PN-AAG-857

DEVELOPMENT AND HEALTH IN THE TROPICS
PART I: WEST AFRICA(*)

Frank L. Lambrecht, D.T.M.& H.
College of Medicine
University of Arizona
Tucson, Arizona 85724

(*) Prepared for Arid Lands Studies Office, University of Arizona
A.I.D. Project 211(d).

PART I

Page

I. Introduction

A. The African environment: climate, geography, soils, vegetation zones, zoogeography 3

B. The ecological zones in West Africa: Guinean zone, Soudanian zone, Sahelian zone, Saharian zone 9

C. Man's impact on the environment

1. Agriculture: slash-and-burn and shifting cultivation, subsistence farming, cash crop production, land tenure . 19

2. Animal husbandry: sedentary and nomadic pastoralism, animal domestication 22

3. Conservation: game and forest reserves, national parks, afforestation. 31

II. Agricultural development and diseases

A. Introduction

1. History 36
2. Parasitic diseases related to water. 38
3. Irrigation agriculture and diseases. 39

B. Description of water-related diseases

1. Schistosomiasis. 44
2. Malaria. 52
3. Onchocerciasis 59
4. Filariasis (Elephantiasis) 64
5. Trypanosomiasis. 70
6. Arboviruses. 76
7. Leptospirosis. 82
8. Dracunculosis. 83

C. Crops related to insect-borne diseases

1. Banana groves, cocoyam fields, pineapple and Dracaena. . 84
2. Bamboo groves, fences and poles. 85
3. Grain crops and storage. 86
4. Cacao and coconut plantations. 89
5. Afforestation. 91

III. Health consequences following human resettlement

A. Changes in social structure and in disease patterns

1. Social shock, introduction of diseases or new geographical strains, susceptibility of migrant populations to diseases in new areas 93

2. Introduction of diseases through domestic and wild animals. 97

B. Housing and sanitation

1. Water supply 99
2. Human and solid waste disposal 102
3. Overcrowding 105

C. Nutrition

1. Changes in food supply and dietary habits. 110
2. Changes in crop production and storage 117

D. Public amenities

1. Health services. 118
2. Social services. 126
3. Transportation 129

IV. Conclusions. 132

I. INTRODUCTION

The natural ecological zones in Africa are the result of long evolutionary development with completely interrelated fauna and flora components. The upset of only a few elements in these ecosystems in many instances results in a gradual breakdown of relationships, followed by degradation of the system.

Bushfire and floods, the destruction of forest through shifting cultivation, overgrazing of grasslands, followed by large scale soil erosion, have depleted large areas, turning them into marginal lands of poor agricultural or pastoral potential. Moreover, these lands often develop into acacia bushland suitable to the tsetse fly, carrier of human and animal trypanosomiasis which further decreases the opportunity for reoccupation.

This state of affairs was recognized from earliest colonial occupation. Local or even regional efforts to change or reverse the process could not stop a continent-wide practice, however, especially when populations, doubling every year, required constant food production increases, followed by a greater consumption of trees for domestic firewood and later for feeding the railway locomotives and river boats.

The degrading process was most marked in areas of shallow soils, and there low rainfall was not conducive to plant regeneration. The 1970-73 drought that occurred in the Sahel zone of West Africa somehow refocused the attention to centuries-old processes and dramatized the need for restudying the whole question of soil degradations and for finding the right technology and resources -- not only to reclaim agricultural land lost

to degradation processes but also to use the momentum provided by international aid programs to start large scale agricultural development projects.

> "The real solution lies not in the world food reserves but in development of the agriculture of the region to the point where deficits in one region or year can be supplied from surpluses in another, with the accompaniment of a sufficiently developed infrastructure to make this possible." (H. Ware, 1975)

Although it attracted wide international attention, the 1970-73 Sahel drought was by no means the worst of similar droughts that had occurred during living human memory. Records of a five-year drought affecting the Niger Bend go back as far as the 18th century (Scheve, 1973). Oral and other evidence suggests that the 1910-15 drought period was worse than that of the 1970's in the savannah farming zones, but perhaps not in the northern Sahel.

The extensive and dramatic coverage of the 1970-73 Sahel drought by the mass media has been largely responsible for promoting international attention resulting not only in immediate aid in the form of direct food supply to stricken areas, but has also started a chain reaction between international institutions to examine the situation in the Sahel and, by extension, to assess and evaluate similar problems in other parts of the developing tropics and arid zones in general.

Perhaps for the first time in large scale projects it has been realized that wide-ranging agricultural development may equally involve wide-ranging ecological implications, and that interdisciplinary expertise will be essential in the planning stage as well as in the executive phases of any development project.

The present document is intended to discuss specific medical and general public health aspects that are inter-related to various development schemes or will result from environmental changes following such schemes.

A. THE AFRICAN ENVIRONMENT

The African continent extends from 37°N to nearly 35°S--more than one-half of it between the tropics of Cancer and Capricorn. Astride the equator, Africa has a higher percentage of tropical areas than any other continent. Unfortunately, half of the continent is desert, arid or semi-arid zones unsuited to cultivation.

Except for the coastal plains and major river basins, most of the continent is plateau country rising to more than 1,000 meters above sea level. (Fig. 1)

Unaffected by advancing and retreating ice sheets, Africa has had relative geological stability over the last 60 million years. Its surface has been subjected to such long periods of erosion that large regions have the aspects of a plenaplain. The last uplifts, as recent as the mid-Pleistocene, have not given enough time for the rivers to grade their courses. A third of the continent's watershed has no drainage outlet at all but is captured by inland basins, such as Lake Chad, Okovango Delta or Lake Malawi.

Isolated mountains and some volcanoes form ecological islands of great interest that have "trapped" and isolated floral and faunal species during periods of wide-ranging vegetational changes following continental climatic changes in temperature and rainfall.

Because of the continent's position astride the equator and the resulting similar succession of seasonal climatic conditions north and south, the African vegetation types are equally broadly similar on both sides of the equator. From the central Congo basin rain forest, the vegetation on both sides of the equator changes into increasingly more xerophytic woodland savannahs, grassland steppes, shrub vegetation, and

finally into semi-arid and arid vegetation types. This succession is broken up in several places by the presence of high mountains, the influence of ocean shores, dominant winds and other elements. High plateaus and mountain ranges, moreover, have their distinctive flora. In the wake of former human occupation, large areas have developed into secondary vegetation types (Fig. 2).

The climatic belts are roughly parallel to the distance north or south of the equator, with the heaviest yearly rainfall near the equatorial zones, diminishing with the distance north and south of the equator (Fig. 4), again modified regionally by land configuration and effect of monsoon winds. The number of rainy and dry months alternates with the passage of the sun across the continent and can be predicted for each parallel by means of the simple geometric design in Fig. 5. Climatic zone maps (Fig. 6) have been composed, taking into consideration all elements that make up the general climate. The most important single factor in tropical Africa is rainfall--its amount, duration and regularity. The equatorial zone is characterized by heavy and continuous rainfall, generally between 1,750 and 3,000 mm per year, and more or less constant temperatures of 26°C or more, with almost continuous relative humidity in the 70-90 percent range.

Most soils in Africa are the result of long weathering and reflect the past rather than present conditions. Good to excellent soils, such as the rich alluvial soils of the Nile flood plains, are rare. Other areas of good soils are the volcanic regions and some of the deltas of larger rivers. One-third the land surface is occupied by stony desert, bare rock, open water or inaccessible mountain slopes and summits. Africa possesses the highest percentage of arid lands of any continent with the exception of Australia. The majority of soils are poor in humus, even thsoe supporting the rain forest where the fallen leaves, under intense bacterial action and heavy leaching by rain, quickly disappear without much

local benefit. Extremely old laterite soils develop a hard "iron pan" at various depths of their profile and present many problems in use and management as far as agriculture is concerned. Savannah soils are usually shallow and poor in nutrients. The richest soils of Africa are dark gray or brown, sometimes called "tropical black earth," and are often found in alluvial valleys. Physical weathering and centuries of malpractice in land use have caused tremendous deterioration of the soils of Afica, while successive natural erosion cycles have further depleted the top soil.

Africa and the Oriental region are the two main regions of the Old World tropics. It is believed that they have probably been the main centers from which vertebrates have radiated into the rest of the world. Africa has 51 families of mammals, a greater variety than in any other zoogeographic region. Twelve families are strictly confined to the region. Three families have only a few representatives in Palearctic Africa, another 16 families are shared in various degrees with Eurasia and 11 families are shared with the Oriental region alone. The eight remaining families are wide-spread or world-wide in their distribution.

Bigalke (1968) remarks on the extraordinarily rich African fauna and the unparalleled radiation in the Bovidae to fill all available herbivorous niches. With regard to the latter statement, Lambrecht (1964, 1967) speculated that the exclusion of trypanosome-susceptible animals in Africa, as a result of the presence of the glossina-vector confined to that continent, provided undisputed ecological niches subsequently exploited by non-susceptible animal forms (including certain primates). An example of specific use of vegetation types by various Artiodactyls in West Africa is illustrated in Fig. 3-b.

Zoologist recognize faunal districts or subregions typical of the presence and prevalence of certain animal groups: the lowland forests

(Guinean in Fig. 3), the highland forests, the savannahs (Soudanian Zambesian and Eastern in Fig. 3), the arid areas (Saharian and Kalaharian in Fig. 3), northern Africa (Mediterranean in Fig. 3), South West Cape (Karoo and Namaqualian in Fig. 3), and Madagascar. Moreau (1952) concluded from his bird distribution studies that the "differentiation of the lowland forest biome from the savannah biome is probably the oldest on the continent (at least as old as the Miocene)". Four mammal families -- Potamogalidae, Colobidae, Pongidae and Tragulidae -- are confined to the lowland forest zone; and most species of three more families -- Lorisidae, Cercopithecidae and Anomaluridae -- are also restricted to that zone. Indications suggest that the lowland forests of west and central Africa have provided a relatively stable environment for a very long time, resulting in the development of a distinct and highly adapted fauna of mammals as well as of birds and other groups (Bigalke, 1968). Moreau (1952) has shown that 94 percent of the bird species in the lowland forests are endemic. Although this environment is substantially homogenous at the present day, the faunal distribution therein is not uniform. Misonne (1963) calculated that only about 30 percent of the mammals were found throughout the lowland forests, while 32 percent were localized in their distribution. Booth (1954) found evidence for the existence of three important refuge habitats for forest dwelling species when severe dry periods caused the forest vegetation to retreat -- possibly several times. Isolation in these refuges resulted in speciation trends that have not been erased by subsequent restoration of forest links. The most striking and effective isolation occurred, and is still in effect, in the forest areas of Guinea, Sierra Leone, Liberia, Ivory Coast and Ghana separated from the Congo Basin forest by the "Dahomey Gap" in the territories of Togo and Dahomey. Although the width of the Dahomey Gap must have

fluctuated during geological times, it probably always served in maintaining the isolation of the "Liberia forest" at least during the evolutionary periods of modern faunas. The "Liberia forest" holds 52 percent of the 84 mammal forest species, of which 20 percent are endemic to the area.

The second forest center of endemism is found in the territories of Gaboon, Equatorial Guinea and the Cameroon south of the Sanaga River. Sixty-nine percent of all the forest mammals have been recorded there and endemism is 13 percent.

The third forest block is found in the northeastern or Upper Congo with 70 percent of the forest mammal species and with 15 percent endemism. Isolated relict patches of lowland forest vegetation occur east of the main rainforest, and in some parts of Angola and Zambia. A very small percentage of lowland forest mammals survive in isolation but none are endemic to any of the relict vegetation. From a study of rodent faunas of the five most important tropical African montane areas, Mt. Cameroon, the Ruwenzori, Mt. Elgon, Mt. Kenya and the Aberdares, and Mt. Kilimandjaro, Misonne (1963) concludes that only 8 out of 70 species might be described as montane forms and that it can be stated that there is no real specific montane mammal fauna in Africa. Exception to this statement is the mammalian fauna occurring in the Abyssinian Highlands which shows an important center of endemism with a number of animals species only found in that region, among which are the hamadryas and gelada baboons.

The savannahs include a large variety of vegetation types, from grassland to densely wooded deciduous forests. They cover about half of the continent and harbor more mammal species than any other biome. This large area can be grossly divided faunistically and botanically into the northern and southern savannahs with the dividing line running from the

southern fringes of the Congo Basin in a northeastern direction to the Tana River watershed south of the Equator.

Savannah groups account for about 105 of the 239 genera and about 290 of the 756 species, including all of the Canidae, Herpestinae (mongooses), Hyenidae, most of the Felidae, most of the Hyracoidae, the Equidae, the Rhinocerotidae and about 80 percent of the Bovidae.

Most of the woodland savannahs are favorable habitats of several species of tsetse flies, carriers of trypanosomes causing fatal diseases in man and domestic animals. Many of the indigenous animals inhabiting savannahs carry trypanosomes in their bloodstreams with no apparent ill-effect to their systems, a result, no doubt, of evolutionary selection following eons of contact within the glossina-trypanosome complex. The presence of this complex and the wild animal reservoirs exclude the use of grazelands by cattle or other domesticated (introduced) animals.

Zoologists recognize three faunal districts with the arid areas of Africa -- the South West (Namibia), Somali and Sudanese zones. The most diversified and numerous species are found in the South Western arid zone: almost half of the 24 species of Muridae are endemic, as well as two hares, two ground squirrels, two mongooses, one hyena, the smallest African cat, two zebra species, and two bovids (Oryx gazella and Antidorcas marsupialis). It is presumed that the region must have been isolated for a considerable period for such a distinctive mammal fauna to have evolved.

The mammal fauna of the Somali arid zone, although less distinctive than that of the South West, has some interesting endemic species: a hedgehog, two elephant shrews of the genus Elephantulus, a number of Gerbillinae, the zebra Equus grevyi and several bovids.

The Sudanese arid zone is much less well-defined than the two other arid zones and is mainly a transitional area between the northern savannah and the Sahara Desert.

Paleontological evidence indicate that the Sahara knew a much better climate during the late Pleistocene and was able to support during those times a mammalian fauna associated with woodland savannah vegetation types. At present the mammalian fauna is composed of arid-zone animals, including three families of insectivorous, five families of rodents, four species of Lepus, two species of Procaviidae, and four families of carnivores. Desert-adapted bovids comprise one Equidae (the wild ass), six species of Gazella , and two large hippotragine bovids [Addax nasomaculatus and Oryx (dammah) beisa].

And finally Madagascar, an island of some 580,000 km^2, separated by an old, deep 250 km-wide channel from continental Africa, contains a fauna with African affinities but of ancient character. The high degree of endemism of ancestral types suggests early colonization followed by early separation from the mainland. The total fauna consists of only 34 genera and 66 species. Specific and confined to the island (and possibly in other Mascarene islands) are the Tenrecidae, a family of insectivores comprising 10 genera with approximately 23 species. The lemurs are perhaps the best-known members of the Madagascan fauna. There are endemic families, the Lemuridae with 6 genera that include 16 species, the Indridae with 3 genera that include only 4 species, and the Daubentonidae with 1 genus and species.

B. THE ECOLOGICAL ZONES OF WEST AFRICA

The ecological classification used is essentially that proposed originally by Lebrun (1947). In it, Guinean ecological zone designates the areas occupied by the tropical rain forest, and should not be confused with

the Guinea savannah, a term currently used to describe the woodland savannahs between the lowland coastal rainforest and the Sahel zones in West Africa.

A broad division of ecological zones is given in Fig. 3 (after Devred, A. de Vos, 1975). Four of these zones are included in West Africa: the Guinean zone, the Soudanian zone, the Sahelian zone and the Saharian zone. The succession of vegetation types in these zones of West Africa is seen in Fig. 7.

1. The Guinean Zone

This ecological zone coincides basically with the area occupied by the lowland tropical rainforest that extends from the Congo River basin along coastal West Africa to about 10°N. There is an interruption in its continuity in its West African extension, between 0° and 3°East, called the Dahomey gap, where the rainforest is replaced by drier vegetation types as a result of various natural recurrent climatic factors apparently in existence for many centuries.

The main climatic characteristics of this ecological zone are rainfall of more than 1,000 mm. per year and a mean annual temperature of about 26°C with little contrast between seasons. These conditions are constant in the equatorial belt but seasons are better defined into wet and dry periods with greater distance from the equator. The outer limit of the zone is reached at the latitude of about 7° north and south of the equator where on the average a period of four dry months and eight wet months divides the seasons.

The edges of the forest are being constantly eroded by human encroachment, while areas inside the forest as well are cut out for commercial tree exploitation or to make place for plantations of other

commercial crops. It is estimated that the African lowland rainforest has been reduced to about half its original area through human action in the last few centuries.

Within the forest, man-made clearings will eventually revert, when abandoned, to original forest species after a reforestation stage by secondary tree species. At the forest edge, however, where climatic conditions are not optimum and where human occupation is perhaps more permanent or of longer duration, the forest is usually replaced permanently by "wet" savannah woodland species. These man-made zones are called derived savannahs. The derived savannahs are typical of the areas adjacent to the rainforest in Nigeria and other West African countries where they form a wide parallel belt that blends with the natural Soudanian woodland savannahs further north.

A more or less natural and harmless exploitation of the forest is by the few remaining hunter-gatherers belonging to the various pygmy groups and by other forest-dwelling tribes. Among the products gathered are the Raphia sp. palm vine, an important source of vitamin B and of palm oil, and Elaeis guineensis, a major source of vitamins and also exploited on a commercial basis. Other indigenous trees produce edible fruits such as the Buthyrosperum parkii (Shea butter), Pentaclethea macrophylla (oil bean), Irvingia gabonensis (dika nut), Cola spp. (Cola nut), Synsepalum dulcificum (sweet berry), Ficus spp. (fig), Parkia clappertonia (wild apple).

The lowland forests are inhabited by a large variety of wildlife --again human occupation and, of course, hunting has been the cause of decrease in numbers to the point of extinction in certain areas. Characteristic of the deep forest are Gorilla gorilla (restricted distribution), various Colobus and Cercopithecus species, Cephalophus niger

(black duiker), Cephalophus zebra (banded duiker), Neotragus pygmaeus (royal antelope), Loxodonta cyclotis (forest elephant), Okapia johnstoni (the Okapi only found in the Ituri forest, Zaire), Syncerus nanus (dwarf forest buffalo), Boocerus eurvceros (Bongo antelope), Hyemoschus aquaticus (chevrodain), Potamochoerus porcus (bush pig), Hylochoerus meinertzhageni (the giant forest hog).

The bird fauna is rich in number and species. Guinea fowl (Numida spp.), Francolins (Francolinus spp.) are quite common and equally well-hunted.

Slash-and-burn and shifting cultivation is generally practiced everywhere in the African forest zones, whereby the trees are felled and then put to fire. The large trees consume very slowly -- their ashes add some mineral substance to the soil. In the yam culture areas (Dioscorea alata) and D. esculenta of West Africa, some additional clearing is done after all the felled trees have been burned. In other parts, crops -- especially maize or cassava -- are planted amongst the debris. The fields are worked three to six years, after which they are laid fallow and another fallow field or new forest is felled and planted.

Cassava (Mannihot utilissima) has become more and more important over the last decades, especially as a secondary staple food, as it grows well on poor soils and needs little attention. The adjuvant crops in the forest areas are taro or cocyam (Colocasia esculentum and Xanthosoma sagittifolium), banana (Musa sapientum and Musa paradisiaca), rice (Oryza spp.), sweet potato (Ipomea sp.).

Natural or planted fruit trees are mango (Magnifera indica), various citrus (Citrus spp.), coconut (Cocos nucifera), pawpaw (Carica papaya), Cola (Cola acummunata or Cola nitida), guava (Psidium guajava).

In addition, each compound may have a small garden with tomatoes, cucumbers, tobacco, and so on.

Except for a few individually owned cows, livestock in the forest is restricted to raising of pigs in some areas. These animals are subject to Trypanosoma infections transmitted by several forest-dwelling Glossina.

2. The Soudanian Zone

The Soudanian zone covers a wide belt of semi-arid land between the West African lowland forests in the south and the Sahel zone in the north -- stretching from the Atlantic coast to the mountains of Ethiopia.

The vegetation cover is basically that of various types and densities of woodland savannah comprising mainly deciduous trees. Included in this wide zone is the derived savannah belt that resulted from the destruction by man of the northern edges of the lowland rain forest subsequently replaced by savannah tree species. This zone, especially that part adjacent to the remaining rain forest areas, is climatically in the humid tropics with a yearly rainfall of 950 to 1750 mm with a dry season of four to five months. The average monthly temperature is close to 21°C with little changes over the year; but in the north, differences between diurnal and nocturnal temperatures may be considerable. Partly as a result of the higher rainfall, derived savannahs have developed into woodland somewhat denser and including more species than the natural woodland savannahs further north. The "wet savannahs," as they are usually called, sometimes include extensive areas of "remnant" or "relict" rain forest-type vegetation cover and forest galleries

along major rivers that still contain elements of the lowland forest. Grasses are high, well-developed and dense, principally belonging to the genera Loudetia and Hyparrhenia. The dominant tree species in both the wet and dry savannah is probably Isoberlinia doka and T. dalzielli. These species are freely mixed with five or six species of Acacia, Lannea sp., Pterocarpus sp., Bauhinia sp., Commiphora sp., Combretum sp. In addition to the above trees, the wet savannahs also contain such species as Lophira lanceolata, Daniella oliveri, Psoropis sp.

The human occupation of this zone is greater than that of the forest zone, and soil degradation and soil erosion is locally very severe. The culture of yam tubers extends from the forest well into the wetter part of the savannah, as well as that of cassava. In the drier northern areas, the staple food millet (several species) and sorghum (Sorghum vulgare) are the main crops. These grains are also extensively used in the preparation of alcoholic beverages, such as millet beer. Groundnut (Arachis hypogaena) is an important adjuvant. Rice is cultivated in wet valleys. Other secondary crops are cowpeas (Ugna sinensis), beans (Phaseolus spp.), and some banana species.

Livestock represents a major economic asset in these zones. Small herds are owned by settled farmers, but the bulk are migratory herds. The latter are transient during the dry season when the pastures in the northern and drier zones have become unproductive while most pastures of the Soudanian savannahs are still suitable for grazing. Moreover, the animals are able to graze the stubble of the fallow fields, their passage coinciding with the post-harvest time. As such, there exists a kind of symbiotic arrangement between the settled farmer and

the nomadic pastoralist, whereby the migratory herds graze the fallow fields and, at the same time, provide much needed manure to the fields. With the onset of the rains, however, cultivation displaces cattle and they return north where the rains have restored the grazing capacities.

The Soudanian zone could be very suitable for large cattle industry if properly managed and provided with adequate water supply during the dry season and improved grasses. At the moment, large areas are overgrazed, leading to the disappearance of the palatable perennial grass species, erosion and the increase of bush and thorn trees. This, in turn, makes these areas suitable for savannah tsetse flies and excludes the further use by cattle because of the risk of Trypanosomiasis. The natural tsetse fly belts in this zone put severe restriction on the use of existing grazing lands.

Because of the need of construction timber and firewood, reafforestation has been attempted in tree-depleted areas. The introduced species are mainly Eucalyptus spp. and the Neem tree (Azadirachta indica). An indigenous tree, Acacia albida, has been proposed as a windbreak in the northern areas. The pods of this legumous tree are said to provide much needed nitrogen content to the sandy soil. The danger of extensive plantation of this tree lies in that they may become suitable tsetse fly habitats.

This zone may be well suited for large scale agricultural and livestock development when such basic and very costly problems as water supply, flood control, irrigation and the control of tsetse flies can be solved.

3. The Sahelian Zone

This zone is a rather narrow belt at the most 370 Km. wide, between the Sahara Desert and the northern limits of the Soudanian zone, lying roughly between 14°N and 20°N latitude and stretching from the Atlantic to the shores of the Red Sea.

The climate is erratic with scattered, irregular rainfall during two to three months during the northern summer of below 500 mm per year and often far less.

The vegetation cover is scarce. The only trees belong to the xerophytic genera Acacia and Commiphora. What groundcover vegetation there is, is further depleted by overgrazing, while the few trees are severely stunted in their growth by the continuous nibbling of new leaves by the large goat population.

There have been increasing conflicts between cultivators and pastoralists, tension enhanced by the recent drought period. A previous plan to increase water supply by the drilling of water holes backfired when the concentration of cattle around these holes resulted in complete depletion of the grazing land in the surrounding areas and in the death of the herds by starvation. The stabilization of the nomads, without provision of stable pasture, will only lead to further degradation of whatever grassland remains.

Stable agriculture is only possible in oases and temporarily inundated lowlying areas. Sorghum is the predominant crop. In addition to the climatic and pedological problems, crops are often object to depletion by the Quelea birds and locust pests in this zone.

Reafforestation by xerophytic plants seems to be a partial correction of this dry area, providing windbreak, a supply of nutrients to

the soil, and fire and construction wood. Several indigenous Acacia species can be used for this purpose, if sufficiently separated from any existing tsetse-belt, so that they do not constitute a risk of invasion by these flies.

Livestock in this zone is essentially owned by nomads. Nomadism is the only way by which the herds and owners can survive at the present state of affairs. This is also an area of camel raising and transport.

The indigenous herds of various wild herbivores, including giraffe, roan and other antelopes, elephants, buffaloes and warthog, have all but disappeared as a result of overhunting and the deterioration of their habitats. The addax (Addax nasomaculatus) and the oryx (Oryx beisa), two antelopes adapted to the dry areas, have maintained themselves but increased hunting with modern weapons have seriously decreased their numbers. Ostriches, once abundant, are now rarely seen.

4. The Saharian Zone

The Sahara Desert occupies most of the region north of the Sahel zone, from the Atlantic in the west to the Nile in the east. It is separated from the Mediterranean by the long coastal Atlas mountains except in several places in Libya and Egypt. The desert areas east of the Nile are known as The Nubian Desert. Relatively uniform in ecological conditions, the Sahara Desert is intersected by several mountain ranges, including the Hoggar and Tibesti massifs reaching over 3,500 meters.

The climate shows extreme variations of some 30°C between day and night temperatures in the summer, with noon temperatures of 45°C. Rainfall is extremely erratic; one-fourth of the area may receive 20 mm per year or less, and other parts between 20 and 50 mm. Rain falls

during the winter months in the northern part, during the summer in the southern parts.

Plant life is very scarce and mostly confined to places with subsoil water, wadis, oases and sheltered places of mountain slopes. Plants are spiny bushes but palm trees with associated plants grow luxuriously in oases created by permanent water wells. Small forest stands have survived in a few isolated massifs, such as the cypress (Cupressus dupreziana) on the Tassili Plateau.

Man can only survive in the widely scattered places where water is available, the oases where date palm is the main crop, supplemented by limited cereal and vegetable production. Other fruit trees in the oases include almond, apricot, fig, orange and olive. The Sahara is inhabited by more than a million nomads and their livestock--mainly camels and goats. They travel from oasis to oasis, trading milk, butter, cheese, hides, wool and hair for vegetable and other grown food.

Large underground water supplies are known to exist in various parts of the Sahara. They could be exploited for irrigation schemes and crop raising development. At the moment human survival in this area is based upon the occupation of the oases and nomadism.

Reafforestation schemes have been used with variable success to stabilize and improve the soil by means of such trees as Acacia, Eucalyptus, Robinia, Tamarix and Pine.

C. MAN'S IMPACT ON THE ENVIRONMENT

In the course of evolution and population increase, man has moved from an ecological component of a general ecosystem to the role of dominant element. He has thus created vast changes in vegetation biotopes directly through agriculture, husbandry, bushfire, exploitation of forests, displacement of

faunas, changes in water systems and drainage patterns. Man-made communities are probably less stable than the natural ones they replace. When left alone, they may revert to the original condition--more often human occupation has provoked a fundamental change to such a degree that replacement communities may be of a different type than the original and mostly less abundant in species.

Man, in several stages, has become the most influential species on the earth especially with regard to the deep-rooted ecological changes he has provoked. The first step in this direction followed the hunter-gatherers stage, when he started raising crops, built shelters and invented irrigation. Then came the domestication of animals followed much later by the period of industrialization. These man-made changes have generally worked negatively on the natural ecosystems by the subtraction from the environment of natural elements and their replacement by selected plant species that require artificial attention, and by replacing natural fauna by domesticated animals. The degree of degradation of the natural environment runs a parallel course with the steady increase of the global human population. The world's concern was awakened when it became obvious that the degree of depletion of natural resources was only matched by the amount of noxious and poisonous waste products, and that the population increase not only was an immediate cause of concern for famine but rapidly deprived whole areas of natural vegetation cover and was responsible for the degradation of natural ecosystems, themselves basic to the regulating mechanisms of life on our planet.

1. Agriculture

The first important human modification of the environment followed the discovery of agriculture, e.g., the man-grown crops. The direct

effect upon the environment was further enhanced by the aggregation of human populations in large towns with ensuing first acts of environmental pollution by waste products.

Although, at certain stages of agriculture, fire must have been used to clear new fields, the first man-made environmental damage by fire could have been the result of ignorance or negligence when man first discovered the use of fire and, later on, when perhaps he intentionally put fire to the savannah to drive game to a spot where it could be slaughtered.

The most extensive, perhaps oldest and most consistent large-scale use of fire is in agriculture by the practice called slash-and-burn technique in use in Africa and other parts of the tropics since man's memory. The fields where this technique is applied are called swiddens (from an old English country word for burning clearings). It is estimated that the technique is applied in about 30 percent of the world's cultivable land by some 200 million people. The basic practice is similar all over the tropics: trees are felled, sometimes leaving a few large forest trees here and there, usually leaving the stumps; creepers and underbrush are slashed away. The litter, or slash, is spread over the cleared area. This is usually done during the dry season so that the slash soon dries out and can be set on fire. The litter, and especially the stumps and felled trees, may smolder for days, leaving a thick layer of ashes that will soak in at the first rain and add to the soil some of the mineral content of the ashes such as phosphorus, calcium and potassium. In southern Nigeria, the swidden is prepared in February, the end of the dry season, and immediately burned. Yams and corn are planted with the first rains in April, together with

pumpkins, melons and calabashes. The corn is harvested in June and replaced by beans, manioc, okra and cocoyams (taro). The yams are harvested in October-November and usually a second crop of the corn which was planted in August. This cycle may be repeated one or two more years. Thereafter, the swidden is left fallow for a number of years, usually sufficient to produce some regeneration of the forest species from the stumps left on purpose or from seedlings in the soil. In the Nigerian rainforest intensive cropping of swiddens is done for one to three years and left under fallow for 8 - 14 years. In the savannah, cultivation is carried out for about four years, and the land left under fallow up to 30 years. These practices are very similar in Ghana. While fields are under fallow, other swidden sites are cleared and go through the same cycle on a rotation basis. Sometimes, the litter after the slashing is not burned but it is left to the termites to complete the final breakdown of the wood. This has the advantage of preserving for the soil certain elements, especially nitrogen, which otherwise is lost during burning.

The slash-and-burn and shifting cultivation technique was admirably suited to the type of African societies over the last thousands of years. But the system can only support a very low population density--generally about 130 people per square mile. If, for example, the cultivation of a swidden is done for two years and left fallow for 18 years, then only 10 percent of the land is under crops at one time. With the rapid population increase of this century, a greater proportion of land was required to fill the need for more food, and when even this could not keep up with the demand for food, the cropping period grew longer and the fallow period shorter. In 1955, for instance, it had shortened in the southeastern rainforest areas of Nigeria from 8 - 14 years to 3 - 4 years; on parts of the

Jos Plateau, the sequence of four years under crops and up to 30 years of woodland fallow, changed to 4 - 6 years under crops and only 2 - 3 years under grass fallow. The woodlands have since disappeared. The disruption of the regeneration cycle has resulted in every instance in the degradation followed by a drastic decrease in carrying capacity of the abused land. Today, large tracts of tropical lands are overgrown by useless grasses and weeds without further economic value, or have been eroded away.

It is clear that the previous environmentally-adapted slash-and-burn, shifting cultivation methods are no longer possible where the population densities have surpassed the carrying capacity of the land cultivated by means of those techniques.

The remedy for the present situation will require changes in the thousands of years of ingrained practice, of solid laws of land tenure, of basic structures in socio-economic relationships and of the relocation of traditional ethnic groups.

2. Animal husbandry

Tropical Africa has a greater diversity of mammals, particularly large ungulates, primates and carnivores, than any other area in the world. The fauna is most closely related to that of tropical Asia. It should be mentioned at this point that through long evolutionary selection and adaptation, the ground dwelling animals of Africa are tolerant to trypanosomiasis (Lambrecht, 1964). These blood flagellates are carried by the tsetse fly which occurs only on the African continent. The presence of trypanosomiasis is a major deterrent to livestock development.

Cattle was introduced in Africa about 5,000 B.C. from the Middle-East area. The first type (Bos primigenius), a humpless domesticated longhorn, is seen in the Egyptian wall pictures from earliest time. A later type of cattle introduced from Euro-Asia was a humpless short-horn, the Brachyceros. Interbreeding occurred between these types and the North African Box opisthonomus. From their northeastern bridgehead, cattle and their owners migrated by five successive waves into various parts of Africa (Ford, 1960). The eventual settlement of some of these groups evolved into strong pastoralist tribes, such as the Masai in East Africa, the Somalis in the Horn, the Karamojong of northern Uganda, the Ovahimbas of southwestern Africa, the Herero in southern Africa, or into kingdoms such as the Watutsi and the Baganda, or into nomad pastoralists such as the Fulani and the Bedouins. The route of these migrations was of great importance for the subsequent history and human distribution in Africa. Some of these first migrants may have been metal workers and may thus have introduced this art along their itinerary. It would seem that the main route for diffusion was southward along the high ridge country on either side of the central Rift Valley (J. D. Clark, 1962). The reason for following this course was most probably to seek a tsetse-fly-free route. This course was subsequently followed by trading caravans and further migrations. Resting places and water holes along this route were permanently occupied and developed into market places and townships. In certain areas, clearings made by agriculturists have created fly-free wedges between the forest and the savannah woodland. These areas were used by the pastoralists not only as a temporary passage but often as permanent settlements (Lambrecht, 1964).

The livestock-owning people in Africa can divided into two major groups: (1) sedentary, (2) nomadic. In the sedentary group can be distinguished: (a) commercial cattle-raising by cooperatives, (b) occasional animal owners and mixed farmers, (c) traditional cattle-raisers (Masai, Herero, etc.).

The social structure of the settled pastoralists can be very sophisticated, such as that of the Watutsi where it forms the basis of the Watutsi Kingdom, to that of the Herero where cattle-raising is, to an extent, a business undertaking. Among the pastoralists who regard cattle as an increasing investment or of prestige value, the danger exists of overgrazing by owning more cattle than the pasture's capacity. Overgrazing and trampling, without pasture rotation, soon is followed by severe erosion and complete depletion of the grazing capacity of such pastures. This situation is found in many livestock areas in Africa occupied by settled traditional pastoralists.

Nomadism is probably a Paleolithic pattern of culture (L. Krader, 1959) and thus existed before pastoralism. In the course of subsequent cultural evolution, the two became coalescent. It is thought that nomadic pastoralism developed in the second millenium B.C. in the arid regions of the fertile crescent. Pastoral people are those who are dependent chiefly on their herds of domesticated stock for subsistence. They are found in Asia and Africa and, in the past, in Europe. They are not native to the New World or Oceania. They are people who have a fixed round of movement--seasonal, annual or multi-annual--with a definite point of return. Pastoral people only rarely kill their herds for food or clothing but live on the replenishable products of the herds: milk, blood, wool, and from exchange between these products and agricultural or other goods in a barter system.

Within nomadic pastoralism are several degrees of attachment to a basic settlement--for instance, permanent tent-dweller with no fixed point, such as the Bedouin Arab nomads, or those who spend several months in regular villages, such as the Fulani. Some nomadic pastoralists may supplement their income by carrying goods between the various places they will visit during their periplus.

The development of pastoral nomadism can be considered from observations (1) regarding the annual cycle of renewal of grasses and water supply, from which we deduct that the herds were led to pasture over the route followed the pre year; (2) of herds of the first livestock, incompletely domesticated, which tended to follow their instinctive call for migratory movements with the seasonal changes and were accompanied on their periplus by their herdsmen.

The latter theory finds evidence, firstly in the fact that African wild bovines follow seasonal migratory routes in many areas (e.g., Ngorongoro-Serengeti Plains); secondly, in the fact that until recently the Labrador herdsmen followed their reindeer in their yearly migrations, and not the other way around.

Areas where nomadic pastoralism is practiced are located in the arid zones of the Old World: interior Asia, southwest Asia and north Africa. In these regions, man and his herds arrive at a precarious balance with the environment only by a series of seasonal migrations, taking advantage of optimum conditions for survival at each grazing stop-over of predilection. Herds are dependent on different kinds of grasses; these and other vegetation cover is, in turn, dependent upon rainfall, water-table, soil factors and topography. Water sources and pastures, often being trampled and grazed down at each visit, are reshaped and replenished during the part of the year during which they are not in use.

Following the decline of the Sudan kingdoms, nomadic pastoralists managed to establish powerful empires based upon the monopoly over cattle herding that lasted more than two centuries. But with the development and structure of the new Sahelian states, the nomads now occupy a very weak position, both numerically and qualitatively -- qualitatively, because of the lack of formal and technical education and their indifference to the national politics; numerically, because national boundaries have divided their ranks. Moreover, farmers are encroaching ever deeper into marginal lands for the cultivation of cash crops. Some of this land has been abandoned because of low yields, and degraded into wasteland by wind erosion and desiccation.

In some areas a long-standing symbiotic arrangement has developed between the agriculturalist and the nomadic pastoralist whereby the former welcomes the herds of cattle to consume the stubble vegetation after harvesting, in the course of which the fallow fields are fertilized by the accumulation of manure. At the same time, dairy products are exchanged for farmer's products. Additional services that benefit both parties, if perhaps not to the same extent, are the transportation by the nomads of goods from one place to another, and the lively commerce between these groups carried out in the various markets. Another traditional economic barter has developed between certain pastoral Fulani groups and rice farmers, whereby milk cows are loaned in exchange for rice.

The demographic pressure of agriculturalists upon the pastoral areas is enhanced by their greater rate of increase due to the lower levels of fertility of the latter (Henin, 1969).

Livestock in Africa was imported from other regions of the world. This fact has two major disadvantages: (1) the animals are not immune against the tsetse fly-carried nagana (animal trypanosomiasis), and (2) they are not adapted and cannot fully utilize the grasses and other plant species found in the African natural savannahs. In spite of these major drawbacks, the imported livestock herds are the very basis of the cattle-raising industry and of traditional African pastoral ethnic groups. This, however, is achieved by accepting large losses due to trypanosomiasis, expensive improvement of pastures, the huge cost of tsetse fly control and the avoidance of vast areas of range lands occupied by the tsetse fly.

Livestock management varies considerably from nomadic systems such as those of the Fulani of the Soudanian Zone, through transhumance, as in Masailand, to commercially managed peri-urban dairies (de Vos, 1975). Intensive cattle raising is especially productive in areas unaffected by extreme heat and drought conditions, such as the highlands, and in the absence of the tsetse fly. The presence of the tsetse fly is responsible for making some ten million square kilometers of valuable grassland inaccessible to cattle production. The fly keeps out cattle from forest or woodland savannahs. The various trypanosomes it carries cause considerable direct loss through the high mortality rate and in their effect on the condition of the animals. Trypanosomes are not the only serious disease-causing organisms. Disastrous losses in livestock and wildlife alike occurred at the turn of the century caused by the rinderpest. Tick-borne diseases, such as East Coast Fever, equally cause severe debilitating infections in livestock.

Except for commercially organized livestock raising in favored areas, most of the "traditional" cattle in Africa is kept under low intensity management which results in slow reproduction and growth rate. Beef cattle is often of poor breeds, maintained in poor condition. It has been estimated that only 30-50 percent of the calves survive each year in some African countries, and that only 8 to 10 percent of the cattle can be slaughtered each year for meat. Carcass weights are 60 to 150 kg., compared to 200-250 kg. in Europe and America (Loosli and Oyenuga, 1963).

Cattle-raising for the meat market becomes unproductive in areas with less than 400 mm. rainfall because of unsatisfactory and inadequate grazing areas. Most of the cattle kept in the drier areas is owned by nomadic pastoralists who move their herds to pastures along a seasonal rotation. Most of these tribes keep their cattle mainly as symbols of wealth, for the acquisition of wives or for barter of dairy products against agricultural products. Some tribes, as the Masai and Karamoja, live almost entirely on diets of milk and blood obtained from their herds. Other pastoralists raise and keep cattle for prestige and wealth. The possession and beauty of the long-horn cattle form the basis of the social structure of the Baganda and Watutsi kingdoms. In most of these cases, the number of animals in the herd is more important to the owners than its physical condition. This fact is at the base of much overgrazing and the degradation of grassland where this type of livestock raising is carried out by sedentary pastoralists.

With all the wonderful wildlife perfectly adapted to the climate, vegetation, tsetse fly and grazing lands, it is quite ironical that the human occupants of the African continent eliminate these animals to

make place for livestock that is ill-adapted in all respects to the African environment. Numerous studies during the last decade show that the African savannahs can support far greater biomass in wild animals than in domesticated ones (Dasmann and Mossman, 1961, 1962; Longhurst, 1958; Talbot, 1963). Acacia savannahs will support two to eight times as much, and bushland (where goats and sheep are the only domestic stock that can be kept) from four to fifteen times as much game as livestock. (Lambrecht, 1966). One of the reasons for these differences is that the various species of African wildlife can feed on several varieties of plants and grasses. Thus, some twenty species of wild herbivores could graze or browse in a single area without competing with each other for food, while using to the fullest extent the complete forage value provided by the land. Domestic animals, however, use only a few species of selected grasses, and cannot utilize the full grazing capacity of a given area. Water requirements of wild animals vary, but most species are able to do without water for days, and are able to travel days to find it. Cattle, in contrast, must be watered at least once every one or two days. Therefore, many wild animal species could survive throughout the year in an area of water shortage, where only a limited number of domestic stock could be kept.

The rate of reproduction of wild animals is far higher than in domestic stock and the live weight gain is equally much faster than that of imported animals (Talbot, 1963). Resistance to most local diseases is far higher in natural animal populations than in imported livestock and, especially important, all African herbivores are trypanosomiasis-tolerant so that all grass and woodland savannah areas can be and are utilized by wildlife--this, in contrast to livestock that can only be kept in tsetse-controlled areas.

Based on these factors, experiments were carried out by Dasmann and Mossman (1961, 1962) in S. Rhodesia, and by Longhurst (1958), which proved that a number of wild animals could be removed each year from a given area without harm to the maintaining capacity of the herds. For instance, a 50 square mile area in S. Rhodesia could yield an estimated yearly game crop of about 311,400 lbs. of marketable meat which would leave a net profit of about $17,000 (1962 value), against an estimated profit of only $3,700 if cattle were kept on the same land (Dasmann and Mossman, 1961, 1962). Experimental game-cropping has indicated similar results in other areas (Longhurst, 1958).

Another consideration that would be more appropriate in West African countries where wild herbivores are restricted to very few remaining areas, is the prospect of the true domestication of certain wild ungulates. Large animals, such as the Eland (Taurotragus oryx or T. derbanius) would be the first choice. The eland is comparable in size to the cow, can be milked, and produces excellent meat much faster than cattle. It is a docile animal and I have often seen eland follow herds of cattle as they are driven to and from the water holes. Efforts to domesticate eland have proven successful (Posselt, 1963) and the animal is being herded in certain parts of the Transvaal and Rhodesia. The buffalo (Syncerus caffer) is another animal to be considered for domestication, although it is less docile than the eland.

With all the problems of human and animal trypanosomiasis in mind, and the complex system of land-use and tenure, Vanden Berghe and Lambrecht (1963) proposed a template plan for community development in tsetse fly belts that would divide a given area into farmland, grazing and game farming (Fig. 8).

Fish production from inland waters in Africa reached at least one million tons in 1968 (FAO). The food values of Africa's inland waters are only slowly realized, and many streams and lakes remain under-utilized (de Vos, 1975). The maximum use of inland fisheries resources and the culture of suitable fishes and shellfish is of particular value in a continent where lack of animal proteins is the cause of severe malnutrition.

Attempts to increase fish production have been pursued through improved methods and devices for catching, better water transportation and by the construction or improvement of ponds and stocking of fishes therein. Most of the fish species used for that purpose belong to the genus Tilapia. The creation of more fish ponds, however, may become a health problem should they provide suitable habitats for mosquito larvae or for the snail vectors of schistosomiasis. Another health hazard would be related to behavioral activities of the fishermen themselves when they travel along land shores and river banks infested with Glossina (tsetse fly). This aspect of the fishery industry is discussed in subsequent sections.

3. Conservation

The principle of wildlife and plant conservation in Africa was initiated by colonial governments during the early years of colonization. By the time African countries gained independence, the national parks and game and forest reserves were well established in vast areas over various parts of Africa. Most of these, fortunately, have been maintained by the new governments.

While the need of protection of fauna and flora for aesthetic reasons was not always well accepted by local inhabitants, the wisdom of providing these reserves and national parks has proven itself over the last decades, not only for the benefit of conservation but also for economic reasons associated with gains deriving from the tourist industry and related business. In Kenya, for instance, more than $67,000 was earned in 1971 in the tourist industry (de Vos, 1975). This exceeded the returns from the export of agricultural products, including coffee and tea. But with population pressure and increase, the danger still exists that some of these wildlife reserves cannot continue to be viable ecological entities. If progress is to be made in wildlife management, there is a need for more general acceptance of controlled wildlife utilization as a legitimate form of land use in the rural economy.

To stop the inroads into virgin rainforest made by the exploitation of commercially valuable lumber, and the felling of the forest by the ever-expanding human cultivations, colonial governments decreed forest reserves of certain still untouched areas and those that were of particular scientific interest or which provided the habitats for certain animal species, such as the mountain gorilla in the Virunga Volcano range. These forest and wildlife reserves have been generally maintained by most of the independent African governments.

By the time the laws on forest preservation were accepted and went into effect, large areas of forest had already been cleared or damaged to such a degree that conditions for regeneration of original tree species no longer existed. Areas of original forest untouched by human hands are now quite small. The forest reserves of Nigeria, for instance, cover only two percent of the total land area (Ogbe, 1966). Large areas of forest

have been converted into crop plantations of cocoa, rubber and oil palm which provide higher financial yields when compared to the exploitation of timber. The latter is only a once-in-a-time operation because the regrowth of valuable timber is too slow. Removal of the tall trees has resulted in quality deterioration of the forest stands--not only by the cutting of the trees themselves but by the clearings and the approach roads that have to be made, changing the ecological environment and funneling bushfires into the heart of the forest.

Only few efforts have been attempted to regenerate forest clearing by means of indigenous forest species. Today's efforts seem to favor intensive forest plantations. Species selected are fast growing, commercially valuable tree species. The choice of the species to be planted depends upon the ultimate use of the trees and the money available for the undertaking. One tree which has many advantages of resistance to termites, and at the same time is useful for many purposes of construction, cabinet and furniture-making, is the teak, Tectona spp. which is now being grown on an increasing scale in many West African countries. Other plantations provide raw materials for various industries, such as paper mills, construction, charcoal, furniture and so on. Reforestation by means of Australian gums, Eucalyptus spp., is carried on in many tropical and sub-tropical areas of Africa. These trees also do well in drier areas. The main purpose of these plantations is to provide construction timber and firewood in areas depleted of tree-cover as a result of dense human occupation. These trees are fast-growing and regenerate well.

A result of the replacement of natural forests by artificial planting is the creation of an entirely different ecosystem. Such pure stands

of single tree species no longer provide suitable habitats for a number of wild animal species and will never develop into the incredibly rich floral and faunal communities of the virgin rainforest.

Another type of reforestation practiced in many parts of Africa, called afforestation, is the planting of suitable trees for "shelterbelts," for soil conservation, land reclamation or for rehabilitation. Shelterbelts or windbreaks, are barriers of trees and shrubs planted to reduce wind velocity, evaporation and wind erosion for the protection of crops, pastures and homesteads. If they are extensive enough, such plantations may have beneficial effect on the microclimate through the conservation of moisture by reducing evaporation. Moreover, these barriers provide firewood and help stabilize the soil. They are especially indicated in dry, flat areas, such as in the Soudanian and Sahelian zones. In those areas, the most valuable tree species are various Acacias, such as A. nilotica, A. tortilis, A. senegalensis, A. albida, and also Onogeissus leiocarpus. Other tree species to be considered are the mesquite, Prosopis chilensis from North America and the cashew tree, Anacardium occidentalis.

Certain trees may also be considered as providing fodder as an adjutant to grazing in arid areas. Species tried for this purpose include the mesquite, the carob (Ceratonia siliqua), the honey locust (Gleditsia Triachantos) and Currajong (Sterculia diversifolia), (de Vos, 1975).

Proposals have been made to improve poor soils by trees that, through leaf and fruit fall, help fertilize the soil. Acacia albida is perhaps the best indicated for this purpose. Its foliage and pods improve the physical and chemical characteristics of the soil with rejuvenating effect. Harvest yield under A. albida can be four to five

times greater than that grown on the unimproved same soil (Giffard, 1966). Another tree increasingly used for these purposes is the neem (Azadirachta indica) native of India. Both trees provide, besides soil rejuvenating benefits, shade, fuel, wood for construction and furniture.

Such protective plantations must be managed for improving water yields, stabilizing and reconditioning soil, preventing erosion and desiccation. They should be maintained for that purpose, with the harvesting of timber and fuel to be only of secondary consideration.

Often long-term plans are being made without the benefit of a master blueprint, sometimes endangering the continuation or the fulfillment of the project. Very seldom are hazards to health due to environmental changes considered in these plans. Such changes may convert a given ecosystem into one that may be suitable to the transmission of certain diseases. These aspects will be discussed in detail in sections below.

II. AGRICULTURAL DEVELOPMENT AND DISEASES

"Above all, it must be recognized that in the long run it is uneconomic to grow a crop that results in a reduced standard of health of the human population involved." G. Surtees

A. INTRODUCTION

1. History

Water is probably the greatest regulating factor in the distribution of animal life. All living organisms need to maintain the exact water balance within their system in which the bio-chemical reactions take place necessary for the normal functions of the cells. As water is profusely and widely distributed on the surface of the earth, the role it plays in the presence and abundance of plant and animal life is not always recognized until places are reached where surface water and rainfall are scarce, resulting in the rapidly dwindling numbers of plant and animal species.

In the desert regions of the world, animal and plant life is mainly confined to oases, occasional water courses, seasonal water collections in depressions, natural springs and wells.

The dependency upon water of all forms of organic life also applies to the elements of diseases. The same need for water will bring together host and vector, an obligatory link to the survival and spread of vector-borne parasites.

The relationship between the human host and disease patterns has changed along with our cultural and socio-economic evolution. The advent of agriculture, a major milestone in the cultural evolution of man that took place nine to ten thousand years ago, marks the division between two periods of man's biological contact with the environment and the kind and degree of exposure to disease organisms.

Previous to settling into permanent dwellings that became possible through food production techniques, human populations led the life of hunter-gatherers. This precluded the aggregation of people into permanent settlements and was responsible for the widely scattered bands of hunters who needed a large physical territory for their daily food gathering activities. Although the discovery of fire and the occupation of caves was already a first step in changing disease patterns (Lambrecht, 1968), the relationship between the human host and parasites was still subject to the uncontrolled evolutionary pressure of the natural environment. This included exposure to disease agents or vectors connected with river banks or lake shores where people bathed, drew water, went fishing or kept cool in the shade of the dense vegetation along the water courses.

In prehistoric Africa, which saw the first stages of human evolution, we then distinguish three foci of human infections: (1) The cave sleeping-quarters, which promoted such parasitic diseases as worm-infections (resulting from increased contact with human waste in the caves' vicinity) (A. W. Pike, 1967), increased malaria transmission, and tick and flea-borne diseases from rodents and, later, from domesticated dogs. (2) The savannah environment, where women and children went on their daily food-gathering expeditions, and men roamed in search of game, was an area of exposure to the tsetse-borne African Trypanosomiasis (sleeping sickness). (3) The riverine vegetation along water courses was a site of risk to infections such as sleeping sickness transmitted by riverine tsetse flies and to mosquito-borne viruses such as yellow fever. Because of the very scarce population, streams were probably not yet contaminated by intestinal parasites such as amoeba, helminths or entero-bacteria.

During this long period, lasting some three million years, human parasitic organisms invaded, killed, adapted or were rejected by the human host, himself subject to natural selection in response to the presence, prevalence, virulence, and infectivity of these parasites (Lambrecht, 1964, 1967).

2. Parasitic Diseases Related to Water

In the tropics, several diseases are directly or indirectly related to the presence of surface water near human settlements or where human activity takes place. Directly, infection may occur by contact or by ingestion; indirectly by providing a suitable habitat for intermediate vectors of diseases. The following is a brief outline of some diseases classified according to the above categories:

a. Direct

i. By ingestion: Contaminated water can be the vehicle of several infectious diseases--typhoid fever, salmonella and shigella dysenteries, amoebiasis, cholera, guinea work, and various helminths.

ii. By contact: Infections caused by organisms that penetrate the skin and invade the human host during bathing--*Schistosoma mansoni*, *S. haematobium*, *S. intercalatum* and *S. japonicum*, and many serotypes of *Leptospira*.

b. Indirect

i. Many important insect vectors of diseases spend part of their life cycle as immature stages in an aquatic environment: Mosquitoes (vectors of malaria, filariasis, yellow fever, dengue, and several other viruses); Simulium flies (vectors of onchocerciasis); Culicoides (vectors of filariasis).

ii. Water courses are the permanent habitats of a number of snail vectors of the Schistosoma: mansoni, haematobium, intercalatum, japonicum, and fasciola. Inasmuch as the infective stages of the Schistosomes (cercariae) are water-borne, the aquatic environment thus provides both the habitat of the vector and the means of transmission. Other trematode worm infections are water-borne in other ways: Paragonimiasis (snail and crab); Clonorchiasis (snail and fish); Diphyllobothriasis (conopod and fish); Fasciolopsiasis (snail and waterplant).

iii. Floating water plants provide suitable habitats for Mansonia mosquitoes, vectors of filariasis, the larvae of which take oxygen from the plants' submerged stems through a modified syphon adapted for piercing the plant cell-wall.

In addition to the direct and indirect relation between water and disease agents, noted above, water courses provide circuitous conditions favorable to the transmission of diseases by promoting vegetation cover used as habitats and resting places for a number of disease vectors. A representative example is the riverine habitat of Glossina palpalis, the vector of gambian sleeping sickness. Many insect vectors are more aggressive in moist environment or at the edge between dense vegetation and open spaces (edge effect) such as typified by riverine gallery vegetation.

3. Irrigation Agriculture and Diseases

Since its invention in ancient times, irrigation has created man-made mosquito breeding places and snail habitats. It was probably during the initial periods that many mosquito species were "domesticated"

and became dependent upon the human environment for larval habitats as well as for their bloodmeals. Following this close association with human communities, such species as Anopheles gambiae and Aedes aegypti became the primary vectors of important human infections, the former of human malarias, the latter of yellow fever and other virus diseases. The man-made mosquito habitats have evolved in various kinds of artificial environments that developed from human social evolution. They constitute under certain circumstances the bulk of disease-transmitting vectors such as reported by Reeves and Hammon (1962) for St. Louis Encephalitis and Western Encephalitis vectors in California where 80 percent of all larval breeding occurred in irrigated fields, and by Lambrecht (1975) who found in Sri Lanka that 80 percent of larval breeding sites of bancroftian filariasis vectors were man-made.

Agriculture by irrigation along the Egyptian Nile, already in practice more than 7,000 years ago, no doubt was responsible for schistosomiasis in a large section of the population if we can judge from the findings of Schistosoma eggs in several mummies.

There are dozens of examples of how man through his activities, structures and modification of the environment, has increased opportunities for the spread of disease agents to a point that certain parasites and their vectors have to rely almost completely on the human environment, so that they are truly "man-made." (Fig. 12-a)

The population increase of two to three percent in undeveloped tropical countries cannot be met by the traditional food production in those areas based mainly upon subsistence farming by the ancient method of slash-and-burn and shifting cultivation. This situation can be rectified by basically two methods: (1) population stabilization by birth control;

(2) increased food production by appropriate agriculture methods. The first method, that of birth control, even if it could be effectively implemented, cannot modify the already existing overpopulation in present inhabited areas, and its effect would only be felt in the next generations. The second method of increased food supply is thus the only solution. Besides the reorganization of land-use and agricultural methods, the most direct and speedy way of crop increase seems to be the transportation of water to large arid and semi-arid areas that could be brought under cultivation by proper irrigation. The problem of distribution of water supply to needed areas is usually solved by the storage of water through the impoundment of a suitable stream by means of a dam and irrigation channels leading from the storage to various distribution points. Large dam constructions are primarily built for hydroelectric power and only secondarily for irrigation purposes. Damming for irrigation purposes only are usually smaller projects carried out at a regional level. The distribution of water from a central point can be done by various methods.

The creation of artificial lakes and irrigation systems is followed by important environmental chain reactions. These will affect all elements that compose the environment, faunal, floral and mineral. The resulting changes will eventually be felt by the human populations inhabiting those areas, and ultimately modify social, economic and disease pattern relationships.

With regard to health, large man-made lakes and irrigation-agriculture schemes could favor the transmission of communicable diseases by (1) expanding the area and types of habitats of insect-vectors

and water-borne parasites; (2) by development of vegetation communities suitable to insect-vectors and animal reservoirs of diseases; (3) by creating a microclimate enhancing the potential of parasite transmission. Furthermore, the construction of dams and artificial lakes, and large-scale agricultural development may (1) be followed by displacement of population with the risks of increased communicable disease contacts; (2) promote the spread of diseases both in human and livestock populations; (3) increase contact with wild animal disease reservoirs; (4) result in the increase or planting of crops that would offer breeding opportunities for certain mosquito vectors. (Fig. 12-b)

In the tropical regions of the world, health hazards following the construction of dams are compounded by the presence of the many parasitic organisms and their vectors not encountered in the temperate zones, by the rural environment with its lack of sanitary control, from the relative absence of available intervention technology, and the economic inability to support research and control measures by local government.

A large number of disease vector species spend part of their whole life cycle in aquatic environment. These include all the (1) mosquito species (related diseases: malaria, elephantiasis and other filariasis, dengue, yellow fever, encephalitides and a host of other virus diseases; (2) simulium species (related disease: onchocerciasis, e.g., river blindness); (3) snail species (related disease: schistosomiasis).

The formation of large lakes following impoundment of streams and the irrigation systems increase tremendously not only the acreage of surface water but, more importantly, that of the shoreline habitats. The lake may spread out into creeks and branches forming marshy areas

and seepage swamps; wave action can produce sandbars and pools, thereby creating diversified types of larvae habitats with resulting larger spectrum of potential disease carriers.

The impoundment of a swift-running river, with perhaps only a few potential snail-breeding places, into a larger lake with stable shoreline and water level will tremendously increase snail-breeding areas. This has been witnessed in all dams built so far in Africa (Gordon Smith, 1975). Snail-breeding is further enhanced in irrigated fields where snail are now thriving in permanent slow-flowing canals where seasonal drying used to kill them. Schistosomiasis is the most important disease of irrigation projects and is a rapidly growing problem in tropical and subtropical areas of Africa, South America, the Carribean and Asia. (Fig. 12-b)

Simulium flies, vectors of onchocerciasis (river blindness) breed in swift-running and well aerated water required by their larvae. The damming of a river will most likely destroy the flies' breeding sites behind the dam by inundating previous sites, thus making them unsuitable for their larvae because of the decrease in oxygen content. The suitability for Simulium breeding below the dam will depend on water flow and whether the level is constant or not. If the river level below the dam is lowered and raised sufficiently often, breeding of Similium will be greatly discouraged. The main risks of breeding sites may be in the spillways of the dam because the constant running of water will provide ideal conditions of flow and oxygen content. (Fig. 12-b)

The other important human filariasis diseases caused by Wuchereria bancrofti and Brugia Malavi, are carried by several different species of mosquitoes, each with different larvae habitat requirements. Impounded

water will normally not be suitable for the main vector of bancroftian filariasis, Culex pipiens fatigans, a species that breeds mainly in water polluted by man and is essentially a peri-domestic mosquito. Malayan filariasis, however, is carried by Mansonia spp. which breeds in floating vegetation. The invasion of man-made and other lakes by such water plants as Eichhornia crassipes, Pistia stratiotes and Salvinia auriculata may vastly increase potential breeding areas of this vector.

B. DESCRIPTION OF WATER-RELATED DISEASES

The direct effect on health from impounded rivers and irrigation systems in the tropics concerns mainly six diseases: schistosomiasis, malaria, onchocerciasis, elephantiasis, African sleeping sickness, and arboviruses. Another important disease carried by water, leptospirosis, is far more cosmopolitan, occurring in the temperate zones as well as in the tropics. These diseases are reviewed in detail in the sections that follow.

1. Schistosomiasis

Schistosomiasis is essentially a water-related disease, since part of the life cycle takes place inside fresh-water snails, while infection of the vertebrate host is achieved through penetration of the skin by the water-borne cercariae escaping from the snail vector. The life cycle of Schistosoma mansoni, haematobium, intercalatum, and japonicum can be represented schematically as follows: man (eggs expelled with urine or feces) ---> into water with release of embryo (miracidium) ---> invades vector snail (development and multiplication) ---> release of infective larvae (cercariae) ---> penetration of skin of new vertebrate host (development into adult male and female worms) with copulation and release of eggs with urine or feces ---> start of new cycle.

Schistosomiasis is a chronic debilitating disease that affects over 200 million people in the tropical belt of the world with the following geographical distribution. Schistosomia mansoni occurs in Arabia, Africa, South America, and the Caribbean; S. haematobium is found in Africa and the Middle East; S. japonicum prevails in Japan, China, and in the Philippines. S. intercalatum, first described in 1912 but of which little was heard thereafter, is being reported more often in the last years, mainly from West African locations.

a. Relationship to water development programs

It is to be expected that by increasing the fresh-water vector snail habitats the ability of spread of the disease is greatly enhanced. Such conditions are created by the man-made lakes and in their associated irrigation channels. In the Far East, S. japonicum is widespread in vast areas under rice cultivation. It is important to emphasize that man is responsible for the dissemination of schistosomiasis by contaminating the aquatic environment with feces and urine containing the schistosome eggs. In any study of the epidemiology of the disease it is necessary to consider the ecology of the human as well as that of the snail host. For instance, the presence of a large lake will promote fishing. Where schistosomiasis may occur only at one part of the shore, fishermen from an uninfected village may become infected and spread the infection by traveling back and forth from the infected focus to other parts of the shore. It is therefore of great importance that known focal transmission of schistosomiasis be contained.

The snail vector species differ with the various species of schistosome. The snail vector of S. japonicum belongs to the genus

Oncomelania in most areas of distribution. In areas in Thailand, Cambodia and Laos, however, Lithoglyphopsis aperta seems most likely to be the intermediate host (Harinasuta et al, 1972). Snails of the genera Biomphalaria and Bulinus are hosts to S. mansoni and S. haematobium, respectively. The host of S. intercalatum is probably Bulinus (Pyrogophysa) forskalii or B. (Py.) globosus. (P. Jordan, 1975).

Data from some of the African man-made lakes shows that schistosomiasis occurs in mostly scattered foci along the lake shores. A survey in Lake Kariba (Zambesie River, Rhodesia) carried out in 1968 (e.g., ten years after the completion of the dam) showed an infection rate by S. mansoni of 16% among all age groups, whereas 69% of the children were infected with S. haematobium (Brown and Deom, 1973). The vector snails were, respectively, Biomphalaria pfeifferi and Bulinus (Physopsis) africanus associated with mats of the water fern Salvinia auriculata. The Kainji Lake surveys (Niger River, Nigeria), reported 31% S. haematobium and 1.8% S. mansoni infections (Brown and Deom, 1973). Communities along Lake Volta witnessed a sharp increase in 1967-68 of S. haematobium in the presence of large numbers of Bulinus truncatus rohlfsi associated with the weed Ceratophyllum. Scattered snail populations of B. (Physopsis) globosus were also observed. Biomphalaria pfeifferi was thought to be present in the northern part of the lake.

In resettled villages where before construction of the dam the infection was not recognized, the prevalence rate among children under 16 years rose from 3% in 1967 to 37% 12 months later (Paperna, 1970).

The area now covered by Lake Nasser was virtually without vegetation and the lake is now bordered by sandy beaches and rock outcrops covered with algae. In spite of the apparent unfavorable conditions, a sizable snail fauna of B. truncatus has developed and S. haematobium is endemic around the entire perimeter.

Infected snails may shed cercariae for about four weeks. Cercariae of S. mansoni and S. haematobium are shed during daylight hours with a peak around noon (Debbe and Jordan, 1966); those of S. japonicum are shed at night. In small bodies of water midday temperatures may rise sufficiently high to kill the cercariae. Laboratory experiments by Sturrock and Sturrock (1970) showed an output of cercariae per single B. globrata snail to be 250,000 over a period of six months.

The infection rate of schistosoma in snails varies widely. In a single focus infection rates as high as 50% are not unusual; over a wider area the average infection rate is usually as low as one percent or less.

Infections, and especially severe infections, are more likely to occur from multiple exposure. In an endemic area, the indigenous population is unlikely to escape infection as a result of constant exposure during water collection, washing of kitchen ware and clothes, bathing and swimming, fishing, fording. There is a clear relationship between degree of contact and infection rate.

b. Control measures

All evidence indicates that the transmission of schistosomiasis is taking place in all man-made lakes in Africa, as well as in the

irrigation systems. Control of the disease calls for management of the impounded water by means of shoreline sanitation, education of the human population in the proper disposal of body wastes, and of engineering such as piped water to minimize contacts between men and lake water.

Control of the disease can be considered with different goals in mind. These include attempting to stop completely transmission, prevent infection, forestall a development of clinical manifestations, or, in a less ambitious vein, reduce the level of transmission, infection, and morbidity. The objectives of a schistosomiasis control program should be clearly defined to prevent false expectations. Objectives will be dictated by the epidemiology and severity of the infection, the resources available for control, and the priority accorded to control schistosomiasis in relation to other prevalent diseases. A most important aspect of control is the prevention of the spread of the disease to areas where it does not yet occur. Planners of water resources development projects should recognize the long-term nature of schistosomiasis control programs. It should be considered on the same basis as some agricultural development projects which are funded in terms of decades rather than short periods.

Briefly, methods at present available for schistosomiasis control are as follows:

i. Molluscicides

The applications of molluscicides have to be planned after careful surveys so as to obtain the maximum effect at a minimum cost. This entails precise knowledge of the local vector snail habitats and seasonal prevalence, the fluctuations of water levels, the

plant communities favored by the local snail vector, and so on. The two outstanding moluscicide compounds are Niclosamide and N-tritylmorpholine.

ii. Chemotherapy

Drugs have been used for many years in the treatment of clinical cases, but the advent of new schistosomicides with improved characteristics and efficacy makes it possible to envisage the use of chemotherapy on a relatively large scale. Through wider application, chemotherapy could play a role in reducing not only the severity of the disease but also the rate of transmission. Hycanthone offers the obvious advantage of requiring the shortest therapeutic course of any schistosomicide. The cure rate is high and there is an impressive reduction in the egg output of people who still harbor parasites. Niridazole activity in S. mansoni infections is probably inferior to that of Hycanthone, but the drug can be used in young age groups in which the infection is of the intestinal type.

iii. Sanitation and mechanical control methods

The following physical modifications may be undertaken to control the spread of schistosomiasis: (1) Location of settlements away from irrigation canals and ditches to minimize infections by casual contact and contamination through easy accessibility; (2) Installation of domestic water supplies to decrease contact with lake and irrigation system; (3) Provision of latrines to discourage use of irrigation systems for that purpose; (4) Provision of facilities for clothes

washing and bathing; (5) Modification of the agricultural system itself by: (a) lining of irrigation ditches and canals with cement; (b) intermittent application of water to fields instead of ponding; (c) fluctuation of 0.5 meters every 5 to 20 days in impounded water levels (automatic siphon spillways); (d) spray irrigation instead of ditch irrigation; (6) Elimination or radical alterations of the snail habitats--e.g., mechanical or other removal of suitable vegetation along waterways.

iv. Combined methods of control

It is generally agreed that a combination of methods of attack on the schistosome life cycle is more likely to produce definite and rapid control than a single method. However, in situations where funds are limited and only one method can be used, epidemiological variables will determine the most useful method. Molluscicidng is favored where the volume of water to be treated per person is small. This is the case in arid zones where transmission is seasonal and confined to a few small pools, whereas it may be unsuitable in large rivers and lakes unless transmission is confined to focal areas along the periphery. The particular advantages of certain physical modifications are low maintenance costs once capital works have been carried out together with concomitant benefits in other fields that follow improvements of domestic water supplies, including the availability of sanitary latrines or alterations in land drainage and agricultural practices.

Schistosomiasis is frequently a disease of arid and semi-arid lands where the chief occupation is farming. A major component of the economic development of such countries is the installation of irrigation schemes and often the creation of lakes to store water and provide hydroelectric power. These projects, however, produce large increases in the level and severity of schistosomiasis with consequent physical disability and loss of productivity. These adverse effects can be partly prevented by designing the system to minimize transmission opportunities and by providing in the budget a fund to meet both recurrent costs of schistosomiasis control and unforeseen related problems. The cost of preventing schistosomiasis after construction is much greater if the design has not taken such problems into consideration. It is therefore strongly recommended that engineers responsible for the design and execution of development schemes consult with health authorities <u>before</u> plans are developed. Schistosomiasis programs have sometimes been avoided because they have been considered too costly. The cost and availability of labor and the epidemiological circumstances vary so much that it is not possible to state the probable costs of a control program. Existing control programs have been estimated to have annual recurrent costs with a range of U.S. $0.40 to 12.00 per capita (W.H.O., 1973).

If possible, the relocation of population should be done in settlements some distance from the lake and water provided to the new settlements by means of a piped system. Laundry

and shower units should further prevent body contact with the lake. Houses should be provided with proper latrines. Expenses for adequate sanitation should be part of the overall budget provision of any development plan. Development cannot take place without healthy human resources.

2. Malaria

History tells us how the ancient capital city of Anuradnapura in Central Sri Lanka, the city of the 90 kings, was abandoned when one third of the population was wiped out by malaria brought on, it is believed, by *Anopheles* mosquitoes breeding in the ancient "wewas" (impounded lakes) and irrigation system that surrounded the city. The microscopic *Plasmodium* protozoa carried by the mosquito has caused the defeat of armies and the abandonment of cities.

With the discovery of the life-cycle, quinine therapy and prophylaxis, and principles of mosquito control, great strides were made during the first decades of this century towards better control of the disease. The advent of DDT and several very effective synthetic antimalarial drugs during the mid-1900's gave the World Health Organization enough confidence to plan complete eradication of malaria. As Macdonald's studies (1957) already foretold, the epidemiology of the transmission of malaria is extremely complicated, often unpredictable, changeable according to endemic areas and further complicated by insecticide resistance of mosquito vector species and drug resistance of plasmodia parasite strains. The idea of "eradication" is now prudently replaced by "control." The almost global effort sponsored by W.H.O. has made it possible, however, to virtually eliminate malaria from many countries and hundreds of millions of people formerly at risk have been freed from the infection.

Human malaria is caused by four species of blood protozoa: Plasmodium falciparum, P. vivax, P. ovale and P. malariae. All are transmitted by mosquitoes belonging to the Tribe Anopheles. When an Anopheles bites an infected host, the mosquito itself will become infective and able to transmit the malaria parasite after about 10-14 days, depending upon the ambient temperature. In the human host the parasites undergo a first development cycle in the liver, then invade the bloodstream where they develop and multiply in a regular rhythm of 48 hours for P. falciparum, P. vivax, P. ovale and of 72 hours for P. malariae, a rhythm that coincides with the moment of release of a new brood of parasites at the end of each development cycle. Whereas the three latter parasites continue to maintain the liver cycle and will survive for several years in the human host even after the blood forms have disappeared, P. falciparum has only the initial liver cycle. Falciparum malaria, however, is the most acute and lethal form because of the many complications it induces in the body, especially in the brain, with often fatal outcome. Parasitaemia with P. falciparum is always high resulting in severe anemia.

a. Role of water impoundment in malaria transmission

The impoundment of a river system and large-scale irrigation schemes will initiate important changes in the environment with direct effect on the distribution of mosquito species and result in changes of malaria transmission patterns.

i. The formation of a large lake behind a dam will increase proportionally the length of shore line and thus, theoretically, that of potential mosquito breeding places.

ii. The increased shore line not only provides additional potential mosquito breeding places but the flooding into creeks and seepage into depressions will provide a greater spectrum and abundance of breeding sites for potential malaria vectors.

iii. Irrigation systems will further expand the amount and types of mosquito breeding places.

iv. Man-made lakes and irrigation systems provide year-round larvae habitats. In semi-arid and arid areas where the long, dry seasons interrupt malaria transmission cycles, as a result of the sharp decrease of the vector population, this may be of great epidemiological significance.

v. Indirect modification of the environment may follow water impoundments from the settlement of people around the lake bringing in cultivation and perhaps cattle. One specific effect of cattle will be breeding of Anopheles gambiae in the hoofprints at the water edge. An. gambiae is one of the two most important vectors of malaria in Africa.

b. Common vectors (Africa)

The following is an abbreviated list of major malaria vectors in tropical Africa with some characteristics of their normal larval habitats.

An. funestus funestus (partial shade): clear water, weedy bank streams, ditches, margins of lakes, seepage pools.

An. gambiae (sun, light shade): puddles, shallow pools, borrow pits, hoofprints, ditches - water often milky.

An. hargreavesi (more or less sun): pools with Pistia in open jungle, swamps, stream margins with vegetation.

An. moucheti moucheti (sun to light shade): among vegetation on margins of pools, streams, permanent swamps.

An. moucheti nigeriensis (sun): clear water in swamps with Pistia and other vegetation.

An. nili (heavy shade): in vegetation along sides of running streams.

An. melas (shade): black mangrove trees in brackish water, coastal streams and swamps.

An. pharoensis (sun or partial shade): swamps, rice fields, vegetation essential.

An. rufipes (sun): Pools, marshes, hoof marks, artificial containers.

It is noted from this list that when, for instance, we may find a river suitable for the breeding of An. funestus and An. nili, the impoundment of a lake with its extensions may provide additional larval habitats for other potential malaria vectors such as: An. gambiae, An. moucheti, An. pharoensis and An. rufipes. The presence of these vectors may affect local malaria transmission cycles as a result of differences in behavior of the adult female - in host preferences, in infection rates, in biting times, in flight range, in seasonal fluctuations and population dynamics, and in susceptibility to insecticides.

c. Control measures

Research by the Tennessee Valley Authority in the 1930's concerning malaria control on impounded waters brought into focus health problems 10,000 years old. Their publication (T.V.A., 1947) is, in fact, a very detailed manual on malaria control of some 422 pages, including strict state laws regulating the construction of water reservoirs and the health measures required to prevent health hazards.

Irrigation, water storage, roadbuilding, and other engineering works have been responsible for shifting breeding places of important malaria vectors, such as An. gambiae and An. funestus in Africa, from their natural sylvatic sites to human communities. Of course, malaria, with a very ancient and worldwide distribution, has been recognized since antiquity as a major disease of mankind. The discovery during World War II that DDT was an inexpensive and very efficient residual insecticide, and its availability in large quantities soon after the war, encouraged the World Health Organization in the 1950's to draw up plans for a worldwide malaria eradication program.

Several factors have intervened with the execution of these plans. The three major obstacles have been:

i. The great increase in public concern over environmental contamination by pesticides used in agriculture and public health;

ii. The development within the vector species of resistance to insecticides;

iii. Difficulties encountered in the implementation of programs under circumstances found in the tropics where rainy seasons, road conditions, and absence of adequate transportation make it impossible to meet the requirements of programs based upon precise time tables and strict application of instructions.

It has been realized that the worldwide eradication of malaria will have to wait another breakthrough before it can be reconsidered for planning purposes. But in spite of the great difficulties and drawbacks, anti-malaria programs have been responsible for the complete eradication of malaria in 35 countries, covering 193

million people, and eradication programs are now being undertaken in 46 countries with a total population of 1193 million. However, 488 million people in 66 countries still live in areas where malaria is endemic, 142 million of whom live in areas with organized anti-malarial activities. Thus, 346 million people are currently living in malarious areas where no protection is given by specific anti-malaria programs (W.H.O., 1974).

Resistance to insecticides has already appeared in 108 species of arthropods of public health importance and it seems certain that this process will continue and increase. Not only have resistant populations spread over wide geographical areas, but some species have become, in the same area, resistant to almost all available compounds, and many others are susceptible only to compounds that few of the developing countries can afford (W.H.O., 1975).

In view of the problems with modern insecticides, other control methods have been sought. Possible alternatives are: (1) Use of new classes of insecticides; (2) Environmental control; (3) Genetic control, and (4) Biological control.

The W.H.O. Expert Committee on Insecticides pointed out that pesticides are purposefully introduced in the environment with a specific aim under the presumption that the benefits from their use surpass the risks to environmental quality. Genetic and biological control are still in the first stages of field experimentation. Furthermore, these methods are self-replicating and results and by-products have to be carefully evaluated. As pesticides must remain the foundations of vector control programs for some considerable time to come, their use, and that of genetic and biological control,

in control programs is being carefully studied by ecological research teams throughout the world.

Chemotherapy is, of course, a powerful means of interrupting malaria transmission. Anti-malaria drugs are used as prophylaxis to protect non-indigenous individuals temporarily residing in a malarious area, to cure a malaria attack in a patient, or for mass treatment to protect an entire population of an area. Whereas the two first uses are highly recommended mass treatment has serious objections. It has been suggested that protected children may fail to achieve the high level of immunity that protects adults in areas of stable malaria from the severe clinical forms of falciparum malaria; that mass drug administration to children in these areas would have the effect of keeping them vulnerable to malaria morbidity and mortality throughout their lives; and that this reduction of herd immunity may alter the epidemiological pattern from stable malaria to the epidemic unstable form. Mass treatment may be considered when the purpose is to reduce mortality and morbidity due to malaria until more efficient anti-malarial measures can eliminate the infection from the community.

By definition, a malaria control program will continue for an indefinite period. Its objective is the reduction of the amount of malaria, but it does not necessarily aim to cover the whole of the country. The cost of malaria control may range between U.S.$0.30 and U.S.$1.50 per head per annum, depending upon the measures employed. The effectiveness of these measures will be a reflection of the effectiveness of the methods used, of their application and supervision, and the degree of cooperation of the target population. With residual spraying, at an annual cost of U.S.$0.50 *per capita*,

interruption of transmission can be achieved under very favorable epidemiological conditions. An estimated cost for a particular level of malaria control in Africa for a population of one million concluded that the estimated cost of anti-malaria measures would amount to U.S.$0.34 per person per annum in this area. Estimation was based upon the following services: In urban areas - three-day treatment of 12,500 attacks of malaria and mosquito control; in rural areas - single-dose treatment of malaria attacks, weekly chemoprophylaxis in children 0-14 years, similar chemoprophylaxis in pregnant women and intradomicilliary residual insecticide spraying combined with larval control. (W.H.O., 1974).

3. Onchocerciasis

Onchocerciasis is a filarial disease caused by *Onchocerca volvulus* transmitted by small flies of the genus *Simulium*. Together with two other filarial infections caused respectively by *Wuchereria bancrofti* and *Brugia malayi*, *Onchocerca volvulus* can cause obstructions of the lymphatic system which may result in the enormous enlargement of limbs and the genitalia, called elephantiasis. The main, most dramatic and enormous economic impact of onchocerciasis, however, is the causation of eye lesions leading to blindness. As the disease occurs essentially along rivers that are the habitat of the *Simulium* vectors, the disease has become known under the name of "river blindness."

Human onchocerciasis is found in the Americas with important foci in Mexico, Guatemala and Venezuela, and in Africa south of the Sahara in a wide belt between 15° north and south of the equator.

a. Relationship to water development programs

In the developing countries of Africa, the inter-relationship between onchoceriasis and the development programs are of considerable

public health importance. Mass blindness can reduce the efficiency of a primitive agricultural community below survival level. The greatest incidence of blindness is usually found in adult males who are more frequently exposed to the infection as a result of their agricultural or fishing activities near or on the river, and who are the backbone of the labor force. In addition, onchocerciasis does not shorten life so that all these blind people remain a burden on the community. In stretches of infested African rivers communities have pulled back from the river banks as far as 15 miles, thus abandoning fertile valleys, and are forced to farm on marginal poor soil.

The presence of Simulium flies and the fear of onchocerciasis are threatening the implementation of vast irrigation and dam-building projects on which the future agricultural and industrial production of developing countries depends. It should be realized that unless these water-resource development schemes are well planned, they may provide ideal conditions for the breeding of insect vectors and result in the spread of diseases among the great concentrations of migrant labor that would be required on such projects.

In the case of onchocerciasis it is true that the construction of a dam and the lake formed behind it actually would destroy Simulium larvae habitats by inundating up-river breeding sites. On the other hand, it may create new breeding sites in the spillways of the dam and in downstream sections. If properly studied and designed, it may be possible to control breeding by sluicing so as to avoid other problems that may occur from this change in the environment.

Multiple small earth dams constructed for irrigation projects in arid areas may often create breeding sites of Simulium in the

spillways and the canals downstream. Such projects, if not properly planned and medically surveyed, increase the area of potential onchocerciasis transmission and raise additional problems of control.

b. Common vectors

In Africa, onchocerciasis occurs in two ecologically different zones determined by the distribution of two groups of *Simulium* flies:

i. Vectors of *S. neavei* group: These flies are dependent upon the perennial streams containing a suitable crab host on which the larvae and pupae develop, and a sufficient forest cover for the adult stages. The adults have a restricted flight range and are mostly confined to forest or riverine vegetation where they find protection from direct sun rays and from high winds. *S. neavei* is a weak flier; the maximum recorded flight was 29 Km. from the nearest breeding place. As such, onchocerciasis transmitted by this vector will have a restricted distribution pattern.

ii. *S. damnosum*: Their larvae and pupae are found in large, as well as in small, streams meeting the following requirements: (1) Adequate velocity of about 60 to 250 cm (2-8 ft.) per second; (2) Adequate organic food supply; (3) Suitable anchoring sites at depths not greater than 15 cm (6 in.) below water surface. Adults of *S. damnosum* have been known to fly at least 40 Km for feeding purposes under favorable conditions such as found in the humid forest or during the wet season in savannah country. In dry savannah, the fly is primarily confined to the immediate river vegetation, but it has been known to travel up or down river for distances up to 85 Km and establish new colonies.

Simulium eggs, white when fresh, turning dark brown later, are laid by the female fly in batches of 200 to 500 close to the water surface or on water-lapped objects or vegetation. The larvae emerge in about 48 hours and attach themselves to submerged objects by means of a caudal sucker and a network of silken threads, produced by secretion from the salivary glands, with which they cover the anchoring place. The larvae undergo 5 to 7 moulds that takes about 8 to 14 days to complete. When the larva is ready to pupate, it spins a crude pocket-like cocoon that is open at the upper end facing the current of the stream. After about 2 to 4 days, the adult fly emerges. The female fly feeds on warmblooded hosts. It becomes infected by taking blood from an infected carrier during which it ingests microfilariae concentrated in the upper layers of the skin. The microfilariae undergo cyclic changes in the insect, but do not multiply. After 6 to 8 days, infective larvae are found in the head and mouthparts of the insect and are injected into a new host at subsequent bloodmeals. In the vertebrate host, the larvae develop into male and female adult filaria worms in about 8 to 12 months. They are found free-living in the tissues or in subcutaneous nodules mostly seen on the trunk, thighs and arms (in South America on the head). The female produces continuous broods of microfilariae which concentrate in subcutaneous tissues and can be picked up by Simulium flies and the cycle starts anew. The female Simulium is a daybiting insect - risks of transmission of onchocerciasis occur during daytime activities of agricultural populations, fishing or other water-related activities.

c. Control measures

The most successful method of control has been, so far, the dispersion of DDT emulsifiable concentrate at dosages ranging from 0.03

to 1.00 ppm, from dosing points along the infested stretches of river banks. The average concentration used is 0.1 ppm and the optimum duration of dosing is 30 minutes. Normally, weekly dosing has been very effective, but where insecticides become the major cost item in a control campaign, increasing the dosing interval may be considered. Actual methods of application vary considerably but all are simple with equipment that can be constructed from whatever material is available locally. The actual application of the insecticide usually presents few difficulties, but there is a considerable amount of advance preparation required in plotting breeding sites, cutting adequate access points, training of staff, transportation (keeping in mind the state of the roads in the rainy season), tracing the effective range of the spread of the insecticide downstream after each dosing and anticipating modifications according to the findings. In preparation of any control project, it is absolutely essential that all the rivers in the area be surveyed continuously throughout a complete year.

Many predators and parasites of S. damnosum and S. neavei are known to exist. Studies in East Africa and elsewhere suggest that continuous larviciding over long periods could, by complete elimination of natural controlling factors, lead to sudden Simulium population explosions and, thus, adversely affect gains obtained by artificial control measures.

World Health Organization has launched a large-scale onchocerciasis program in the Volta River basin, and an operational agreement was signed between the seven governments concerned with W.H.O. as executing agency. The program area covers about 700,000 Km^2 in the seven basin countries and it is estimated that among the 10 million inhabitants more than one million are infected with onchocerciasis, of whom at

least 70,000 are considered "economically blind" and many more suffer serious visual impairment. The disease constitutes the most important deterrent to human settlement and development of the largely uninhabited and unproductive Volta River basin. Development schemes in the endemic zones depend on the services of administrators and technicians. In the course of their duties, many of these persons will be exposed to infection with onchocerciasis for the first time in their lives, and similar considerations apply to their families.

Control of the simuliid vector at the larval stage by a biodegradable insecticide offers the only means at present for interrupting the transmission of onchocerciasis. However, since people already infected may remain infective for as long as 15 years, the elimination of the vector must be continued for no less than this period after the appearance of the last case in the program area, unless an effective chemotherapy is discovered in the interim that would eliminate the source of infection from the host population.

4. Filariasis (Elephantiasis)

Elephantiasis is a disease caused by two types of filarial worms that result in the gross enlargement of limbs and genitalia in humans infected with *Wuchereria bancrofti* or with *Brugia malayi*. Both parasites are carried and transmitted by mosquitoes of different genera, *W. bancrofti* mainly by *Culex pipiens fatigans* and by *An. gambiae* (in West Africa), *B. malayi* mainly by *Mansonia* mosquitoes. Because of the difference in the biology and ecology of the vectors, the two filariae parasites have different distributions and epidemiology. *W. bancrofti* is endemic in most warm regions of the world: Latin America, Africa, Asia and the Pacific Islands. *B. malayi* is endemic in Southeast Asia, India, Central China, South Korea and Indonesia.

The disease is transmitted by mosquitoes taking a bloodmeal from an infected host with filaria larvae in the peripheral blood, called microfilariae, that are produced by the adult female filaria worm living in the lymph glands. After a period of 10-14 days, during which the larvae undergo development but not multiplication in the mosquito, the insect can infect mature larvae in the new host at a subsequent bloodmeal. Within the vertebrate host, the larvae develop into mature male and female adult worms that invade the lymphatic system and cause blockage and tissue reactions that are responsible for the permanent swellings of limbs, genitalia or breasts. Two forms are known: the nocturnal type in which the microfilariae appear in the peripheral blood of the vertebrate host during night time; diurnal type in which the microfilariae are present during the day. The occurrence of one or the other type coincides with the presence of the day- or night-biting mosquito vector, a result of evolutionary adaptation. Because of these differences, a large number of mosquito species are involved in the transmission of the disease, including Anopheles, Culex, Mansonia and Aedes species. The diurnal type is found mainly in Southeast Asia and Pacific Islands where it is essentially transmitted by Aedes spp.

a. Vectors

i. Bancroftian Filariasis: An. gambiae, An. melas and An. funestus are the principal vectors of W. bancrofti in West Africa. The rapid urbanization of settlements and polarization of rural population around cities under very poor housing and sanitation are creating ideal conditions for the rapid increase of C. p. fatigans. This mosquito has become the dominant species in most African towns, where it used to be scarce only a decade ago (Hamon, et al, 1967). The use of DDT in specific Anopheles control may have favored the

establishment of C. p. fatigans for whom the method of control was less selective.

Lakes, irrigation and development will have a double effect in relation to bancroftian filariasis. As mentioned above, man-made lakes may cause an increase of An. gambiae and An. funestus breeding sites and thus provide higher risks of W. bancrofti transmission. Secondly, the developing area will attract populations which (1) may introduce filariasis; (2) live under temporary, unsanitary conditions suitable for C. p. fatigans breeding. Once a W. bancrofti-C. p. fatigans cycle is established, the rate of transmission will be probably higher than a W. bancrofti-An. gambiae cycle because of the very high infection rate of C. p. fatigans under natural conditions and the close peridomestic contact between man and this mosquito.

ii. Malayan Filariasis: This type of filariasis occurs only in the Far East, roughly from eastern India, Ceylon, Southeast Asian countries to Japan. The main vectors are mosquito species belonging to the genus Mansonia, the larvae of which attach to the roots and leaves of aquatic plants from which they obtain oxygen by means of a modified syphon adapted to pierce the plant cell walls. The commonest plants associated with the breeding of Mansonia mosquitoes are the water hyacinth (Eichhornia crassipes), the water-lettuce (Pistia stratiotes) and the water-fern (Salvinia auriculata).

One or more of these plants have appeared in man-made lakes sometimes with massive invasion that caused many problems including navigation. The presence of these floating plants will encourage and sustain large mosquito populations of Mansonia species. In

Africa, where B. malayi does not occur, health risks related to these mosquitoes will be mainly as carriers of viruses such as Spondweni and Wesselstron fevers. In the areas of Malayan filariasis, however, the floating plant growth on artificial lakes will be of great epidemiological significance in encouraging the spread of the disease.

iii. Subperiodic filariasis

The periodic (nocturnal) forms of bancroftian or malayian are endemic in Latin America, Africa, Asia and the West Indies. The vectors of these forms of elephantiasis are night-biting mosquitoes, mainly C. p. fatigans for W. bancrofti and Mansonia species for B. malayia with secondary vectors such as An. gambiae for W. bancrofti, and several Aedes species for B. malayia. The coincidence of the optimum of microfilariae in the peripheral between 10 p.m. and 2 a.m. with the optimum of biting activity of the principal vectors must be assigned to natural selection.

In the South Pacific Islands, mosquitoes which serve as vectors of W. bancrofti, essentially Aedes, are day-biting species. As a result, the bulk of the microfilariae appear in the peripheral blood during daylight hours and are thus available and transmissible by day-biting Aedes.

Ae. togoi and Ae. polynesiensis are widespread in many Polynesian Islands, and so is elephantiasis.

Both nocturnal and diurnal bancroftian filariasis are carried only by man, but malayian has also been found in primates and felines. It seems likely that patent infections are produced only when a susceptible individual receives a large number of infectiv larvae

during a given period. Humoral and tissue reactions leading to elephantiasis seem to develop as a result of continuous challenge to reinfections and adult worm load.

Microfilariae are not usually found in the blood of patients with advanced filariasis.

b. Relation to water development programs

Man-made lakes and irrigation will increase the larvae habitats of several *Anopheles* mosquitoes, including *An. gambiae*, a potential vector of bancroftian filariasis in West Africa.

The eventual development of floating water plants will encourage the establishment of *Mansonia* mosquitoes, the vectors of Malayan filariasis in Far Eastern countries.

The most active transmission potential of filariasis may develop from the aggregation of people in uncontrolled, unsanitary settlements creating favorable conditions for the breeding of *C. p. fatigans*.

c. Control measures

Not all infections with *W. bancrofti* or *B. malayi* develop into elephantiasis. These serious clinical manifestations develop only as a result of prolonged exposure and reinfestations that result in a high adult filaria population within the lymphatic system. Once this process of tissue build-up starts, however, it is irreversible, so that the disease should be cured before it reaches the final stage if we want to save the patient from a horrible malformation and handicap for the rest of his life. It means that infections have to be diagnosed at an early stage of the infection. This can be done by examining a bloodsmear from each person living in an endemic area and treating those found with

microfilariae. In areas of nocturnal filariasis, blood samples have to be taken at night and this may pose some problems in organization and in winning the confidence of the inhabitants to come out at night or to open their doors for strangers.

People found infected can be treated with diethylcarbamazine (Hetrazan, etc.) which is usually effective. In known endemic areas of high infection rates with microfilariae, mass treatment of the whole population is often applied which dispenses with the preliminary, often costly and not always accurate, microfilaria surveys.

The other method of control of the disease is by elimination of the mosquito vector. Depending upon the type of filariasis, bancroftian or malayan, and the vector species involved, mosquito control may vary widely from one region to another. If the vector has been proven to be mainly or solely An. gambiae, any measure as applied for malaria control, such as house spraying with an appropriate insecticide, can be used. In areas where C. p. fatigans is present, the use of larvicides in the main breeding sites will be more effective than adulticides. Where Mansonia species are the main vectors, the elimination of the plant-host from water surfaces will be the most effective way to achieve control. The effectiveness of such control measures was demonstrated in Ceylon (Sri Lanka) during the late 1940's by the use of weedicides on floating vegetation (Chow, 1953).

Complete elimination of mosquito vectors from a large endemic filariasis area will prove to be extremely difficult under most circumstances, especially of C. p. fatigans which breed profusely in peridomestic, man-made breeding sites. Case-treatment or mass-treatment is equally often only partially effective except when it can be applied in

an isolated area. The most effective method is probably a combined action of mosquito control and treatment applied during the same period, if the area is to be made safe from subsequent reintroduction (Lambrecht, 1974).

5. Trypanosomiasis

Human trypanosomiasis (sleeping sickness) is a continuous threat to the health of some 35 million people in Africa and a serious obstacle to the development of 6 million Km^2 of fertile land, while the threat of trypanosomiasis in livestock denies the use of thousands of square kilometers of grazing pasture. Following political changes after independence, many of the previous sleeping sickness surveillance programs were relaxed or, in some countries, abandoned, with grave consequences. Focal outbreaks have been reported over the past few years, leading in some areas to the depopulation of villages.

In the majority of endemic areas, risk of acquiring the disease is likely to remain for many years as there is no practical method for its total eradication. The results of operations that are apparently technically sound tend to fall short of expectations owing to the difficulties of maintaining an adequate follow-up. With regular medical surveillance, the human reservoir of infection, in the case of *Trypanosoma gambiense*, can be kept at reduced levels. Infections can also be prevented from developing to the advanced stage at which successful treatment becomes far more difficult.

a. Vectors

There are two types of ecologically and biologically distinct human African trypanosomiasis. One, the chronic type, is caused by *T. gambiense* and is essentially a man-to-man transmitted disease carried by tsetse flies of the *Glossina palpalis* group. The

distribution of T. gambiense coincides with the riparian habitats of this group of flies in west and central Africa river valleys. The second form of human sleeping sickness, an acute disease that may kill in a matter of weeks or months, is a true zoonosis. Trypanosoma rhodesiense, the causative organism, is maintained in wild animals of the woodland savannahs in eastern and southern Africa and is transmitted by tsetses of the Glossina morsitans group.

At the beginning of the century, the first medical survey teams, visiting areas in central Africa, found whole villages and fertile valleys abandoned as a result of sleeping sickness outbreaks. With the discovery of the cause and vectors of the disease, and of chemotherapy, some of these areas could be reclaimed. But with the population pressure of recent years, some uncontrolled population movements have occurred and tsetse fly areas have been reoccupied with the predictable result of sleeping sickness outbreaks. Such circumstances have developed south of the Sudano-Sahelian zone, since drought has driven people to the more fertile areas which had been abandoned in the past because of trypanosomiasis. These new settlers are thus being exposed to the risk of the disease.

b. Development projects and disease transmission

Occasional contact between tsetses of the G. morsitans group, with consequent risk of T. rhodesiense infection, will occur when people venture into the woodland savannahs, the habitat of these Glossina and of the animal carriers, for hunting, honey or firewood collecting, travel and similar activities. Agricultural development projects, population movements, the introduction of livestock, the intentional seasonal bushfires, have substantially altered vector-host

relationships. Adaptation to man-made habitats have occurred, resulting in close man-fly contact with resulting sleeping sickness outbreaks.

Development projects will have to consider the actual or potential risk of trypanosomiasis that may result from the implementation of such programs. In many cases it can be expected that the clearing of tree cover and of massive occupation of an area will be detrimental to tsetse flies as a result of the destruction of their habitats and, in the case of G. morsitans, of the disappearance of their animal hosts. If, however, occupation and settlement is light or tsetse fly pockets have remained unaltered, the settlers may be exposed to close tsetse fly contact with risk of trypanosome infections.

This double effect also applies to circumstances following the construction of dams and irrigation systems. The lake formed behind the dam may very well destroy extensive tsetse fly belts through inundation of their woodland savannah habitats. On the other hand, the long shoreline of the impoundment will provide suitable tsetse habitats whenever they develop dense tree vegetation. This was the case in the Kossou and Kariba lakes. Furthermore, the lake may become an intense focus for trypanosome transmission because of its attractiveness to man for farming and fishing, and to tsetses because of the riparian vegetation that will develop into suitable habitats and will also attract wild and domestic animals and thus provide the fly with alternative sources of bloodmeals.

Trypanosomiasis in livestock is a serious drawback to the economy of an African country. Where it occurs, the subject is treated with the same priority as human sleeping sickness. Its importance not only relates to the economy of the country and supply of animal protein,

but is also related to its social impact on traditional pastoral ethnic groups for whom the possession and number of cattle forms the basis of social structure.

Most tsetse fly species have rather specific habitat requirements which can be broadly summarized as related to: (1) adequate availability of a bloodmeal; (2) suitable climate; (3) suitable resting habitats. Whereas all these requirements are interrelated, the degree to which they occur, and many secondary elements, characterize the habitat of each Glossina species. Host preference, for instance, may be a determining factor for a given tsetse species, but then again, the presence of a preferred host may be related to the type of vegetation which, in turn, results from the local climate, topography, and soil.

Other aspects of development related to the spread of tsetse flies are afforestations recommended to improve soil conditions, to provide firewood or for use of windbreaks. Often the density and the types of trees used, especially Acacias, such as A. albida, may form vegetation communities suitable as Glossina habitats. The ultimate occupation by these flies of such artificial woodland will depend upon: (1) transportation of flies from another area by road, train, cattle herds; (2) direct or close contact with an active fly belt. Whenever afforestation projects are carried out, measures should be taken to prevent them from becoming tsetse-infested communities with resulting risks of trypanosomiasis.

c. Control methods

The rather fastidious ecological requirements of Glossina have been the basis for certain methods of control. Firstly, it was found that changes in the tree cover, whether by thinning out through partial

clearing, or by allowing vegetation to become denser, by exclusion of bushfire, for instance, achieved complete or partial control of certain tsetse fly species. Secondly, in areas of long dry seasons, when the fly is forced to retreat to the denser and moister parts of their vegetation habitats, it was found that the fly could be eliminated by making these refuges unsuitable for their maintenance by thinning out the dense vegetation or by the application of residual insecticides.

On the basis of current knowledge and experience, large-scale eradication can only be achieved by the use of insecticides. The possible exploitation of the sterile male release method is also dependent upon an initial reduction of the population using insecticides. Game reserves are reservoirs of tsetse and trypanosomiasis. This has to be considered when control of the disease is planned in neighboring areas.

The application of insecticides for tsetse control can be carried out in two ways: (1) by selective spraying of the resting sites and dry season retreats; (2) by space (blanket) spraying of the entire fly belt.

i. Selective spraying

In the first method, the insecticide is applied to the vegetation which has previously been identified to be essential to the fly population when it retreats to the denser part of the savannah tree cover during the dry season months. Essential requirements for the success of the operation are: (1) correct identification of plant communities regularly frequented by a substantial proportion of the tsetse community; (2) the identification within these settings of locations preferred for resting at some stage of the 24-hour activity cycle; (3) the application of an insecticide

formulation with adequate persistence and surface availability.

This method can be implemented by ground spray or by helicopter. The great advantage of this approach is that only a small proportion, sometimes less than 5% of the total area covered by the fly, has to be treated. On the other hand, preparatory surveys to determine the essential fly habitats may be quite involved and, if not accurately done, may leave important fly refuges untreated.

ii. Blanket spraying

The second approach relies on repeated space applications which destroy all, or a very high proportion, of the adult population at or shortly after the moment of each application. The operation has to be repeated at intervals so that ultimately all emerging adults are killed before they deposit more larvae.* Detailed understanding of tsetse behavior becomes less important and, thus, lengthy surveys less critical. Essential requirements are (1) a precise knowledge of meterological conditions that will ensure maximum coverage of the target areas; (2) sufficient knowledge of the bionomics of the local fly communities to determine the number and spacing of applications.

The usual method of application on a large scale is by fixed wing aircraft and the larger the area that can be covered each day (or night), the better. Space application may be indicated where tsetse behavior patterns have not been identified or are diffuse, as in southern Guinea savannahs, or in forest vegetation zones.

With regard to riverine flies of the G. palpalis group, their control is in many instances simplified by their more restricted

* Reproduction of Glossina is by a living larva deposited by the female every 11th day. The larva pupates in the soil, whence the adult fly emerges after 20-30 days.

and better defined habitats. Sheer clearing of the riverbank vegetation at points of contact with man reduces drastically risks of infection. Over long distances of river, the application of residual insecticides on the vegetation facing the stream has been found extremely effective, a method that was the result of direct observation that G. palpalis travels over the water surface with frequent rest periods on the inside vegetation.

The presence, abundance and role in the transmission of the various trypanosomiasis of tsetse flies is so closely related to local ecological conditions that, although a basic method of approach for control may be acceptable, many adjustments are probably necessary to comply with specific circumstances. As remarked earlier (I.C.2.), the feasibility of the practical use of wildlife in development should be seriously considered. Firstly, the possibility of the domestication of certain wild ungulates, such as the eland, an animal resistant to trypanosomiasis and adapted to the African grazelands, may offer rewarding results. Secondly, the cropping or harvesting of existing wildlife in certain areas may very well open an accessible market of animal protein to populations suffering from malnutrition.

Taking several of the above facts into consideration, a kind of general principle of combined tsetse control and land-use is schematized in Fig. 11 (Vanden Berghe and Lambrecht, 1963) and discussed (Lambrecht, 1966).

6. Arboviruses

The arboviruses (arthropod-borne viruses) comprise 300 recognized viral organisms grouped into 41 types based upon antigenic relationships.

Most important human virus diseases fall in group A or group B, and include Central and North American encephalitides (WE, VEE, EEE), Chikungunya and O'nyong nyong (group A), and Yellow Fever, Dengue, Japanese Encephalitis and St. Louis Encephalitis (B). Several infections caused by these viruses have high mortality rate, especially yellow fever, that may result in an 80 percent or more death rate in a single epidemic. Other viruses cause a febrile illness often accompanied by crippling joint pains. Although usually non-fatal, they may cause long-lasting discomfort or, more seriously, have neurologic sequela.

All viruses mentioned above are carried by mosquitoes, including a wide spectrum of species belonging to Aedes, Culex and Anopheles genera. Profound changes in the environment, such as those following water and agricultural development projects, will not only favor breeding of several vector species but also attract large migratory and permanent bird populations which may include several species that harbor virus infections transmittable to man.

Of all the many virus infections found in the tropics, dengue and yellow fever are clinically the best documented--the first, because of the rather severe illness during the first days, the joint and muscle pains and the long period of rehabilitation characterized by fatigue and depression; the second, by the often very high mortality rate and acute illness that may result in death within a week. Dengue is prevalent in tropical Asia, Central and South America, and also occurs in Polynesia. Only recently have cases been reported from Africa. Yellow fever virus is found in many tropical countries except in Asia and the Far East.

Because of the often explosive, sudden epidemics and the high mortality rates, yellow fever is probably the most important anthropod-borne

virus disease to be considered in development and resettlement schemes. The development and application of effective vaccines, together with the favorable results of the first campaigns for the eradication of Aedes aegypti, the main vector in the Americas, projected the possibility of the eradication of the disease. The discovery in the 1930's that the virus was carried by monkeys and that a natural transmission cycle existed between tree-canopy-dwelling mosquitoes and non-human primates, dissipated the illusion that yellow fever could be completely eliminated from the earth. On the contrary, the events of the past two decades show that yellow fever remains an ever-present threat (Fig. 13).

a. Vectors

The existence of a yellow fever-monkey-cycle, with its own mosquito vectors, makes the epidemiology of the disease far more complicated than the earlier assumption that the virus was a man-to-man infection transmitted by Ae. aegypti. The various pathways of linkages between the monkey and the human cycle in Africa is depicted in Fig. 14. As can be seen, there are two possible links in the chain: (1) Infected monkeys coming down to raid fields are bitten by ground-dwelling mosquitoes that can then transmit the virus to the human population; (2) Infected canopy mosquitoes do sometimes bite at ground level and in the process can infect man. These processes are reversible and both uninfected mosquitoes and monkeys may acquire their infection at ground level from the infected human or infected ground-dwelling mosquitoes, thus introducing the virus into the forest canopy cycle. In Africa, two Aedes yellow fever vector species are found in the canopy and feed on monkeys: Ae. africanus and Ae. simpsoni. They are also known to feed occasionally on man and thus provide a

possible link between the two ecological levels. At ground-level, the following vector species are the proven potential vectors in the human transmission cycle: Ae. aegypti, Ae. vittatus, Ae. taylori/furcifer, Ae. luteocephalus, Ae. dentatus. (Other species of Aedes, Eretmapodites, Mansonia can be infested with yellow fever virus but their role in natural transmission cycles is uncertain.) From the above and from actual observations, it would seem that human infections occur in two ecologically different environment: (1) rural, where risks to the human population will be related directly to the monkey-mosquito-man cycle involving "sylvatic" Aedes species such as: simpsoni , taylori/ furcifer, luteocephalus, vittatus, dentatus; (2) urban, where the transmission occurs between man by means of the "domestic" Ae. aegypti. Ae. aegypti is known to occur in two ecologically distinct races, an urban race, responsible for the urban yellow fever cycle, and a "feral" or "sylvatic" race which may play a role in jungle of yellow fever.

In South America, the link between the monkey cycle may be affected by Haemagogus mosquitoes, mainly a canopy-dwelling insect but often found biting at ground level in clearings, roadside and even occasionally inside houses. Urban yellow fever in the Americas is associated, as in Africa, only with the Ae. aegypti vector.

b. Relation to water development programs

The African Aedes vectors of yellow fever are all small water collection breeders. The larvae are found in natural sites such as tree holes, rock pools, plant-axils, bamboo stumps, or peridomestic man-made breeding places such as broken bottles, discarded tins and pots, old tires, and so on. As such, impoundment and resulting lakes or irrigation

systems will normally not promote the distribution or prevalence of these mosquitoes. Indirectly, however, the concentration of population around a newly formed lake will be followed by the accumulation of solid waste which could eventually become important peridomestic Ae. aegypti breeding sites.

The aggregation of people following development schemes would favor the distribution of yellow fever mosquito vectors through the plantation of certain crops such as banana and cocoyam. These plants have axil-leaf systems that collect water during the rains, or even from the dew, which form the aquatic habitat of certain mosquito larvae adapted to these breeding sites, specifically Ae. simpsoni, a potential yellow fever vector. (See below II.C.1.)

A very important peridomestic source of mosquito breeding, particularly of Aedes, is the traditional water storage in clay pots or similar vessels in most areas of Africa, where piped water supply is absent and people have to rely on water-hauling from a river, well or a distant public tap. In areas of long dry seasons, such as in the Soudanian and Sahelian zones, water is collected and stored in large clay jars during the months of rain. These vessels, sometimes up to one hundred per compound, are half-buried in the soil to prevent evaporation and keep the water cool. When filled with water, every single pot is a potential mosquito-breeding site. During a one-year study in villages located in a derived savannah zone of Nigeria, 36 percent of these storage pots contained mosquito larvae of 14 species, among which were the yellow fever vectors Ae. aegypti and Ae. simpsoni, in addition to an Anopheles, An. brunnipes. (Peterson and Lambrecht, 1976).

Secondary breeding sites in this water storage system are the pieces of calabash, broken pots, or similar implements by which the openings of the jars are sometimes covered in an effort to prevent the introduction of foreign objects, such as leaves, twigs, and so on, and to keep out chickens or rodents. These hollow covers collect water during the rains and provide additional mosquito larvae habitats. Interestingly, some of the mosquitoes found in the covers are of a different species than those found in the water in the jars, thus not only offering the opportunity for additional breeding sites but also for a more diversified mosquito fauna (Peterson and Lambrecht, 1976). Furthermore, it was found that the dry sediment in the pots from which the water had been used contained eggs from mosquitoes that are drought-resistant. When the sediment was submerged, up to 60 percent of jars yielded mosquito larvae of the following species: Ae. aegypti, Ae. simpsoni, Ae. luteocephalus, Ae. apicoargenteus, Ae. unilineatus and An. brunnipes (Lambrecht and Peterson, 1976).

c. Control measures

The control of the "sylvatic" mosquitoes is extremely difficult because their larval habitats are located in natural sites such as tree-holes, rock pools, plant-axils, bamboo stumps and the like. As mentioned above, some species are propagated through the planting of certain crops that provide plant-axil larval habitats: banana trees, cocoyams, pineapple and certain ornamental hedges, such as Dracaena spp. used in certain African countries to delimitate compound boundaries. Bamboo stumps and sections such as used for support of yam plants are prolific mosquito breeding places, especially of Ae. aegypti (II.C.1.). In addition to the difficulties of the elimination

of the larval habitats, the "wild" mosquitoes are usually exophilic, e.g. they do not come or rest inside the houses but take their bloodmeal from the human or animal host outside. The application of residual insecticides to the walls of habitations, effective in the control of other mosquitoes, is of little value in the control of "wild" Aedes.

Aedes aegypti, however, breeding essentially in peridomestic larval habitats of discarded tins, bottles, tires, water storage vessels, and similar man-made water collectors, can be eliminated if these objects are removed or covered in such a way that they are no longer available for ovipositioning. In urban areas, the breeding of Ae. aegypti is entirely dependent upon man-made larval habitats. The control of this yellow fever vector can be achieved without costly and undesirable insecticides by personal action of each inhabitant.

7. Leptospirosis

Leptospirosis, or Weil's disease, is caused by spirochaetes of the genus Leptospira. Human and animal leptospiroses are found throughout the world with infections of pathogenic strains of Leptospira interrogans complex grouped into 16 serotypes.

The disease in man causes severe febrile reaction followed by marked jaundice in acute cases. Depending on the serotype involved, the disease can be mild or severe but is seldom fatal, except in elderly persons where the mortality rate may reach 20 percent.

The infection is carried by a large number of animal species including nine domestic animals such as camels, cats, cattle, dogs, goats, horses, sheep, swine and buffalo. In addition, 35 wild animals have been found infected throughout the world.

The disease is acquired by contact with water contaminated by carrier animal urine in wet soil, water holes, marshy swamps, stagnant water and slow-moving streams with neutral or slightly alkaline reaction and occurring in a climate of 22°C or above. Under these circumstances, the pathogenic leptospirae may survive for several weeks.

a. Relation to water development programs

Flooded rice fields, cane fields, market gardens and similarly cultivated areas provide both the habitat for several animal reservoirs of leptospirosis and the medium of infection for those working these fields. Rice fields are probably the most favorable environment for the spread of liptospirosis -- this is especially the case in Southeast Asia. Babudieri (1953) mentions the proportion of serological-positive rice-field workers in parts of Italy as high as 80 percent.

b. Control

In known contaminated fields or in endemic areas, where risk of infection is high, workers in the fields can be protected by wearing rubber boots and gloves. Control of wild animal reservoirs will prove very difficult because many species are involved. Rodent control in the house and compound will help prevent direct contamination of food and water supply. The source of local focus should be identified. Swimming or wading should be avoided in potentially contaminated waters.

8. Dracunculosis

This disease is caused by the filaria, Dracunculus medinensis. Adult worms of this species inhabit the cutaneous and subcutaneous tissues. The life span of the female is 12 to 18 months. In about a year the gravid

female migrates to the subcutaneous tissues of the leg, arm, shoulders and trunk. When ready to discharge the larvae, the cephalic end of the worm produces an indurated cutaneous papule which soon vesiculates and eventually forms an ulcer. When the surface of the ulcer comes into contact with water, a loop of the uterus, which has prolapsed through a rupture in the anterior end of the worm, discharges the motile larvae into the water. Repeated contacts with water produce successive discharges of larvae. These larvae are ingested by a number of Cyclops (water fleas) in which they develop in a matter of 3 weeks. When infected cyclops are ingested in drinking water by man or other susceptible host, the larvae penetrate the wall of the digestive track into connective tissues to mature into adult filaria worms and start a new life cycle.

The disease is widespread over the globe but localized mostly in arid or semi-arid areas where people draw water from wells -- in Africa, India, Middle East, West Indies and northeastern South America. As the larvae has to be discharged into the water where cyclops live, only the type of wells called step-wells, are the main sources of infection. These wells are not provided with bucket and rope, but people have to go down and stand ankle deep or knee deep while filling containers. The construction of wells in such areas has, therefore, to take into account the possible presence of this disease and prevent its transmission by means of a type of structure that would eliminate direct contact or contamination of the water by human and animal carriers.

C. CROPS RELATED TO INSECT-BORNE DISEASES

1. Banana groves, cocoyam fields, pineapple and Dracaena

A number of natural or raised plants have a leaf structure whereby the V-shaped leaf stems or branch form a more or less large

cup where it joins the main stem or trunk of the plant. Rainwater or dew collect in these cavities which attract certain mosquitoes to lay their eggs. Common plants in which mosquito breeding occurs in Africa are banana trees, pineapple plants, cocoyam (two species: Colocasia esceelentum and Xanthosoma sagittifolium) and Dracaena arbocea. In Nigeria, Peterson and Lambrecht (1976) found 12 species of mosquitoes in 3680 of the four plant types mentioned above, including three potential vectors of yellow fever: Ae. simpsoni, Ae. luteocephalus and Ae. aegypti. Ae. simpsoni found in 11.7% of the wet axils examined was by far the predominant larvae in the plants examined, totaling more than the rest of the species combined. Banana, cocoyam and to some extent pineapple are common food crops in West Africa and some other parts of Africa. Dracaena plants are probably more restricted in their use as a hedge or to mark the limit of a compound field.

It is thought that in East Africa Ae. simpsoni is an important link between monkey yellow fever and the human disease as the mosquito has been found to feed on both primates. (Haddow, 1948). Banana groves where Ae. simpsoni breeds in the plant's leaf axils and which are regularly raided by monkeys are potential links in the monkey-vector-man transmission cycle. This type of transmission was strongly suspected in the very large 1960-62 yellow fever epidemic in Ethiopia.

2. Bamboo groves, fences and poles

Bamboo of some 70 species grow profusely in many parts of the tropical world in lowland as well as highland areas. They have all in common the sectioned hollow stem. When a bamboo is cut it leaves exposed part of such a section which will eventually collect rainwater.

The size, and the bacterial growth that develop in the collected rain-water are ideal as larvae habitats of several mosquito species, especially Aedes.

Bambusa vulgaris is probably the most commonly grown bamboo species in most tropical countries because of its many uses as carrying pole, for construction, ladders, as stake for climbing plants (yams), fences, furniture, animal houses, and so on, even water-pipes. To provide ready access to this very useful plant, many villages in West Africa grow bamboo groves at the periphery. Unfortunately, the dark groves also provide the privacy used for defecation and are probably important foci of intestinal worm infections. Their main indirect health hazard derives from the breeding of mosquitoes in the stumps left after the poles are cut, as well as from the top of the poles themselves when they are implanted in each yam-heap as stake for the climbing vine.

Peterson and Lambrecht (1976) found that in an area of derived savannah in Nigeria, B. vulgaris was the most proliferous contributor to mosquito breeding during a survey in which 754 tree holes were examined from 27 species plant species. B. vulgaris yielded six different mosquito species, including the four yellow fever vectors: Ae. africanus, Ae. aegypti, Ae. luteocephalus and Ae. simpsoni. In the same area, a complaint from an army commander regarding the sudden outburst of mosquitoes in the army barracks and grounds proved to derive from larvae breeding in bamboo poles by which the camp had been recently fenced off (Lambrecht, personal observation).

3. Grain crops and storage

The grain crops now in African countries belong either to one of the millets, maize or rice species. The millets commonly planted by African

and Asian farmers are known from ancient times: Ludian millet (Panicum miliaceum - known from the Indus valley from 2,500 B.C.); Chinese millet (Setaria italica - known from Turkestan to China from 2,500 B.C.); Finger millet (Eleusine cocaeana - known in Abysinia from 2,000 B.C.); Great millet (Sorghum vulgare - known in Central Africa from 1,500 B.C.) (Darlington, 1971). Their cultivation for subsistence or for cash has, of course, a great impact on the environment mainly because the laying out of the fields means the removal of the original vegetation. But in addition to the physical changes of the environment, several crops are directly or indirectly involved in health hazards.

Millet and maize fields attract rodents as do other certain crops such as rice, sugar cane, cacao, and so on. Besides attracting wild rodents, grain crops are also responsible for encouraging domestic rodent infestation when surplus harvest is stored near habitations, as is traditionally the case in most rural villages of the tropical world.

The most common and world-wide domestic rodents are the two species of rats, the "roof rat" (Rattus rattus), the Norway rat (Rattus norvegicus) and the house mouse (Mus musculus). Additionally to these three cosmopolitan species, two other small house animals are similar pests in subcontinental India and Southeast Asia: the lesser bandicoot rat (Bandicota bengalensis) and the house shrew (Suncus murinus).

Throughout historical times, the domestic rodents have been responsible for the pandemics of the most dreaded, and still potentially one of the most feared infectious diseases, the plague. The plague bacillus, Yersinia (Pasteurella) pestis, however, is normally not harbored by domestic rodents but is carried and maintained by a number of wild rodents and other animals: prairie-dogs and ground-squirrels in western

U.S.A., and by many gerbil species (genus Tatera) in Asia and Africa. Contact between these wild animal reservoirs and domestic rodents may cause infection in the latter. The plague bacilli multiply rapidly in the body of the rats and are ingested eventually by the rat flea, Xenopsylla cheopis. As the rats start to die and their numbers in the household environment decrease, the fleas, in search for other hosts, will eventually feed on man and domestic animals thereby transmitting the disease.

Another disease with a very similar transmission cycle involving wild and domestic rodents and flea vector is murine typhus caused by Rickettsia typhi (endemic typhus fever). Besides domestic rats, the cat may also be a reservoir and its flea, Ctenocephalides felis, the intermediate vector.

Other rat-borne diseases do not require an insect vector but are transmitted by direct contact. Salmonella typhimurium and S. enteritidis are two species of bacteria found in the gut of domestic rodents. They cause food poisoning when food thus contaminated by rodent feces is eaten.

Leptospira, particularly L. icterohaemorrhagiae, are carried by a high proportion of numerous animals including domestic rodents (see II.B.7). The organisms are passed in the urine of infected animals and remain infective for a long period in damp environments and in water where they can penetrate the skin through the smallest abrasions of bathers.

Two disease-causing organisms are directly transmissible to man through rat-bite. Spirillum minus (causing a disease called sodoku) and Streptobacillus moniliformis (causing so-called Haverhill fever).

These diseases are similar in clinical and epidemilogical behavior and are usually referred to as rat-bite fever.

Other diseases in which rodents play a role as reservoir include Tularaemia, Rocky Mountain Spotted fever, Rickettsial pox, Q-fever, Haemorrhagic fevers, Trichinosis.

As mentioned in section II.B.4 above, rats are indirectly involved in the propagation of mosquito-vector of filariasis in areas where coconut production is a major industry. If the trees are not protected, such as by metal collars, rats will climb to the top and hole the nuts to get to the nut-meat inside. Such damaged nut will eventually rot, fall and become suitable larvae habitats for C. p. fatigans, the most important filariasis vector in India, Far East countries and Indian Ocean islands.

4. Plantations

a. Cacao plantations

Whereas no Anophelis have been described from plant axils in Africa, three species of the subgenus Kerteszia are found in South America and the Carribean in the axils of certain bromeliad plants (Bromeliaceae). The ones described as harboring Anopheles are all sun-epiphytes, e.g. parasite plants that attach to host-trees. A man-made situation developed from the use of Erythrina as shade trees in cacao plantations in many South American countries--apparently several Erythrina trees used for this purpose are favorable host plants for a large number of bromeliad epiphytes. Downs and Pittendrigh (1946) reported 34 species of epiphytes on Erythrina trees in cacao plantation of Trinidad, but only a few species were to contain regularly larvae of M. bellator and of An. homunculus, both malaria vectors, the former by far the more important.

Gravisia aguilega was the most common larval habitat which was also among the five most common epiphyte growing on Erythrina trees, followed by Aechmea nudicaulis, Vriesia procera, and Guzmania monostachia. Three malaria vectors are associated with bromeliad epiphyles in South America: An. bellator, An. homunculus and An. cruzi. The importance of these mosquitoes to malaria transmission is essentially their close contact with man who provides firstly the opportunity of breeding places in cacao plantations and, through the presence of plantation workers, the opportunity for bloodmeals.

In most African plantations, cacao is grown without the use of shade trees and the "bromaliad"malaria problem does not exist. Moreover, no African anopheles have been found breeding in axil plants.

b. Coconut plantations

Coconut groves occur naturally or in plantations along most tropical coastal sandy ocean-shores. In some countries or regions they are the main crop: Seychelles Islands, Pacific Islands, Sri Lanka, and many other tropical oceanic islands. Coco plantations may contribute to the breeding of mosquito vectors in two ways: directly through providing larval habitats in spent nuts; indirectly through the coir industry during the process of which coconut husks are soaked in huskpits, suitable for mosquito breeding.

During a study on bancroftian-filariasis in Sri Lanka, Lambrecht (1974) found that 7.0 percent of 75,924 mosquito larvae were collected in broken or damaged coconuts that had fallen to the ground, often as a result of cutting by rats; 9.8 percent were found in the huskpits. (The same study showed that 40.5 percent of larvae

occurred in discarded receptacles). The mosquito larvae found in spent coconut belonged to the following species: C. p. fatigans, vector of bancroftian filariasis (elephantiasis); C. tritaeniorhynchus, vector of Japanese B encephalitis ; Ae. aegypti and Ae. albopictus, vectors of dengue (in Asia). In addition to the mosquito species above, the largest proportion of mosquito larvae found in the huskpits belonged to Culex gelidus, possible vector of Japanese B encephalitis.

5. Afforestation

Afforestation, here, will be used to indicate the planting of trees on new soil or where no trees existed in recent times in contrast to reforestation, a term used to describe the planting of trees in an area previously occupied by the same or related species.

Afforestations are done for barriers to reduce wind velocity, prevent erosion, stabilize soils, protect crops, homes and livestock. Shredded leaves, fruits and pods may help build up humus in areas of poor soils and help improve crop yields. When properly managed, afforestations will provide firewood, and wood for construction and furniture. The various types and trees used have been discussed in section I.3 under Conservation.

With regard to health hazards, afforestation can in various indirect ways be a factor, depending upon the species of trees, the density and extent of the "artificial" forest.

If the surface of the developing forest is large enough it may have a marked effect on the microclimate and even rainfall. This, in turn, may favor the establishment of certain insect-vectors or prolong their life cycle in such a way that they may become more efficient vectors.

A forested area in an expanse of arid or semi-arid areas may become the focal point for faunas that may be disease reservoirs such as rodents and their relation to the diseases mentioned in section 3 above, or antelopes and other animal carriers of trypanosomiasis.

Afforestation with certain trees such as Acacias may develop into a community complex that would be suitable as potential habitat for certain Glossina (tsetse flies) and risks of trypanosomiasis.

Risks of developing tsetse communities would be greatly enhanced if the area would be connected by intensive railway or road transport from a tsetse fly infested area or when the afforestation should connect with a pre-existing fly belt.

A direct threat to health from afforestations is related to a large number of tree species that develop rot holes or have an above-ground root system that collects rainwater and are favorite larvae habitats of several mosquito disease vectors. Tree holes are typical larvae habitats of several Aedes, including Ae. aegypti, Ae. africanus and Ae. simpsoni, all affective yellow fever carriers.

We have seen in previous section 4 above that in an indirect way planting of trees may contribute to the transmission of malaria, by growing parasitic epiphyte bromeliads that are habitats of Anopheles vectors.

Afforestation by means of trees that have axil-leaves are subject to becoming mosquito breeding problems. Compounds and houses in many West African villages are surrounded by fences of Dracaena spp. or Pandanus spp. and are sources of peridomestic mosquito breeding of Aedes yellow fever vectors in the axils of their leaves.

III. HEALTH CONSEQUENCES FOLLOWING HUMAN RESETTLEMENT

"Health is a continuing property potentially measurable by the individual's ability to rally from insults, whether chemical, physical, infectious, psychological, or social." J. R. Audy, 1971.

A. CHANGES IN SOCIAL STRUCTURE AND IN DISEASE PATTERNS

1. Social shock, introduction of diseases or new geographical strains, susceptibility of migrant populations to diseases in new areas

Health or disease, and certainly communicable diseases, are directly related to the environment. Studies concerned with differentials of health in relation to the ecological context or to man-environment relations are rare. A recent exception is the work of F. L. Dunn (1972) reporting the pattern of parasitic infections of several Malayan aboriginal populations in relation to epidemiological components. In an earlier paper, Dunn (1968) demonstrated that the number of parasitic species infecting hunter-gatherer populations vary with diversity and complexity of the ecosystem. Variables considered in Dunn's 1972 study were, in addition to climatic conditions, village population density, village population size, land availability around the village, community mobility, subsistence strategies, and house types.

The subject of "change" is of special importance in relation to differentials in health. Some studies carried out on recent resettlements of population displaced by artificial lakes all indicate that the subsequent decline in health of such populations was entirely unanticipated. Not a single cause could be held responsible for this observation but a number of small differences in life-style were thought to combine into a stress pattern that influenced health, such as microsocial differentiation, economic transition, shifts in diet, in fat consumption and amino acid utilization. Small, accumulating

changes as these may be gradual and subtle or blunt and catastrophic in effect (Montgomery, 1973). Scudder (1973) theorized that stress of relocation is such as to restrict the capacity for major innovations and adaptation one would expect to follow the type of challenge and conflict of a new environment.

While the social shock may be subtle and gradual, the health consequences are often reflected in increased morbidity and mortality rates during the transition period. At Aswan, for instance, Fernea and Kennedy (1966) reported that diseases such as dysentery, measles and a form of encephalitis quickly spread in resettling populations. The high temperatures typical of the region cause a rapid rise in mortality especially among the very young and the very old. At Kariba, an outbreak of human sleeping sickness reached epidemic proportions in one resettlement area (Scudder, 1973). Forty-one children of the 1600 people resettled on the Central African Plateau (several thousand feet above their old valley habitat) died within a three-months' period. Almost 100 out of 6,000 people died from dysentery diseases in the Lusitu area below the dam during the first months after the relocation (Scudder, 1973).

Aside from the psychological stress of resettlement, the increased population density of many of the new settlements (since they are planned to provide better services to the greatest number of people) increases the risk of communicable diseases.

Relocation should be examined under two circumstances: (1) resettlement of populations into virgin areas; (2) resettlement into inhabited areas. In the first case the introduction of diseases is unilateral, e.g. the diseases imported into the new areas are those

carried by the migrant population. Two variants are to be considered here. Firstly, if the relocated population is composed of inhabitants of different villages, an interchange of different pathogenic organisms is to be expected. Secondly, animals in the new areas may be reservoirs of human parasites different either in species or in virulence to those of the migrant population.

In the case of the migration of people to already inhabited areas, two variants are also possible: (1) the exposure of the new population to disease patterns in the inhabited areas; (2) the introduction into the new area of diseases by the migrant workers on dam sites. Depending upon the geographical and ecological distance of the blending population, the degree of parasite exchange may be insignificant or may be substantial and may result in epidemic outbreaks. The potentials and seriousness of an outbreak are related to: (1) the degree of immunity to the disease challenge, and (2) the presence and characteristics of geographical strains if different from those carried by either population.

The importance of resistance to local strains, or to the high susceptibility to non-endemic strains of disease agents cannot be underestimated. Striking examples are geographical strains of Leishmania tropica (causing ulcerations called Oriental sore). To avoid later ulcerations at unsightly spots in the face, for instance, children in several Middle East countries deliberately inoculate the leishmania parasite where the resultant scar will be least disfiguring. The protection is only valid, however, in the areas where the strain used is endemic but will not protect against L. tropica from other areas.

The principle of immunity to relapsing fever (caused by Borrelia duttoni and transmitted by the tick Ornithodorus moubata) is well known among African people living in infected areas. An often quoted example of this century-old knowledge concerns the Ruanda and Burundi emigrants seeking seasonal work in Uganda or Tanzania who are said to carry ticks in small boxes which they feed on themselves in order to maintain immunity so that they would not become subject to severe relapsing fever upon their return to their homeland where the disease is endemic.

Construction of major dams involves the employment of thousands of laborers, and smaller numbers of technical and managing staff. If not properly planned, the sudden population build-up in insalubrious areas and under unsanitary conditions can have disastrous results. Laborers attracted to such projects in the tropics often come from areas with poor health services and may be expected to be carriers of malaria and schistosomiasis. Or, on the contrary, laborers, and especially staff from temperate zones, may be exposed to pre-existing diseases at the dam-site to which they have never before been exposed.

Many of the numerous cultural and health problems mentioned above will be difficult to eliminate, especially when they concern many thousands of people, as is usually the case. Certain preventive measures can be taken, however, to alleviate at least psychological and physiological stress. One of the most serious offenses that can be imposed upon forceful relocation of villages is by crash programs through the absence of proper planning well in advance (Scudder, 1966), and later effective organizations of transport and capable staff.

The labor force and staff could be screened for major communicable

diseases at the time of their hiring to avoid spreading among other workers and their families. The same could be done for the displaced families. Medical examination centers may be set up temporarily during construction and resettlement movement or in permanent quarters which could become the health service center of the new community.

During the construction period and while earth-moving machinery is available, it would pay off to find out if by simple mechanical means some local vector breeding sites of mosquitoes, simulium flies, tsetse flies, and snail habitats can be eliminated.

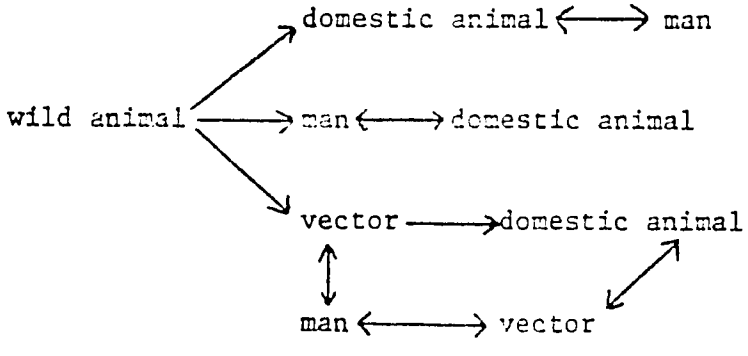
Before, during and after dam construction it would be advisable to request that medical and entomological surveys be carried out in the area so that high risks of epidemics can be foreseen and avoided. The medical teams could help in the planning of medical facilities and sanitary measures and part of the reception committee at the time of the relocation of displaced persons, while also serving as diagnostic and treatment center for laborers during dam construction.

Deom (1975) emphasizes that the support of WHO, with its knowledge and growing experience, is available to any national authority from the earliest stage of planning for the dam. It has created to that effect a separate section entitled appropriately "Man-made Lakes and Human Health."

2. Introduction of human disease through domestic and wild animals

A list prepared by the World Health Organization mentions 150 diseases carried by animals that can cause infections in man. Such diseases are called zoonosis. It is probable that these originated in animal species and that the causative agent later adapted to a certain degree to the human host as a result of his intrusion into the animal

transmission cycle. Time, agriculture and general economic development define the degree of contact and the intensity of transmission. Living standards are directly related to the degree and type of animal diseases people are exposed to. It is to be expected that people living in poor dwelling in a rural community in tropical environment are at higher risks of becoming part of a zoonosis pattern involving wild animal reservoirs than city dwellers living in concrete, modern apartments on a clean city block. Changes in the environment may result in different epidemiological patterns. Thus urbanization may disrupt contact between man and animal reservoir and vectors causing the human infection to disappear. Or the wild vectors may establish themselves within the settlement and, becoming synanthropic or "domiciliated," transmitting the infection directly from man to man (such as urban Oriental sore, Indian Kala-Azar). Still another possibility exists whereby domestic animals may replace the wild animals as reservoir hosts (Mediterranean Kala-Azar, Chagas' disease). The various zoonotric disease patterns could be represented as follows:



in which we see that the link between the wild and the domestic reservoir can be achieved in three areas, either directly through man, domestic animal or through a vector to man and/or domestic animal whence the transmission pattern can further develop and eventually

involve all elements.

Within an enzootic territory, natural foci may have a discrete or patchy distribution, restricted to animal burrows and lairs, as in the case of leishmaniasis; or their distribution is diffuse, as in the case of Chagas' disease and Sleeping Sickness (Hoare, 1962). Such foci may remain undetected and, as it were, dormant for indefinite periods of time, in fact as long as human beings do not intrude into them. They, therefore, constitute a potential epidemiological hazard, and it is important that their existence and localization should be recognized beforehand, so that they can be avoided and brought under control (Hoare, 1962).

Among the preventive measures against zoonosis are the various methods which can be used to eradicate the vectors or control sufficiently to interrupt the transmission cycle. This method, of course, presupposes an intimate knowledge of their ecology. Should the obligatory link in the transmission cycle be a domestic animal, then its elimination may be desirable.

B. HOUSING AND SANITATION

1. Water supply

Publications about water supply in industrialized countries all refer to the quality of the water and what should be done to improve upon its purification, chlorination, fluoridation, and so on. In the rural areas and even in many urban areas of tropical Africa these factors pose no problems: there is no public water supply to worry about. Here the problem is not the quality of the water but its absence, or, when available, its location at only a few scattered street water-taps. Household cooking and drinking water in Africa

is obtained in the following increasing, sophisticated manner: (1) from the river; (2) from collecting rainwater; (3) from storage of rainwater in clay pots during the rainy season; (4) from water wells; (5) from a street tap. This system of water collecting may promote the exposure or transmission of diseases in many different ways. By drawing water from the river, the water collector, commonly a woman or a child, is exposed to schistosmiases by wading into a contaminated stream. Moreover, the dense vegetation lining most African rivers are typical habitats of tsetse flies, carriers of sleeping sickness--in fact, water-hauling and bathing is the main mechanism that provides close man-fly contact and thus the major source of infection and transmission.

The collecting and storage of rainwater is directly linked to mosquito breeding as pointed out earlier (II.B.6). It concerns the breeding of Aedes, vectors of yellow fever and other virus diseases, and of Anopheles, possible vectors of malaria. The water storage system further promotes the survival of drought-resistant Aedes eggs as mentioned above (II.B.6).

Water from wells is mostly fairly pure. It may become a source of diseases in many ways, however. The most classical disease related to wells in West Africa is Dracunculiasis, a filarial disease caused by the worm Dracunculus medinensis of which the cyclops (water flea) is the intermediate host. Rodents may contaminate the water with their feces and urine containing disease agents of leptospirosis and salmonellosis. One of the most serious and perhaps most frequent source of contamination of water wells (and bore holes) is infiltrations of waste products from nearby septic tanks, manure heaps, or

sewage ditches. This may be an important and sometimes unrecognized source of typhoid fevers or cholera.

The street tap is often the only type of public water supply in African large villages or even large towns. Most of the time this water is not safe for consumption without first being filtered and boiled. However, the street tap is a great improvement upon the method of water supply described above. Unfortunately, there are two reasons to make the street tap still an indirect source of disease. Firstly, waiting lines may be very long and discourage its daily use, especially as the supply is not always assured. Secondly, the storage of water is traditionally ingrained even in the urban population so that in spite of the piped water supply, water is still being stored in clay pots for the two reasons here mentioned and are sources of mosquito breeding.

Authorities on environmental health in many developing countries have been unusually slow in considering environmental sanitation in general, and domestic water supply, sewerage and drainage, in particular, one of the high priorities in development plans of their country. This is often due to the ramification of departments within the government where, in most cases, health plays a secondary role in decision making because "it does not produce anything, but just costs money." Often it is not realized that health of the population may be one of the country's greatest assets and that preventing disease may, in the long run, be cheaper to keep the population healthy than the never-ending system of treatment.

Although statistics may be hard to find, there is not a trace of doubt that proper and adequate water supply, sewerage and drainage

would prevent the largest proportion of major infections and parasitic diseases. Effective public health education would further decrease "avoidable" man-made diseases.

2. Human and solid waste disposal

Sewerage systems are usually developed simultaneously with water supply in most developed countries. However, in small or rural communities, where financing is a problem, water supply has enjoyed a higher priority both in industrialized as in unindustrialized countries, and the provision of sewerage is often postponed or completely neglected.

Not only has sewerage drawn more attention than in the past for aesthetic and health reasons, but the rapidly dwindling water supply in industrial areas has given sewerage and its treatment an important role in water conservation.

In West Africa, the proportion of the population served with an adequate waste water disposal system is very small. Nigeria, for instance, with a population of 65 million, with 23 percent in urban areas, provides piped water house connection for 22 percent and only a few percent with sewerage. The existence of a water-carried waste disposal system is not in itself a guarantee of adequate hygiene if final disposal is unsatisfactory.

Disposal of human waste, and the available methods for doing so, may by themselves become directly or indirectly a source of contamination — for instance, where fecal materials are carried to surface waters that are the source of drinking water supplies or recreation, or where they may reach underground water storage through seepage.

An ironic situation developed in Sri Lanka where pit-latrines,

declared unsightly and unhygienic, were replaced by septic tank latrines. The faulty construction of many of them and the negligence of the inhabitants to repair broken tank covers made hundreds of these septic tanks proliferic C. p. fatigans breeding places in southwest Sri Lanka and the main cause of the establishment in that area of bancroftian filariasis (elephantiasis).

The means by which unhygienic disposal of human waste leads to transmission of parasitic and infectious diseases are multiple. Helminths are probably the most common parasites infecting man directly linked to improper waste disposal. The disposal of excreta on the ground is common in most rural areas of Africa. It often takes place in sheltering vegetation in the immediate vicinity of the village, such as the bamboo groves in Nigeria. Such places probably play a leading role in communicating helminthic diseases and in maintaining a high incidence in the population, directly through the infective larvae of the hookworm (Ancylostoma duodenale) or of Strongyloides, while the eggs of other worms such as Ascaris, Trichuris, Enterobrus and Schistosoma are carried away by rainwater into the next stream that may serve as the community's water supply.

Another major source of intestinal infections is the use of human night soil to fertilize vegetable gardens. In some areas, outhouses are built above the river bank or lake shore so that feces falling into the water below contribute directly to its pollution.

Besides the helminthic parasites mentioned above, impure water may harbor several enteric, bacterial organisms such as cholera and typhoid viruses such as infectious hepatitis, and parasitic protozoan such as amoeba or leptospoira.

Because of greater risks of exposure through bathing, unclean hands, ignorance, and walking barefoot, and perhaps greater susceptability, children are the age-group most affected by the above diseases. Correlating and contributing to parasitic diseases in children is malnutrition--their combined cause-and-effect are largely responsible for the high mortality rate of this age-group in underdeveloped countries.

Whereas human waste products contribute directly to transmission of intestinal pathogens, man-made waste materials that litter and accumulate in the human environment are indirect sources of disease agents.

The major role these materials play in disease transmission is as larvae habitats of mosquito vector species of several viral diseases, filariasis and malaria. Such materials include any type of container or broken pieces thereof one finds around the neglected compound or neglected garbage dumps: broken bottles, tins, pots, pipes, tires, and so on. In some underdeveloped tropical countries the introduction of some of these materials occurred quite recently and so must have been their adoption by certain mosquito species for breeding sites. In African countries the very prolific breeding of mosquitoes in used tires can only date from the massive introduction of the motorcar after World War I. The Seychelles Islands, with a severe shortage of animal proteins, became huge consumers of canned meat and several mosquito species adopted nicely to the discarded empty tins (Lambrecht, 1969). The importation in general of canned food in the tropics has multiplied by so many units the potential mosquito breeding places.

The solid wastes of some rural industries have added to mosquito breeding. Prominent among those are coconut shells, cacao husks, and so on.

By blocking the ditches and drains, even amorphic waste can become the cause of mosquito breeding.

In many areas such as shipping ports, army camps, heavy industry dumps, machine parts collecting rainwater are major mosquito larval habitats, especially of Ae. aegypti. Harbors seem to be places of predilection for these mosquitoes and yellow fever outbreaks that occurred in international seaports of the past are perhaps linked to this particularity (Lambrecht, 1969).

3. Overcrowding

I am not aware of recent statistical studies that would relate human density to specific parasitic diseases but it is to be expected that the transmission of communicable diseases will be greatly enhanced whenever people live in close quarters. Moreover, high human density results in more waste products which will promote conditions for multiplication of insect vectors and transmission of parasites.

In many developing tropical countries the rapid urbanization is responsible for enormous and often uncorrected health problems stemming from overcrowding largely due to the influx of rural populations into the cities that are already congested. The problems of urbanization are realistically described in a book by Nnochiri (1968). One can imagine the kind of congestion on Lagos Island where the density of population is estimated at 88,000 per square mile. The tightly packed old houses, mud dwellings in a poor state of repair, abandoned warehouses, the narrow streets with badly constructed open drainage system, the slums and shanty towns with neither privacy nor sanitation, provide profuse breeding grounds for flies, mosquitoes and rats. The lack of sanitation service and facilities is one of the most important

features differentiating African urban areas from their western counterparts. Exceptions are some of the larger cities where substantial European settlement has occurred over the years. Examples are Johannesburg in the Republic of South Africa, Salisbury in Rhodesia and Nairobi in Kenya (Nnochiri, 1968). These cities were planned and built very much along western patterns by the settlers themselves who had the money and the expertise. In most cases, African labor in industry, domestic and maintenance services, were housed in quarters at the periphery of the city which was accordingly designated as "Black City" or "African Township." In order to preserve their own health, the European town authorities kept a watchful eye on the sanitation of these towns (Nnochiri, 1968). Whenever such quarters developed into a slum area, a resettlement program was initiated and a new township was built to replace the old. One such example is the township of Souwete near Johannesburg.

Nnochiri (1968) lists several causes for the poor health and housing conditions in Nigerian urban centers: lack of money [illegible] riorities for other government projects, ignorance and conservatis[illegible] and traditional family holdings. The role of ignorance in health matters, including the causes of communicable diseases, among the large proportion of illiterate members of any urban community is quite obvious. The attitude to disease of the urban worker is very much influenced by his cultural background, his fears, and superstitions instilled from infancy in his native village. He, therefore, does not ask <u>what</u> causes his disease but <u>who</u> has caused it. Whereas the attitude based on belief in witchcraft and spirits is common in patients in southern Nigeria, a fatalistic attitude is more commonly seen among people of Islamic faith of the northern regions.

Living in houses with western standards of comfort and style has become generally recognized as one of the privileges of the elite class in most African cities (Nnochiri, 1968). Of the 156 persons of elite interviewed by Smythe and Smythe (1960), 86 lived in official housing, 70 in houses on Government Reservation, 16 in quarters provided to holders of high positions. Provided with good accommodation in a decent, low density part of the urban area, the elite is spared the hazard of overcrowding which is favorable to the transmission of "backyard" parasitic infestations of Ascaris, Ancylostoma and Trichuris roundworms. By virtue of their high economic status, they can afford such luxuries of proper mosquito screening, prophylactic drugs, medical care and hospitalization. Better and more complete clothing, better diet and different lifestyle add to the better protection against diseases of these elite groups.

A parasitic survey by Okpala of Lagos Government workers revealed such high infection rates as: Ascaris: 71.5%; Trichuris: 66.6%; Ancylostoma: 58.3%; Strongyloides: 11.7%; Taenia saginata: 2.1%; Entamoeba histolytica: 10.9%; Trichomanas: 11.0%; Giardia: 7.2%; Chilomasti mesnili: 6.2%; Endolimax nana: 3.3%, and smaller percentages of Enterobius vermicularis, Schistosoma mansoni, Iodamoeba butschlii, Balantidium coli, and Enteromonas hominis. In the northern areas of Nigeria, the incidence of Schistosoma infections was much higher ranging from 8 to 26 percent for S. mansoni and 10 to 49 percent for S. haematobium (Ramsay, 1934).

Although health conditions in the rural villages may seem more primitive than in the urban settlements, other factors, such as lower population density, may be in favor of village life. While the urban

dweller may be highly exposed to diseases that are favored by close contact and through the profusion of waste materials favoring the multiplication of disease vectors and animal reservoirs, the villager is more exposed, through his environment and his occupation, to specific infections, absent in the urban environment, such as onchocerciasis and trypanosomiasis, for instance. The differences in disease patterns between the urban and rural dweller are directly related to the differences in the environment, the behavior, housing and beliefs of the two groups. Differences of exposure to diseases between urban and rural population can also be related to the amount of exposure due to differences in clothing. A fully clad office worker is obviously less exposed to insect bites that carry diseases than a farmer working all day almost naked in his field. The shodded city dweller has less chances to get infected by larvae of hookworm or strongyloides worms than the barefooted villager, as shown from the figures given by Nnochiri (1968): stools examined from 515 urbanites showed 58.3 percent with hookworm and 11.7 percent with strongyloide worms, against respectively 71.0 and 21.0 percent in the villages.

The resettling of populations has to take into account the various factors discussed above. Most of these have to do with the health problems related to the natural environment or to man-made changes thereof. In this section, "overcrowding," has to be considered the types of human dwellings and how they can play a role in the transmission of diseases.

There is little doubt that the dark and dank "thatch-and-wattle" huts common in the tropics are dwellings that provide ideal habitats for numerous insects, vectors of diseases, and for disease-carrying animals.

To give an idea of what infestation of insects inside such a dwelling might be, let me quote the counts of anopheles mosquitoes inside huts in the Ruzizi Valley, ex-Belgian Congo, where a mixture of 1792 An. gambiae and An. funestus was recovered from a single one-room hut and 1273 from a second hut.

The mud-hut structures play a major role in the transmission of Chagas' disease in Central and South America. Cracks in the mud walls and similar hiding places are the resting habitats of the Reduvid bugs that transmit Trypanosoma cruzi, the pathogen. The open storage of food and the hut structure in general are attractive to rodents, carriers of ectoparasites and disease pathogens. Bloodsucking larvae and ticks are often found in or on the earth floor, some harboring disease organisms. The types of houses, their internal partitions, presence or absence of domestic animals, the use of an open-fire, all play an important role in certain communicable diseases.

One of the most complete studies about hut design related to the transmission of a disease is Walton's study (1962), "The Ornithodorus moubata superspecies problem in relation to human relapsing fever epidemiology." Figs. 15-20 show the different types of dwellings illustrated in Walton's work and how they relate to the presence of domestic animals, of ticks and the transmission of relapsing fever. In a practical experiment, Walton showed that by changing the platform beds to bedstead type, and changing the location of the fire, relapsing fever case could be brought down to almost nil.

C. NUTRITION

1. Changes in Food Supply and Dietary Habits

The World Food Conference of 1974 reemphasized that if the world's growing millions are to be fed, major gains must be obtained during the coming years, far exceeding previous progress. World population has now reached 4 billion people and is projected to reach 6.5 billion by the year 2000 (UNESCO, 1974). At present, well over 450 million people are hungry and lack the basic necessities to live a normal life. The demand for food in developing countries is likely to expand at the rate of about 3.6 percent per year during the next ten years, which is well above the actual average production increase of about 2.6 percent a year achieved over the past twelve years (U.N. World Food Conference, 1974). The population of fourteen West African countries is expected to increase by approximately 65 million during the next fifteen years. To feed this growing population, some 4 million additional hectares of arable land will need to be cultivated during the next ten years, including 300,000 hectares of additional irrigation areas.

Based upon the figures quoted above, it is clear that malnutrition will remain a major health problem in developing countries for many years to come. It has been recognized that diseases and malnutrition are mutually debilitating, each enhancing the weakening and injurious effect of the other. (Fig. 21)

Some evidence suggests two ways by which nutrition can affect host resistance, i.e. antibody synthesis and cellular immune response. Protein malnutrition seems to impair the production of circulating antibodies. This effect is reversed when proteins are added to the diet. The basic mechanisms in cellular immunity are lymphocyte-mediated phenomena such as

delayed hypersensitivity. Undernutrition and the depletion of protein reserves result in atrophy of liver, spleen, bone marrow and lymphoid tissues from which phagocytes and lymphocytes originate. Other mechanisms are probably also involved in lowering host resistance to infectious diseases. Ineffective response to vaccinations, e.g. against measles, pertussis, have been reported in malnourished, probably due to the inability in those persons to stimulate a primary antibody response (Neumann, et al, 1975). Deficiencies of specific vitamins also affect immune responses (Gordon and Scrimshaw, 1970). Vitamin A and pantothenic acid deficiencies in animals resulted in defective antibody production, while pyridoxine deficiency leads to defective cellular immunity (Axelrod, 1971; Hodges, et al, 1962). Mata, et al (1971) studied the infection and nutrition of children of a low socioeconomic rural community in Guatemala. The study followed the first three years of 95 children born in Santa Maria, a village located in the highlands at 2,000 meters. Their report illustrates the magnitude of infection during these first years of childhood and its effect on the growth of the infants.

The term protein-calorie deficiency (PCM) was adopted by the FAO/WHO expert committee on nutrition in 1962 which suggested the following three categories: (1) kwashiokor, including marasmic kwashiokor; (2) marasmus, including athrepsia, cachexia, and extreme wasting; (3) unspecified, including starvation in adults, famine and oedema. The various factors responsible for malnutrition in a given population have been summarized in the following two tables compiled by Manocha (1972).

It has been recognized that food habits are integral parts of a culture and that faulty dietary practices may greatly contribute to the high

PREVALENCE OF SEVERE AND MODERATE PROTEIN-CALORIE MALNUTRITION (PCM)

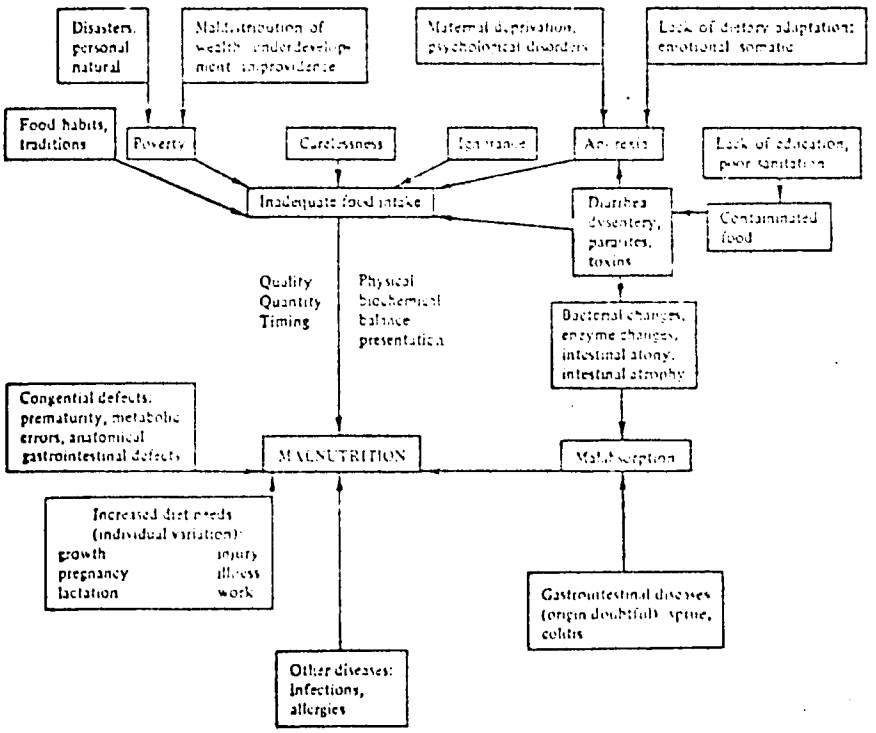
Country	Year of survey	No. of children examined	Age (years)	Cases of PCM			Source
				Severe[a] (%)	Moderate (%)	Total (%)	
Africa							
Algeria	1963	2 105	0-4	5.9	16.6	22.5	Rabult (1966)
Algeria (Sahara)	1964	1 106	0-4	5.4	—	—	Rabult (1967)
Kenya	1969	353	—	1.0	25.0	26.0	Bahdal, M. (personal communication)
Malawi (South)	1969	619	—	3.2	25.8	29.0	Burgess, H.J.L. (personal communication)
Nigeria	1961	1 268	0-15	1.7	5.6	7.3	Dean (1967)
Nigeria	1965	432	0-5	3.2	—	—	United States, Office of International Research (1967)
Senegal	1964/5	164	0-5	—	—	13.4	Cros & Bayet (1967)
Tanzania (Hombolo)	1965	401	0-4	3.2	17.8	21.0	Burgess et al. (1969)
Tanzania (Kisarawe)	1968	630	0-5	7.6	19.3	26.9	Burgess et al. (1969)
Tanzania (Tabora)	1969	551	—	0.5	7.3	7.8	Burgess, H.J.L. (personal communication)
Tanzania (West)	1969	393	—	1.5	10.5	12.0	Burgess, H.J.L. (personal communication)
Uganda		—	1-4	5.0	25.0	30.0	Musoke (1968)
Uganda (Ankole)	1965	286	0-7	4.9	27.2	32.1	Cook (1967)
Zambia	1965	359	0-5	—	—	17.0	Med. J. Zambia (1967)
Zambia		1 104	0-3	1.7-4.4	—	—	Blankhart (1963)
Americas							
Chile	1965	1 549	0-5	2.6	32.0	34.6	Monckeberg et al. (1967)
Colombia	1968	3 373	—	1.7	19.3	21.0	Rueda-Williamson, R. (personal communication)
Costa Rica	1967	738	—	1.4	9.0	10.4	Instituto de Nutrición de Centro América y Panamá (1967)
Dominican Republic	1968	10 333	—	2.5	10.9	13.4	Deza, C.H. (personal communication)
El Salvador	1967	574	—	3.3	20.9	24.2	Instituto de Nutrición de Centro América y Panamá (1967)
Guatemala	1967	763	—	4.1	24.5	28.6	
Honduras	1967	633	—	2.0	20.5	22.5	
Mexico							
rural areas	1958/68	5 576	pre-school	3.4	27.5	30.9	Perez Hidalgo et al. (1970)
urban areas				1.3	14.8	16.1	
Nicaragua	1967	708	—	1.4	11.1	12.5	Instituto de Nutrición de Centro América y Panamá (1967)
Panama	1967	624	—	0.6	11.0	11.6	
Peru (Puno)	19..	3 313	1-4	0.5	4.4	4.9	Bol. Ofic. sanit. panamer. (1969)
Windward Islands (St Vincent)	196	2 490	0-4	1.5	25.7	27.2	Jelliffe, D.B. (personal communication)
Asia							
India	1969	15 000	—	1.4-2.9[b]	16.0	7.4-18.9	Gopalan, C. (personal communication)
Indonesia	1963/65	1 958	0-5	—	—	18.0	Tie et al. (1967)
Pakistan	1962/64	1 020	0-4	2.7[b]	—	—	Pakistan, Directorate of Nutrition and Research (1966)
Philippines	1963	534	—	—	43.1	—	Bailey, K.V. (personal communication)

[a] Including weights below 60 % of the standard weight.

[b] Percentage of cases of kwashiorkor and marasmus and/or percentage of cases below 60 % of standard weight.

Table 1

Geographico-climatic	Unproductive soil Climate (high temperatures, extremes of rainfall)
Educational	Too few schools (illiteracy)
Social	Illegitimacy; family instability Absence of family planning (children too closely spaced; population pressure) Poor communications (food distribution) Alcoholism
Economic	National poverty (low gross national products) Family poverty (low per capita income) Low level of industrialization
Agronomic	Old-fashioned methods of agriculture Inadequate protein production (animal and vegetable) Concentration on inedible cash crops Poor food storage, preservation and marketing
Medical	High prevalence of conditioning infections (measles, diarrhea, tuberculosis, whooping cough, malaria, intestinal parasites) Inadequate health facilities (too few; incorrect orientation) Inadequate staff (too few; ill trained in nutrition and child health)
Sanitational	Unclean, inadequate water supply Defective disposal of excreta and rubbish
Cultural	Faulty feeding habits of young children Recent urbanization (changing habits) Limited culinary facilities Inequable intrafamilial food distribution Overwork by women (limited time for food preparation for children) Sudden weaning (psychological trauma)



The multiple etiology of malnutrition.

Table 2

incidence of protein-calorie malnutrition in certain areas. Numerous examples can be cited where the children suffer from deficiency diseases, not because of the inadequate means but because of traditional food habits which fail to support good growth and development during the growth periods of the children (Manocha, 1972). Besides certain taboos that may be responsible for absence in the diet of essential nutrients and vitamins, children may also suffer from deficiencies because of cultural customs, as among the Zulus for instance, where they are served at the end of the meal when most of the food has been used up by the adults. Nutritional deficiencies in children causes retardation in physical development and also may lower their resistance to diseases. Severe PCM in early infancy affects brain growth and may interfere, subsequently, with mental development. Pregnant women are also a nutritionally vulnerable group because of their high nutrient needs. Low birth weight was demonstrated in women of low income and poor nutrition by Mata, et al (1971) who also showed how many of them had high infection rates with enteric protozoa, helminths and enteroviruses.

Health and diseases related to food also depends upon its preparation: long periods of cooking, the addition of herbs, or the consumption of raw food. Food handled and prepared in an unhygienic manner by disease carriers is an important source of parasitic diseases. Street-hawking of food, common all over Africa, no doubt is responsible for a fair amount of intestinal infections.

The consumption of raw food is directly linked to a large number of diseases. Uncooked vegetables, grown often by means of fertilization with

human and animal waste, are direct sources of the whole spectrum of intestinal helminth and protozoan parasites. Infections from raw food are not confined to direct ingestion of contaminated vegetables but are also directly linked to the life-cycle of certain helminthic parasites. Chinese liver fluke disease, caused by larvae of Clonorchis sinensis, is common in many areas of the Far East where raw fish is part of the national diet. Lung fluke disease, caused by ingestion of larvae of Paragonimus westermani when certain fresh water crabs and crayfish are consumed raw or undercooked, is a widely scattered disease found in parts of Asia, Africa and South America.

The dietary habits of preindustrial populations are generally based upon the food locally grown. Relocation may thus result in a change in diet should the new settlement be in an area of different crops. This, in turn, may influence the state of nutrition and, indirectly, resistance or susceptibility towards diseases.

The relocation of people in areas of cash crops may encourage them to neglect their subsistence farming, thus becoming dependent upon food imported from other areas, adopting different food habits, which, occasionally, may result in dietary deficiencies. Manocha (1972) mentions examples, such as in India, where the northern regions prefer to grow food crops and the southern part devotes its energies in raising cash crops. A marked contrast in health and growth patterns are observed between these two regions. Similar differences are found among the agriculturally-oriented Kikuyu tribes of Kenya who raise cash crops with their own diet composed of

cereals, tubers, plantains with only small quantities of green vegtables or other food, and the Masai subsisting on blood, meat and milk in addition to cereals, bananas and beans. The Kikuyu are generally lethargic, lacking in stamina, and subject to disease. The Masai are taller, heavier, and endowed with 50 percent greater muscular strength (Manocha, 1972).

Drinking, whether it is milk, beer, blood, or some other beverage contributes, often substantially, to intake of energy and nutrients. The nutritive value of locally brewed beer should not be ignored because, produced from germinated grains, it contains vitamins C and B, as well as other nutrients. Moreover, beer-drinking is in many African societies an integral part of social behavior and community spirit.

An astonishing amount of arable land is used to grow crops that are not only useless from the nutritional aspect but are harmful in various degrees to the consumer. Crops such as tobacco, tea, coffee are grown on a large scale in India and China where years of starvation are common occurrences. (True, it provides money to buy imported food.)

In several societies, religion has played an important role in food habits and has influenced, for better or for worse, the general health of the followers.

Buddha preached the sanctity of animal life and Buddhism prohibits strongly against eating animal food. Therefore, followers of this belief are spared many helminthic diseases carried by the eating of undercooked meat. The same holds true for Jewish people who are not allowed by their religion to consume pork, a major source of taeniasis (tapeworm). However,

a Western nutritionist may question the wisdom of the rigidity of Hinduism or Buddhisim when hundreds of deaths are the result of starvation in a country believed to have one fifth of the total cattle population of the world.

2. Changes in Crop Production and Storage

As discussed above, the relocated farmer may be attracted to cash crop planting in new locations where such farming is in practice and, thereby, neglect subsistence food crops. The planting of cash crops may be the logical result of the availability of better soil and especially of better irrigation so that one may expect a shift from traditional small-holder farming to large-scale agriculture. This shift may not always be only in method and quantity but may also concern a shift towards an entirely different food product. Both the quality and quantity of the new crop may change presence and distribution of animals, eventual reservoirs of diseases and ectoparasites that may be potential health hazards to the people.

The presence, storage and handling of certain crops in relation to diseases have been discussed above in section II.C. Although the risk factor of importation of diseases should not be used in condeming the development of cash crops of a given kind, it should at least be recognized and, if possible, measures should be taken to reduce or eliminate the risks. One such method would be the easy access of existing or relocated population to medical facilities and a system of surveillance with regard to disease agents that may relate to the type of crops now in the area.

D. PUBLIC AMENITIES

1. Health Services

To the new African leaders and government, the nationwide economic development is a new concept. Attracted by the single goal of "economics," the side-effects of development have often been overlooked. The only true economic development, however, is one which aims at promoting man and the environment in which he shall have to toil to bring about that economic gain. Ideas have changed rapidly and today health is recognized as an important factor of production, investment and consumption. The concept of health economy is slowly submerging from the development planning boards where, previously, only engineers and politicians had a say.

The importance of the agricultural sector in African economy has been generally recognized. Africa's hope of emerging from underdevelopment is by using its abundant human resources. However, malnutrition, infectious and parasitic diseases lead to a permanent state of physical weakness and lowered efficiency, even if the individual is not aware of being sick. The quality of manpower finally depends on the status of health of its population.

The health level today in Africa is undoubtedly better than in past centuries. Many of the so-called tropical diseases are under control or reduced to a low level of endemicity. Such diseases that produced long-lasting disabilities were a heavy handicap for progress and economic development. Their effect upon the population in general is far from over, particularly in the rural areas where health services are the least applied. Population growth, shortage of doctors, and a stagnating economy threaten the return of certain diseases. Adding to

this are the changes in the environment, such as agricultural irrigation, that create conditions favorable to the development of pathogens and vectors.

Under present circumstances in Africa, physicians alone cannot ensure development of health services -- their activities must be supplemented by qualified paramedical personnel (Table 3). But even such personnel is in short supply, and costly. Some of the medical services under colonial administration resorted to medical and paramedical auxiliaries. This system would find useful application in developing countries.

In industrialized countries one finds the concentration of health care in the main economic activities. If this principle were adopted in Africa, the rural areas should benefit from a greater concentration of health services and personnel since agriculture is the main economic activity. Nothing could be further from the actuality. Realizing this imbalance, some governments have requested WHO assistance for the development of rural health services.

A number of factors are responsible for the neglect of rural health services. One of the important ones is the little interest shown by the African doctors trained in Western medicine to practice in rural areas. This attitude results from financial considerations, the physician being in a better position to make money from private practice; from social considerations of better schooling for his children, and other amenities; and as a result of specialization which entices the physician to live in a large enough community where he may expect to exercise his speciality. In some cases the desire and incentive to learn and practice Western medicine is so great that learning of tropical diseases and public health

Thousands of inhabitants per physician in African countries, 1962, and number by which the present number of physicians would have to be multiplied to reach a target of 2,000 inhabitants per physician without taking account of normal attribution and replacement

Country	Population per physician	Adjustment factor to reach 2,000 per physician
Gabon	6,600	3.3
Tanzania	7,900	4.0
Zambia	9,200	4.6
Madagascar	9,400	4.7
Kenya	11,000	5.5
Congo	15,000	7.5
Liberia	16,000	8.0
Lesotho	18,000	9.0
Guinea	19,000	9.5
Senegal	21,000	10.5
Sierra Leone	22,000	11.0
Dahomey	24,000	12.0
Mauritania	26,000	13.0
Nigeria	27,000	13.5
Cameroon	29,000	14.5
Ivory Coast	30,000	15.0
Togo	34,000	17.0
Malawi	35,000	17.5
Mali	39,000	19.5
Chad	56,000	28.0
Niger	65,000	32.5
Upper Volta	76,000	38.0

Source: "Number of inhabitants per physician." ECA, *A Survey of Economic Conditions in Africa, op. cit.*

Table 3

is completely overlooked. For all the reasons above it is clear that rural medicine in Africa is in very poor shape.

In addition to the personal preference by medical personnel, there are several shortcomings in health services organization, such as lack of realistic plans for reorganization and development; lack of understanding and communication between the economist and health authorities; ill-defined objectives, often related to the whims of the people responsible; lack of research and understanding for the population's needs and priorities; absence of methods, standards, organization and management; shortage and inadequacy of supervisory and senior personnel; insufficient and inexperienced training institutions and teaching staff; lack of coordination between the various departments of the health services and those responsible for economic planning and development.

In rural areas, the raising of crops and livestock forms the basis of the economy; there is little diversity of skills and few or no community services are organized; dwellings are scattered or clustered in small groups -- this makes it difficult to organize such services as water supply, excreta disposal, vector control and other public services. The inhabitants waste a great deal of time and energy in collecting water from rivers, brooks, wells, canals and lakes. These sources are often contaminated by human and animal wastes so that the incidence of water-borne diseases is quite high. Food hygiene is very low. Vector control activities or other preventive disease measures are rarely applied in rural areas. Means of transportation may be inadequate to reach medical services for consultation or for emergencies.

From the discussions of facts above it seems imperative that an adequate and efficient health system be considered in the planning of

any development program. Resettlement schemes should include the pre-establishment of health facilities to provide adequate care for the number of resident population as well as the expected increase from relocated people.

WHO (1976) has suggested five types of health services and the number of people that should be served by each type: dispensary, 5,000 to 10,000; rural health center, 40,000 to 200,000; rural or district hospital, 100,000 to 200,000; specialized provincial or national hospital, 1,000,000; university hospital center, 3 to 5 million. Adequate staff should be provided to make full use of the facilities. Too often are health centers showcases without soul or their effective function dwindles as funds are diverted to other programs. Emphasis should be placed on preventive services and on the most economically possible utilization of resources. Dispensaries and rural health centers are much cheaper to build, equip and run than are hospitals. It has been estimated that care cost about half as much in a dispensary as in a rural health center which, in turn, is 40-100 times cheaper than a hospital (WHO, 1976).

In the system of health care in rural areas, the dispensary is the basic local health unit. It is the closest to the inhabitants and should offer them adequate services satisfying their basic needs, including health education, vaccinations, maternal and child health, diagnosis and standard treatment of minor disorders and highly endemic diseases, vector control according to an approved plan, referral of severe cases to the rural health center, and education and advice with regard to food hygiene, water purification, disposal of body and household wastes. Proper patients' records should be kept and filed. The combined records of all dispensaries would be a true reflection of the population's health.

It should be recognized that the African traditional healers still play an important and influential role in some communities. Their presence cannot be ignored and dealings with them should be done with much tact.

Some countries, such as Niger and Tanzania, recognize the importance of the community involvement in health services and have organized health teams serving as a sort of liaison between the individual villager and the basic health unit. In communities in Tanzania health services are organized at the village level. Dispensaries and health centers are [illegible] by the villagers, the state merely providing the materials, equipment and services. They also help to construct water supply networks and are encouraged to build their own latrines.

From the description of some of the diseases in section II.A. one can appreciate that a number of diseases and disease vector habitats are man-made and should, therefore, be easily preventable. Public health education, however, has proved to be the most ineffective medium for fighting diseases, so frustrating indeed that it has been often estimated too unrewarding, too costly and too uncertain. While more direct methods of disease control undoubtedly should take care of the sick, each health worker should be capable of carrying out the duty of an educator. The health education of an entire community can bring about a general improvement in hygiene and encourage the inhabitants to take part in community development projects. Although effective health education may require long-term effort, its effect on general health of the community, in return, will also be long-lasting and eventually become permanently engrained in the traditional way of life of the people.

Efforts to improve health will fail unless they take into account the social and cultural elements of the community. Attitudes towards life and death determine the value placed on health by a community and may, thereby, decide the demand for health services and the use made of them. Cultural beliefs should be respected, studied and understood by all workers in a community. Some beliefs are harmless to health and can perhaps be employed to advantage; others may be harmful and a long-term educational program may be necessary to effect change.

The village school and schoolchildren are the obvious starting point for health education programs (Read, 1957). It should be borne in mind, however, that in spite of the four to six hours a day attendance, children are subject to their parents' authority or elders', and have to carry out certain duties such as fetching water, watching over cooking fires, minding younger children, herding goats and so on (Read, 1957). In their minds there is a separation between school life and the reality they face at home and in the village. Rather than come into conflict with their parents or elders, children will adopt practices of the villagers as a whole instead of those preached during class hours. It is for those lessons that education of the parents should proceed at the same time as that proposed for the children, through a carefully planned program of public health for all the villagers correlated with the teaching being given to the children in school.

Consideration should be given to include in the health program a family planning unit. Family planning will have a positive effect on health when it is used to postpone the first pregnancy until the woman has completed her own growth, thus avoiding the double burden of growth and reproduction; and when it is used to space births and extend the

interval between pregnancies, so that the mother has time to recuperate after each birth; and when it is used to limit the total number of births (WHO, 1972). Cultural and traditional rules of several African ethnic groups are actually a form of birth control and may therefore be to the advantage of the family planning unit.

In the French-speaking countries of West Africa, the "Organisation pour la Coordination et la Cooperation de la lutte contre les Grandes Endemies" (O.C.C.G.E.) is assisting in the reorganization of rural health services based on the development of polyclinics supported by mobile units, especially in the control of endemic diseases. In many countries in West Africa, it is now recognized that given the restraints on national health budgets and the limitations imposed by inadequate numbers of personnel, it is not possible to deliver high quality medical care to all of the population (Imperato, 1976). The resources to do this simply do not exist. Therefore, the emphasis has been placed upon developing high quality national centers in capital cities and secondary centers in provincial capitals. Depending upon these centers is a network of peripheral units, e.g. dispensaries and medical units which reach out into the rural population but which by no means reach the vast majority of them. Imperato (1976) points out, however, that long-term planning should carefully analyze population trends which, in some instances, indicate a rapid flow of populations from rural areas into urban centers. Estimations show that in 1965 about 10 percent of the population of Africa lived in cities. It is projected that by 1980, 17 percent of the population will reside in large cities. Investments in health service organization and planning must be made with this trend in mind.

Whether in the city or the country, the thrust of health services must be in the direction of preventive medicine, communicable disease control, maternal and child care and environmental sanitation. Family planning must be given increasingly greater emphasis in most countries. (Imperato, 1976)

2. Social Services

One of the few correct generalizations about the continent of Africa is that it is a land of villages (Read, 1957). T. Scudder (1975), who followed the Kariba resettlement, described the traumatic experience of the relocated populations. Most resettlement authorities are unaware, he wrote, that compulsory relocation is an incredibly complex process -- they tend to underestimate the amount of time, capital, personnel and equipment necessary.

The matter of resettlements should be a major consideration because it affects literally thousands of people at each large dam construction site. To quote some figures: Kariba Dam, 56,000; Volta Dam, 70,000; Kainvi Dam, 42,000; Kossou Dam, 80,000; Oswan Dam, 100,000; all located in Africa.

In planning social and public amenities of a new or relocated settlement, not only materialistic and physical elements should be considered, but also the psychological well-being of the inhabitants. A problem may be that of the installment of village authorities. Social structures may vary widely in different regions and to install a "chief" when such a person is unheard of in a given ethnic group would be a grave error.

The planning and execution of resettlement has to be carefully worked out, preferably in consultation with a knowledgeable anthropologist who

has spent some time in the area prior to the move. A specialist in tropical medicine and a medical entomologist should participate in all stages of planning and phases of resettlement, including a prior survey of the selected areas.

Housing is a matter of priorities, of course. Again, it would be a grave error to impose, as I have seen, a type of house, however of high standard in western eyes, to people who are accustomed to their traditional dwelling, unless for an imperative reason of health, such as to avoid Triatoma bugs infestations in South America. The type of construction should be discussed beforehand with the villagers or with someone of authority -- care should be taken, however, to avoid structures that may be favorable to promote disease transmission, such as, for instance, relapsing fever and others discussed above in section III.B.3.

The number and type of public structures in a settlement depend upon the number of inhabitants and the level of economics. The majority of present-day rural African villages are based upon subsistence crops. The organization of such usually small villages is commonly based on traditional social structure that go back to many generations, even centuries perhaps. A cash-crop producing village of any importance may require a more bureaucratic organization than just a chief or headman. Firstly, it must have a transportation connection to promote the sale of its cash crop. This, in turn, will attract ancillary activities and businesses, a complex which may develop into a commercial town, common in all parts of West Africa.

The social services required to satisfy the need of the traditional rural village or that of its commerical outgrowth will be quite different in complexity. The single public amenity that would best serve the

inhabitants and help prevent exposure to a number of diseases is the availability of adequate, clean water supply. The problem of the disposal of wastage-water becomes more complex and costly with the number of inhabitants. In most small and medium size, or even large, African towns wastage-water and rainwater collect in open ditches and sewage canals. They are a major source of mosquito breeding, firstly because the rubbish that is thrown in them blocks the even flow; secondly, by the formation of pockets in the bottom of earthen ditches in which water remains stagnant during the non-rainy season (see section III.B.2).

Other important sources of mosquito breeding are the water reservoirs on some of the roofs of higher buildings. Although they are originally installed with a fitting lid, these are often blown off by windstorms and usually never replaced.

Finally, the most common mosquito breeding in connection with water supply, or the lack of it, are the earthen pots in which water is stored in villages, small and large African towns where the water supply is <u>not</u> delivered inside the houses, and this is the case in the majority of West African countries (section III.B.2).

A major source of infections with intestinal parasites derive from the unsanitary disposal of human excreta or their use as fertilizer in vegetable gardens. It is, therefore, of the utmost importance that proper latrines are provided for each household, of a type that prevents their becoming a source of mosquito or fly breeding.

Any village or town of some importance will have a weekly, or daily, market. Held at some central square, these places are often disgustingly filthy, harboring rats and other vermin that feed on the food. Exposed meat and other food attract flies by the thousands.

Traders arriving from various parts of the country may be carriers of disease agents.

The school has become an integral part of the community. Although the style and structure are important and should be planned in consultation with appropriate experts, it is the educators who will eventually be responsible for the success or failure of the school. The schoolyard or annex may be a good place for the installation of public showers, to be used during school hours by the children and at other times by the rest of the villagers. Their use will help reduce contact with natural streams, having a double effect of decrease of exposure to contaiminated water and decrease of pollution of the water.

Planning means mapping. Nothing is more useful in the initial stages of planning than the use of large-scale maps. Aerial photos are very precious aids for the selection of relocation sites during the preparatory phases and later to plan the layout of the new settlement, approach roads and eventual sanitary engineering to reduce foci of vectors and disease reservoirs.

3. Transportation

Many small villages in rural Africa are still hours, even perhaps days away from adequate medical care. Resettlement schemes should take into account that if cash crops agriculture is planned, the proximity of an all-weather road is desirable. It was an ironic stroke of fate that in areas of the Sahel lorries carrying food to relieve famine in areas of drought could not reach those points because the dirt roads became impracticable as a result of heavy rains.

Road networks are imperative to the economy of a country as well as for the benefit of the population, especially the rural areas, for

reaching, by means of public transportation, market places or medical care.

Roads, however, can be instrumental to the dispersion of diseases and vectors. The role played by the roads starts at construction when earth is moved from certain places to level the profile. These "burrow pits" fill with rainwater and become permanent mosquito breeding places, especially favored by An. gambiae, the most effective malaria vector in West Africa. These pools, stretching along dozens or more miles, may form a chain along which malaria can make deep inroads in perhaps malaria-free areas. Drainage ditches and culverts also are favorable mosquito breeding sites when erosion forms water pockets.

Roads mean easy human and cattle movement and these may be carriers of diseases and, therefore, directly involved in their dispersion. Villages tend to gather along roads, thereby serving as relay points to the propagation of diseases.

Other means of transportation are equally sources of disease dispersion, not only over short distances in the same country but on an international and intercontinental scale. Mosquitoes, including Anopheles, Aedes and Culex have been collected inside airplanes arriving from various parts of the world. Tsetse flies are commonly found on the train crossing Tanzania from the east coast on its arrival at Kigoma on Lake Tanganyika. Ships, during the days of sail, were sometimes mid-ocean high yellow fever risks when the Ae. aegypti breeding in the wooden water caskets fed on infected African crew members.

International harbors have always been the receiving end or the source for the propagation of Ae. aegypti and of the yellow fever virus

carried by them. Inland landing places along African lakes and rivers are places of prolific mosquito breeding -- firstly, because they have more than their share of water-collecting, discarded containers; secondly, because of the rainwater collecting in new, unused or abandoned canoes that line the banks. An interesting situation of mosquito breeding was found in Uvira (ex-Belgian Congo), where An. pharoensis bred in abandoned canoes along the shores of Lake Tanganyika. Normally, the larvae of this mosquito is found in vegetation lining lakes or inundated fields. The constant and sometimes violent wave-action on the western shores of Lake Tanganyika was probably too strong for the larvae to survive, but the abandoned canoes in which grasses had started to grow, simulated a suitable larvae habitat. (Personal observation.)

Extremely prolific mosquito breeding sites that are indirectly related to motor transport are caused by the numerous used motorcar tires thrown in ditches or stacked in the backs of garages, all collecting rainwater and providing ideal larvae habitats for Ae. aegypti. Abandoned machinery and motorcars are typical Ae. aegypti breeding sites.

IV. CONCLUSIONS

Discussions concerning the various subjects in the sections above show that the planning and execution of development programs in tropical and subtropical areas has to be viewed through a large spectrum of disciplines. In the past, many development schemes were considered with only the target goal in mind, thereby largely neglecting related secondary effects and totally ignoring possible long-term damage to the environment.

As the target objectives of development programs are in all instances the economic improvement, subjects that are not directly related to the main goal are often not considered, especially when they seem to subtract gains rather than add to the economic benefits. It has been realized for the last decade that human resources, especially in underdeveloped countries with 80 percent of the people engaged in producing food, are as precious as the minerals in the soil, or the crops above it.

The preservation of human resources is achieved through physiological, as well as psychological, well-being. The two disciplines concerned with these subjects are medical and social.

It is remarkable how, over the last decade, these two disciplines have reached out for each other and how they have met, often unintentionally, to create interdisciplinary merges. They have evolved in a sphere of common interests which, perhaps, we can call the Sciences of the Human Environment.

To justify their deviation from their disciplines, medical workers have classified their interest in terms such as "medical anthropology," "environmental health," "social medicine," while anthropologists have characterized their interest in terms of "nutritional anthropology" or "applied anthropology." Typical of such aberrant disciplines are studies by F. L. Dunn regarding parasitic disease-prevalence in relation to human environment and behavior, mentioned

earlier in this review, and T. Scudder's studies of populations affected by resettlement schemes, also quoted in sections above.

It has come somewhat as a shock to many of us that everything we do has some effect on the rest of us. In the "carefree" hunter-gatherers days, nature ran our destiny and we had nothing to worry about, at least not with regard to our neighbor family, 20 miles or so away. By taking our destiny in our own hands, we have to try to match adjustments previously freely supplied by natural forces. Not an easy task.

It is fully realized that this review can not cover all the ramifications of the complex subject of health related to human environment and behavior. It could have been written in ten, a hundred, or a thousand pages and still fall short of all the things that can be said on the subject.

The lack of household water and waste disposal systems are major problems throughout the African continent which, together with housing, food sanitation, vector control and industrial pollution, should be of primary concern to health planners. The scope of water and sewage problems, coupled with the limited resources available to most African countries to improve them, will require that they remain one of the key issues of environmental problems.

There is a great need, therefore, for research to identify inexpensive and easily operated techniques and systems for water treatment and distribution. While the final objective must be to supply everyone with an adequate quantity of safe, piped water, in most places it will be necessary to pursue the less ambitious goal of installing water points within easy access of all dwellings from a distribution network adapted to local techniques and financial resources (A.I.D., 1975).

BIBLIOGRAPHY

AFRO/WHO. 1974 National health planning: its value and methods of preparation. Technical Paper No. 7.

AGENCY FOR INTERNATIONAL DEVELOPMENT, WASHINGTON. 1975 Health in Africa.

AXELROD, A. E. 1971 Immune processes in vitamin deficiency states. Am. J. Clin. Nutr., 24: 265-271.

BABUDIERI, B. 1953 Wld. Hlth. Org., Monograph Series, #19: 117-126.

BIGALKE, R. C. 1968 Evolution of mammals on southern continents. III -- The contemporary mammal fauna of Africa. The Quarterly Rev. Biol., 43: 265-300.

BOOTH, A. H. 1954 The Dahomey Gap and the mammalian fauna of the West African forests. Rev. Zool. Bot. Afr. L(3-4): 122-133.

BRADER, L. 1959 Nomads and Nomadism in the Arid Zone. Internat. Soc. Sci. J., XI(4).

BUECHNER, H. K., A. H. HARTHOORN, & J. A. LOCK. 1960 Control of African wild animals. Nature, 185: 47-48.

CHOW, C. J. 1953 *Pistia* clearance with herbicides in rural filariasis control. Bull. Wld. Hlth. Org., 9: 521-573.

CLARK, J. D. 1962 The spread of food production in sub-Saharian Africa. J. Agri. Hist., III: 211-218.

DARLING, F. F. 1960 Wildlife husbandry in Africa. Sci. Amer., 203: 123-128.

DASMANN, R. F., and A. S. MOSSMAN. 1962 Abundance and population structure of wild ungulates in some areas of Southern Rhodesia. J. Wldlf. Mgmt., 26(8): 262-268.

DASMANN, R. F. and A. S. MOSSMAN. 1962 Reproduction in some ungulates in Southern Rhodesia. J. Mammal., 43(4): 533-537.

DASMANN, R. F., and A. S. MOSSMAN. 1962 Commerical utilization of game animals on a Rhodesian ranch. Wildlife, 3(3): 6-14.

DE VOS, ANTOON. 1975 Africa, the devastated continent? Monographiae biological, 26, W. Junk, The Hague.

DOWNS, W. G., and C. S. PITTENDRIGH. 1946 Bromeliad malaria in Trinidad, British West Indies. Amer. J. Trop. Med., 26: 47-66.

DUNN, F. L. 1968 Epidemiological factors: health and disease in hunter-gatherers. In: "Man the Hunter," R. B. Lee and I. de Vore (eds.), Aldine, Chicago, 1968.

DUNN, F. L. 1972 Intestinal parasitism in Malayan aborigines (Orang Asli). Bull. Wld. Hlth. Org., 46: 99-113.

FERNEA, R. A., and J. G. KENNEDY. 1966 Initial adaptation to resettlement: a new life for Egyptian Nubians. Curr. Anthropol., 7: 139-154.

FORD, J. 1960 Distribution of African cattle. Proc. 1st Scientific Congress, Salisbury, S. Rhodesia, pp. 357-365.

GORDON, J. E., & N. S. SCRIMSHAW. 1970 Infectious diseases in the malnourished. Med. Clinics of N. Amer., 54: 1495-1508.

HADDOW, A. J. 1948 The mosquitoes of Bwamba County, Uganda. VI. Mosquito breeding in plant axils. Bull. Ent. Res., 39(2): 185-212.

HAMON, J., G. F. BURNETT, J. P. ADAM, A. RICHENBACH, & A. GRJEBINE. 1967 Culex pipiens fatigans Wiedemann, Wuehereria bancrofti Cobbold et le developement de l'Afrique tropicale. Bull. Wld. Hlth. Org., 37: 217-237.

HARINASUTA, C., S. SORNMANI, V. KITIKOON, C. R. SCHNEIDER, & O. PATHAMMAVONG. 1972 Infection of aquatic hydrobiid snails and animals with Jehishpoma japonicum-like parasites from Khong Island, Southern Laos. Trans. R. Soc. Trop. Med. Hyg., 66: 184.

HENIN, R. 1969 The patterns and cause of fertility differentials in the Sudan, with reference to nomadic and settled populations. Population Studies, 23: 171-198.

HOARE, CECIL A. 1962 Reservoir hosts and natural foci of human protozoal infections. Acta tropica, 19(4): 280-317.

HODGES, R. E., W. B. BEAN, M. A. OHLSON, & R. E. BLEILER. 1962 Factors affecting human antibody response. III. Immunologic response of men deficient in pathothenic acid. Am. J. Clin. Nutr., 11: 85-93.

IMPERATO, P. J. 1976 Health care in Africa: the country and the city. Document presented at "The West Africa Conference," Tucson, Arizona, 1976.

JORDAN, PETER. 1975 Schistosomiasis-epidemiology, clinical manifestations and control. In: "Man-made lakes and human health," N. F. Stanly & M. P. Alpers (eds.), Academic Press, N. Y., 1975.

LAMBRECHT, F. L. 1964 Aspects of evolution and ecology of tsetse flies and trypanosomiasis in prehistoric African environment. J. Afri. Hist., 5(1): 1-24.

LAMBRECHT, F. L. 1966 Some principles of tsetse control and land-use with emphasis on wildlife husbandry. E. A. Wldlf. J., 4: 89-98.

LAMBRECHT, F. L. 1974 Entomological aspects of filariasis control in Sri Lanka. Bull. Wld. Hlth. Org., 51: 133-145.

LEBRUN, J. 1937-38 La vegétation de la plaine alluviale au sud du Lac Edoward. Inst. Parcs Nat. Congo Belge, Explor. Parc Nat. Albert, Mission Lebrun, 1947.

LONGHURST, W. 1957 Park and game management problems in the northern part of the Kigezi district. Fulbright mimeograph.

LONGHURST, W. 1958 Wildlife research in Uganda. Fulbright Progress Report, No. 3.

LOOSLI, J. K., and V. A. OYENUGA. 1963 Role of livestock in developing countries with emphasis on Nigeria. Fed. Proc., 22: 141-144.

MACDONALD, G. 1957 The epidemiology and control of malaria. Oxford Univ. Press, London.

MANOCHA, S. L. 1972 Malnutrition and retarded human development. Ch. C. Thomas, Illinois.

MATA, L. J., J. J. URRIETIA, and A. LECHTIG. 1971 Infection and nutrition of children of a low socioeconomic rural community. Am. J. Clin. Nutr., 24: 249-259.

MISONNE, X. 1963 Les rongeurs du ruwenzuri et des régions voisines exploration du Parc National Albert (deuxième série). Fasc. 14. Institut des Parcs Nationaux du Congo et du Ruanda, Bruxelles.

MONTGOMERY, E. 1972 Ecological aspects of health and disease in local populations. 1973 Am. Res. Anthropol., pp. 30-35.

MOREAU, R. E. 1933 Pleistocene climatic changes and distribution of life in East Africa. J. Ecol., XXI: 415-435.

MOREAU, R. E. 1952 Africa since the Mesozoic: with particular reference to certain biological problems. Proc. Zool. Soc. Lond., 121: 869-913.

MOREAU, R. E. 1963 Vicissitudes of the African biomes in the late Pleistocene. Proc. Med. Soc., London, 141: 395.

NEUMANN, Ch. G., G. J. LANLOR, E. R. STIELM, M. E. SWENDSEID, C. NEWTON, J. HERBERT, A. J. AMMANN, and M. JACOB. 1975 Immunological responses in malnutritioned children. Amer. J. Clinical Nutrition, 28: 89-104.

NNOCHIRI, ENYINNAYA. 1968 Parasitic disease and urbanization in a developing community. Oxford Univ. Press, London.

OGBE, G. A. E. 1966 Regeneration practices in the high forests of Nigeria. Proc. Sixth World Forestry Congr., Madrid, III: 3167-3169.

OKPALA, I. 1961 A survey of the incidence of intestinal parasites amongst government workers in Lagos, Nigeria. W. Afri. Med. J., 10: 148.

POSSELT, J. 1963 The domestication of the Eland. Rhodesian J. of Agri. Res., 1: 81-88.

RAMSAY, G. W. 1934 A study of schistosomiasis and certain other helminthic infections in Northern Nigeria. W. Afri. Med. J., 8: 2.

READ, M. 1957 Social and cultural backgrounds for planning public health programmes in Africa. W.H.O. Seminar on Health Education in Africa (Dakar), Document S. 3G1(63).

REEVES, W. C., and W. J. HAMMON 1962 Epidemiology of the arthropod-borne encephalitides in Vern County, California, 1943-1952. Univ. of Calif. Publ. in Publ. Hlth., Vol. 4.

BIBLIOGRAPHY continued

ROCHE, M. 1973 Note sur la secheresse actuelle en Afrique de l'ouest. In: "Drought in Africa: Report of the 1973 Symposium," Dalby & Church (eds.), Univ. of London.

SCHOVE, D. J. 1973 African droughts and weather history. In: "Drought in Africa: Report of the 1973 Symposium," Dalby & Church (eds.), Centre for African Studies, School of Oriental and African Studies, Univ. of London.

SCUDDER, T. 1973 The human ecology of big projects: river basin development and resettlement. Ann. Rev. Anthropol., pp. 45-61.

SMITH, G. E. GORDON. 1975 Changing pattern of disease in the tropics. In: "Man-made lakes and human health," N. F. Stanley & M. P. Alpers (eds.), Academic Press, New York.

SMYTHE, H. H., & M. H. SMYTHE. 1960 The new Nigerian elite. Stanford Univ. Press, Calif.

STURROCK, R. F., & B. M. STURROCK. 1970 Laboratory studies of the host-parasite relationship for Schistosoma mansoni and Biomphalaria globrata from St. Lucia, West Indies. Am. Trop. Med. Parasit., 64: 357-363.

TALBOT, L. M. 1963 Comparison on the efficiency of wild animals and domestic livestock in the utilization of East African rangelands. IUCN N.S., 1: 328-335.

U. N. WORLD FOOD CONFERENCE, ROME. 5-16 November 1974 The world food problem: proposal for national and international action. E/Conf. 65/4.

UNESCO COURIER. May 1974 The grinding arithmetic for the year 2000.

VANDEN BERGHE, L., & F. L. LAMBRECHT. 1963 The epidemiology and control of trypanosomiasis in Glossina morsitans fly belts. Am. J. Trop. Med. Hyg., 12(2): 129-164.

WALTON, G. A. 1962 The Ornithodorus moubata superspecies problem in relation to human relapsing fever. Symp. Zool. Soc. Lond., 6: 83-156.

WARE, HELEN. 1975 The Sahelian drought: some thoughts on the future. United Nations mimeographed document ST/SSO/33.

WEBBE, G., & P. JORDAN. 1966 Recent advances in knowledge of Schistosomiasis in East Africa. Trans. Roy. Soc. Trop. Med. Hyg., 60: 279-312.

WHO. 1976 Health care in rural areas. WHO Chronicle, 30: 11-17.

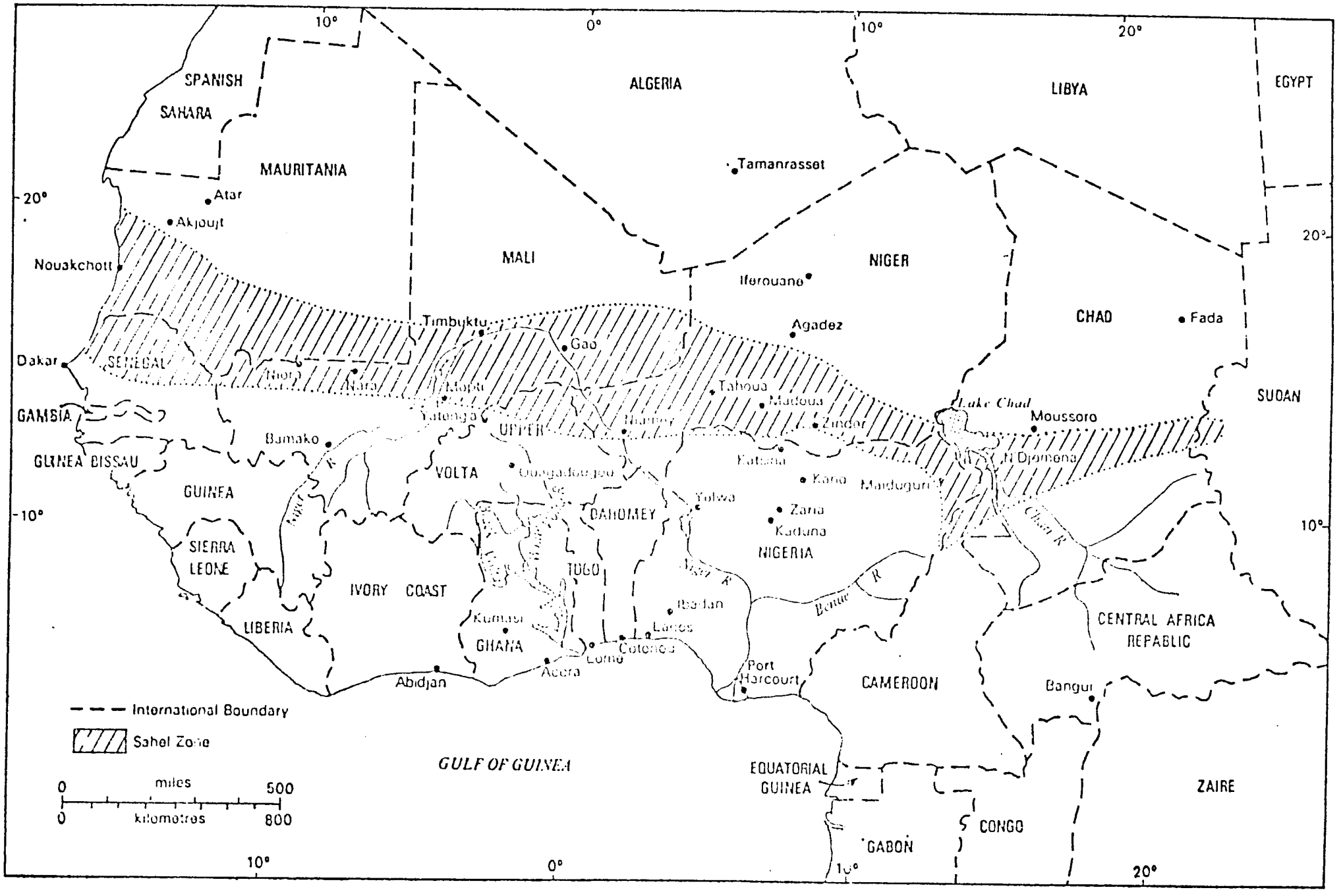
WHO. 1972 Human development and public health. WHO Technical Report Series, No. 485.

MAPS AND ILLUSTRATIONS

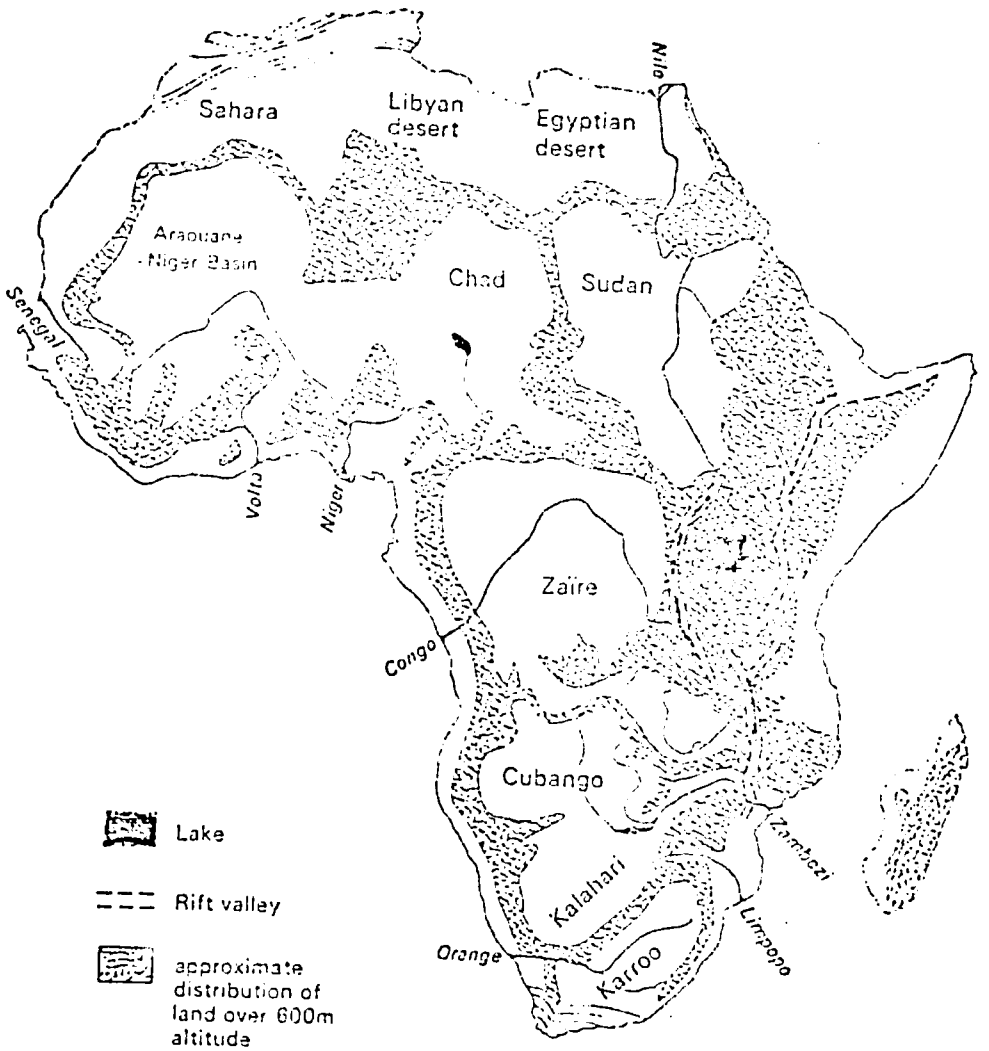
CONVERSION FACTORS

From	*To*	*Factor*
Length		
millimetre (mm)	inch (in)	0.0394
metre (m)	foot (ft)	3.2808
kilometre (km)	mile	0.6214
inch (in)	millimetre (mm)	2.54
foot (ft)	metre (m)	0.3048
mile	kilometre (km)	1.6093
Area		
square centimetre (cm^2)	square inch (in^2)	0.1550
square metre (m^2)	square foot (ft^2)	10.7639
hectare (ha)	acre	2.471
1000 m^2	acre	0.2471
square kilometre (km^2)	square mile	0.3861
square inch (in^2)	square centimetre (cm^2)	6.4516
square foot (ft^2)	square metre (m^2)	0.0929
acre	hectare (ha)	0.405
acre	square metre (m^2)	4046.8
square mile	square kilometre (km^2)	2.5900
Volume		
litre	cubic foot (ft^3)	0.03531
cubic metre (m^3)	cubic foot (ft^3)	35.31
cubic foot (ft^3)	litre	28.317
cubic foot (ft^3)	cubic metre (m^3)	0.0283
Liquid capacity		
litre	quart (US)	1.0567
litre	gallon (US) (US gal)	0.2642
litre	quart (UK)	0.8799
litre	gallon (UK) (UK gal)[1]	0.2200
quart (US)	litre	0.9464
gallon (US)	litre	3.7854
quart (UK)	litre	1.1365
gallon (UK)[1]	litre	4.5461

[1] Known also as "Imperial" gallon (Imp. gal).

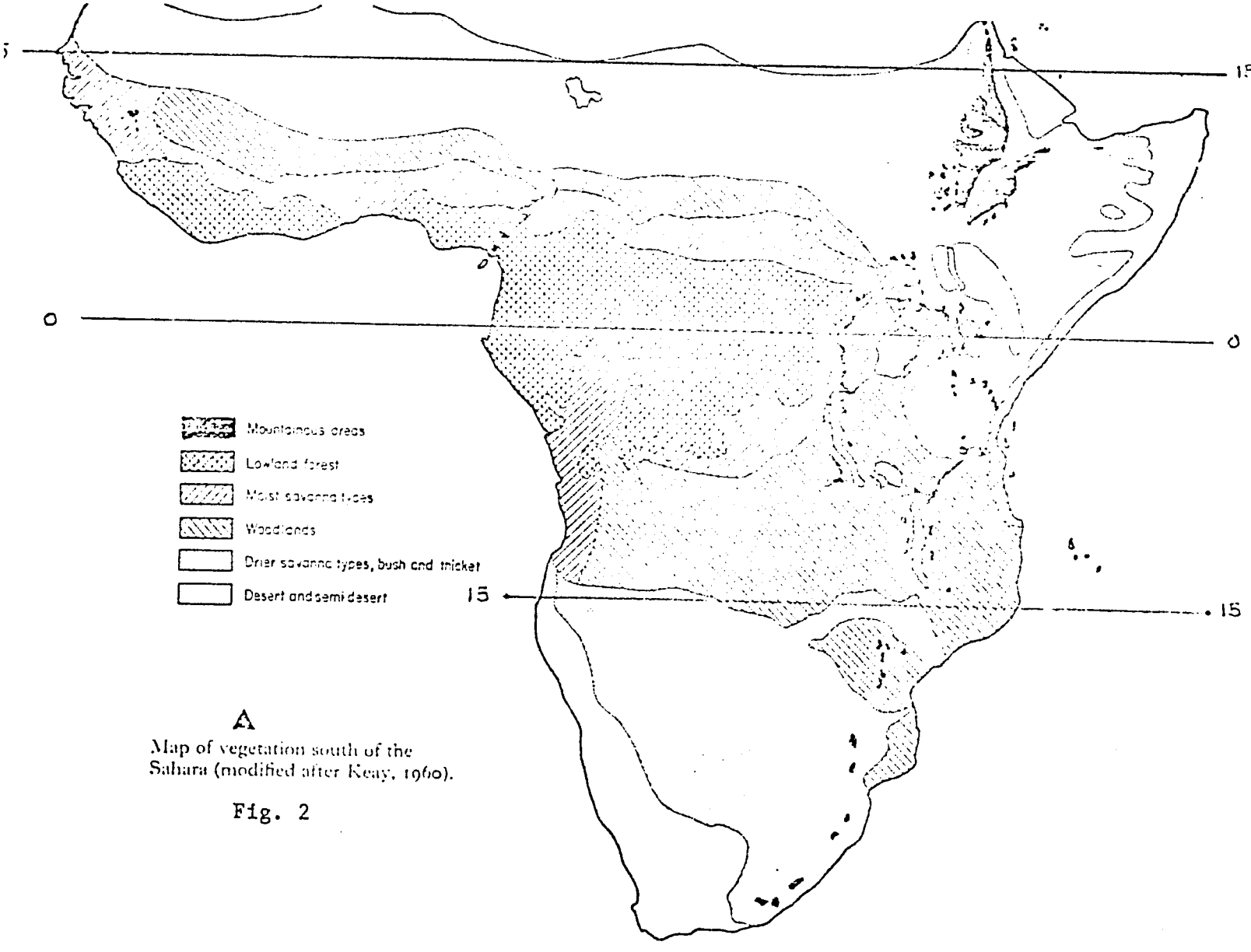


THE SAHEL AND THE SAHELIAN COUNTRIES



Diagrammatic representation of the basin and swell structure of the African continent (redrawn from Holmes, 1965)

Fig. 1



A

Map of vegetation south of the Sahara (modified after Keay, 1960).

Fig. 2

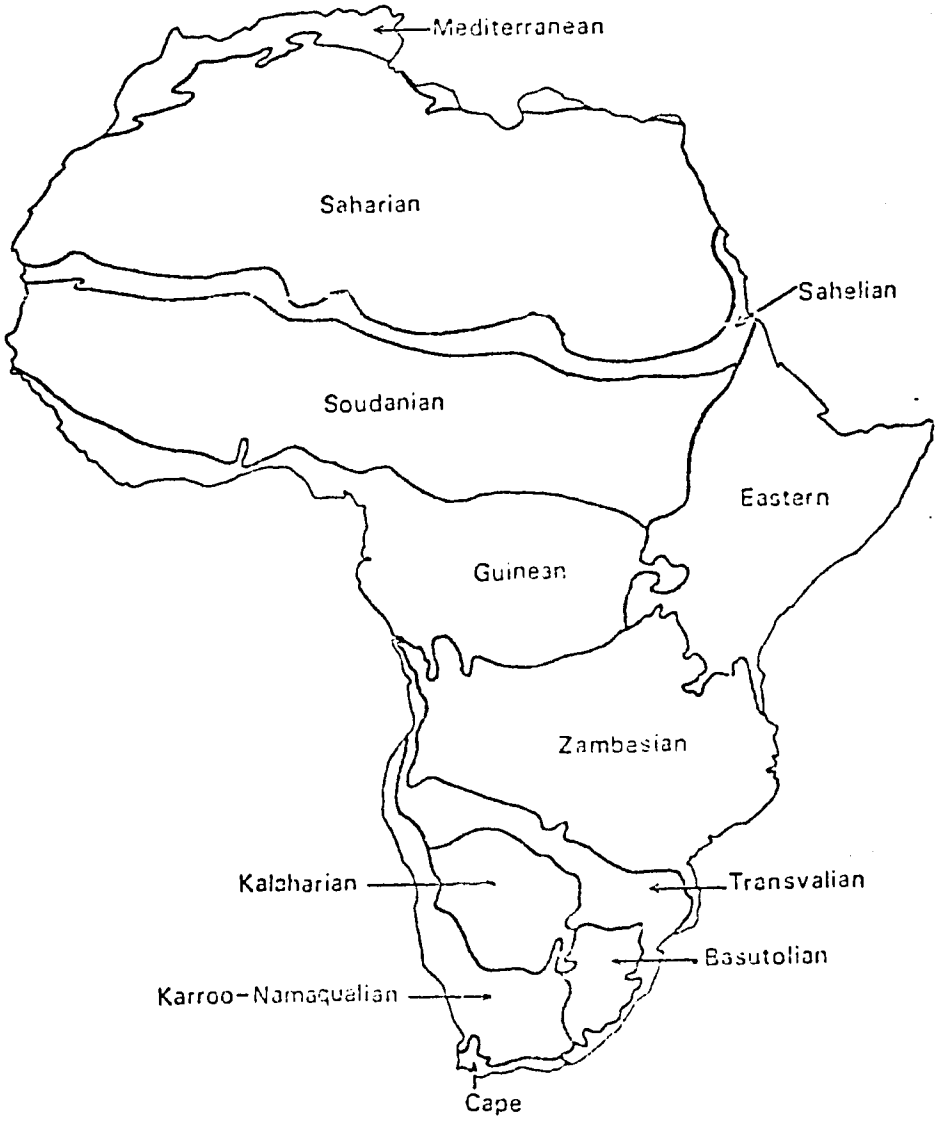
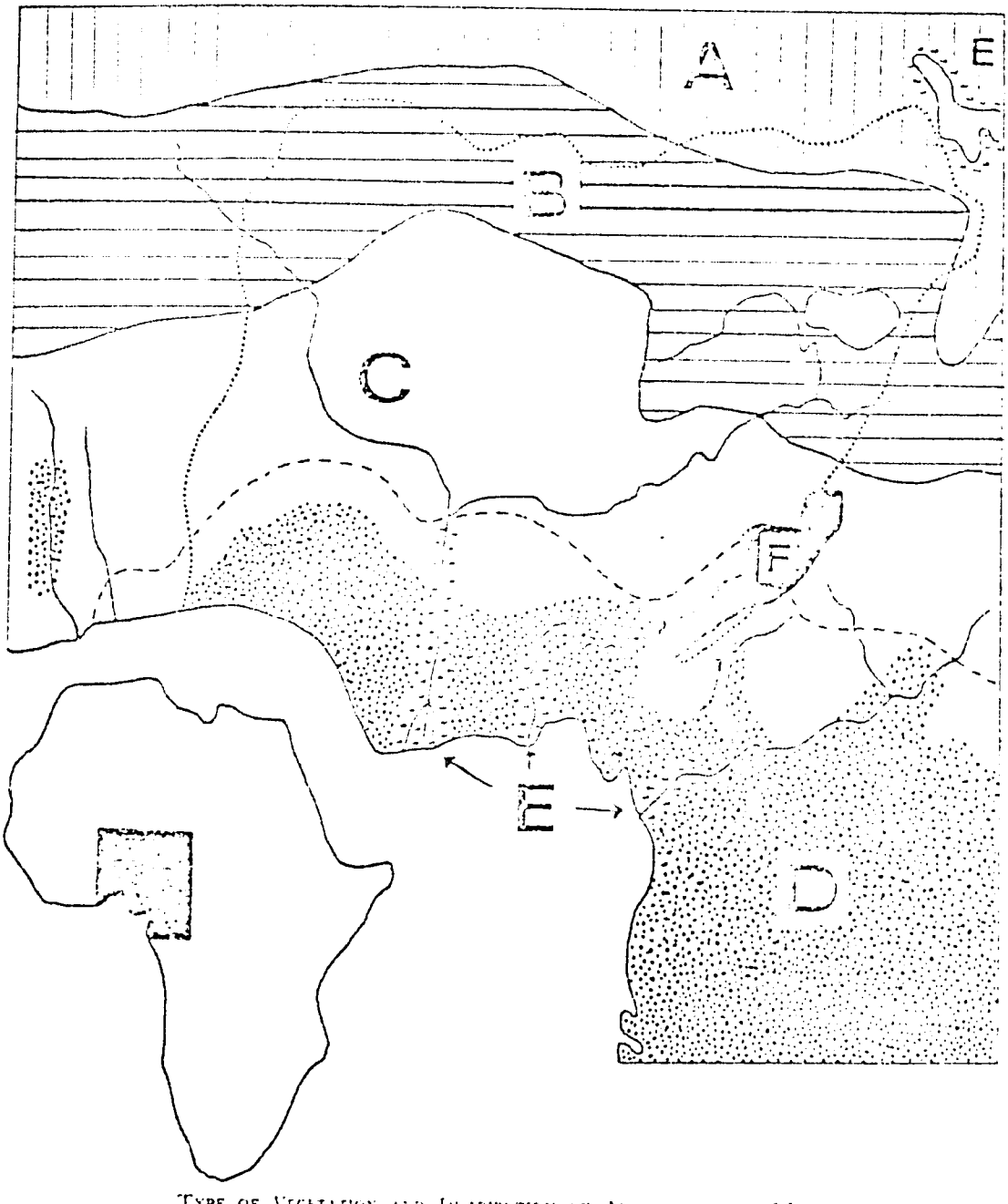


Fig. 3 The ecological zones of Africa (after DEVRED).

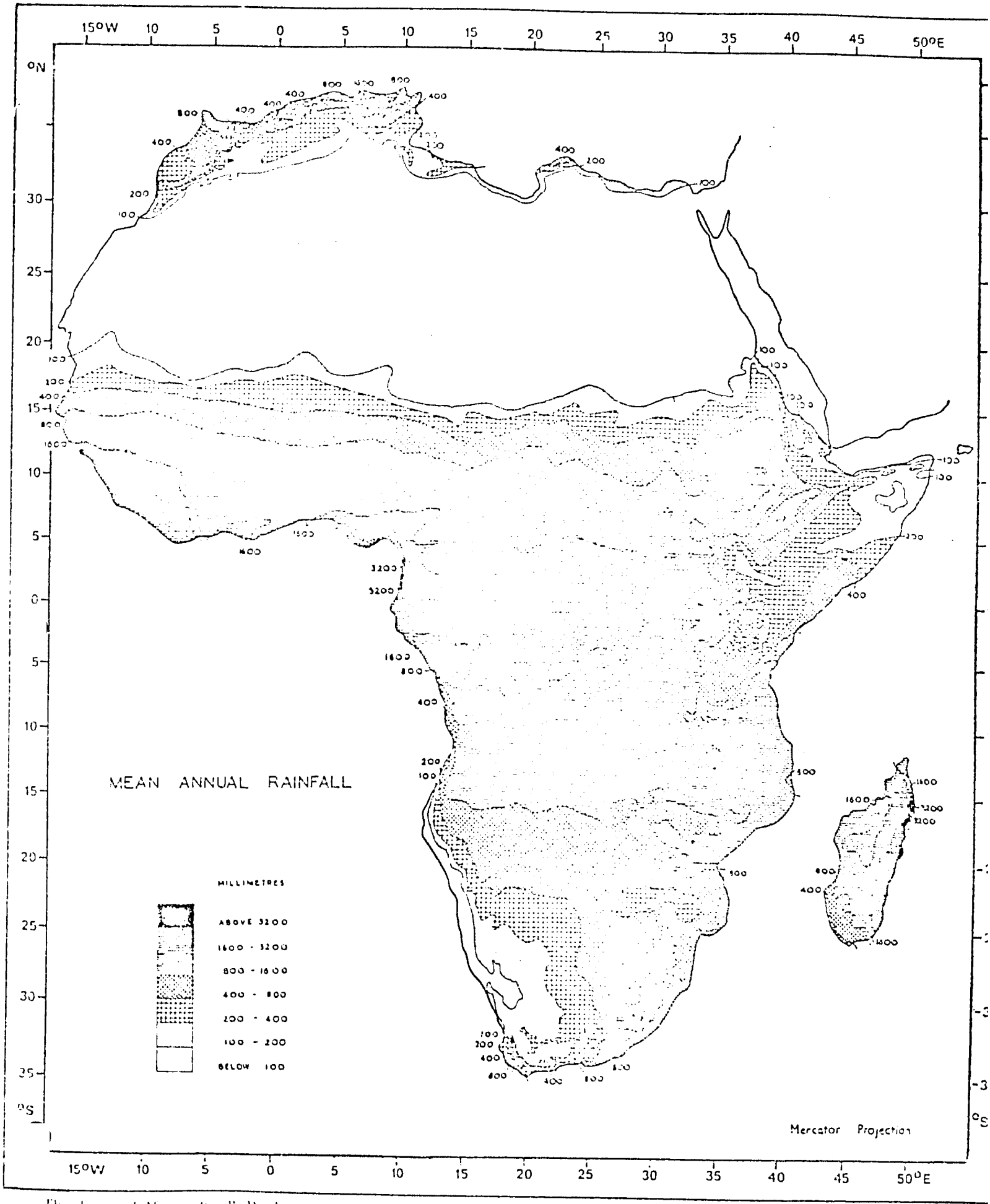


TYPE OF VEGETATION AND DISTRIBUTION OF ARTIODACTYLS IN WEST AFRICA

Rainfall and vegetation belts lie in broad east-west bands. While some large herbivores range through several of these zones, others closely follow the limits of one or another of them: The Sahel Savannah (A) is populated by the dama gazelle (*Gazella dama*, dorcas gazelle (*G. dorcas*), and white oryx (*Oryx dammah*); the sudanese savannah (B) by the Senegal hartebeeste (*Damaliscus lunatus*), red-fronted gazelle (*Gazella rufifrons*), and kob (*Adenota kob*); the Guinea Savannah (C) by the western hartebeeste (*Alcelaphus buselaphus*), red-flanked duiker (*Cephalophus rufilatus*), and giant eland (*Taurotragus derbianus*); the tropical rain forest (D) and montane forest (E) by about 7 species of duikers (*Cephalophus callipygus*, *C. dorsalis*, *C. jentinki*, *C. leucogaster*, *C. niger*, *C. silvicultor*, *C. zebra*), the water chevrotain (*Hyemoschus aquaticus*), and red river hog (*Potamochoerus larvatus*); and the rivers and marshes (E) by the hippopotamus (*Hippopotamus amphibius*), and sitatunga (*Limnotragus spekii*).

Specialization to habitat is one of the mechanisms enabling Africa to support such a diverse fauna of large herbivores. (Based on distributional data in Roseveat, 1955).

Fig. 3-b



The climate of Africa after B. W. Thompson, Oxford University Press, Nairobi office, 1965.

Fig. 4

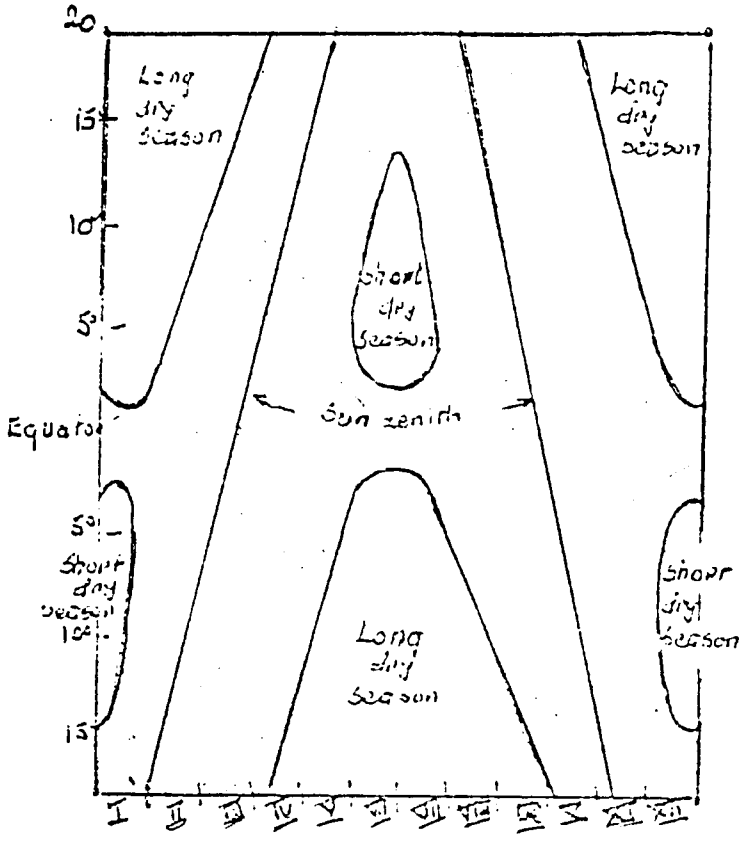
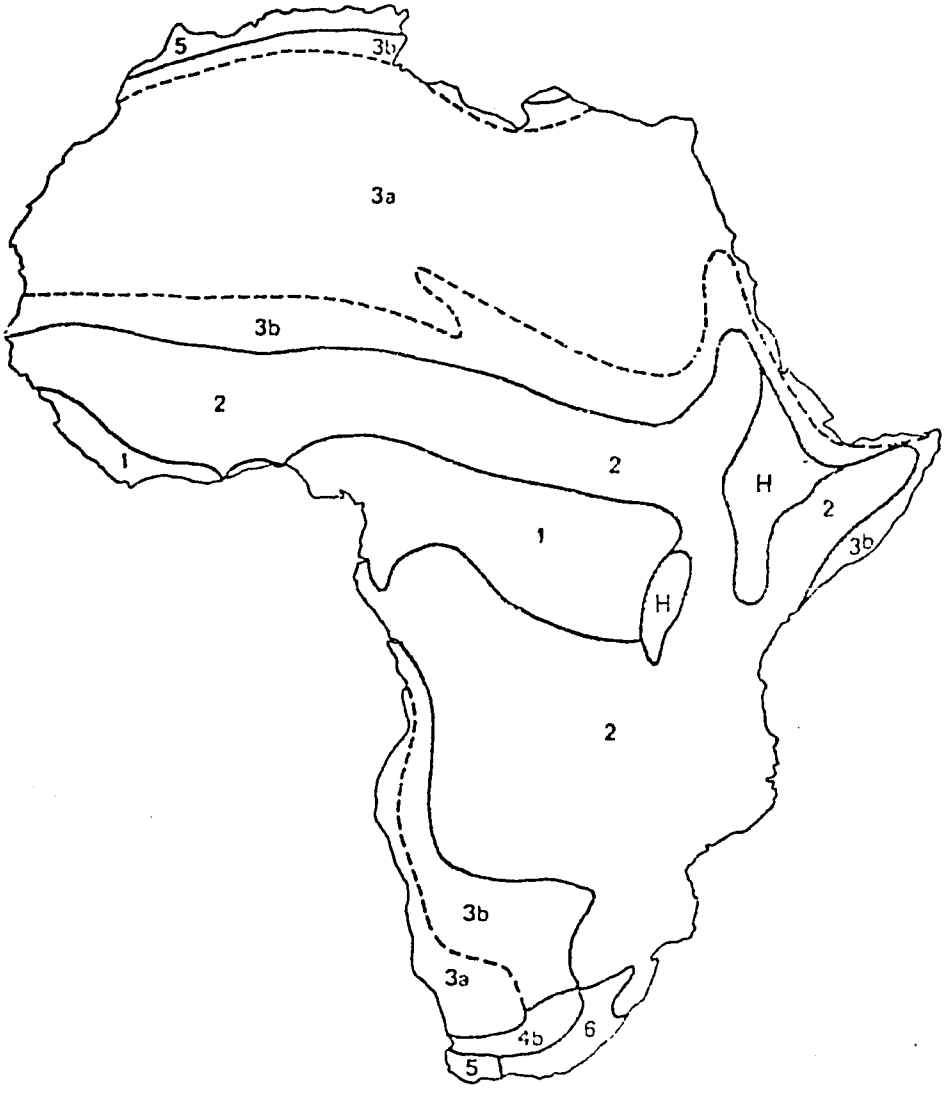

20
15
10
5
Equator
5
10
15
Long dry season
Long dry season
Short dry season
Sun zenith
Short dry season
Short dry season
Long dry season
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII

Fig. 5



The climatic regions of Africa (after FINCH & TREWARTHA, Atlas of World Maps, Army Service Force Manual, M 101, 1943). 1. Tropical Rainforest Climate, better called the Equatorial Climate, limited to areas within 10° of the Equator; 2. Tropical Savanna or Summer Rain Climate; 3. Low Latitude Dry Climates, 3a. Desert, 3b. Steppe; 4. Middle Latitude Dry Climates, 4b. Steppe; 5. Mediterranean; 6. Humid Subtropical; H. Humid Tropical (high elevations)

Fig. 6

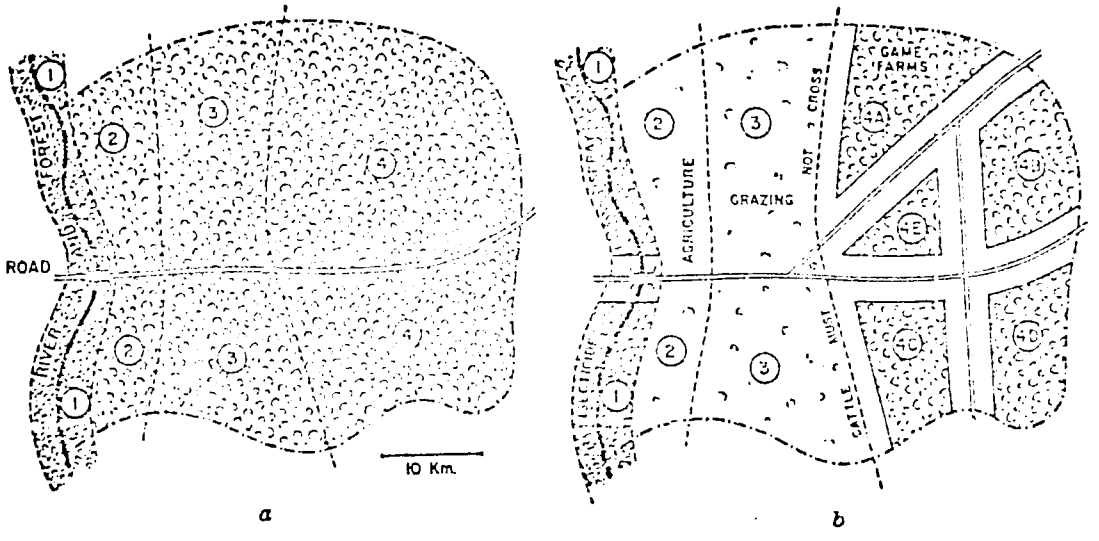
Natural landscape belts - basis for classification

Number of humid (or dry) months	10 – 12 (0 – 2)	9 – 10 (2 – 3)	7 – 9 (3 – 5)	3½ – 6 (6 – 8½)	2 – 3½ (8½ – 10)	1 (11)	0 (12
Mean annual precipitation in mm	Mainly > 2000 mm	Mainly > 1500 mm	Mainly > 1000 mm	750 – 1000 mm	> 400 mm	Under 400 mm	
Schematic graph of annual rainfall Examples:	Aiyem 2100 mm	Tafo 1656 mm	Tamale 1081 mm	Kano 845 mm	400 mm	200 mm	
Typical economically useful plants	Rubber, Tropical timbers	Oil palm, Cocoa, Coffee	Yams	Cotton, Millet, Ground-nuts	Ground-nuts		
Simplified transect sketch							
Plant-geography terms (Mansnard, 1960)	Wet evergreen forest (rain forest)	Partly deciduous seasonally green wet forest (monsoon forest)	Wet savanna with galleried and riparian forest)	Dry savanna	Thorn-bush savanna	Semi-desert	Desert

Schematic summary of climatic vegetation formations (between the equator and the tropics of Cancer and Capricorn), taking West Africa as an example (Sketch: W. Mansnard)

In: "Tropical Agriculture", Longman, N.Y. 1974.

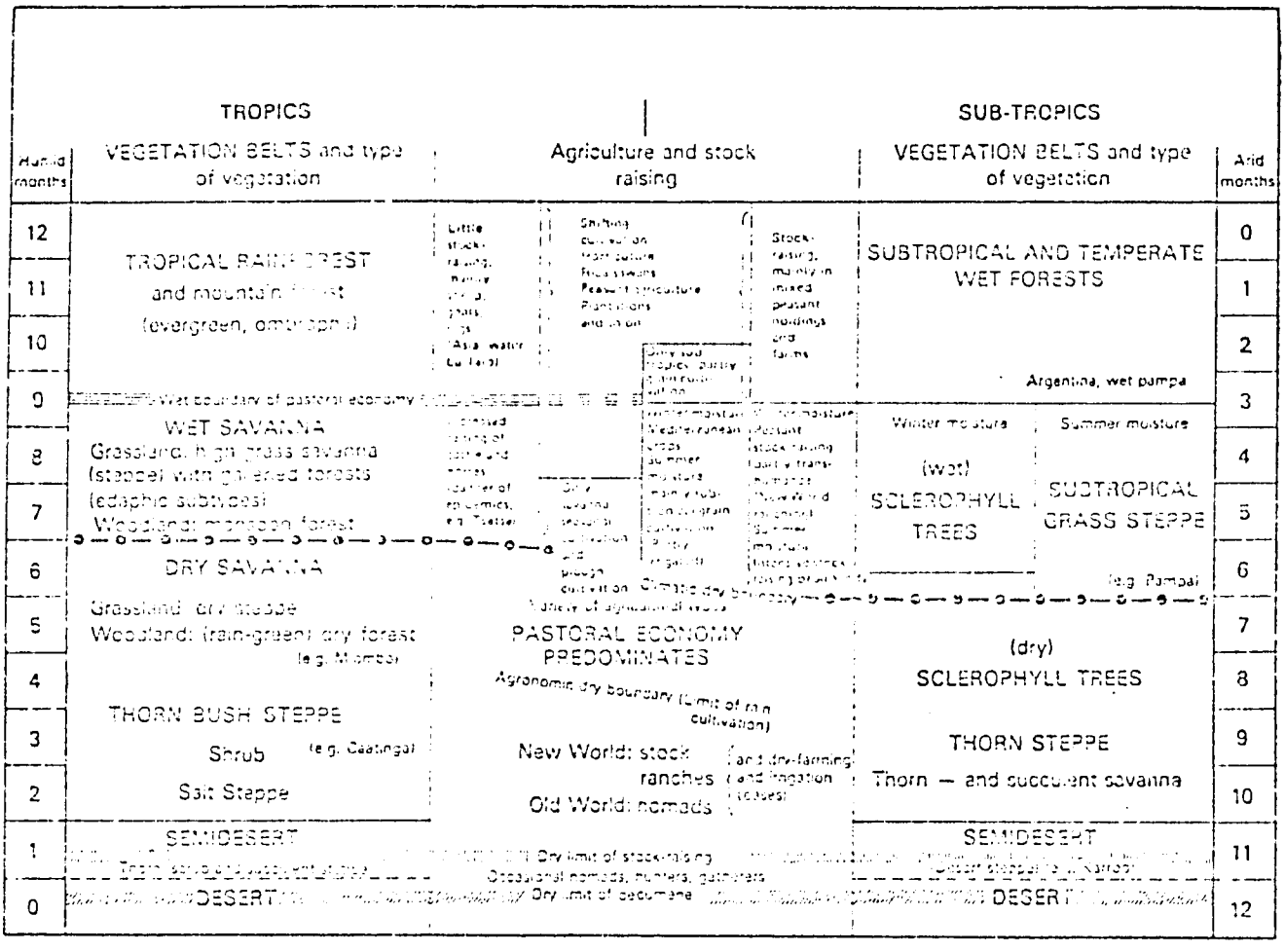
Fig. 7



Hypothetical tsetse fly-belt showing: (1) forest gallery; (2) alluvial soil; (3) slope, shallow soil; (4) poor marginal land and rock.

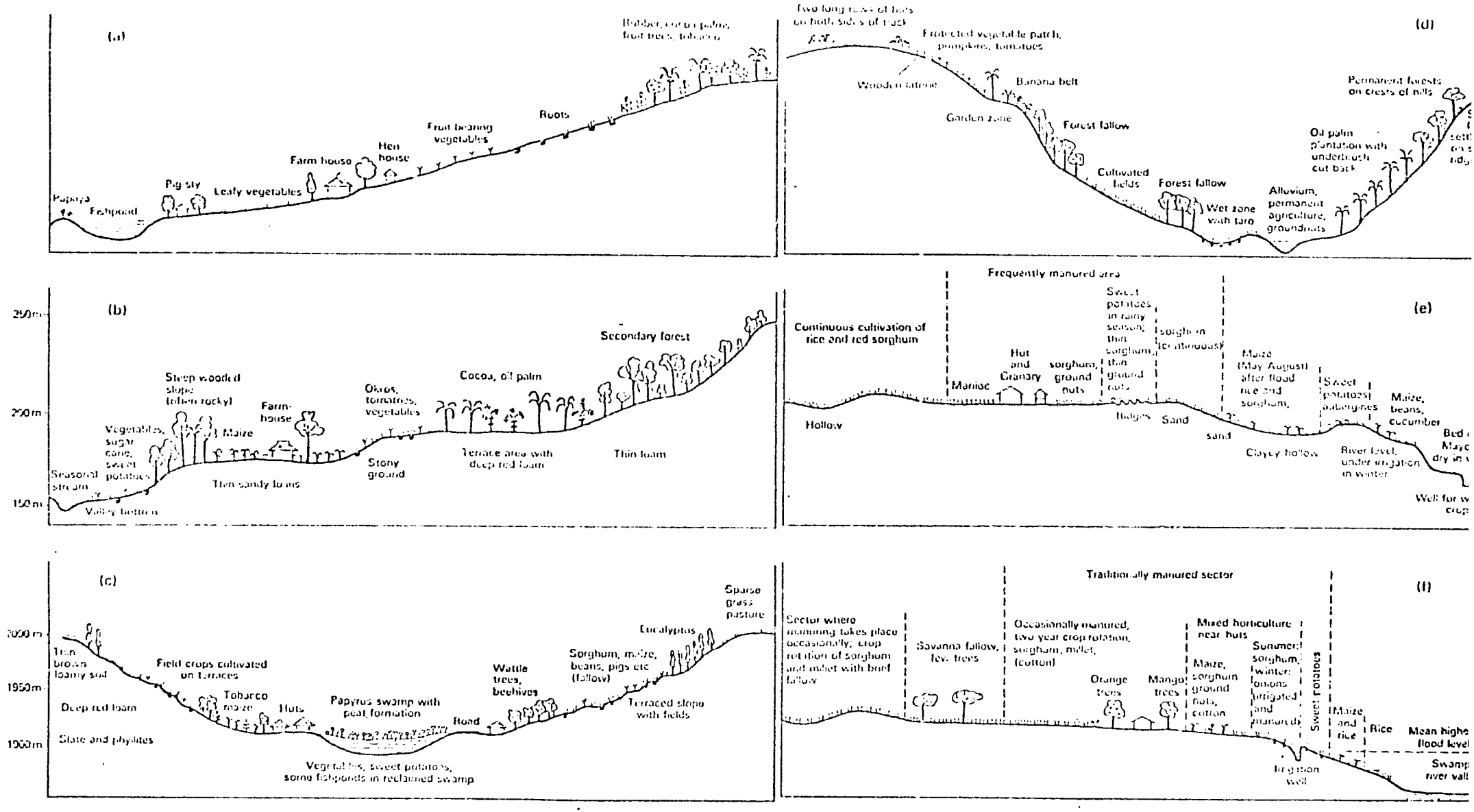
Proposed clearings and game-farming based on principles of land-use (see text) (Illustration from van den Berghe and Lambrecht, Amer. J. trop. Med. Hyg. 12 (2): 157 with the kind permission of the American Journal of Tropical Medicine and Hygiene, New Orleans, Louisiana, U.S.A.).

Fig. 8



Types of agricultural economy in the tropics and subtropics (showing their relationship to the number of humid and arid months and to vegetation types). After Uhlig (1965) and Lauer, Jaeger, Troll, von Wissmann, Penck, Wang, Falkner, Jatzold and others.

Fig. 9



Examples of typical sequences of land use in various parts of the tropics, presented as cross-section profiles: *catenas*

(*a*) Crop sequence on a slope in the area northwest of Singapore (after Ho, 1962)

(*b*) Diagrammatic profile of a '*kuga* hide of land' in the Krobo district, southeast Ghana (after Manshard, 1961b)

(*c*) Soil and land use: *catena* in Kigezi, southwest Uganda (after Manshard, 1965b)

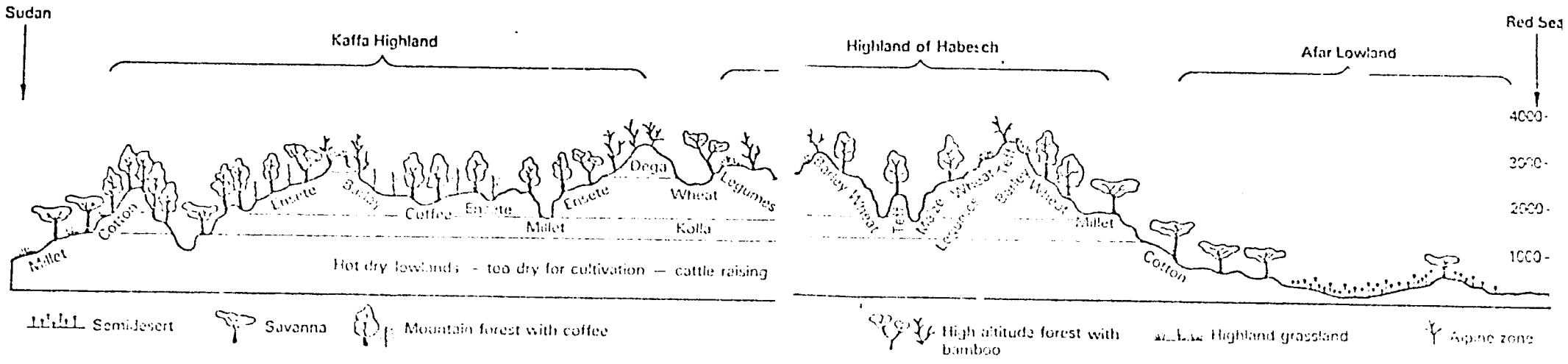
(*d*) Diagrammatic cross-section showing the sequence of land use in a valley in the Pene Niolo district, Congo (after Dumont, 1957)

(*e*) Agricultural profile of the Be district, northern Cameroons (after Dumont, 1957)

(*f*) Typical land use sequence in the M'Pesoba district, Mali (after Dumont, 1957)

In: "Tropical Agriculture", W. Manshard, Longman, 1974.

Fig. 10

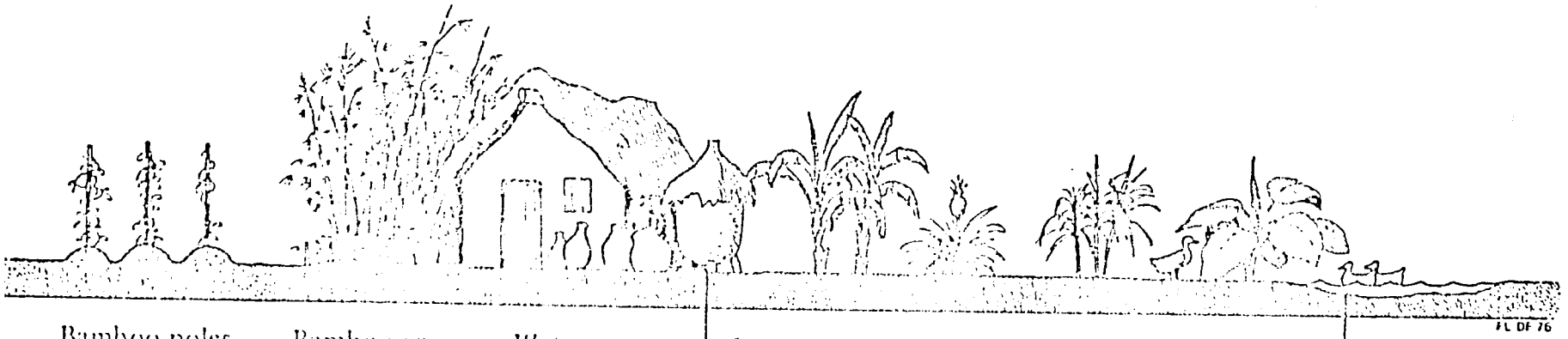


Transect across Ethiopia (SW to NE). The most important vegetation levels and their agricultural uses become obvious in this cross-section (after Kuls, 1958)

In: "Tropical Agriculture", W. Manshard, Longman, 1974.

Fig. 11

Diseases related to peridomestic man-made environment



Bamboo poles (for yam-vines) Bamboo grove Water storage

are favorable breeding sites for *Aedes* mosquitoes

(Various virus diseases)

Banana trees, pineapple, Dracaena sp., cocoyams

are plants with axil-leaves that are specific breeding sites of *Aedes simpsoni.*

(Yellow Fever)

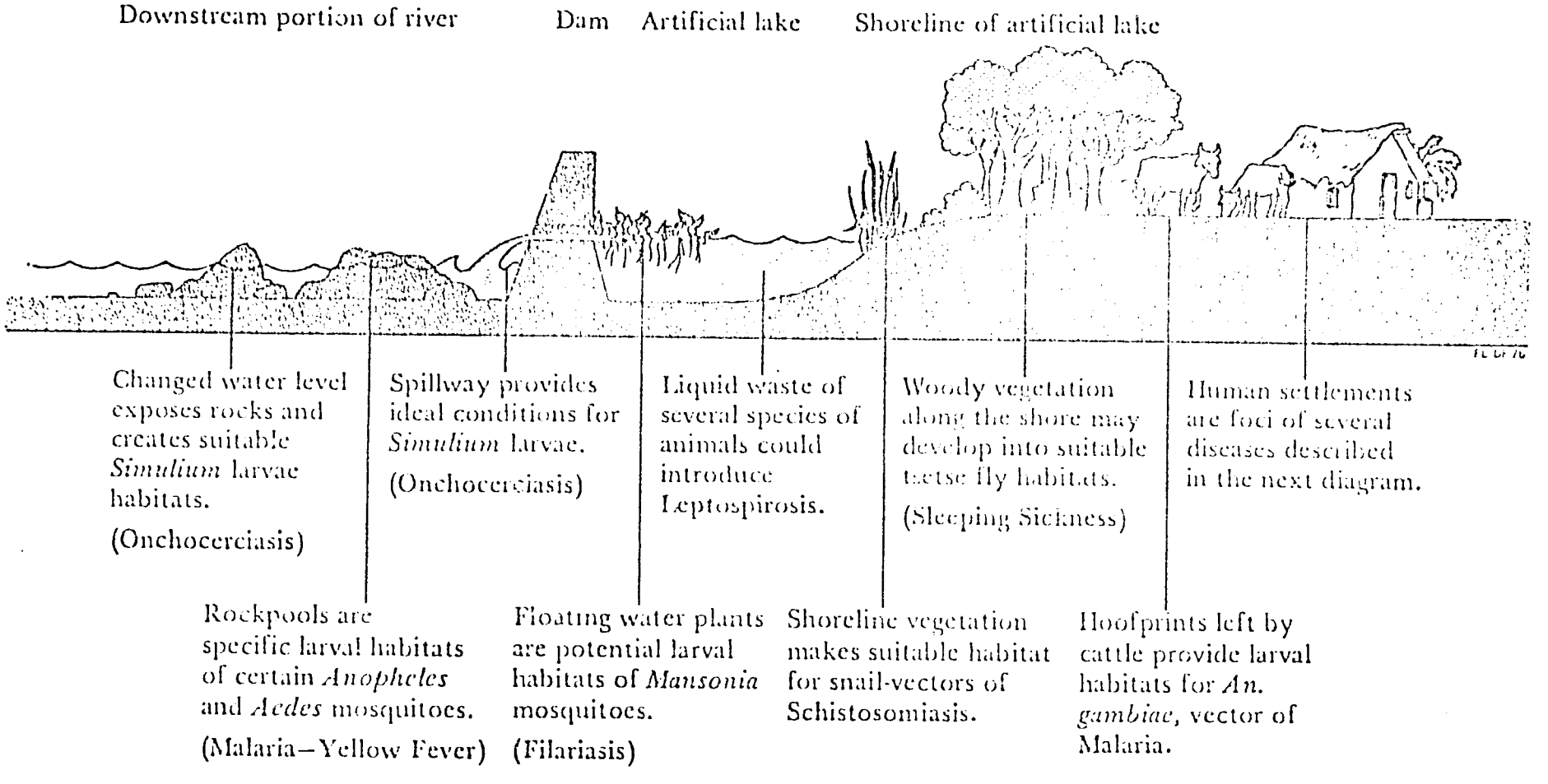
Grain storage bins attract rodents and their fleas.

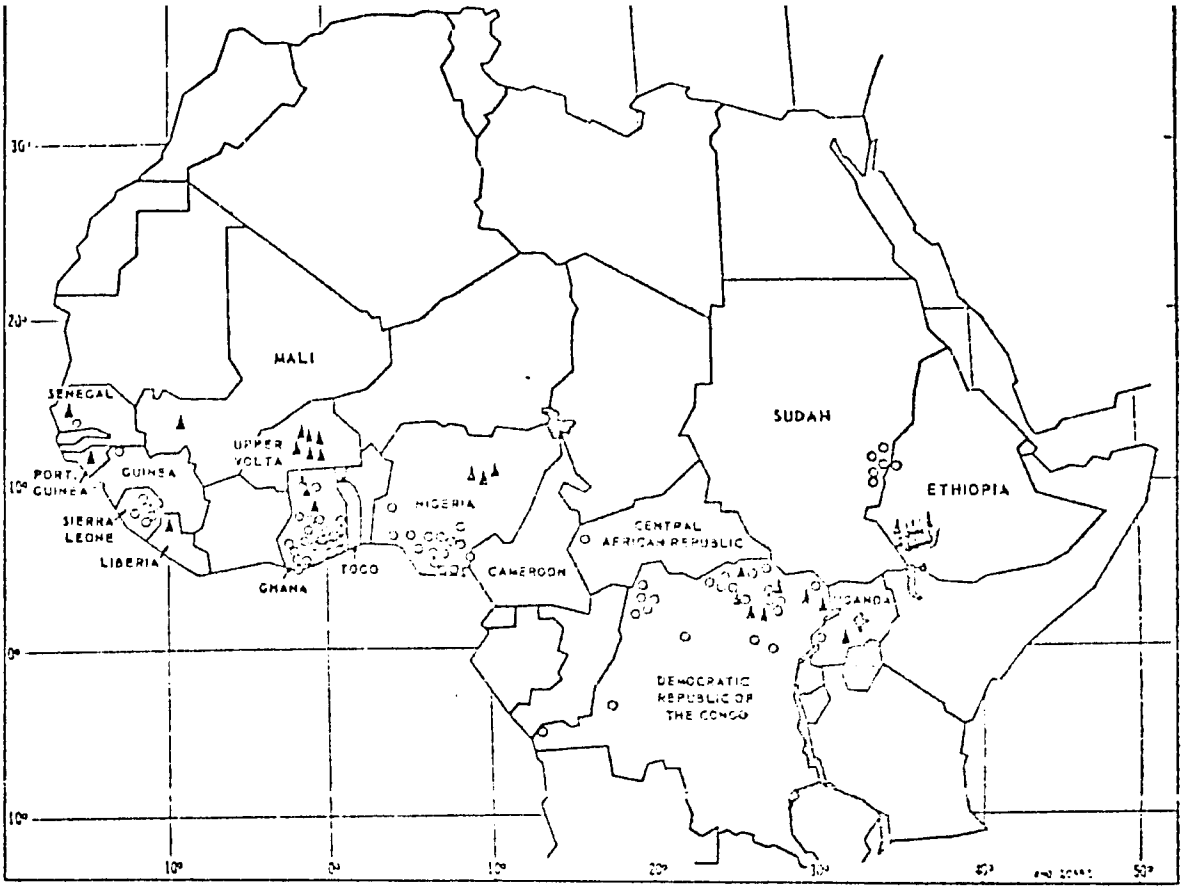
(Plague)

Duckpools provide habitat for snail-vector of Schistosomiasis

Fig. 12a

Development or increase of the transmission potentials of diseases resulting from water impoundment





• Each circle or triangle represents one or more cases.

○ 1950–1959

▲ 1960–1969

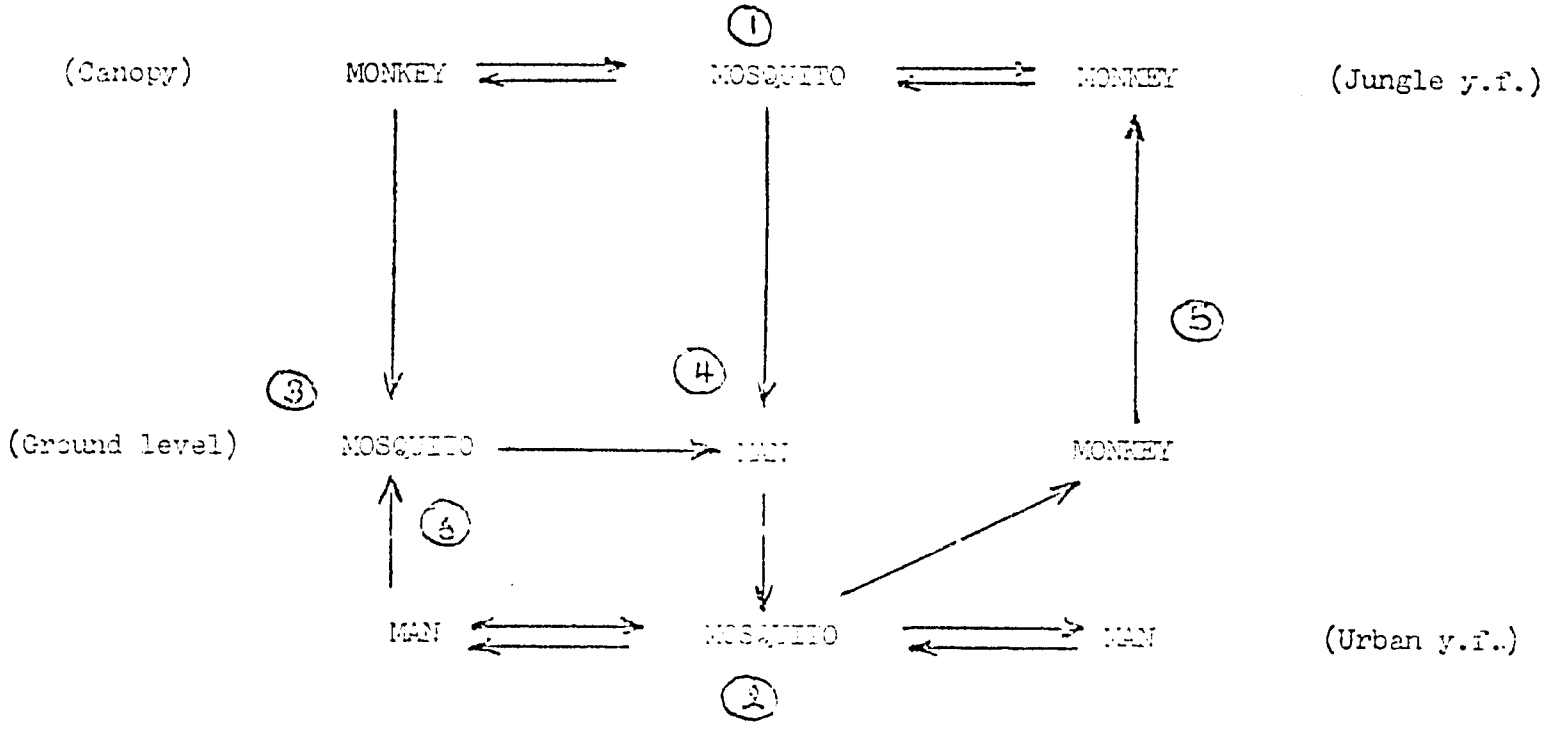
FIG. 1. NOTIFIED CASES OF YELLOW FEVER IN THE AMERICAS, 1950–1969 •

• Each circle or triangle represents one or more cases.

○ 1950–1959

▲ 1960–1969

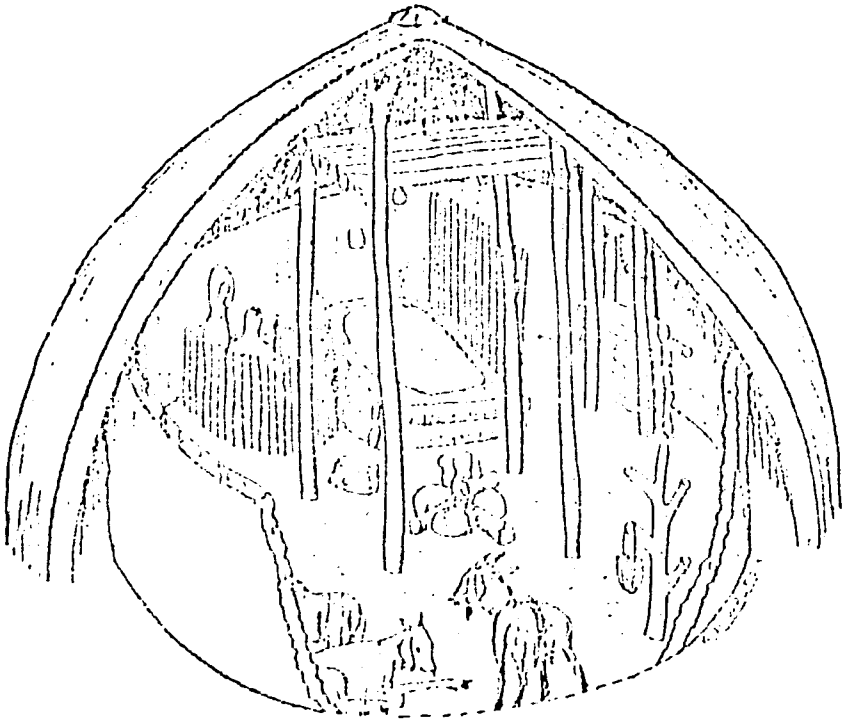
Fig. 13



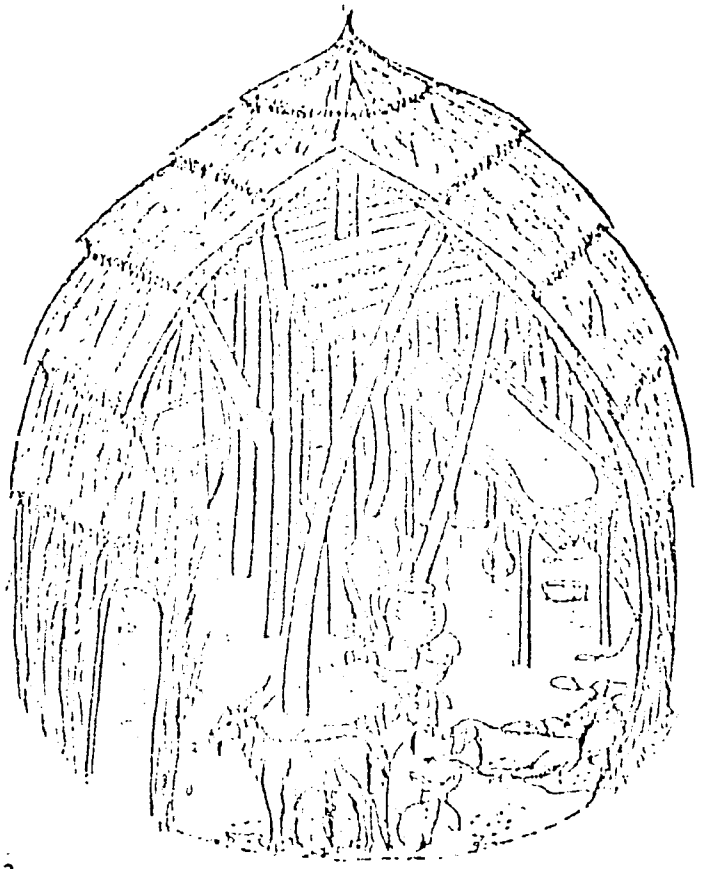
fl.'76

Fig.14 Links between monkey and human yellow fever cycles.

1. Jungle yellow fever cycle between monkey hosts and mosquito vectors.
2. Urban yellow fever cycle between human hosts and mosquito vectors.
3. Infected monkeys leave canopy to feed at ground level are bitten by mosquitoes which become infected and can transmit the virus to man thus starting an urban yellow fever cycle.
4. Infected mosquitoes fly from the canopy to feed at ground level may introduce the infection into human population and start an urban y.f. cycle.
5. Infected ground level mosquitoes can transmit the virus to monkeys during their temporary visit on the ground - upon their return to the canopy, monkeys thus infected may start a jungle y.f. cycle.
6. Canopy mosquitoes may pick up human y.f. virus during their temporary stay at ground level and introduce the virus into monkeys after their return to the canopy.



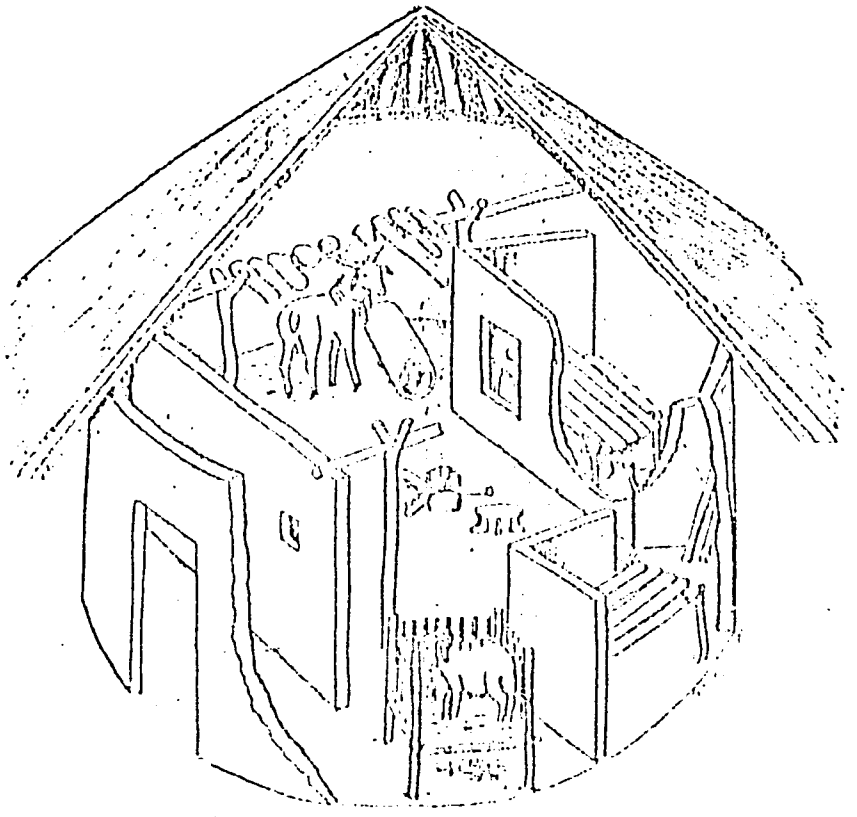
1

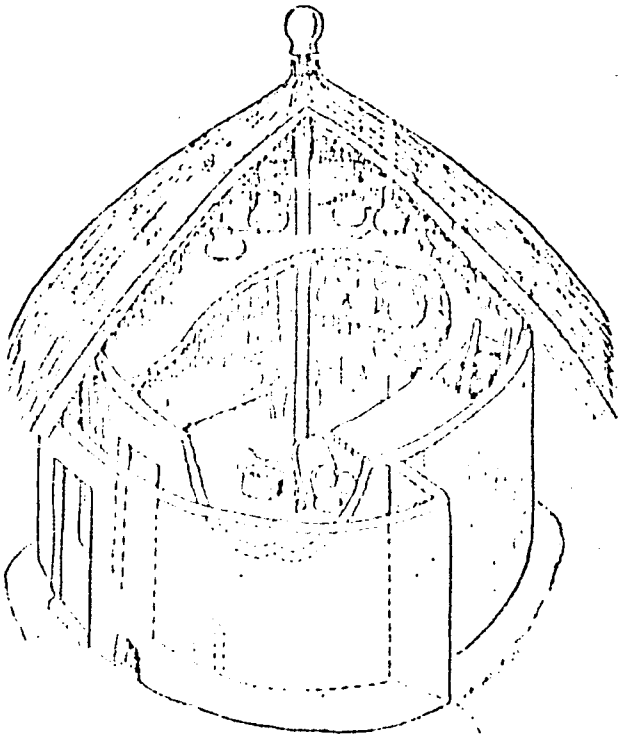


2

East African traditional hut interiors.
(1) Meru tribe (Igembe division) Jombeni Mountains, Meru District, Kenya.
(2) Kamba tribe. Bantu type hut constructed entirely of grass tied on frame of saplings. (Descriptive note facing page.)

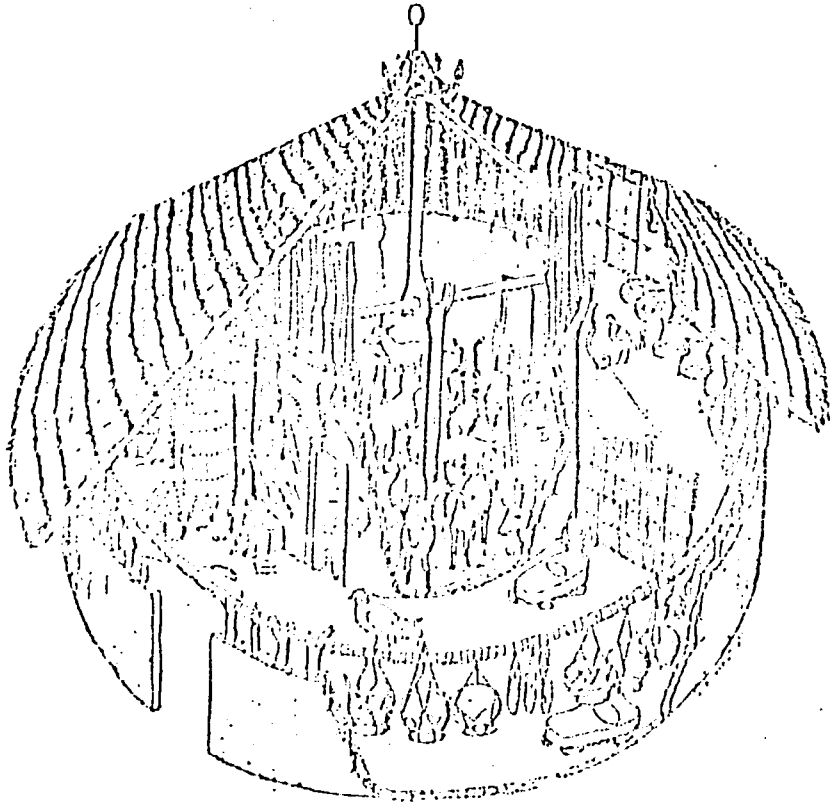
Fig. 15

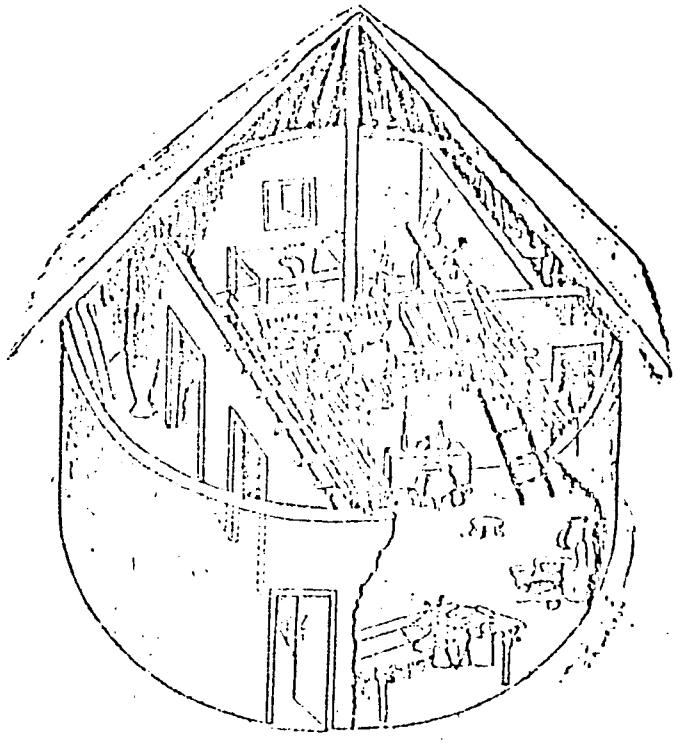




East African traditional hut interiors.
(1) Traditional Kikuyu "m'songe" hut as found in 1949 in Nyeri District Kenya.
(2) Taita tribe. Type of "m'songe" hut found at high altitudes in Kenya Taita Hills. (Descriptive note facing page.)

Fig. 16





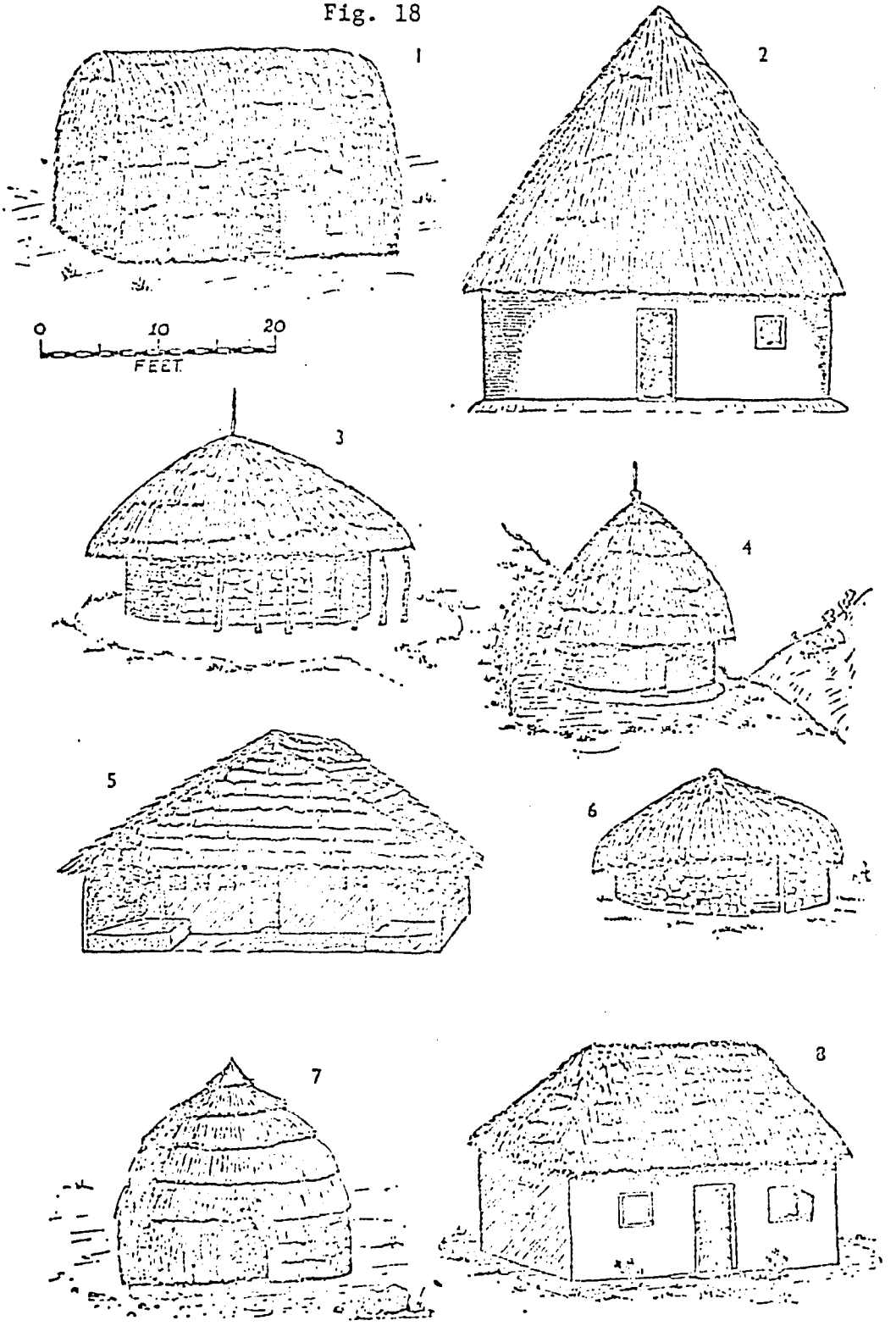
East African traditional hut interiors.
(1) Double m'songe house as extensively used by Sukuma tribe south east of Lake Victoria.
(2) Large subdivided m'songe hut, Shambaa tribe, Usambara mountains, North East Tanganyika.
(Descriptive note facing page.)

Fig. 17

Examples of East African native dwellings.

1. Giriama and Duruma tribes, Kenya coast. Grass tied to frame of saplings. Tick infestation very rare. 2. Large m'songo hut of Shambaa tribe near Lushoto, Usambara Mountains, Tanganyika. Frequently tick infested. 3. Traditional Kikuyu m'songe hut, Nyeri District, Kenya. Following the Mau Mau insurrection many of these were abandoned. Tribesmen concentrated in villages now rebuilding in improved designs. 4. Traditional m'songe hut as used by Taita tribe in Kenya Taita Hills. 5. Swahili "Kibanda" house common in Digo District on the Kenya coast. Usually infested with chicken-feeding race of *O. porcinus domesticus* subsp. n. 6. Traditional m'songe hut found in Jombeni Mountains, Meru District, Kenya and generally adopted extensively in East Africa by Bantu speakers to replace various types of grass hut used in past. 7. Wakamba grass hut. Type of hut extensively replaced in East Africa by the "m'songe" mud and wattle hut in the nineteen forties by m'songo huts and in nineteen fifties by cottages as illustrated in 8.

Fig. 18



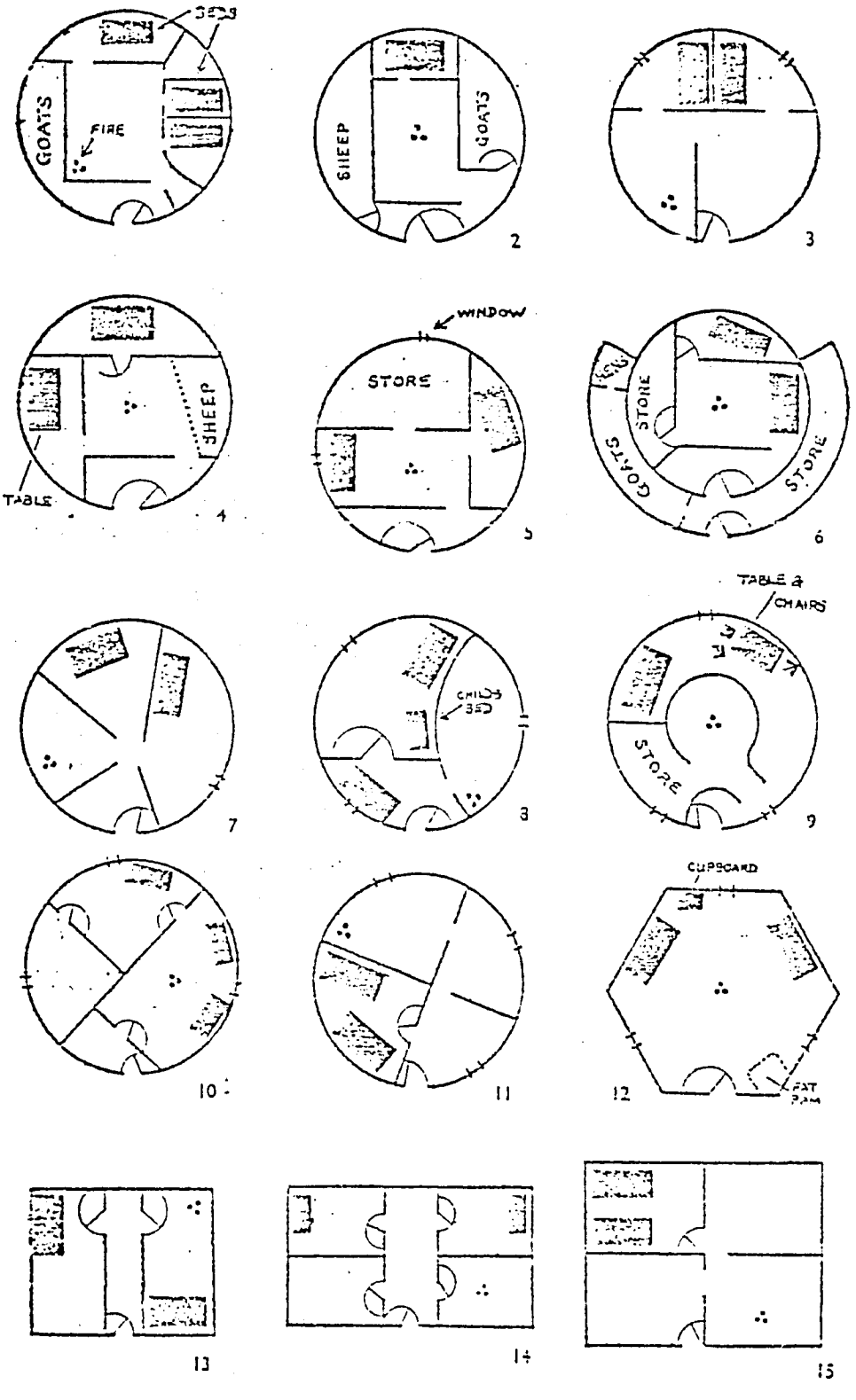
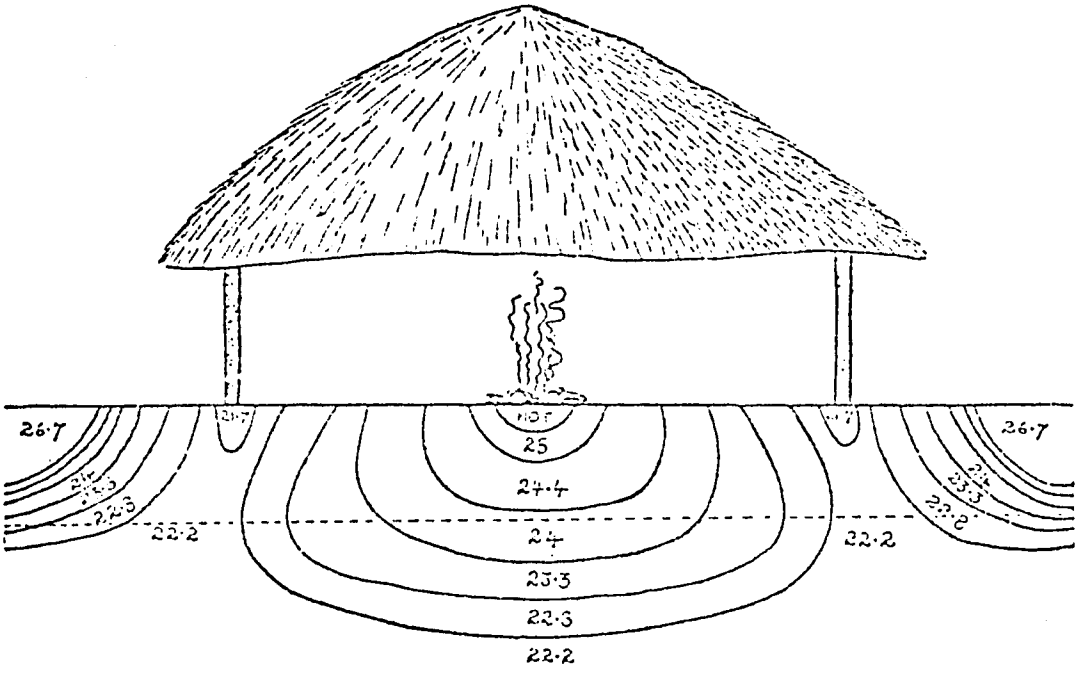

GOATS
FIRE
SHEEP
GOATS
2
3
SHEEP
TABLE
4
WINDOW
STORE
5
STORE
GOATS
STORE
6
7
CHILD'S BED
8
TABLE & CHAIRS
STORE
9
10
11
CUPBOARD
12
13
14
15

Fig. 19



Temperature zones in soil on site of traditional round hut in Nyeri District, Kikuyu reservation, Kenya, altitude 2,000 metres. Temperatures below dotted line not measured, zonation hypothetical. Readings made in verticle holes made with mild steel probe marked at six inch intervals. At altitude 1,000 metres or less, temperatures are suitable to tick infestation in absence of fire and any part of hut may be infested. At lower altitudes walls and floors must be smooth plastered to prevent infestation. Cement floors not recommended. Unless strong foundations are provided, thin layer of cement likely within present economy, liable to extensive cracking and tick infestation not easily eradicated without use of B.H.C.

Fig. 20

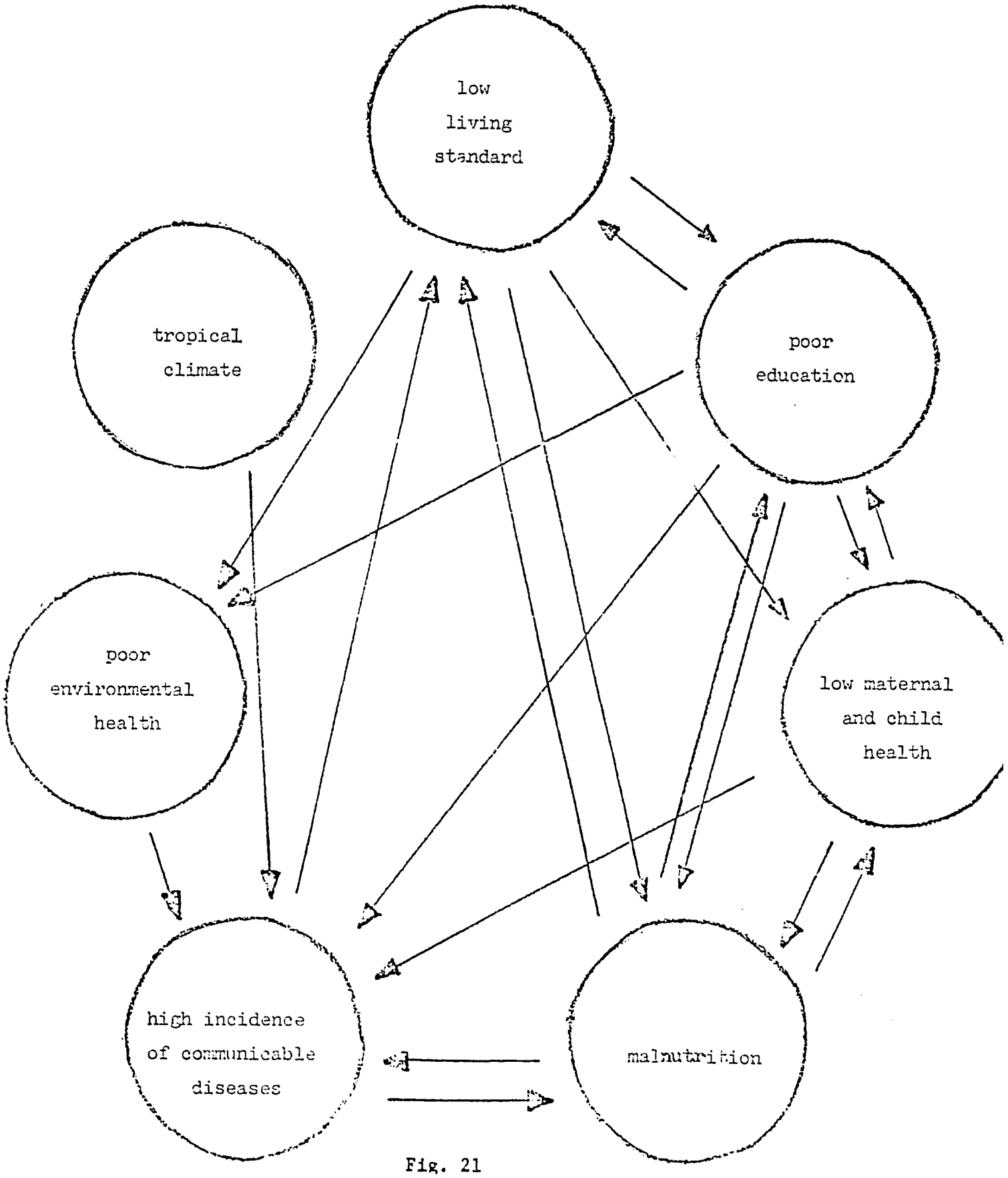


Fig. 21

(modified from Sansarricq, 1970)