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AN AGROCLIMATIC MAPPING OF AFRICA

This paper represents principally an attempt to demarcate for the African continent and Madagascar the broad regions that are on the one hand climatically too dry to permit sustained rain-fed annual cultivation of any basic starch-food plant, whether grain or root, and on the other hand regions sufficiently moist. The approximate distribution of population, and by implication of total starch-crop acreage, between these regions is portrayed. A further effort is made to subdivide the rain-sufficient zone into four regions likely to be characterized by differing combinations of rain-fed starch crops and to indicate whether differences are in fact to be found in the complex of starch crops characteristic of each. The inquiry has been prompted largely by the recent appearance of Wernstedt's exceptionally extensive compilation of climatic data on Africa (*1*), which gathers into a single volume data on average monthly rainfall for more than 2,000 weather stations. It is hoped that students of African economic development, particularly of agricultural potential, may find useful descriptions in the maps that follow. But nothing is said here about crops other than the starch crops, which constitute by far the largest component of the food supply of African populations aside from the relatively few herdsmen and hunters and gatherers.

DEFINITIONS OF RAIN DEFICIENCY

Three archetypes of seasonal rainfall are found on the African continent and the large adjacent island of Madagascar (now the Malagasy Republic).

A Mediterranean or summer-drought type prevails all across the northern fringe of the continent bordering the Mediterranean Sea, from Morocco in the west through Egypt on the east; and in the extreme southwest of the continent, around Cape Town in the Union of South Africa. Here the great bulk of the annual rainfall comes in the cool winter months, typically November–April on the northern and May–October on the southern fringes of the continent. Grain crops are sown with the seasonal onset of rain and harvested after its seasonal cessation; the summers are dry and hot so that staple starch-food plants cannot be grown at that season in the absence of accumulated water to feed them.

About midway between the northern and southern fringes of the continent, near the Equator, the seasonality of rainfall tends to be such that there are two seasonal peaks each year, occurring in spring and autumn, with two drier periods between. One of the seasonal peaks of rainfall tends to lose amplitude and eventually to disappear with distance north or south of the Equator. In some parts of this equatorial regime of double rainfall peaks the general level of monthly rainfall may be so high that there is no really dry season although duality of peaks and troughs may persist, and growth of starch-food plants is possible at any time of the year. In other parts, notably in equatorial East Africa, both peaks and troughs tend to have lower levels of rainfall, and seasonal droughty periods inhibiting plant growth prevail.

The third rainfall regime, covering the great bulk of the continent in bands lying between the equatorial double-peak regime and the peripheral winter-rain regimes, is characterized by longer or shorter concentrations of rainfall occurring in the high-sun or "summer" part of the year. The summers or high-rainfall periods are always hot, except as elevation moderates temperatures. Starch-crop plants must generally be grown, if unirrigated, during the rainy season of summer.

Deficiency of rainfall such as to preclude unirrigated cultivation of any starch-food crop at any season might be found under any of these three seasonal regimes of rainfall. In the regions of the winter rains, deficiency would refer to the winter or cool-season rains. With respect to the summer-rainfall regime, the deficiency would refer to the summer rains coming in the high-sun period of the year. In the regions of double rainfall peaks, the deficiency would tend to refer to low levels in the two peak seasons.

It is generally known that shortage of rainfall inhibits unirrigated cultivation of starchy root crops more severely than it inhibits at least some of the starchy grain crops. Taros and yams (and also the banana-plantain, a starch crop though not a root) require higher levels of rainfall than sweet potatoes or manioc; but all five of these common starchy staples of Africa require more rainfall for cultivation without irrigation than do the winter-grown barley and wheat of the African winter-rain climates or the summer-grown millets and sorghums at the dry peripheries of the summer-rain regions. Into the vast reaches of the Sahara Desert it is wheat and barley which probe southward, and millets and sorghums which probe northward from the rainy equatorial regions toward the desert fringes. The other fall-sown grains of the winter-rain regions, oats and rye, require more moisture than wheat or barley and probe the dry lands less deeply. In those regions, if unirrigated wheat sometimes probes toward drought more deeply than barley, the main reason is not its superior tolerance of low rainfall but its higher value per unit of output. The other common grain crops of regions with summer or double peaks of rainfall in Africa are maize and rice. Maize appears not to tolerate low rainfall—if unirrigated—as well as sorghums and particularly millets, and unirrigated rice requires a notably high level of rainfall during its growing season.

A geographical limit to sustained unirrigated production of staple starchy food plants accordingly seems to be set by the amount of rainfall sufficient to support barley crops in the winter-rain regions of the continent, and to support millet crops in all other regions. No comparable limits of production of one or another starch crop are set by natural abundance of rainfall; and of course various devices of managing water supplies can and do permit production of such food plants in areas where rainfall alone will not suffice. Irrigation by gravity from man-made dams and tanks that receive water at the flood of streams for later release, lifts or pumps that tap streams or springs, pumps that raise underground water, planting in the mud along streams as they recede from flood levels—all represent such water-managing devices. But such devices are or can be put to use on only a minute fraction of the land that receives insufficient natural rainfall to permit cultivation of barley or millets without them.

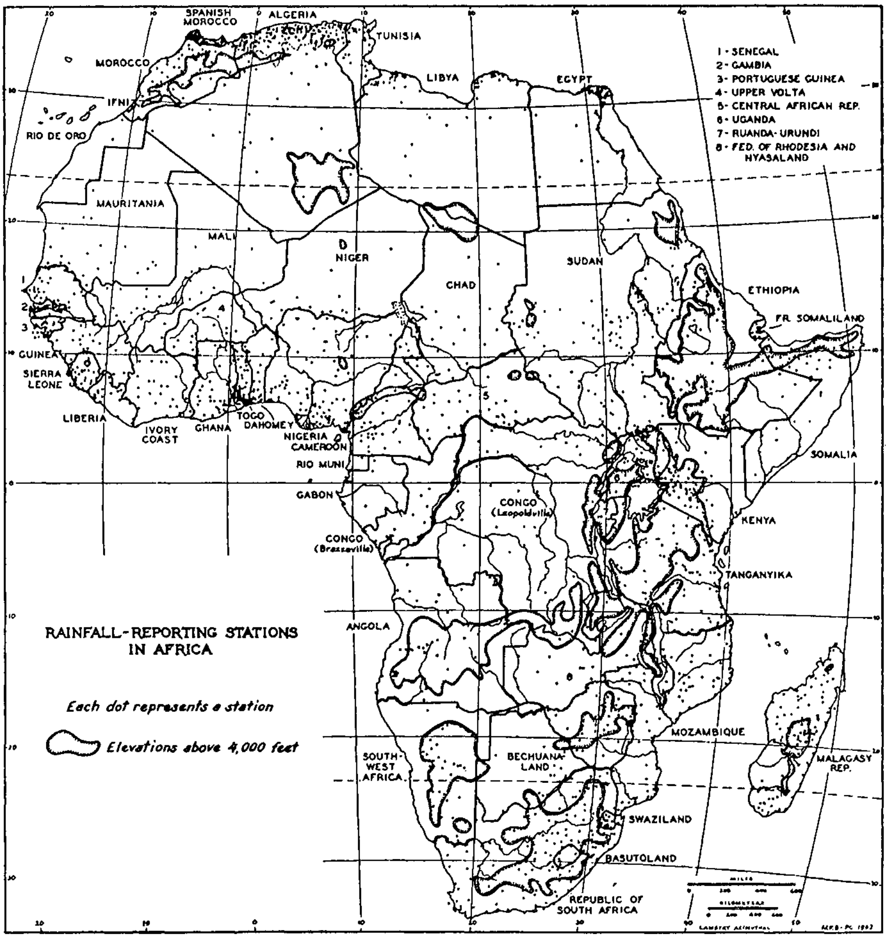
Opinions may well differ about the average annual or seasonal amount of rainfall required to sustain unirrigated cultivation of barley or millet under African conditions of temperature, which except at the poleward fringes and higher elevations are such as to make for a high level of evapotranspiration during the growing season when there is rain. It seems fairly clear, however, that in Africa one climatological datum, the 10-inch isohyet, can properly be taken as a limit beyond which, in the drier direction, neither barley nor millet can be produced without irrigation, and this regardless of seasonal types of rainfall and of elevation. Probably, however, the necessary level of annual rainfall is higher than 10 inches. Without sufficient evidence to defend the conclusions adequately, I take it (1) that sustained unirrigated cultivation of barley is unlikely to be feasible in the summer-drought climates unless total rainfall in four consecutive months of winter (winter being November–April in the north, May–October in the south) equals or exceeds 8 inches, except at elevations above 4,000 feet; and (2) that sustained unirrigated cultivation of millet is unlikely to be feasible in other climates unless rainfall equals or exceeds 15 inches coming within three consecutive summer months, except at elevations above 4,000 feet and except in places where the rainfall, while falling somewhat short of 15 inches within three months, nevertheless exceeds 25 inches in annual total.

Thus the rain-deficient area of Africa, where cultivation of unirrigated starch-food crops seems not to be feasible, is here taken to comprise (1) all places where annual average rainfall is less than 10 inches, plus (2) places in summer-drought climates (except at high elevations) where average rainfall in four months of the winter rainy season is less than 8 inches, plus (3) places elsewhere where average rainfall in three months of the summer rainy season is less than 15 inches (except at high elevations and in places where there are 25 inches or more of annual rainfall).

LOCATION OF RAIN-DEFICIENT TERRITORY

The records of rainfall at weather stations scattered throughout Africa provide the basic numerical evidence essential for locating areas which, by the definitions stated above, may be regarded as respectively rain-deficient and rain-sufficient with regard to sustained production of starch crops without irrigation.

The basic data are drawn chiefly from Wernstedt's extensive compilation (*1*) of records from hundreds of stations scattered throughout the continent and in Madagascar. Data from smaller offshore islands and the Sinai Peninsula are not taken into account. It has been possible to expand the coverage slightly to the extent of 47 stations, by reference to the British Air Ministry's compilation of African meteorological data (*2*), and further, to the extent of 23 stations, by reference to Bernard's special study (*3*) pertaining to the north-central portion of what is now commonly called Congo (Leopoldville). Map 1 shows the location of all weather stations yielding usable meteorological statistics—that is to



MAP 1.—AFRICA: LOCATION OF RAINFALL REPORTING STATIONS

say, averages of monthly precipitation covering a period of several years, or, in relatively few instances, only averages of annual precipitation. These few, about 25, are located in Bechuanaland and Madagascar; they are usable because the broad features of seasonality of rainfall can be inferred by analogy with neighboring stations. The total number of rainfall-reporting stations shown on the map is 2,386. It is not asserted that usable data for still more stations could not be found by search of literature or by correspondence. What can be asserted is, as Wernstedt says of his unsupplemented compilation, that the coverage of climatic data is extensive.

For purposes largely of convenience of reference, Map 1 also indicates "national" boundaries as they stood in February 1962, and elevations above and below about 4,000 feet. Designation of elevations is somewhat rough, representing an attempt to locate the contour of 4,000 feet of elevation by interpolation between the contours of 1,000 and 1,500 meters (3,281 and 4,921 feet) as shown in Hammond's atlas (*4*, p. 63), though with reference also to elevations of rainfall reporting stations.

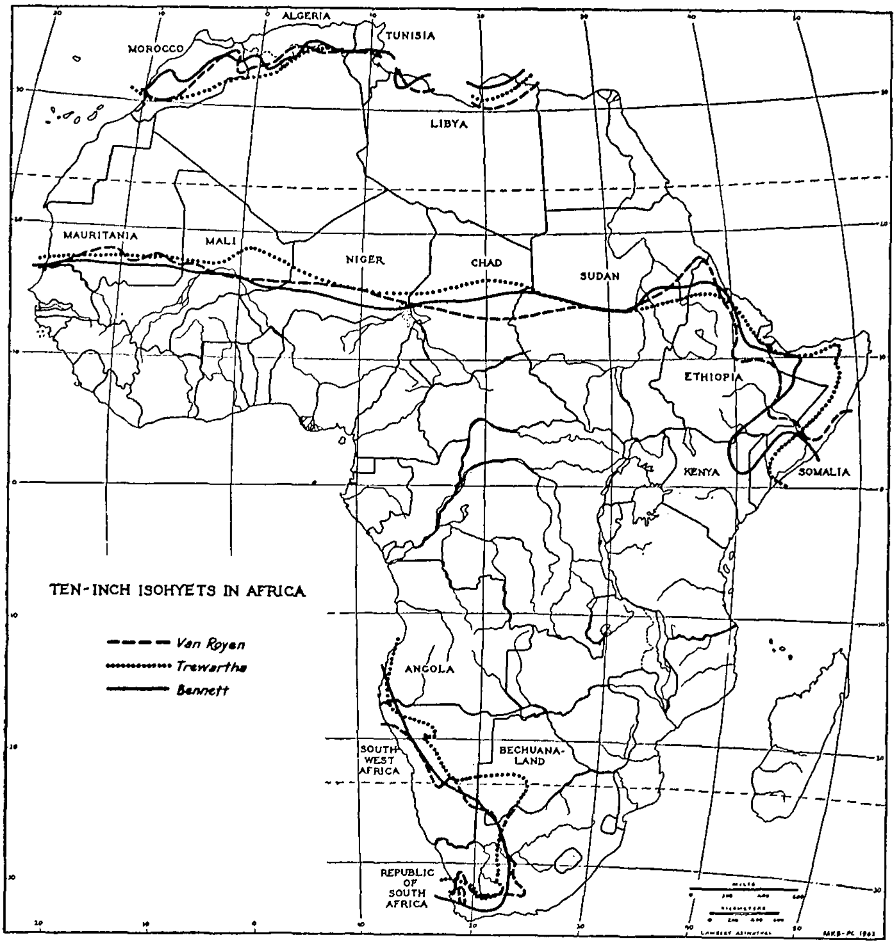
The reliability of the rainfall averages must be somewhat uneven. The averages do not refer to any given sequence of calendar years, and the number of years included in averages differs widely from station to station. Of the total number of stations, 1,967, or 82 per cent, give annual average rainfall covering 10 or more years of observation, and only 56, or 2 per cent, give averages made up of less than 5 years observation: the bulk of these refer to Togo and Portuguese Guinea, areas not important in the matter of differentiating between rain-deficient and rain-sufficient regions.

The scatter of rainfall observations over the continent is obviously uneven, although there is no major political entity where no weather station can be found. Well-known desert and semidesert regions—the Saharan, Somalian, and southwestern African—show conspicuously low densities of points of observation. So also does the central portion of the continent, roughly between the 20° and the 30° meridians, and between the Equator and the 20° S. parallel with extension westward near the Equator into Gabon.

Aside from the Tibesti uplift in the Sahara Desert, the highlands of the continent appear to have been at least moderately well "sampled" as to rainfall and its seasonality, at least for the purposes of this inquiry. Climatologists classify the Tibesti uplift as having less than 10 inches of rain annually; it therefore may be taken as a rain-deficient area according to the definitions followed here. Perhaps the considerable prevalence of weather stations in highlands of eastern and southern Africa reflects a concentration of European influence, for the highlands have commonly been regarded as relatively suitable for European settlement and open to occupation—an attitude presumably less common today, in the course of the retreat of colonial jurisdiction, than it was even as late as two decades ago.

Explanations of the geographical scatter of weather stations are of no direct concern here, even if they could be offered. The climatological sampling of the continent as a whole was surely unplanned. Uninhabited places such as deserts and deep forests presumably tended to discourage weather-recording apparatus first by European originators of it, later by emulators. Areas of relatively long-established European control or contact, as in northern Africa, the Senegal-Gambia area of the west coast, Ghana, southern Nigeria, the highlands of Kenya, the Union of South Africa, show relatively heavy concentrations. Elsewhere it may be that coasts (if promising for trade or settlement), river banks, ancient caravan routes and newer railway lines, and perhaps also national boundaries, provided relatively suitable and convenient locations.

The effects of unreliability of basic climatic data and of wide geographical scatter of points of observation, and no doubt also of differing principles underlying procedures used by those who attempt to draw climatic isolines, are suggested by Map 2. Therein are shown three differing versions of the 10-inch isohyet in Africa: the line of dashes is Van Royen's version (*5*, p. 4); the line of dots is Trewartha's (*6*, p. 140); and the solid line is one derived independently in the course of the present inquiry from the climatic data described above. There is general similarity but specific diversity. It turns out that my version resembles Van Royen's more closely than it resembles Trewartha's, the chief exceptions being centered (1) east and west of the 20° meridian in Chad and

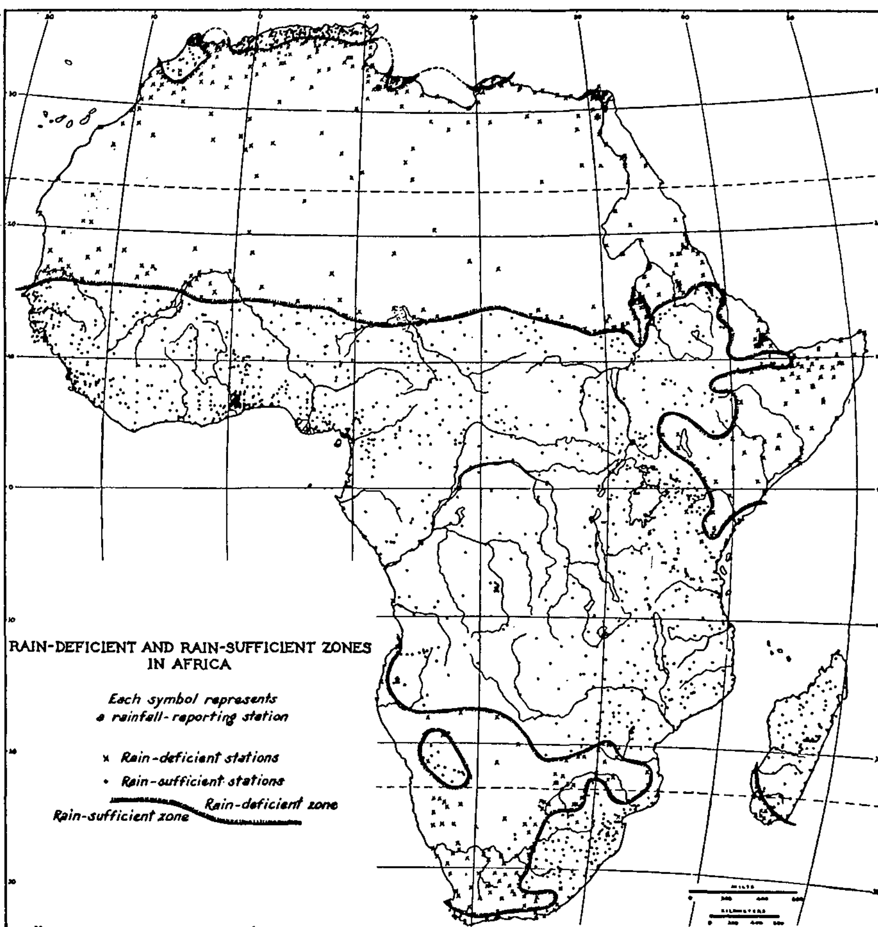


MAP 2.—AFRICA: THREE VERSIONS OF THE LOCATION OF THE 10-INCH ISOHYET

western Sudan, and (2) between the 10°S. and 20°S. parallels along the coasts of southern Angola and northern South-West Africa. Differences between Van Royen's version and mine are perhaps most notable in those two areas, and also in Morocco on the northwest coast, and on the east between the 40° and 50° meridians. In that area of wide divergence, the data available in this study point to considerably deeper inland penetration—into northeast Kenya—of the 10-inch isohyet that Van Royen indicates. It may be that neither Van Royen nor Trewartha had much information in hand for that neighborhood, since the bulk of it, from Somalia, is stated by Wernstedt (*1*, p. 70) to have been provided him in a personal communication dated October 30, 1958. But the data consist of five-year averages only and may therefore be of doubtful reliability.

The immediate problem was to draw, under similar circumstances of sparse or unreliable observations, an isoline broadly differentiating the rain-deficient from the rain-sufficient regions of Africa. It has been approached simply by classification of all stations as, on the one hand, those whose rainfall records meet the criteria of rain-deficiency described above, and, on the other hand, those whose rainfall records do not. The locations of stations of these two categories are shown in Map 3. The symbols (x) on the map represent (1) stations where annual rainfall is reported as less than 10 inches; (2) stations in the summer-drought (or winter-rain) climates of extreme northern and extreme southwestern Africa where annual rainfall exceeds 10 inches but there is less than 8 inches of rain concentrated within four successive winter months, except at elevations above 4,000 feet, and (3) stations elsewhere with rainfall exceeding 10 inches annually but with less than 15 inches of rain concentrated within any three-month period, except at elevations above 4,000 feet or unless annual rainfall exceeds 25 inches. Dots (•) on the map represent all other stations whatever their rainfall status, including those classified above as exceptional.

Such evidence as is available seems to provide a reasonably clear-cut basis for drawing the line of differentiation between the rain-deficient and the rain-sufficient regions. In most parts of the continent, x's and dots are not much inter-



Map 3.—Africa: Location of Rain-Deficient and Rain-Sufficient Zones

mingled. All across the continent from the Atlantic to the Red Sea south of the Sahara, for example, there are very few stations indicating rain-sufficiency which in the interests of smoothing need be included in the rain-deficient region, and around the Horn of Africa even fewer. Along the northern fringe of the continent, lines of differentiation also seem easily located in Morocco and eastern Algeria. On the other hand, differentiation in broad strokes can only be somewhat arbitrary in western Algeria and two small areas in Libya. In the southern part of the continent, the line of differentiation in its north-central part has had to be placed with reference to very few scattered stations, and below the Tropic of Capricorn there is considerable intermingling of rain-deficient and rain-sufficient stations. A few rain-deficient stations are also scattered among a much larger number of rain-sufficient ones southeast of Lake Victoria, mostly in Tanganyika.

The huge rain-deficient areas are mainly contiguous, one on the north and east, another in the southwest. An isolated one appears, however, along the southwestern coast of Madagascar. An enclave of rain-sufficient area appears in South-West Africa between the 20°S. parallel and the Tropic of Capricorn. It would not have made its appearance, however, in the absence of the arbitrary rule of classification that stations in the summer-rain regime having more than 10 inches of rain annually but less than 15 inches within three consecutive months are classified as rain-sufficient if they lie at elevations above 4,000 feet, as do all the points of observations so classified in South-West Africa. This same rule of procedure transforms all stations in the Orange Free State from rain-deficient to rain-sufficient, and so with many in the Transvaal, Natal, and Basutoland.

Comparison with Map 2 will indicate that the total rain-deficient area is considerably larger than the territory encompassed by any of the 10-inch isohyets. The difference is not notable along the northern fringe of the continent. Across the continent south of the Sahara, the margin between the 10-inch isohyet and the isoline of rain deficiency ranges generally from some 100 to 200 miles wide—a large area, of course, since the distance from coast to coast exceeds 4,000 miles, but not large in relation to the total Saharan area with less than 10 inches of rain. Around the Horn of Africa, however, the rain-deficient area having more than 10 inches of rainfall exceeds that having less, and this is even more conspicuously true in the southern part of the continent.

Writing about two decades ago, Shantz remarked, "Africa as a whole has half its land area too dry for the successful production of cultivated crops" (7, January 1940, p. 2). At another point, he estimated the continental area "incapable of crop production or suitable only for grazing" as 5,215,000 square miles or 45 per cent of the total (7, October 1940, p. 379). His criterion for differentiating crop-producing from non-crop-producing areas appears to have been the 20-inch isohyet, for he states, "production without some form of irrigation is limited largely to regions approximating 20 inches of rain per year or over" (7, January 1940, p. 11). If one takes the total area of the continent and the island of Madagascar as about 11.53 million square miles, measurement by planimeter indicates that the total area presumptively so deficient in rainfall as to preclude production of starch crops according to definitions used here is about 5.62 million square miles, around 48.8 per cent of the total. Thus the broad conclusions are not far apart despite differences in criteria and territorial reference. This implies a considerable similarity in the locations of a 20-inch isohyet and the isoline separating rain-deficient from rain-sufficient regions developed in Map 3.

DIFFERENTIATION OF RAIN-SUFFICIENT REGIONS

Varying degrees of sufficiency of rain to allow production of starch crops without irrigation are of course to be found in those parts of continental Africa and Madagascar shown in Map 3 as generally "rain-sufficient." Map 4 provides the basis for an effort to differentiate broadly regions of varying degrees and types within the general rain-sufficient areas.

This map shows the location of all weather stations lying within the rain-sufficient area in a four-component classification.

(1) The symbol (/), appearing only on the northwestern and southwestern portions of the continent, represents stations where the seasonal regime of rainfall is of Mediterranean type, winter rain and summer drought, and more than

MAP 4.—AFRICA: LOCATION OF FOUR RAIN-SUFFICIENT ZONES

8 inches of rain falls on the average within four consecutive months of the season of winter rain. Unirrigated starch crops must with trifling exception be sown in the autumn, brought to maturity in the rainy winter, and harvested in spring or early summer after the onset of summer drought. All such stations experience more than 10 inches of annual rainfall. In localities surrounding such stations the risk of crop-damaging drought may be high if the four-month winter concentration of rainfall is close to the lower limit of 8 inches; it may be low if the winter concentration exceeds 20 or 25 inches. But, since in general the areas experiencing the regime of winter rain and summer drought are obviously small, no effort is made to differentiate within them the parts respectively of lower and higher risk to the unirrigated winter-grown starch crops. The regions where stations characterized by the symbol (/) prevail may conveniently be called the "single-crop winter-growth zone," since with minor exceptions only one unirrigated starch crop can be produced annually, and that during the winter rains.

(2) The symbol (•), tending to appear widely around the center of the continent except on the east, represents weather stations where the rainfall occurring within five consecutive months of the year exceeds 25 inches but no period as long as six consecutive months experiences less than 4 inches of rain in each of those six months. Thus there must be at least one five-month period with generally sufficient rain to mature a starch crop, yet there is no period of drought of a duration as long as six months. (We accept the common view that under tropical and subtropical temperature conditions of Africa outside the winter-rain zone, a month with less than 4 inches of rain is a month of drought.) Stations whose rainfall records meet these specifications may represent a considerable range of rainfall conditions. A few may experience no months in which the rainfall fails to reach 5 inches. Some may experience one period of, say, five months in which rainfall averages 5 inches or more, then a brief period of a month or two of drought, then a period of, say, three months with more than 5 inches of rain per month, then another brief period of drought. Some may experience seven to ten or eleven months with rainfall in each month above the assumed level of drought, and then one or two to five months of drought.

The common characteristics of these localities are that the planting of unirrigated starch crops is usually not necessarily tied closely to onset of rainy season after drought, and that there is in most places sufficient rainfall sufficiently protracted within a calendar year to permit two starch crops to be grown in succession on the same piece of land if circumstances of soil conditions and fertility warrant it. Since temperatures are always high, peasants are commonly in position to plant crops one later than another (either on the same land or on different plots) over a period of several months, thus achieving a flow of harvests and avoiding prolonged storage. Practice need not, of course, accord with the successive crop potential. The regions where stations characterized by the symbol (•) prevail may conveniently be called the "potential successive-crop zone."

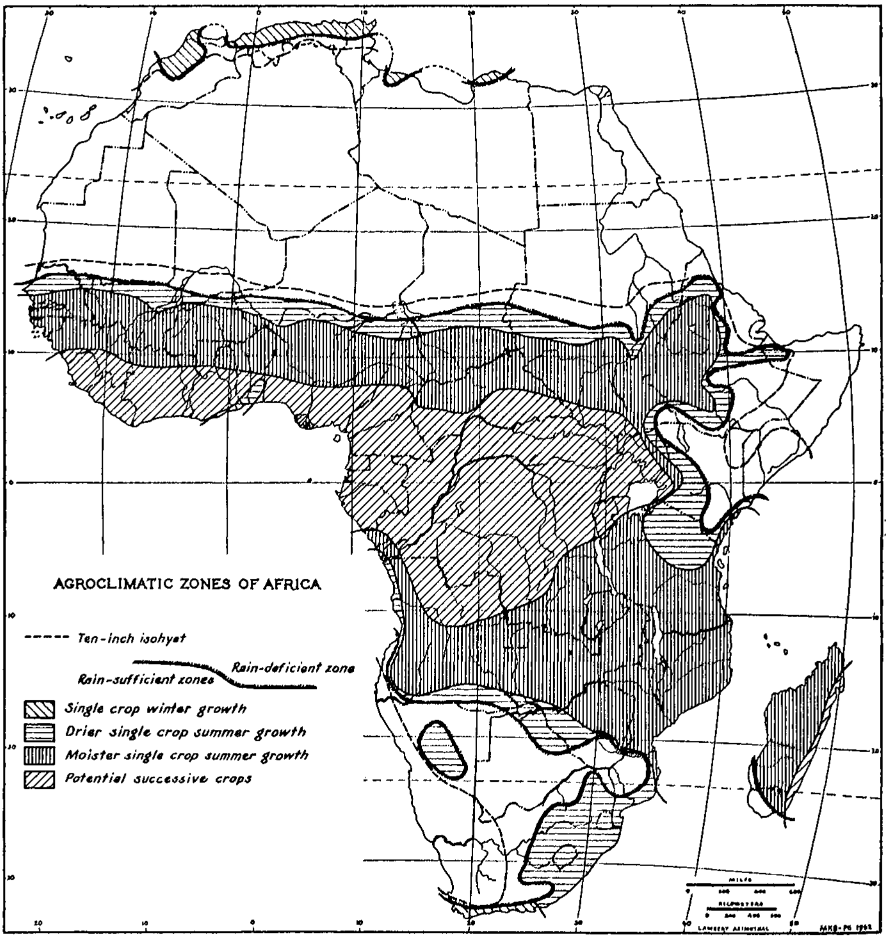
(3) The symbol (x), appearing in regions generally circumscribing those where the symbol (•) prevails, represents stations where, as in the potential successive-crops zone, there is rainfall totalling at least 25 inches concentrated within five consecutive months of the calendar year. But stations marked (x) also meet the criterion that during at least six other successive months of the

year conditions are droughty, with less than 4 inches of rain in any month of the six. Some localities, while receiving 25 inches of rain within five months, may receive most of it within a period of three months and up to eight or nine months of the year may be droughty. They may indeed be nearly rainless. In other localities a great deal more than 25 inches of rain may fall within five months, but the onset and cessation of the rainy season may be so sharp and extreme that at least six months of drought follow the high seasonal rainfall level of the rainy season. The general characteristics of localities designated by the symbol (x) are that a fairly adequate to a fully adequate supply of rainfall is available for an unirrigated starch crop, while the duration of the rainy season is too short to permit production of more than a single crop from a given piece of land within the calendar year, or to permit a sequence of sowings and harvests protracted over several months. Here the requirements of the population for starch crops throughout the year must generally be met not partly from a succession of harvests without prolonged storage, but by almost year-long storage of a single harvest. The region where stations characterized by the symbol (x) prevail may conveniently be called the "moister single-crop summer-growth zone."

(4) The symbol (–), appearing generally in areas lying between the rain-deficient zone and the moister single-crop summer-growth zone, represents in all instances stations where less than 25 inches of rain falls within any five successive months of the year. On the other hand, all stations receive at least 10 inches of annual rainfall, and most of them receive more than 15 inches of rain concentrated within a period of three months, being thus differentiated from stations lying within the rain-deficient zone. It will be recalled, however, that in delimitation of that rain-deficient zone, a considerable number of stations were excluded from it, although they experienced less than 15 inches of rain concentrated within three months, if they either lay at elevations above 4,000 feet or received more than 25 inches of rain within the calendar year; this was done in order to allow for the favorable effects, upon capacity to produce a starch crop, of lower temperatures due to elevation, and larger supply of soil moisture where a low level of seasonal rainfall is somewhat protracted. The zone where the symbol (–) tends to prevail may be called the "drier single-crop summer-growth zone." On account of the generally low level of seasonal rainfall, it is probably, among the four rain-sufficient zones, the zone of relatively highest risk of starch-crop failure by reason of drought.

A reasonably well-defined differentiation of the four rain-sufficient zones emerges from the rainfall-reporting stations of diverse symbol shown on Map 4. The evidence which supports the location of the differentiating isolines on the map is, of course, scanty in places, perhaps most notably between 15° and 20°S. latitude west of about 25°E. longitude and along the west coast between about 5° and 17°S. latitude. It is also somewhat indeterminate in some areas, in the sense that rather uniformly intermingled groups of symbols appear. The differentiation is rather insecurely based especially in the highlands of East Africa near the Equator and in Ethiopia north of Lake Rudolph; also in the highlands of South Africa and, less conspicuously, in the highlands of western Angola and of Southern Rhodesia. Westward of Lake Victoria in particular, the evidence of the symbols might well support the view that an area included in Map 4 within the potential successive-crops zone ought to be placed within the zone of drier single-crop with summer growth. But the high elevations with accompanying relatively low temperature and evaporation, and double seasonal peaks of rainfall, may justify classification of that region as part of the potential successive-crops zone rather than as part of the drier single-crop summer-growth zone. It might indeed appear reasonable to extend the potential successive-crops zone eastward along the Equator into the highlands of Kenya, though I have not done so. This general region invites comment because of the juxtaposition and intermingling of symbols indicating relatively high drought risk to starch crops with symbols representing least risk, rather than (as is more common) with symbols suggesting only moderate risk. Another such region lies in western Africa, in southern Ghana, Togo, and Dahomey; but here there is little intermingling of symbols and the enclave of relative drought is both well defined and familiar.

The outcome of the inquiry is summarized in Maps 5 and 6, facing, which



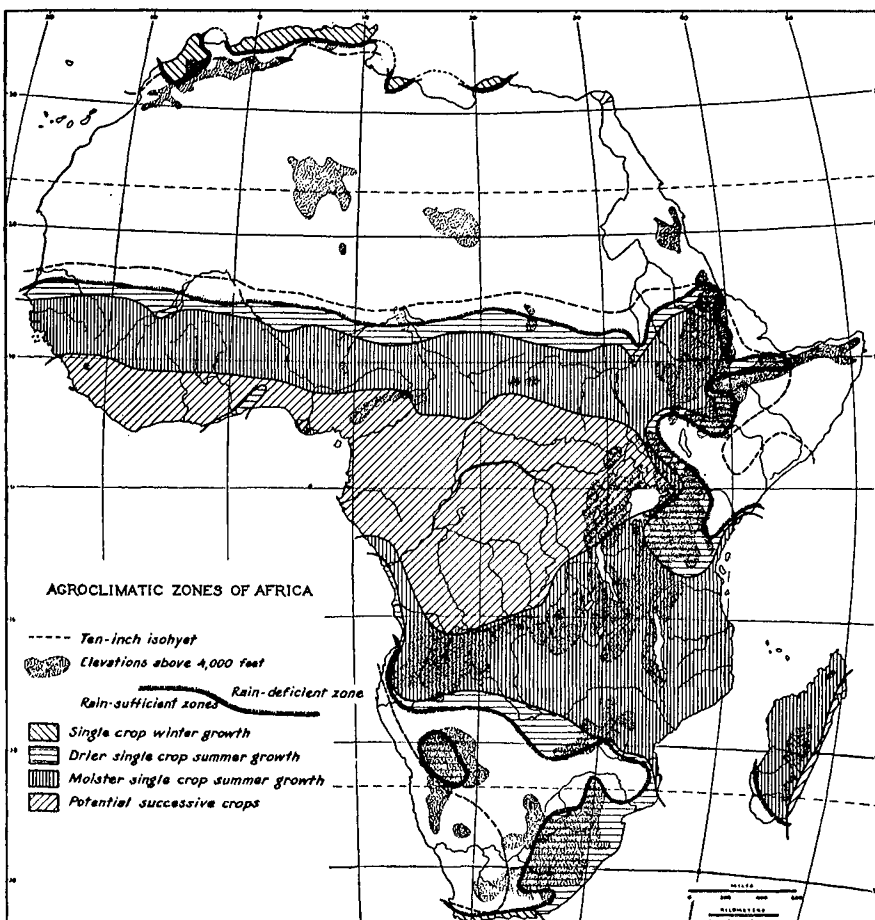
MAP 5.—AFRICA: AGROCLIMATIC ZONES, WITH POLITICAL BOUNDARIES

locate on the one hand the rain-deficient fraction of the continent (divided into drier and moister parts) and Madagascar, and on the other hand the four categories of rain-sufficient territory.

Measured by planimeter, the areas comprised within the five agroclimatic zones are as follows, in million square miles:

Rain-deficient		5.62
Under 10 inches	4.74	
Other	.88	
Rain-sufficient		5.91
Drier single-crop summer-growth	1.12	
Moister single-crop summer-growth	2.81	
Potential successive-crops	1.86	
Single-crop winter-growth	.12	
Total	11.53	11.53

It will be noticed that the rain-deficient area as here estimated is nearly a fifth larger than the area, commonly taken as precluded from unirrigated starch-crop



MAP 6.—AFRICA: AGROCLIMATIC ZONES, WITH HIGHER ELEVATIONS

production, lying within the 10-inch isohyet. Of the four rain-sufficient zones, something under half lies in the zone of moister single crops with summer growth, where precipitation exceeding 25 inches falls within five consecutive months but there is a droughty period of six months or more. The zone of potential successive crops makes up about three-tenths of the total rain-sufficient area, and the relative high-risk zone, drier single crop with summer growth, something under two-tenths. Relatively, the zone of single crop with winter growth is much the smallest, only about two per cent of the total rain-sufficient area.

For the convenience of those who may wish to see how the several agroclimatic zones impinge upon the political entities of Africa, political boundaries are shown in Map 5. Students of the agricultural potential of African countries, so many of which are regarded as falling within the broad category called "underdeveloped," may be interested to form an impression of the great differences between countries in at least one aspect of their resource base, their supply of rainfall adequate to produce one of the basic starch crops without recourse to irrigation.

Map 6, showing the location of highlands above 4,000 feet in elevation to the five agroclimatic zones, is presented largely as a reminder that within any of the four rain-sufficient zones, the range of starch crops that are or may be grown is conditioned in some degree by differences of temperature in the crop-growing seasons due to elevation. There are small portions of the highlands of Ethiopia and Kenya within 10 degrees of the Equator where the rainy season is sufficiently cool to permit cultivation of wheat and white potatoes, typical temperate-zone starch crops, and where, conversely, typical tropical crops like rice, yams, and manioc would not thrive. But the contour of 4,000 feet of elevation is clearly too low to differentiate these islands of temperate-zone conditions; it merely indicates that the islands lie within the designated territory above 4,000 feet in elevation. It will be recalled also that some of the area of Tanganyika and the Republic of South Africa was classified as rain-sufficient (drier single-crop summer-growth) rather than rain-deficient in the face of meteorological evidence that, while rainfall exceeded 10 inches annually, it was not so distributed within the year as to meet the criterion of 15 inches of rain occurring within a three-month period.

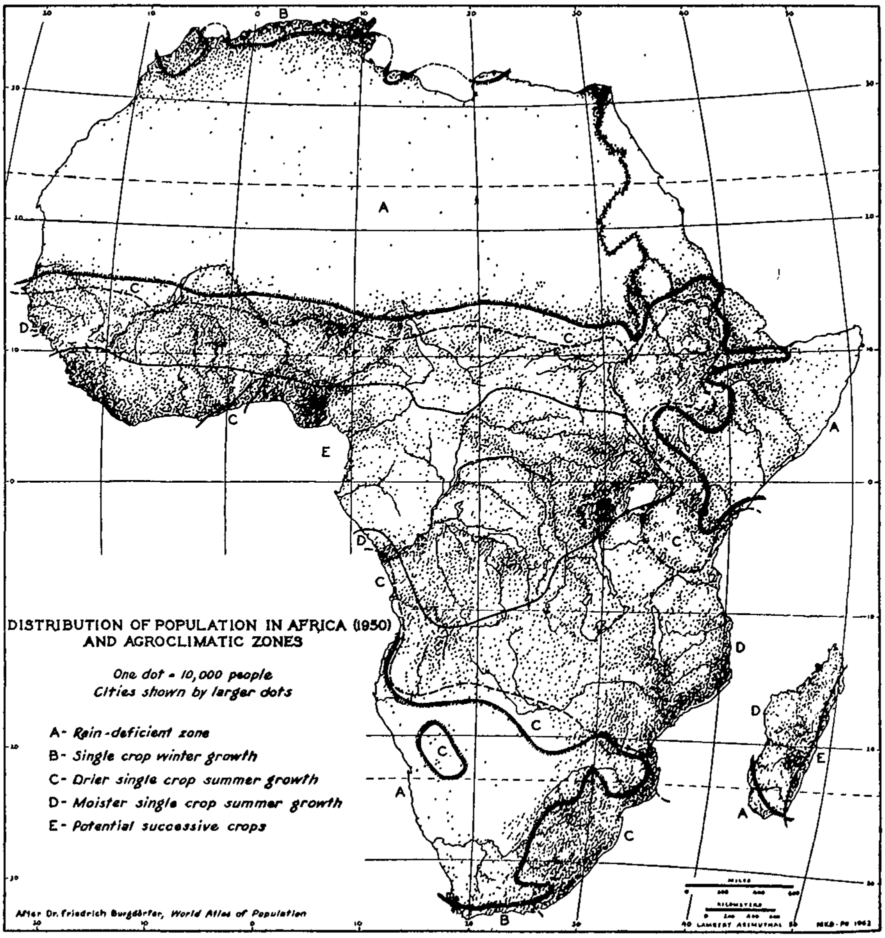
POPULATION AND CROP DISTRIBUTIONS

It would be desirable to conclude with an examination of the geographical distribution of unirrigated acreages of the major starch crops of Africa actually sown or harvested, in total and separately, in order to form impressions whether the rain-deficient zone as mapped in fact excludes the starch crops, how acreages of individual crops are dispersed among rain-sufficient zones, and to what extent dominant-crop combinations differ one from the other among the four zones classified as rain-sufficient. Not much can be said definitively on these subjects, however, for statistics showing locations of crop acreages in total and by crop, and whether irrigated or rain-fed, are notably scanty.

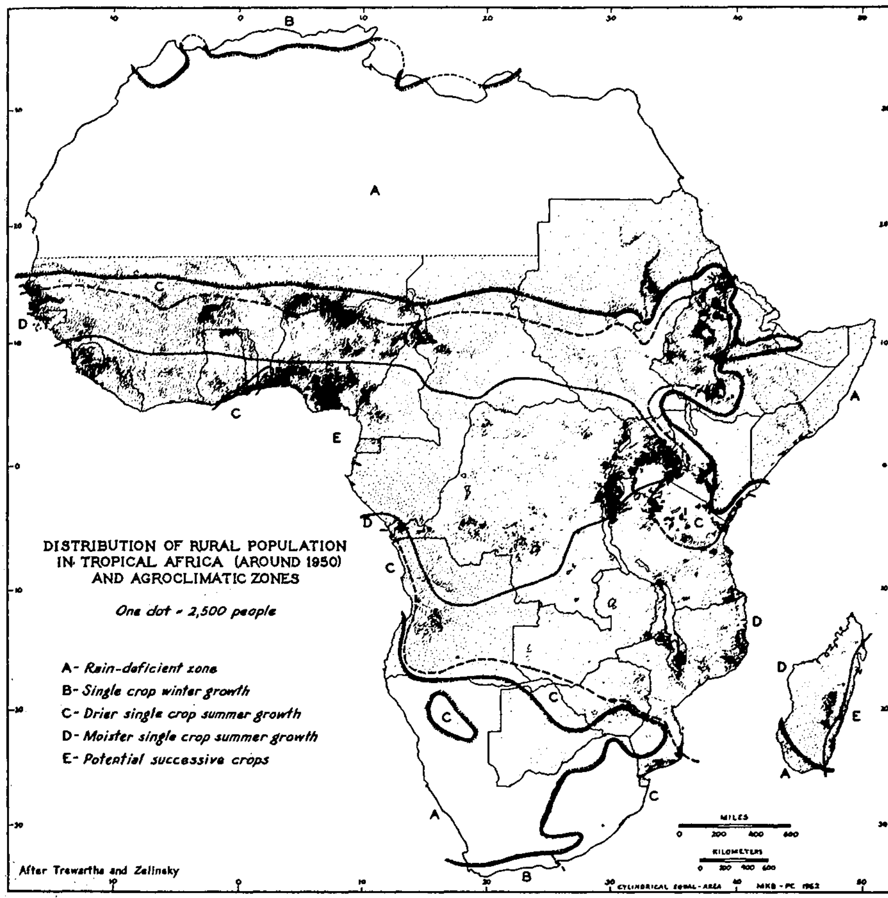
Perhaps as useful an indication as is available of the location of total starch-crop acreage (though without distinction between irrigated and rain-fed crops) is afforded by a map showing the geographical distribution of population in Africa, such as was prepared by Burgdörfer and by Trewartha and Zelinsky with reference to population in or about 1950 (*8, 9*). Those mappings are here reproduced in Maps 7 and 8, together with indications of the location of the rain-deficient and the four rain-sufficient zones of Maps 5 and 6. As a general proposition, it can certainly be said of Africa or any continent that where there are no people, there is no starch-crop acreage. Of Africa, something approximating the reverse can be said, for dependence upon starch crops for food is heavy, the continent is slightly and spottily urbanized, there is little long-distance trade in starch crops, and therefore those crops must be grown close to where the population lives and population densities may roughly, though only roughly, approximate densities of starch-crop acreages. In short, if Maps 7 and 8 represent closely the distribution of population (as they may not do with maximum precision) they probably also present at least a broad outline of what would appear in a dot map showing the distribution of total starch-crop acreage. A major qualification is probably that fairly numerous groups of people still subsist almost entirely on the milk, blood, and meat of their herds whether of cattle, goats, or sheep, and a few groups on food derived by hunting wild animals and by gathering wild plant products; in areas inhabited by such peoples there may be little or no starch-crop acreage.

Obviously the density of population and presumptively of total starch-crop acreage is relatively lower in the rain-deficient zone than in any of the four divisions of the rain-sufficient zone, exception taken of the valley of the Nile. There the high density of population and starch-crop acreage rests not upon rainfall, but almost exclusively upon irrigation. Additional irrigated or subirrigated or annually flooded land exists within the rain-deficient zone certainly in Morocco, Algeria, Tunis, Senegal, Mali, Chad, Sudan, Eritrea, Somalia, the Republic of South Africa, and South-West Africa, and in minor degree elsewhere (including Saharan oases), although available data are inadequate to permit precise analysis (*10, passim; 11,* p. 72). If it were feasible to eliminate on Maps 7 and 8 all dots within the rain-deficient zones representing populations dependent upon irrigated agriculture, a great many would disappear—certainly more than half if only because of those in the Nile Valley. A considerable number would remain, representing chiefly a combination of populations depending for food upon the herding of animals and of populations depending on unirrigated agriculture. For present purposes it would be desirable to locate the latter, in order to appraise the validity of the isoline purportedly separating rain-deficient from rain-sufficient zones. While such appraisal seems impossible, the conclusion may be warranted that in a broad sense, though not in detail, the isoline in fact approximates a valid demarcation of Africa into segments where on the one hand rain-fed production of starch crops is precluded and on the other hand is feasible. It will be noticed that in extreme eastern Africa particularly, the map by Trewartha and Zelinsky supports the conclusion more firmly than the map by Burgdörfer.

Among the four rain-sufficient zones, Map 7 suggests that average density of population and starch-crop acreage is greatest in the zone of single-crop winter growth, notably on the Mediterranean coast. Among the other three regions, it appears from Maps 7 and 8 that the average density is probably greatest in the zone of potential successive crops, because of the high densities around Lake Victoria on the east and along most of the coast of western Africa west of Cameroon, and in spite of sparse population in most of the vast Congo basin. As between the drier and the moister zones of single-crop with summer growth, the maps afford less persuasive evidence of an appreciable difference in average densities: both zones contain relatively high and relatively low ones, although Map 8 points somewhat to higher average density in the zone of moister single crop with summer growth. In short, it appears that greater or lesser climatic scope for production of starch crops, aside from its near exclusion from the unirrigated rain-deficient zone, has not exerted a strikingly clear-cut influence on the geographical distribution of population and presumably of total starch-crop acreage. No doubt the pattern of settlement has been influenced by many factors other than rainfall during crop-growing seasons: topography, swamps, soils, lack of



MAP 7.—AFRICA: DISTRIBUTION OF POPULATION (1950) AND AGROCLIMATIC ZONES



MAP 8.—TROPICAL AFRICA: DISTRIBUTION OF RURAL POPULATION (AROUND 1950). AND AGROCLIMATIC ZONES

surface water in the dry season, prevalence of tsetse fly, warfare, migrations, continuation of grazing economies in places suitable for agriculture, establishment of routes of communications and of national and tribal domains and of forest and game reserves, the historical development of mining and commercial centers, and others. It might be interesting to consider whether in half a century's time a dot map of the distribution of starch-crop acreage in the three non-Mediterranean rain-sufficient zones of Africa, if ever one were made, would be likely to show a gradation of average densities that clearly accorded with gradations of the rain resource. But this would be to engage far too heavily in conjecture.

The several starch crops which have found a place of some prominence in the unirrigated agriculture of Africa are wheat, barley, rye, oats, upland rice, maize, sorghums, millets (including teff), manioc, white potatoes, sweet potatoes, yams, taros, banana-plantains, and ensete. Not many starch crops of some degree of importance elsewhere in the world are missing from the list. Little or nothing is heard, for example, of buckwheat, sago palm, quinoa, or canihua in Africa.

Of the 15 unirrigated African starch crops, five are substantially confined by climatic circumstances to the zone of winter rain: wheat, barley, rye, oats, and white potatoes. Of these the rye, oats, and white potatoes are of negligible importance either with respect to acreage occupied or to position as major staples in national or broad regional diets. Either wheat or barley is a true staple in all of the winter-rain areas shown on Maps 5 and 6. To some extent they are grown also in the upper reaches of highlands near the Equator, notably in Ethiopia under native cultivation and, under European culture, in slight degree elsewhere, Kenya especially; here temperatures are low enough to permit their growth in the rainy seasons. Under irrigation at sufficient distance from the Equator to make for relatively cool winters, wheat and barley can be and are grown as fall-sown crops under circumstances of winter drought. Outside of Egypt there appear to be no notable concentrations of such irrigated winter-grown wheat and barley, though some is found at least in the Republic of South Africa, and the crops are locally important in some of the Saharan oases.

It appears difficult or impossible, considering the state of statistical information, to portray with satisfying accuracy the acreage distributions or the importance to populations of the remaining 10 unirrigated starch crops of Africa, and thus to perceive their distribution among or concentrations within the three rain-sufficient zones here called potential successive-crops, moister single-crop with summer growth, and drier single-crop with summer growth. What is stated below rests chiefly on the works of Murdock (*12*), who shows throughout the continent and in Madagascar where each ranks or once ranked as a staple or co-staple food in tribal (thus excluding European) diets, of Johnston (*13*), who has studied relative crop acreages by administrative districts in West Africa and the Congo, and of Jones (*14*), who has given particular attention to manioc and presents a map of the distribution of manioc acreage on the continent.

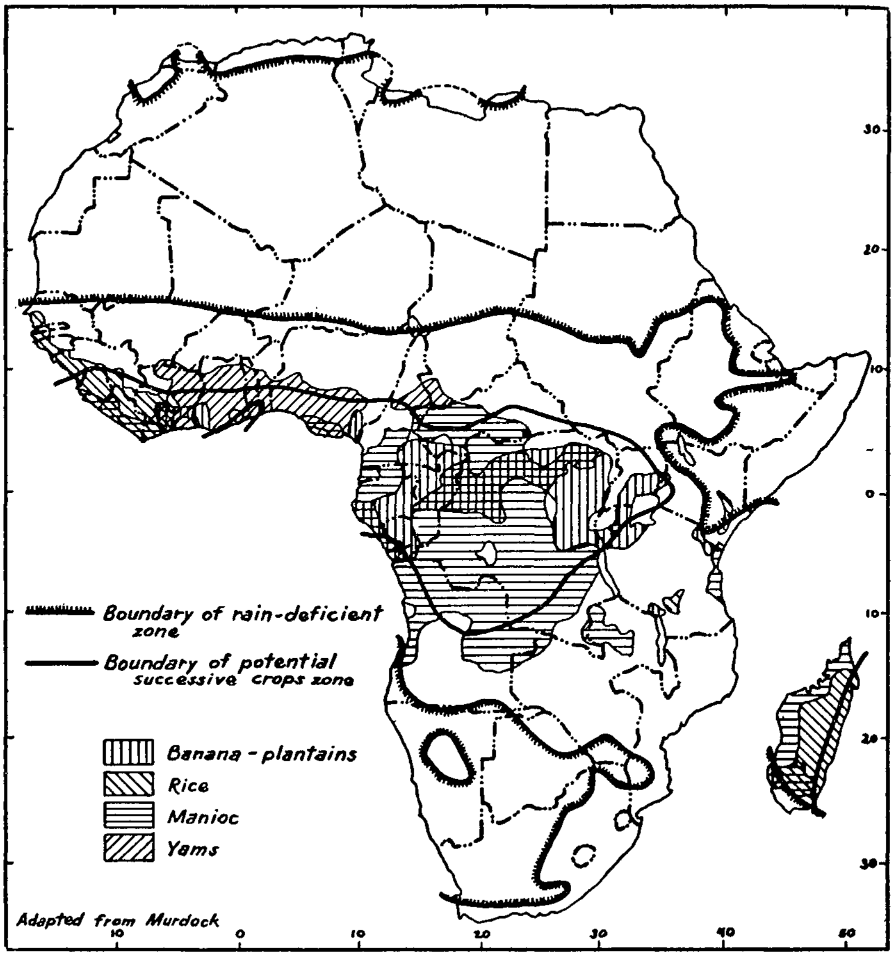
Of the unirrigated starch crops characteristic outside the winter-rain zone, three can apparently be regarded as of minor importance in acreage or consumption. Ensete, a banana-like plant of which the roots provide the starch, is grown and attains some importance in the local food supply only in Ethiopia (*12*, p. 529). Murdock finds the sweet potato as a staple or co-staple only in Madagascar, chiefly in the moister single-crop summer-growth zone on the western portion of the island (*12*, p. 534), and Johnston writes that "sweet potatoes do not rank as a dominant or even a secondary crop in West Africa" (*13*, p. 73). He finds its heaviest occupance of total starch-crop acreage in West Africa in Guinea, with about 15 per cent. Judging by Murdock's map, the range of territory wherein the sweet potato is grown, mostly in the moister single-crop summer-growth region outside West Africa, is rather wide; it appears to be a geographically common crop though rarely a staple or a co-staple one. Of the taro or cocoyam, Murdock indicates its presence as a staple "only in a cluster of tribes on the coast and in the hinterland of the Bight of Biafra opposite the island of Fernando Poo" (*12*, p. 539). There, and additionally in southeastern Ghana, Johnston (*13*, p. 70) finds taro dominant though among root crops rather than in total starch-crop acreage. Apparently the taros, with their high moisture requirement, are confined rather closely to the potential successive-crops zone but are rarely the principal staple within it.

With respect to the remaining seven more important starch crops outside the winter-rain zone, it seems possible to obtain a broad picture of the areas where one or the other ranks highest at least in terms of consumption. Maps 9 and 10 are constructed by combining Murdock's maps showing separately where each of these crops ranks or ranked as a staple or co-staple, on evidence offered by ethnographic studies of widely differing dates rather than by recent statistical inquiry. Map 9 indicates the areas where, according to this evidence, the four starch crops of high moisture requirement—rice, yams, banana-plantains, and manioc—rank as staples or co-staples. Map 10, facing, indicates the areas where the three starch crops of lower moisture requirement—maize, sorghums, and millets—attain these ranks. Both maps show the boundary between the rain-deficient and the rain-sufficient regions as set forth above, and also the boundary between the potential successive-crops zone and the two zones of single-crop with summer growth.

It appears clearly that in combination the four crops having high moisture requirement attain the status of staple foods pervasively in the zone of potential successive crops, but only in rather restricted areas outside that zone. Intrusion of rice into the drier zone in the far western coast reflects the practice of irrigation rather than conditions of natural rainfall, and much if not most of the rice in central Madagascar is irrigated. The banana-plantain emerges as a staple outside the potential successive-crops zone only in a restricted area southwest of Lake Victoria. Yams, however, reach the status of staple or co-staple in West Africa beyond the zone of potential successive crops, on the wetter fringe of the moister single-crop summer-growth zone, but not elsewhere. Manioc ranks as staple or co-staple in more territory beyond the drier margin of the potential successive-crops zone than any of the other three crops having high moisture requirements. It is indeed found, though probably rarely ranking as a staple or co-staple, even in the high-risk zone here called drier single-crop with summer growth (*14,* p. 56). Comparing extrusions of yam-staple and manioc-staple areas into zones drier than the potential successive-crops zone, one is struck by the prevalence of yam extrusions in West Africa, of manioc extrusions in the south and in Madagascar. Explanation probably lies partly in cultural and historical influences.

Such influences probably explain also why maize appears (Map 10) as staple or co-staple over such wide territory in the southern and eastern parts of the continent, while it seems not to do so all across the northern portion south of the Sahara, where sorghums and/or millets prevail. Rainfall conditions seem not to be sufficiently different to account for this. A similar reflection of nonclimatic influences would appear if the several plants here called "millets"—pearl or bulrush millet, fonio or acha, finger millet or eleusine, and teff—were to be mapped separately, as was done by Murdock. Teff would be seen as a staple only in Ethiopia, fonio in central Nigeria, finger millet only in the east-central part of the continent; and each could probably be grown in much of the far wider areas where pearl or bulrush millet is mapped as a staple or co-staple (*12,* pp. 527, 528, 531, 532).

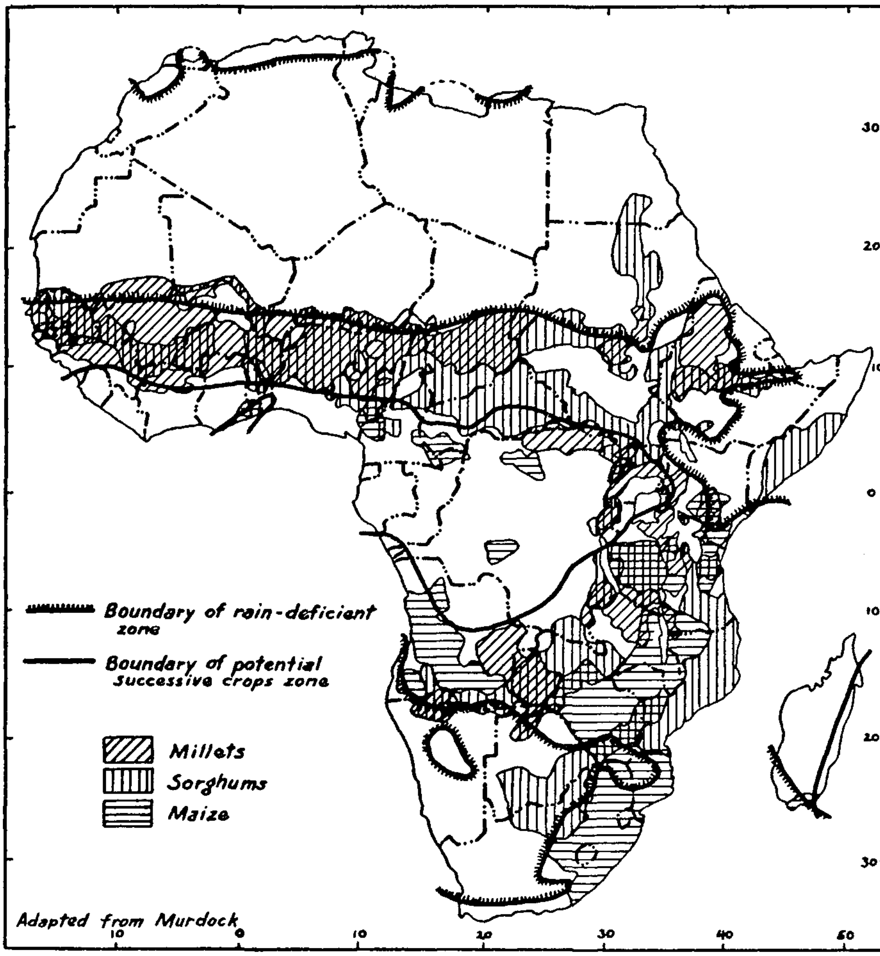
The three lower-water-requirement crops in Map 10 do not attain the position of staples in much of the wet potential successive-crops zone. Maize is probably



MAP 9.—AFRICA: LOCATION OF AREAS WHERE RICE, BANANA-PLANTAINS, YAMS, OR MANIOC ARE STAPLE OR CO-STAPLE FOODS

the chief intruder of the three, although both sorghums and millets invade the eastern periphery. Murdock maps maize, but not sorghums and millets, as an "economically important" starch crop throughout the bulk of the potential successive-crops zone (*12,* p. 530), and characterizes it as "now more widely distributed in Africa than any other food plant" (*12,* p. 525).

While maize as a staple somewhat invades the wet potential successive-crops zone, it is either millets or sorghums that appear as the staples chiefly invading the rain-deficient zone, as in Senegal, Mauretania, Mali, Sudan, Somalia, and Bechuanaland and the Republic of South Africa. In the main, though not exclusively, these invasions seem to represent the presence of irrigated starch-crop production, so that Murdock's mapping looks to be a rather striking validation of the delimitation made above of the area of Africa so deficient in rainfall as to exclude production of any unirrigated starch crop.



MAP 10.—AFRICA: LOCATION OF AREAS WHERE MILLETS, SORGHUMS, OR MAIZE ARE STAPLE OR CO-STAPLE FOODS

One may note in passing that several fairly extensive areas within the rain-sufficient part of Africa appear to lack any of the seven specified starch crops as staples or co-staples. That in southern Ethiopia merely reflects omission from Maps 9 and 10 of any indication of ensete as a staple crop. Others, in Sudan, Kenya, and South-West Africa, suggest absence in consumption of any starch crop definable as a staple; there the staple foods are perhaps animal products.

On the whole, the differentiations here made between rain-deficient and rain-sufficient zones of Africa, and of the winter-rain zones and the potential successive-crops zone, appear significant with reference to unirrigated starch-crop distributions and potentials. It cannot be said, however, that the differentiation of the moister from the drier zones of single-crop with summer-growth affords equally useful explanation of the distribution of staple crops as between these zones, although it may tend somewhat to differentiate zones more and less favorable for cultivation of manioc. From the characteristics of the plants, one might expect areas with maize as staple or co-staple to appear chiefly around the peripheries of the potential successive-crops zone and the millets chiefly around the peripheries of the rain-deficient zones, with sorghums in an intermediate position. But from the evidence at hand, such an arrangement does not appear.

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