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Land-Use in Semi-Arid Southern Africa [and Discussion]

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Land-use in semi-arid southern Africa

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[Plate 1]

Africa south of the Equator has a low population density which reflects the scarcity of reliable supplies of potable water. Productive agricultural methods have been demonstrated and are practised on advanced enterprises throughout the sub-continent, but most of the population still live by subsistence agriculture which is increasingly destructive of soil and water resources as numbers increase. Higher priority for agriculture, better rewards and status for food producers and the urgent application of known techniques of soil conservation are all necessary if the semi-arid areas of southern Africa are to feed their increasing populations.

Southern Africa is an instructive sub-continent in which to study land use in semi-arid climates, since it provides current examples of the widest possible range of practices, from the subsistence patterns of pre-history to the most sophisticated large-scale irrigation developments. In remote areas of northern Zambia, tribal patterns of shifting cultivation in the open Brachystegia woodland on geologically old leached soils, still depend on the lopping of tree branches over a wide area, burning them in a central clearing, and growing two or three crops of millet on the areas temporarily enriched by the ash. It is believed that this practice has continued unaltered from the distant past (Trapnell 1953; Allen 1965; Lawton 1963). In contrast, the scientific development of the Vaal and Orange river system with its many dams, diversion weirs, canals, tunnels and pipe-lines, ranks with the Tennessee Valley in the intensity of combined hydro-power and irrigation development.

The geography of the sub-continent is also full of contrasts, from high altitude mountain forests to hot coastal deserts. I must remind you that most of the area is a high plateau, 1000 m or more above sea level, so that temperatures are a little modulated by altitude, and the hottest semi-arid areas are near the lowland coasts of Kenya and Somaliland and of SW Africa on the edge of the Kalahari desert.

For the purposes of this brief paper I shall take the Equator as my northern limit, although I shall quote some examples from the semi-arid areas of Ethiopia a little to the north.

The climax vegetation, to which more than half of the area reverts when undisturbed, is of open woodland, or tropical grasslands carrying varying densities of scattered trees, and known collectively as savanna. It has been ecologically described and classified but in this short talk I must concentrate on how it is used.

The human population looks sparse on a world map of population density, and indeed it averages less than 4 per square mile (1.5/km^2) overall but, as a world map of poverty shows, Africa represents the largest geographical area of incomes less than $300 p.a. The total numbers are small, and yet their uneven distribution overcrowds favourable areas to the point of soil destruction, while large areas are, effectively, uninhabited.

This distribution of human settlement is determined mainly by water supplies, both as rainfall to sustain vegetation and as surface water or potable groundwater for people and livestock. The characteristically high evaporation rates of 1.5–2 m per annum, combined with the erratic annual movement of the inter-tropical convergence zone which causes the main seasonal rains, together render the reliability of the rainfall more important than the long-term annual average. For example, Glover, Robinson & Henderson (1954) showed that the ecological boundaries of vegetation types in East Africa fitted far more closely to the areas in which rainfall of a given amount was received in seven years out of ten than to the mapped areas of average annual rainfall. The boundaries of reliance on 750 mm outlined the maize-growing areas, while in areas for which 500 mm could be expected, sorghum is the main crop. An intriguing result of the mapping of Tanzania is that the corridor of reliable rainfall outlines the historical slave-trade route from Zanzibar to Lake Tanganyika, which evidently followed the course of the most reliable food and water supplies.

Rain seasons of erratic duration and amount are followed by severe dry seasons in which desiccation of the vegetation and of exposed soil leaves the surface vulnerable to soil erosion. Indigenous trees, shrubs and grasses root deeply and widely. When assessing semi-arid land for productivity, the soil depth and capacity to store water sufficient to mature a crop or to maintain grass growth for grazing is of far more critical importance than are the soil nutrient reserves. The nutrients can be reinforced by fertilizer, while resources for irrigation are available only for a small proportion of the land.

This liability to a premature cessation of the rains and hence to a shortening of the growing season indicates two major thrusts of agricultural research and development. The first is to select for rapid growth of crops and livestock, and the second is to develop supplementary irrigation wherever possible.

The interaction of energy reflected from a hot land surface with the wet oceanic air of the convergence zone results in characteristically violent storms with high rainfall intensities. These effects are more acute as the rainfall total decreases, while the vegetation protecting the soil is more sparse. Thus, paradoxically, the less the amount of annual rainfall the greater the erosion damage tends to become.

Potential productivity

Ample available solar energy and freedom from frost give almost the whole of southern Africa a basic advantage over temperature-zone farmlands. That we already have the knowledge and skills to develop these advantages into highly productive agriculture is widely demonstrated throughout the sub-continent. Scattered throughout all these countries, from the Equator to the Cape, are large estates with efficient science-based management and high agricultural output. Some indeed have high capital expenditure on irrigation but many more have grown from small beginnings with a main characteristic of managerial skill and resourceful application of scientific advances in tropical agronomy. I am not referring to the plantation crops of tea, coffee and oilpalm, which are confined to the higher and wetter country, but to maize and livestock enterprises, to sisal in the 500 mm rainfall, and to irrigated cotton, sugar and citrus. There is no doubt that the potential for agricultural production is high, but the fragile soil and vegetation cover need exacting standards of contour cultivation and soil conservation planning, of rotational grazing control and well distributed watering points.

The tribal traditions, however, have been founded on centuries of a scattered and rather stable population, nomadic herdsmen and shifting cultivators, with plenty of new land to use. There was no need to develop the elaborate terracing and water control as found in tropical areas of other continents. The tradition was to consume the accumulated natural fertility and to move on. Western medicine has now overcome the former population controls and Africa is now second only to Latin America in population growth; in fact, Swaziland, with 5.2 % p.a. tops the *U.N. Population Handbook* (1974). This population growth has already rendered the African tribal traditions of agriculture destructive to their environment, for there is now very little new land with water supplies, but still there is no general acceptance of the need to conserve the soil. A few heartening signs of response to agricultural teaching serve by contrast to emphasize the serious lack of progress in the tribal lands throughout the semi-arid areas of the sub-continent.

Technology for arable crops

The blunt statement that we already have enough proven technology to produce a vast increase in the productivity and prosperity of semi-arid areas of Africa may cause surprise, but there is abundant evidence for it. The main reason for this technical advance is that most of the same problems had already arisen acutely in the drier areas of the U.S.A. some 50 years earlier. In the U.S.A. agriculture is highly regarded as a source of wealth, and therefore the problems were tackled vigorously. The solutions were found to depend on complete watershed planning; on tillage and planting on the contour; on cut-off ditches to protect tilled soil from runoff from higher up the hillsides; on reducing the velocity of overland flow from heavy rainstorms by encouraging infiltration and by provision of grassed waterways, routed along natural drainage lines which freely cross farm boundaries.

When a majority of American farmers on a watershed voted for creation of an 'intensive conservation area' the rules became mandatory. These techniques were tested thoroughly in Kenya, which developed a vigorous soil conservation service on American lines, led by the redoubtable figure of Colin Maher of the British Colonial Service. In the areas of European settlement, the soil conservation rules were rigorously imposed. This service worked in the tribal areas also, but was less understood and less welcomed; conservation policies were pursued much more slowly, by persuasion only. Many square kilometres of the badly eroded Machakos area were thoroughly reconstructed from 1948 onwards with terraces and cut-off drains and for a while soil erosion was held at bay. Aerial photographs taken in 1948 have been carefully analysed by Thomas (1975) and compared with a later set taken in 1972. Thomas used the gulley-length measurement technique originated by Keech in Salisbury. The area had remained in subsistence agriculture in spite of study and demonstration that productivity could readily be doubled by simple improvements to management at a low level of inputs (Pereira & Thomas 1961). In spite of a terracing intensity of 75 m terrace length per hectare (330 yards per acre), cultivation onto steeper unprotected slopes had increased and the total area of severe erosion had increased from 26 to 37 % in the 24 years. The thin crops, grown without fertilizer or manure, gave so little protection that not even well-built terraces could succeed. Such fully documented examples are rare, but the general experience, uniform throughout Southern Africa, is that the whole standard of agricultural productivity must be increased simultaneously

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and that, although loss of soil is irrevocable and progressive, it is pointless to arrest it mechanically without tackling the root cause, which is the low agronomic standards of the arable cropping.

Irrigation techniques were also successfully adapted from overseas; the basic physics, which Howard Penman of this Society applied to the problems of Britain, were tested on a series of catchment area water balances in East Africa and shown to apply effectively in the tropics (Pereira 1959; Pereira *et al.* 1961). The essentials for irrigation management – evaporation rates as well as rainfall and temperature – have been studied, mapped and published (e.g. by Manning 1950; Griffiths 1960; Walker & Rijks 1967; Woodhead & Waweru 1970). Similar studies in the former Federation of Rhodesia and Nyasaland, continued in Rhodesia, Zambia and Malawi, and in South Africa (Bibliography by Rodier 1963). These make possible the more effective design of irrigation schemes, which have more probability of success today than many of the major irrigation schemes had 30 years ago in the U.S.A.

Major irrigation schemes have been developed successfully only where a fully commercial economy has been established; the largest schemes are the 1800 km Vaal River–Orange River System in South Africa, where there are many smaller schemes. The Sabi–Lundi scheme in Rhodesia now exceeds 100000 ha of highly productive wheat, maize, cotton, citrus and sugar production. There are 85 major dams, holding 3 km^3 of irrigation water, and over 7000 small dams already built in Rhodesia, with many more sites surveyed for development.

Not all irrigation schemes need massive capital and an enterprising example from the barren sandy coastal wastes near Asmara at the foot of the steep mountain escarpment illustrates this. Annually water pours down the escarpment and crosses the coastal strip in wide torrents. An Italian and Ethiopian partnership brought a small bulldozer in each dry season to spend three days in throwing up a small bund across the wide flat dry torrent bed. This deflected the first three or four floods into an adjacent flat flood plain area, where the water soaked in. Bigger floods then washed the bund away and salad crops were planted on the watered area. Small diesel pumps in shallow wells raised the stored water and irrigated the peppers, egg plants and tomatoes, which gave excellent crops.

Grazing lands

Since Professor Tribe will be discussing animal husbandry in the semi-arid tropics of Africa and Australia, I will deal mainly with effects on soil and water resources. Cattle-owning subsistence farmers keep large herds of low productivity, without regard to their efficiency in yielding meat, milk or money. Even African farmers entering the trading economy tend to keep excessive numbers on the communal grazing grounds. Irrigation schemes attract only the more enterprising from traditional tribal society, but they invest their profits in cattle on the surrounding areas. The result is soil erosion on a massive scale. Figure 1, plate 1 illustrates the state of thousands of square kilometres of southern Africa at the end of each dry season. Under good management the scrub is either slashed or cleared mechanically, and the grazing areas are closed in turn to provide tall dry grass which can be burned to destroy regenerating thorn scrub. Over-grazing leaves no grass to burn. Two experimental watersheds, each of 500 ha, in this condition in Uganda were instrumented and flumes were built to measure torrent flow. Water penetration was measured electrically on 20 profiles. Over four years, penetration of the annual 750 mm of rainfall reached a soil depth of only half a metre, and

FIGURE 1. Results of overgrazing in dry season. Thousands of square kilometres of savanna are reduced annually to this state in East, Central and Southern Africa.

FIGURE 2. Results of bush-clearing and two seasons without grazing. In spite of loss of more than 50 mm of topsoil these natural grasslands show great resilience. Fifty species of grasses were identified in this experimental catchment area.

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40 % of all rainstorms was lost immediately as surface runoff. One valley was then cleared. Regeneration was rapid; (figure 2; plate 1) the rainfall penetrated 1.5 m into the soil and the stock-carrying capacity was approximately doubled. This and other examples are discussed in more detail elsewhere (Pereira 1973). Thus the soil erosion was not brought about by sheer numbers of stock but by lack of any form of grazing management.

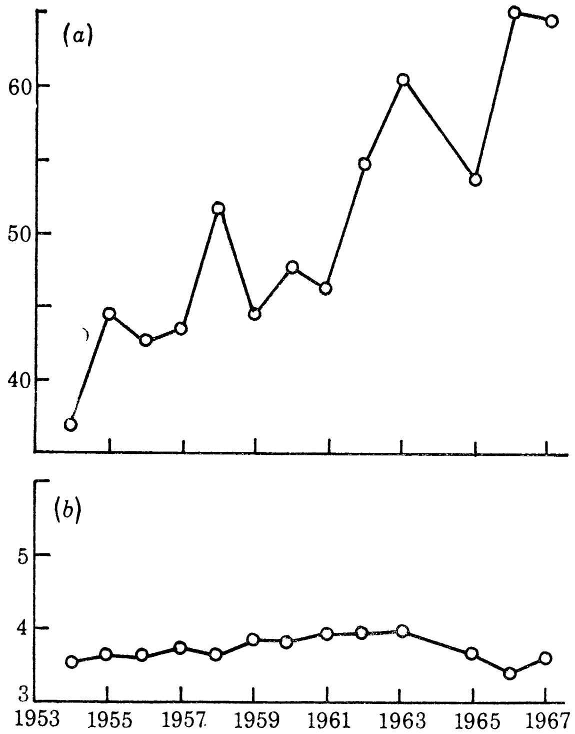

FIGURE 3. Progress in productivity of tribal cattle herds on communal grazing. (*a*) Total number of cattle sold. (*b*) Total number of cattle in Bantu areas (including Transkei but excluding SW Africa). (From Hamburger & Waugh 1968.)

However, the big annual variations in rainfall characteristic of the semi-arid areas cause major changes in the volume of feed produced. Carrying capacity can be reduced, by two successive bad years, to one-third of that of the previous five or more years. Recovery is rapid only if the grass is protected for the first few weeks of the rains. This faces the most sophisticated ranch management with very serious problems.

As early as 1923 the South African Government set up a Commission of Enquiry into Drought. A national Fodder Bank Committee reported in 1949. A major study and report on drought feeding followed in 1965. In 1967 an Enquiry into the Marginal Lands of Rhodesia studied the 1966 drought, in which 60000 cattle were moved by rail from the low veld to more favoured areas. Farmers are usually convinced that rainfall is dwindling, but the records, since the turn of the century, show no indication of decline; four or five successive seasons of rainfall well below the long-term average may occur by chance; such a drought can result in severe destruction of rangeland if stocking is not promptly reduced. The reports of the official Commissions show that fodder reserves are an essential provision for each ranching enterprise. Central fodder banks have been reported by successive Commissions to be expensive and ineffective. Maintenance of stocking below full level of herbage production in good years, and efficient off-take and marketing arrangements, are more essential in semi-arid country than in temperate climates. The problem can arise even in well-watered countries, such as Britain; we were seriously over-stocked in 1974/5. The development of offtake and marketing facilities in the Bantustans of South Africa is making encouraging progress, as illustrated by figure 3 (from Hamburger & Waugh 1968). Throughout southern Africa grazing control is complicated by the communal systems of land tenure, but their large scale offers great advantages for control, as is demonstrated on communal lands in western U.S.A.

A production constraint second only to drought throughout southern Africa is the incidence of both epidemic and endemic cattle diseases. Rinderpest, a major fatal epidemic virus, has been brought under control by large-scale vaccination campaigns, with the South African Veterinary Laboratories at Onderstepoort supplying vaccines to many countries to the north. Trypanosomiasis, eliminated from South Africa, is still spread by several species of tsetse flies over many thousands of square kilometres, and is held at bay in Rhodesia and in Kenya only by expensive 'fly barriers'. These are wide strips of country from which all bush is continuously cleared. The clearings, over hundreds of kilometres, are protected by expensive heavy wire fencing to exclude migrant elephant, buffalo, zebra, various antelopes, bush pigs, warthogs and other species; many carry the trypanosomes and most provide food for the tsetse fly. Steady progress in the containment of foot and mouth disease is encouraging, but quarantine measures have been necessary which sadly disrupt the offtake and marketing of stock. A serious tick-borne protozoan disease, 'East Coast fever', is controlled by weekly dipping of cattle. In sparsely roaded country this involves long weekly treks for thousands of beasts which leave wide scars of soil erosion for hundreds of kilometres. Soil erosion progressively spreads downhill and these trails cause major damage to semi-arid country.

The wildlife, which most countries in southern Africa are learning to respect for its tourist value, is a major complication for the veterinarian. In addition to the tsetse problem already mentioned the wildlife acts as a reservoir for other parasites and pathogens. Many studies and some commercial enterprises have explored the exploitation of the wildlife as a food resource (De Vos & Tecwyn Jones 1967; Talbot *et al.* 1965). Overall, these possibilities appear attractive but they have generated more discussion than profit. Eland have been successfully domesticated, but disease control is always likely to be a problem, since the veterinary profession has not yet the knowledge of the pathogens which affect wild species. A herd with which I was personally acquainted, however, had a better health record than most cattle enterprises (Posselt 1963). Eland certainly show very much better adaptation to marginal land conditions than do domestic cattle. The possibilities of game exploitation have been studied in southern Africa by a U.N. team (Swift, Pereira, Talbot & Beaton 1963) and some pilot schemes for harvesting wild species for fresh meat supplies to large industrial areas have provided encouraging practical experience. Costs have, as yet, remained too high for any widespread development (Pereira 1964).

International input of agricultural science

Successful experience by the Rockefeller Foundation in Mexico demonstrated that a major impact on the agricultural output of a developing country could be achieved by a vigorous team of international scientists, applying modern techniques of plant breeding, with

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management levels capable of reducing all of the main constraints on crop yields from the improved varieties. This was combined with training of Mexican agronomists, to use the new materials. As a result Mexico ceased major food imports and began wheat exports.

A joint effort by the Rockefeller and Ford Foundations launched a similar effort, with equal success, for the rice crops of SE Asia. Sponsored by the World Bank with two cooperating U.N. Agencies, F.A.O. and U.N.D.P., a consortium of national and institutional donors, the Consultative Group for International Agricultural Research (C.G.I.A.R.) now maintains a chain of eight International Centres around the tropical belt. C.I.M.M.Y.T. in Mexico (wheat and maize); C.I.A.T. in Columbia (cattle, pigs, cassava and beans for the vast barren Llanos of the Andes); C.I.P. in Peru (potatoes); I.I.T.A. in Nigeria (cowpeas, soya beans, yams, etc.); I.L.C.A. in Ethiopia (livestock systems of Africa); I.L.R.A.D. in Kenya (two major animal diseases of Africa); I.R.R.I. in the Phillippines (rice, both flooded and dry) and finally I.C.R.I.S.A.T. in India. The International Crop Research Institute for the Semi-Arid Tropics, set up three years ago at Hyderabad, is applying to sorghums, millets, pigeon peas, chick peas and groundnuts the process of assembly of a world collection of genetic material and breeding and selection under intensive pressure for suitability to the semi-arid tropics. A sophisticated programme aims at incorporation of resistances to many of the main diseases and even to some of the main pests, but the essential basis is rapid growth. Rain seasons which fail are characteristically of short duration, and early maturity is an essential stage in the reduction of the farmer's risks from an erratic climate.

It is necessary here to stress an issue which has been widely misunderstood and misquoted by economists and sociologists. While ability to respond to fertilizers is important, these new high yielding varieties (h.y.vs) have outyielded the traditional varieties even when no fertilizers are given, as a result of their ability to make better use of available moisture. Adoption of the new h.y.vs thus reduces the farmer's risks and does not involve him in extra costs unless he is enterprising enough to use fertilizers. They then enable him to profit from his enterprise.

The 30 donor-members of C.G.I.A.R. are helped by a small Technical Advisory Committee (T.A.C.) which works out priorities and policies for this very effective form of international aid. Since the crops of the semi-arid tropics have had far less attention than have the major world crops such as wheat and rice, substantial progress can be expected in spite of the harshness of the agricultural environment.

Conclusions

The low population densities shown by the maps of southern Africa do not imply that the continent could support vastly greater human populations. The overriding constraints are the scarcity of surface water and of potable groundwater supplies, together with the severity of the semi-arid climates for agricultural purposes. These sharply limit the areas suitable for intensive settlement. The fragility of landscapes whose geological rates of erosion are severely accelerated by man's activities of tillage, of livestock grazing and trampling, and even by his footpaths and roads, has already resulted in irreversible losses of soil resources over large areas.

The objectives of the Royal Society 'for improving natural knowledge' must still be applied, on the spot rather than from a distance, for nature is full of surprises and we have much to learn. But we are not 'starting from scratch' as all too many newcomers to Africa tend to assume. If the rapidly growing human population is to avoid many more disasters of the type experienced recently in the Sahel and Ethiopian famines, then there must be far more vigour

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in the application of what we already know and have fully tested. Contour farming, use of fertilizers and improved seeds, pest and disease control are the main issues for crop farming. Urgent reduction of livestock numbers by elimination of unproductive beasts and by rapid offtake of surplus cattle, is even more essential for the animal industry.

If the semi-arid country is to carry double the number of people in the next 25 years, the rural communities must give up their traditions of keeping large numbers of uneconomic livestock. Alternatively, if they are to preserve their traditions, then they must limit the increase of human populations. There is no way of carrying twice the population by the traditional destructive methods in this vulnerable country.

I do not believe that this essential change will be achieved, even with maximum international aid, until agriculture is recognized by each country's leaders as their most urgent concern. Until they allot rewards and status to food production which will attract the more able and enterprising, it will remain the occupation of the poor and ignorant, as it did for 1000 years of European history. Dr Boerma, speaking last year to the World Food Council as Director General of F.A.O., said that less than 10% of international development assistance has been allocated to agriculture. This degree of attention will not secure the development of the resources of the semi-arid areas of Southern Africa to carry the human populations which they are now generating.

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Discussion

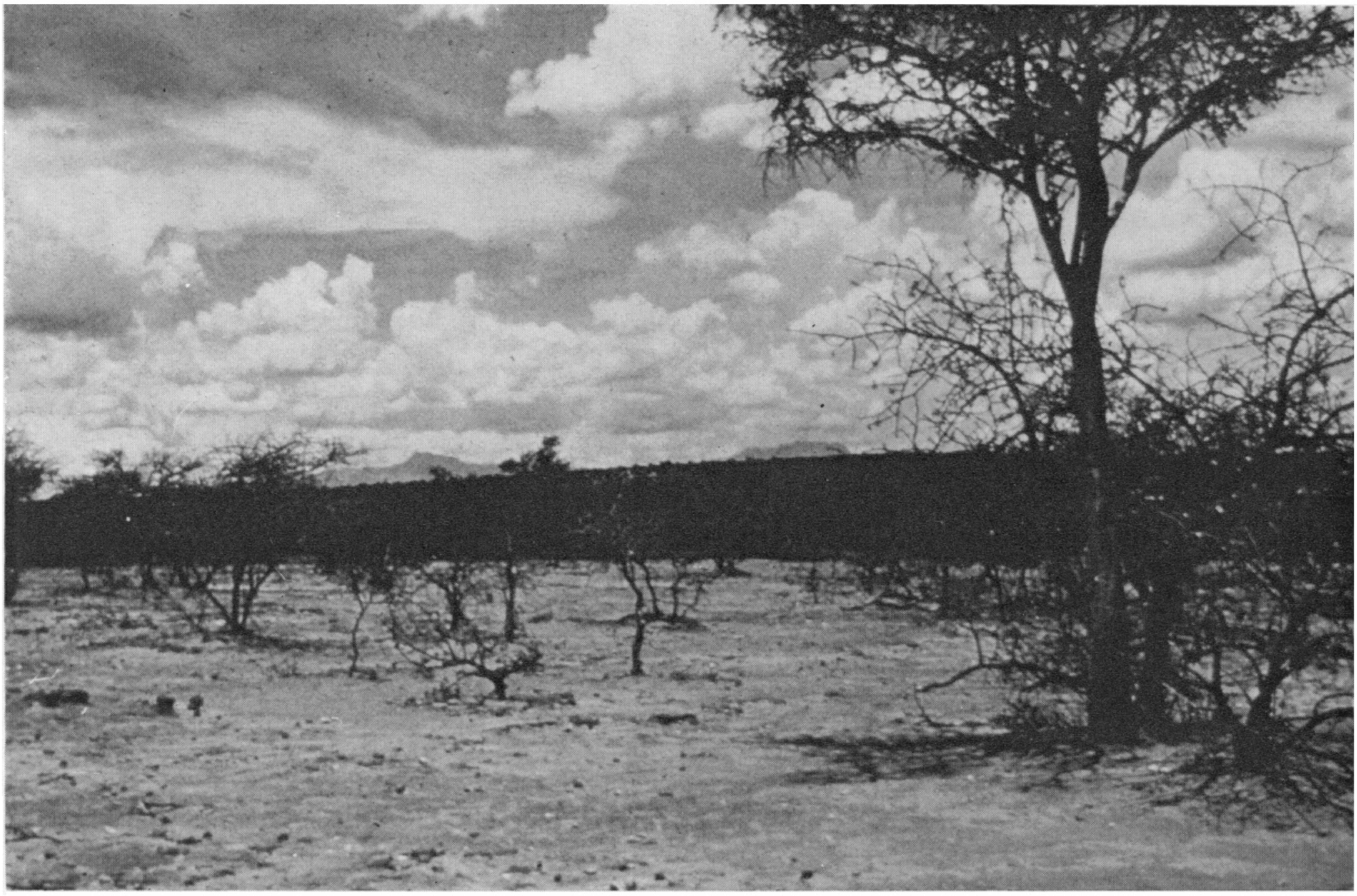
H. C. Pereira, F.R.S. (Comment following mention of a field study in Botswana in which analyses had shown that browse from shrubs was higher in mineral elements than the grasses, and that this was related to the geomorphology of the subsoils). Minerals are important components of feedingstuffs but they do not keep starving cattle alive in the dry season. In Rhodesia, at Matopos, a large-scale comparison of cleared paddocks with heavily shrub-infested paddocks was conducted in a severe drought. When the sparse grass between the bushes was eaten, there was not enough energy supplied by the browse. The browsing cattle were reduced to acute starvation and had to be rescued, while those in the cleared paddocks needed no help. Some shrubs are indeed useful, but they can only supplement the grasses as a basic ration for domestic cattle.

On the question of the need for local study and measurement there is no dispute. Competent local scientific study for the detailed adaptation of techniques is a basic part of modern agriculture, as necessary in Britain as in Botswana.

T. Riney (*Department of Forestry and Natural Resources, Kings Buildings, University of Edinburgh, Edinburgh* 9). My question is based on Dr Pereira's emphasis on the importance of development and management of the headwaters of watersheds. In recent years in several areas of under 750 mm rainfall and in different continents, research and demonstrations have been made on raising the levels of water tables by changing the balance between woody vegetation and grassland in favour of grassland. Several successful examples are known from both the Western United States and Africa where it has been possible to control grazing, burning and other management practices. I would appreciate your opinion regarding the development potential this approach may have in under 620 mm rainfall areas with a recent history of lowering water tables and a present high proportion of shrubs or trees.

B. Dasgupta (*Institute of Development Studies, University of Sussex*). May I sound a note of warning to younger western scholars, that they might often find the poor countries which need technological help most, reluctant to receive such help. I would like to make two or three points to explain such reluctance on the part of the poor country governments. Firstly, it is often the experience of the l.d.cs (e.g. the implementation of the Bimas programme in Indonesia) that the technological help given from the West does not cater for the specific needs of a country given its environmental and social peculiarities. Secondly, often the foreign advisors recommend energy-intensive, capital-intensive, import-intensive technologies which are unsuited to the conditions of energy-scarce, low import capacity, poor countries with abundant labour supply. Thirdly, such technological help usually comes through the institutional form of multinational corporations which, because of their past colonial association and profit-maximizing motives, are distrusted by the governments of poor countries.

A. B. Rains (*Land Resources Division, Tolworth Tower, Surbiton*). Dr Pereira's inclusion of areas not usually considered to be in the semi-arid category is welcome. In the higher rainfall Sudan Zone of West Africa there is continuing environmental deterioration as the result of the activities of both the cultivator and the pastoralist; some of the latter's practices are particularly damaging. Throughout the zone there is also a largely uncontrolled exploitation of woody vegetation for fuel. Because of the large population in the Sudan Zone any decline in yields could be extremely serious.



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