of my bioclimatic studies in Sub-Saharan Africa, published more fully elsewhere (Phillips, 1959, 1961, 1966) and applied to specific purposes (Phillips, 1965, 1968, 1970)?

My purpose in working on the subject during the decade ended in 1959 is as applicable today as thirty years ago, i.e. a desire to provide an ecological background for the guidance of those responsible for selecting habitats suitable for the satisfactory production of annual or perennial crops; pastoral conditions and livestock; conservation and management of wild animals; and the conservation and silvicultural management of indigenous forests and species, as well as the possible role of selected exotics. To grosser experience gained in Sub-Saharan Africa and parts of S.E. Asia and Latin America have been added, during almost two subsequent decades, opportunities in southern Africa for application of the concept and associated practice on scales still relatively extensive, but yet demanding finer detail and additional criteria.

Humbly, I believe that in the still developing countries in the tropical to subtropical continents, the concept and discipline are capable of helping the cause of sound ecological criteria and bases becoming more effectively involved in the selection, development and management of aptly selected projects for the production of renewable natural resources.

To give some background to the anxiety of an octagenarian, may I record that in several continents during the decade subsequent to the placing of the East African Groundnut Scheme on a 'pilot' basis, my experience with international, state and other individual enterprise made clear that it would be fairly long before ecological criteria would mean much to developers of terrain on a large scale in the farflung vegetation of Africa and elsewhere in the tropics. Although some signs of improvement appear from time to time, the overall challenge still remains strident, hence my endeavour to draw attention, once again, to the necessity of infusing more ecological understanding into political and administrative circles and into the citadels of the developers of agricultural and related projects.

METHODS OF APPROACH

During the years of my endeavour to obtain climatological, vegetational, pedological and other edaphic information adequate to my requirements for drafting a bioclimatic map and a supporting text, there was not yet a modern vegetation map (Keay's AETFAT work appeared in late 1959); nor comprehensive climatological maps (Jackson's atlas was published in 1961); nor was D'Hoore's S.P.I. map of the major soil groups completed until 1964.

Despite these serious lacks, there was a varying amount of information, both published and other: British, German, French, Belgian, Italian, Portuguese, of older and more recent vintage, and American. This, much collaboration and visiting of such examples of the terrain as I could possibly arrange, formed the basis for my admittedly simple and crude attempts at synthesis of map and text.

It behoves me to note one outstandingly useful publication by the notable French forester-ecologist, M.A. Aubréville (1949), Inspecteur Général des Eaux et Forêts des Colonies which, together with other papers and the author's interest, from time to time, proved invaluable, mainly in West Africa.

From various sources I was able to collect and collate climatological data (various parameters of temperature, vapour pressure, saturation deficit, rainfall, potential evapotranspiration, ecologically dry months, drought periods during the seasons of precipitation), to correlate with vegetation communities of major extent and signifance. This information was summarized in tabular form in the text (Table 1). Walter (1955; 1958) had not yet published the useful technique of climatic diagrams, the calculation of which would have given a greater precision to subdivisions of the bioclimates.

At the reduced scale at which the map (Fig. 1) had to be produced (1: 20 million), it was essential to adopt a limited number of growth forms of vegetation for description. A summary follows:

Forest

Forest may be evergreen to mixed evergreen and in some instances partially and temporarily deciduous; 18–60 m tall, with crowns touching, overlapping or almost so, to stratified so as to create a closed to almost closed canopy. Tree, shrub, fern, forb and other layers may number 3–5 or more, but from some types ferns may be wholly absent. In some types, the general top canopy may not be formed by the tallest emergent trees, which form a higher, very much more open canopy. Epiphytes and lianas vary greatly in kind and density. This physiognomic community is frequently climax, but may often be associated with successional stages such as thicket, woodland and wooded grassland, mostly secondary in origin. Only rarely to occasionally are the species of trees relatively restricted in number, but more commonly they are numerous.

Thicket

Thicket may be evergreen to wholly or partially deciduous; the height may range from 10–24 m, the stems may be branched or clear; the trees and taller shrubs are often closely spaced, with stems clear; the trees and shrubs are often closely spaced, with stems and crowns intertwined.

Derived savanna

A general term relating to woodland, open woodland, wooded grassland and thicket secondary to forest into which various elements of wooded savanna vegetation have entered in the course of

TABLE 1. – A general comparison of climatic factors conditioning the major bioclimatic regions of the tropics and subtropics of Sub-Saharan Africa, with notes regarding extent and degree of disturbance (Phillips 1957, 1959, 1961, *et seq.*)

Map symbol Bioclimatic region	Temperature °C mean shade	Humidity and saturation deficit : mb	Rainfall : mean annual mm	Drought : ecologically dry months : edm*	Extent and degree of disturbance
1. HHF : highly humid forest, low and medium elevations, equatorial and subequatorial	Megatherm : +23°C range very slight annual and daily	+27–20–27, sat. deficit 1 – below 4	Above +2500; 1800–2500: regular	Nil to rare; edm : 0, rarely 1–2	Shifting cultivation locally extensive, edaphic factors moderately to severely deteriorated
1/5. Swamp forest and HHF in Congo	Similar to 1	Similar to 1	Similar to 1	Similar to 1	
1-16. HHF being converted to derived wooded savanna : relics numerous	Essentially as for 1, except for aerial changes caused by extensive disturbance of forest canopy	Somewhat less humid than 1	Similar to 1	Similar to 1	Shifting cultivation, steadily removing forest relics – open woodland on increase, edaphic factors deteriorating
2. HF : humid forest low and medium elevations, equatorial and sub-equatorial	Megatherm : +23°C but above 750–900 m meso-megatherm 20–22° Range slight/very slight annual and daily	20–27, sat. deficit 4–7, to 4–1	1800–2500 (to 1400–1800); regular to moderately regular	Short-mild, rare, but locally and occasionally longer and more acute : edm : 1–2–3	Exploitation and shifting cultivation take marked toll of edaphic factors
2/16. HF : humid forest : as above, being converted to derived wooded savanna: relics numerous	Essentially as for 2 except for aerial changes caused by disturbance	Somewhat less humid, during drier periods	Similar to 2	Similar to 2	Exploitation and shifting cultivation take steady toll of edaphic factors
2/17. HF : humid forest : being converted to derived wooded savanna : relics rare to occasional	Temperature markedly greater due to removal of forest canopy	Sat. deficit greater due to removal of forest canopy : 4–7–9	Similar to 2 but less effective owing to edaphic changes caused by insolation	Similar to 2 but becoming more effective due to edaphic deterioration	Fuller exposure to insolation, cultivation inducing edaphic changes
2. A : HFS : humid forest subtropical (South Africa)	Mesotherm : 20–23°C and less	20–27, ranging to 13–20, sat. deficit 7–9+	900–1400 regular	Short-moderate, rarely severe, edm : 1–2–3	Some well conserved, others over exploited and converted to thicket grass and arable
3. HSFG : humid – sub-humid forest Guinean and Gabon subequatorial	Megatherm : +23°C	+27 to 20–27 rarely 15–20, sat. deficit 4–7–9	1400–2200 regular	Short, edm : 1–2–3	Extensive and severe
3/16. As above, being converted to derived wooded savanna, relics numerous	Essentially as for 3 excepting aerial changes cuased by disturbance	Somewhat less humid, during drier periods	Similar	Similar to 3 but becoming more effective due to edaphic deterioration	Steadily being converted to cultivation and pastoral (where tsetse permits)
3/17: Relics rare	Changes more marked than above	Changes more marked than above	Similar	More marked	More advanced conversion
4. HMF : montane forest (with variant 4A : HMSF humid-subhumid montane forest) equatorial and subequatorial	Mesotherm : due to elevation (1200–3500 m); 20–23°C, range moderate	20–27, rarely 15–20; and sat. deficit 4–7 rarely above	900–1400–1800, humid – subhumid variant 900–1400; regular, to occasionally irregular	Short-moderate very rarely severe, edm: 2–3 but in humid-subhumid variant : 4	Despite attempted conservation in some states, exploitation and shifting cultivation taking steady toll, with resulting deteriorating water resources
5. Freshwater swamp forest West Africa	Not discussed				
6. Mangrove equatorial/ subequatorial	Not discussed				
GENERALIZED NORTH AND SOUTH OF EQUATOR, FOR BREVITY IN EXPOSITION					
7. SHWS : subhumid wooded savanna – variants 7A: more luxuriant north of equator 7B: less luxurant north of equator 7C: south of equator sub-tropical low, medium, upland, submontane elevations	Megatherm : +23; mega-mesotherm above 1000 m	20–27 during rains, but 13–20 during short dry periods; during longer dry seasons 13–20 to below 13; sat. deficit ranging from 7–9 to 13	990–1400–1800, regular to irregular	Moderate to fairly long and severe, edm 4–5 to 6	Extensive to local disturbance – due to shifting cultivation, and to pastoral over-stocking, where tsetse permits
Generalized : north and south of equator : not discussed					
7/8. Transition : SHWS/ MSAWS subhumid/mild subarid wooded savanna, low, medium and upland elevations					Much as for 7 above
8. MSAWS : mild subarid wooded savanna, low, medium and upland elevations subequatorial	Megatherm : +23°C, mega-mesotherm above 1000 m	20–27 during rains, ranging to 13–20, sat. deficit ranging over 9–13	600–900–1100 less regular than in 7, irregular frequency	Fairly frequent dry spells often severe; edm 5–6	Extensive to local disturbance – erosion due to livestock; reduction locally of tsetse may intensify deterioration
8/9. MSAWS/SAWS transition subequatorial	Not discussed				Much as for 8 above
9. SAWS : subarid wooded savanna low, medium, upland elevations subequatorial	Megatherm : +23°C, mega-mesotherm above 1000 m	20–27 to 13–20, sat. deficit ranging 9–13–16	400–600, less regular than in 7, irregular frequently	Frequent dry spells, very severe, edm : 6–7	Extensive to local disturbance – erosion due to livestock
9/10. SAWS/AWS subarid wooded savanna, transition equatorial, subequatorial	Not discussed				Much as for 9
10. AWS : arid wooded savanna, equatorial, subequatorial	Megatherm, +23°C; mega-mesotherm above 1000 m	20–27 during rains, often 13–20 during dry periods; during long dry season sat. deficit 9–13–20	300–500, irregular, but in poorer rainy season down to 100 mm	Frequent dry/hot spells, very severe, edm : 7–8–9	Disturbance extensive to local, erosion due to over stocking
10/11. AWS/SD arid wooded savanna transitional to sub-desert wooded savanna, equatorial, sub-equatorial	Not discussed				Much as for 10
FOR BREVITY, ONLY SOME OF THESE REGIONS ARE VERY BRIEFLY SUMMARIZED					
Variants of sub-desert 11, 11/12A, 11/13, 12A 12B	Megatherm : 24–28°C; monthly maximum : 30–34				
11. Subdesert wooded savanna, (transitional to sahara) very arid subdesert	Monthly minimum : 23; (December/March)	Moister months (2-3): 13–20, rarely 20–27, edm: less than 13; saturation deficit : 13–20	(150–200–400)	edm 9–10–(11)	Highly variable : open short grass – wooded grassland, stunted thicket : locally to extensively and severely disturbed
12A. Subdesert/Karoo type (several faciations in aridity) including 12B the most arid	Megatherm/mesotherm 22–29°C; frost moderate/severe 40/90 days	Moister months 13–20; edm : less than 13; saturation deficit : 9–13	125–200–(300)	Marked, irregular and long; edm : 9–10–(11)	Locally and extensively and severely disturbed : overstocking, the cause of intense erosion
12A/14A. Example of grassland converted to Karoo; also noted in 14A : OGS – arid	Invasion of arid grassland by Karoo : Tidmarsh (1948), Acocks (1953). Noted invasion of grassland by Karoo species, mainly the non-palatable, lesser to wholly unacceptable browsing/grazing spp.				
Example of southern coastal desert : 13 : (Namib Desert) : D-SD-S (0–400–600 m)	Mean : 20–22°C. Mean maximum 27–29, mean minimum 11–15, absolute maximum 38+; frost in colder season on high ground	During medium moist months (2) : 13–20, 20–27; edm : 8–9; saturation deficit : 9–13 during edm's; benign influence of fogs	100–200–(350). Fogs blown inland by west and south west winds	edm : 9–10–11–(12); marked – but somewhat ameliorated by fogs	Local deterioration but efforts to control increasing
13. Main southern Saharan fringe – transition north Sahel and true Saharan desert	27–29°C; mean maximum 32–38°C, mean minimum 16–23; cooler during 2 months of Harmattan wind	During medium moist months (1)–2–(3); 13–20; during edm 2–4–7 saturation deficit 13–+20	Less than 50–200 to 350, July/September : 250–250	edm : 10–11–(12)	Ranging from nil to widely espaced to open desert : grassland, stunted wooded grassland to stunted open shrubland thicket; locally to more extensively despoiled, often severely
11 & 11 13. Somalia 'desert' : 'near desert' Phillips (1957)** : coast	27/29°C; coolest month 20°C	During 1–2 moister months 13–20–27, during edm : below 10 (coast effect); saturation deficit : 13–20–27	(25)–50–75–100	edm : 10–11; drought severe	Sub-desert/desert grassland and also with stunted shrubs and short trees severely despoiled, by livestock
Open grassland north and south of equator sub-equatorial but not sub-tropical South Africa	Not mapable at scale adopted; relatively small areas e.g. highland grassland in Kenya, Cameroon Mountain, Nigeria; doubtfully climax grassland Ethiopia (Montane)				Probably seral to thicket or short forest
A TENTATIVE GROSS CLASSIFICATION BIOCLIMATIC REGIONS : SOUTH AFRICA (PHILLIPS : 1959)					
OGS – ST : open grass savanna : subtropical South Africa : 14A: OGS – A : arid : also in 12A/14A in part	Mesotherm; mean minimum 4–8°C; frost severe, many weeks; monthly mean maximum December/ February 18–23°	Less than 13–20, rarely 20–27; saturation deficit : 9–13	250–500	edm : 5–8, severe	Probably climax short open grassland; long continued overstocking has induced invasion of Karoo elements and stunted woody communities
14B. OGS – SA subarid	Mesotherm; somewhat milder than 14A	13–20; in moister months 20–27; saturation deficit : 7–9–13	500–750	edm : 3–8 fairly severe	Possibly climax widely where lower humidity and rainfall, prolonged and severe frost prevail; in more congenial sites *Acacia-Rhus-Maytenus* – other wood shrubs form short thickets; much overstocked
14C. OGS – MSA – SH mild subarid/subhumid	Mesotherm; cold, dry 'winter', frost moderate/severe	13–20–27; saturation deficit : 4–9	760–890	edm : 3–4–(5)	(i) In exposed high elevations – cold, frost, wind, the grassland probably climax (ii) Less exposed sites, woody elements occur in short thicket, if not killed by fire, probably grassland seral (iii) Congenial sites protected from fire, stunted forest relics remain; elsewhere grassland proclimax
14D. OGS – SH/H sub-humid/humid 3000–2000 m montane	Mesotherm; cool-cold; snow short periods annually at higher localities	20–27; saturation deficit : 4–7 below 4, in edm 7–9	900–1000+	edm : 1–3	Possibly climax *Themeda-Festuca* – other spp. grassland; fynbos; stunted evergreen thicket in sheltered sites; possibly climax locally; extensively disturbed severely
Generalized outline : M : 15 : arid, subarid, subhumid/(humid)					
Fynbos; macchia; AETFAT map 1981 : Cape shrubland 15A: arid : 15B: subarid 15C: SH/(H) : subhumid· 15D: humid	Mesotherm : October/ March 17–21°C; April/ September 10–14: frost nil to local, infrequent mild hotter in berg (hot, dry)	13–20 to 20–27; during drier periods less than 13–20; saturation deficit 4–7, to 9–13 in drier months lower, saturation deficit higher during berg winds	(300)–600–800 according to subregion; rain often follows berg winds	edm : 5–6 : arid 1–2–3: subarid 0–1 : sub-humid; drought severe in arid; moderate in subarid slight in subhumid	Extensively and severely disturbed : fire and poor pastoral control
15D: derived from destruction of humid forest and humid montane forest, Knysna type	Mesotherm, cooler, colder, notably in upland and montane localities	20–27–above 27; saturation deficit 4–7, but higher during berg winds	Former humid forest elevations 800–over 1000; former montane forest elevations 1000+ m	edm : 0. Drought : rare and moderate; edm : 0. Drought : rare and mild	Fynbos 60 years ago luxuriant today much despoiled, except where conserved and managed by state; efficient afforestation by state, exotics

* edm : ecologically dry months, each with less than 25 mm rainfall

** In Int. Bank Report of Trust Territ. of Somaliland. Washington DC

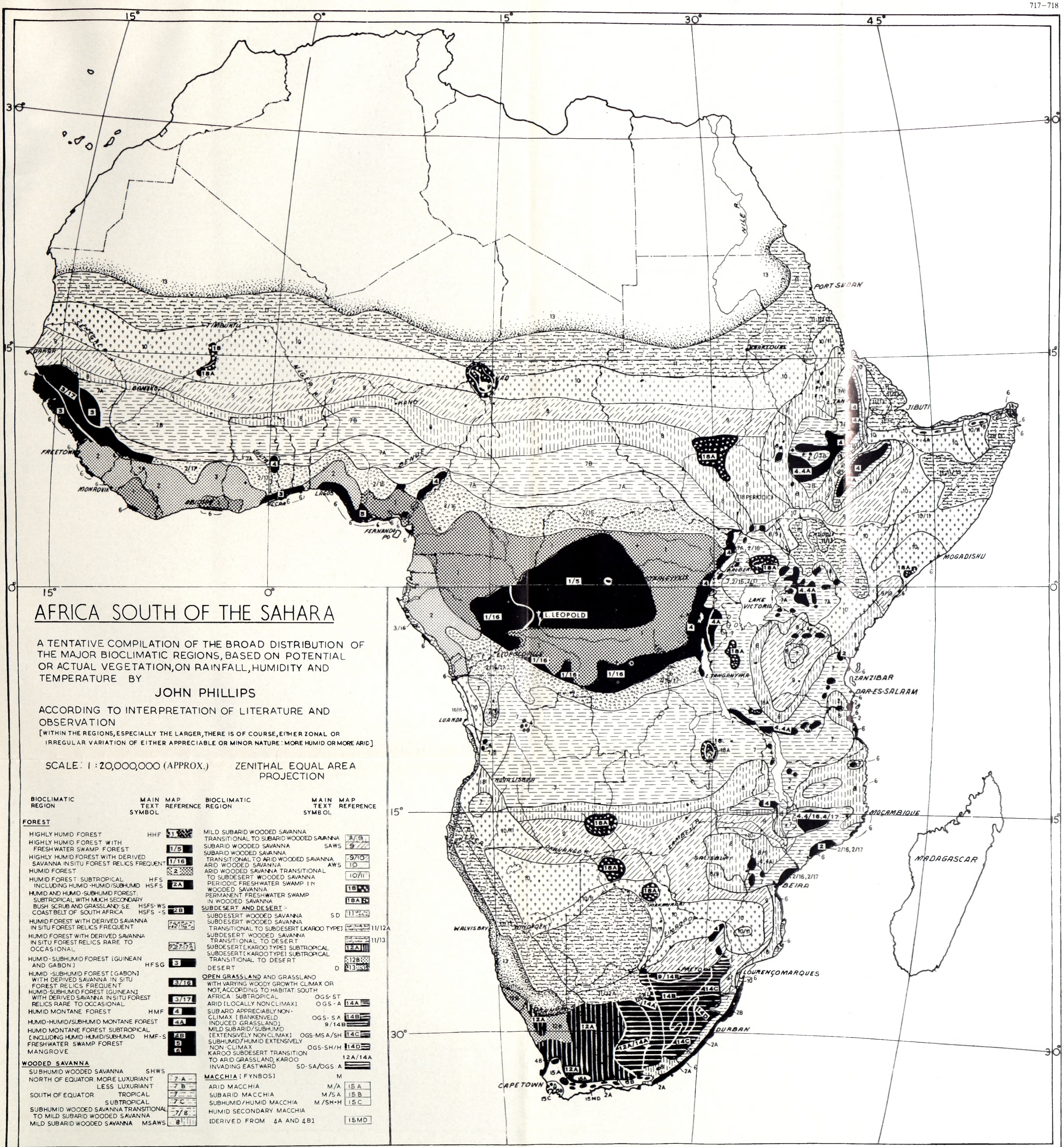

FIG. 1.—Africa, south of the Sahara, showing the major bioclimatic regions.

succession; if not severely impeded by fire, shifting cultivation and the like, this kind of wooded savanna of former forest sites will develop into either advanced woodland or the earlier phases of forest.

Wooded savanna, not successional to forest

This community occurs in the form of Woodland, open woodland, wooded grassland, thicket, in habitats not ecologically conducive to the development of forest.

Space does not permit the detailed definition of these several growth forms of vegetation. Briefly, they are defined by their degree of stocking and espacement of stems of trees and large shrubs. None of these has either a true canopy or a true forest floor and soil as exists in a true forest.

Fynbos (Cape shrubland in AETFAT Map: 1982)

Fynbos is of local interest in several parts of montane East Africa, the Mediterranean, more extensively in the south-west districts of Cape Province and less so in the montane Eastern Cape Province. It is a sclerophyllous woody type of evergreen thicket bearing a rich flora, in places successional to Humid forest of Cape faciation, and now widely altered through pastoral and crop farming.

Karoo subdesert

This community comprises the South African forms of xerophytic and xeromorphic shrub, sub-shrub and succulent to sub-succulent vegetation, from about 0,3 m to 2 m tall, characteristic of portions of the more arid districts of Cape Province and beyond.

Desert of various faciations

These faciations occur in the Saharan fringe, Somalia, Ethiopia, portion of Kenya, the Namib and Angola: several instances of desert severity are given in the text (1959), and several types are merely noted in this note.

Grassland

Possible examples of climax grassland are noted in the text (Cameroun Mountain, Ethiopia, Namib), but several more extensive sectors of grassland in South Africa are considered, either successional or climax at varying elevations in South Africa and Lesotho (see Tabular Summary: AA, AB, AC, AD).

ROLE OF PHYSIOGRAPHY AND STUDY OF SOILS IN BIOCLIMATIC SURVEY

On a somewhat reduced but none-the-less still a fairly extensive scale in the Province of Natal, a number of African homelands in South Africa and in parts of Mozambique, I have been able to check the significance of examining and interpreting other parameters: physiography and pedological and other edaphic information. These, clearly, have cast light upon the admittedly somewhat broad information yielded by the bioclimatic unit. To some measure, the Loxton, Hunting survey (1974) teams in Mozambique derived the principles of taking into consideration the physiography (land form), slope, aspects, rainfall in the defining of natural units and their finer subdivision. This has been accomplished even more satisfactorily by the Soil and Irrigation Research Institute, in South Africa, in the defining of land forms (in press). These have certainly improved the sensitivity of the bioclimatic unit as a unit of physio-biotic comparison.

Physiographic and pedological criteria are illustrated for Natal in my maps and related references (Phillips, 1972), and the marked role of physiography is shown in Phillips (1973) for Lesotho.

THE OUTLOOK FOR BIOCLIMATIC STUDIES IN AFRICA

I ask that it be not held presumptuous that I should believe that the latest vegetation map of Africa (White, ed. 1983 UNESCO-AETFAT) holds the possibility of producing a far better bioclimatic map than ever I could have attempted. The application of Walter's climatic diagrams, especially derived for the investigation, could prove a useful undertaking: a map useful to students of developments within the whole biological field, could doubtless be completed within several years.

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