FORESTRY & LAND USE IN THE SUDAN

Galal El Din El Tayeb

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I. FORESTRY AND OTHER LAND USE TYPES

At the stage when man is dependent on nature, as in the primitive parts of the southern provinces, his activities are determined to a very large extent by the forest. The attitudes of different people to the forest vary considerably: to the forest dweller, it provides food and shelter; to the pastoral man it is repellent and the home of predators; and to the cultivator it is a loss of land which could otherwise be put under agricultural production.

Man, to satisfy his clothing and dietary requirements, makes ever increasing demands on land. In previous times agriculture expanded at the expense of the original vegetation and many types of forest were transformed. Human intervention with the natural vegetation has given rise to varying modifications of the climax forests and the complete eradication of the forest over extensive areas. In the Democratic Republic of the Sudan this human intervention has been related to different activities practised in the forest; these, which include various types of agriculture, grazing, settlement, firing and woodcutting, will change the natural vegetation cover in the north to steppe and finally to desert conditions, if such activities are not controlled in one way or another.

SHIFTING CULTIVATION

Shifting cultivation has a long history in almost all parts of the country except the desert and the semi-desert where rainfall is rarely sufficient to permit unirrigated cultivation; the regions infested by the tsetse fly; and the permanently inundated swamps of the southern clay plain. It is essentially the main type of cultivation practised apart from irrigated agriculture. It is not appropriate to generalize about shifting cultivation because the various practices and the nature of the terrain in each case have different impacts on forest and soils. Jackson and Shawki [1] have distinguished eight types of which the one practised in the gum belt is perhaps the most beneficial to the forest and soil, but unless it is controlled the increasing

1 J.K. Jackson and M.K. Shawki, Shifting Cultivation in the Sudan, *Sudan Notes and Records*. Vol. 31, pt. 2, 1950, pp. 211–216.

pressure on land may shorten the fallow period and consequently lead to the final disappearance of the forest and the exposure of the soil to erosion.

In Equatoria Province the practice should ideally be eradicated from all mountain areas by their declaration as forest reserves to protect the remaining forests and soils. In the woodland savannah the local shift of agricultural land, as a result of exhaustion, may be accompanied by movement of the whole village, but more often the houses remain in their place because of domestic water supply. The fallow period is not determined by the availability of agricultural land but by the desire of the people to remain as near as possible to their villages and to avoid the heavy task of clearing new land. The effect of this practice on the fertility of the soil is determined by the length of the fallow period and the intensity of cultivation between successive fallow periods; no permanent or serious damage will be done to the soil if the fallow period is long enough (twelve to fifteen years) to allow the regeneration of the trees. The proper fallow system is disturbed in many places, especially where settlements have been stabilized in the interest of tsetse fly control, and health, educational and other social services.

Within the domain of the Nilotic people, which had originally been covered by a local type of savanna (palm woodland),[2] the agricultural practice may vary slightly from one place to another. Shilluk cultivation is mainly confined to riversides and it is continuous (with no form of rotation) for three to four years before the land is abandoned. The practice of the northern Dinka and Mabaan is different in that the cultivators do not clear the trees but simply lop and top them. Thus the effect of the practice on forests is not generally significant, although some places are suffering from overcultivation and severe soil deterioration; but large scale deforestation for the provision of agricultural land has not yet taken place.

The protection of the forests and slopes of the Nuba Mountains and Jebel Mara necessitates the transfer of settlements from the slopes down to the plain or, in the case of Jebel Mara, to the southern third where perennial streams are numerous enough to minimize the pressure on forests and soils.

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2 J.H.G. Lebon, *Land Use in Sudan*, Geographical Publications Limited, Bude, Cornwall, 1965, p. 96.

Though very little information on the ecological rate of change of forests has been collected in the Democratic Republic of the Sudan, there is considerable evidence in the southern parts that during the last hundred years large areas of closed forest have been reduced to fire-swept woodlands by the combined effects of shifting cultivation and fire.[3] There is, therefore, an urgent need to modify shifting cultivation and adapt it to forestry, since little immediate change is foreseeable. There is as yet no land hunger in the country, but local over-concentrations have already appeared; these have been unavoidable in Kordufan and Darfur provinces, where there is a marked restriction of water supplies, but in areas infested by tsetse fly these have deliberately been created to facilitate the control of sleeping sickness. Such over-concentration of agricultural people causes the fallow period to be short and the dangers of erosion to be prominent. The creation of new water points can alleviate these over-concentrations but it can equally mean mere new areas of denudation owing to lack of control and failure to grasp the capacity of each newly created water centre.

Some modifications for improving this system of cultivation have been introduced in different parts of the country. In Equatoria Province the greatest modification is found in the Zande scheme, where the modified system of cultivation consists of subdivision into plots: the farmer is permitted to cultivate any part of his plot for three successive years only, after which he must allow it to revert to bush fallow, and another piece of land within his area is prepared for cultivation. It is strictly prohibited to cultivate bare slopes, steep slopes or any area along, or in the immediate vicinity, of stream valleys, rivers and springs. This system ensures that forests outside the allotted areas will not be devastated, and that forests along streams, rivers and springs will be secured for protective measures.

The replacement of fire in the 'hariq' system of cultivation by disc harrowing after the germination of the new season's grass, has been successfully attempted in a few places. The application of this modification to as large an area as possible will greatly reduce the risk of fires spreading from the cultivation areas into forests. In the case of 'bildat', the introduction of a fallow period where it does not exist and its lengthening where it is short, is necessary; but where the pres-

3 Jackson and Shawki, *op.cit.*, 1950, p. 220.

TABLE I: Effects of shifting cultivation

Locality	Natural vegetation	Cultivation	Crops	Effects on soil	Remarks
1. Central Kordufan Central Darfur Southern Kassala and Southern Blue Nile Provinces	The gum-yielding *Acacia senegal*	Shifting cultivation with a well-defined rotation	Sesame, dura and dukhun	Helps the soil to retain its fertility during fallow period	The working of soil for cultivation facilitates the regeneration of *Acacia senegal*
2. Equatoria Province	Woodland savanna	Cultivation for 3–4 years on the slopes of Dongotona	Sweet potatoes, cassava and millet	Soil washed down slopes and most of hills below 6000 are converted to bare rocks	The small remnants of the tropical rain forest are not yet seriously affected
3. Bahr el-Ghazal Province	Woodland savanna	Cultivation with a short fallow period(2–5 years)	Ground-nuts,cassava, millets, sesame, maize and tobacco	Severe soil deterioration in many places; sheet and gully erosion in Raga and Deim Zubeir	Forest reduced to fire-climax, and broad-leaved forests to thorny forests in many places
4. On the clay plain and to a lesser extent on the sandy loams west of the White Nile	Grassland	'Hariq' cultivation for about 3 years; rest period for 2–5 years	Mainly millet	Soil fertility may be maintained if during colonization period grasses escaped fire	It does not affect forests because the area is predominantly a grassland

Locality	Natural vegetation	Cultivation	Crops	Effects on soil	Remarks
5. Along the main Nile between Khartoum and Atbara, the Blue Nile between Khartoum and Er Roseires, and on Dinder and Rahad tributaries	Dominants are *Zisiphus spinachristi* on 'gerf' land and *Acacia arabica* on basins	Except for a very short fallow period cultivation is continuous	Mostly fruits and vegetables	It is not harmful to soil because fertility is renewed by flood annually	Forests on 'gerf' land not affected but on basins they are drastically affected, especially north of Khartoum
6. Areas in the vicinity of villages (bildat)	Various grades of semidesert scrub and low savanna	It is perennial or with a very short fallow period	Dura, dukhn and other cereals	Severe erosion even on sandy soils, and its effects may be permanent	When soil is worn out the whole village may move to a new site: severity of erosion is proportional to length of fallow period and density of village population
7. Margins of the clay plain in Upper Nile Province	*Acacia spp.* and broadleaved deciduous species	Varies from light to intensive with no rotation at all	Mostly dura	In local areas the soil has seriously deteriorated	Its effects on forests are not significant because rainfall is heavy, and the Nilotic people are interested in their cattle more than in agriculture
8. Jebel Mara and the Nuba Mountains	Savanna	Terraced cultivation on steep slopes	Cereals and some fruits and vegetables	Over-cultivation has led to severe soil erosion	The woodlands have been restricted to fairly limited areas

Sources: (1) Jackson and Shawki, *op.cit.*, 1950.
(2) Lebon, *op.cit.*, 1965, pp. 79–100.

sure on land is so great that the cultivation cannot afford a long fallow period, the application of fertilizers and manures is vital to keep the land in good heart. In the gum belt, suggested modifications include the adoption of extensive fire protection systems and the cultivation of agricultural crops with 'hashab' seeds (Fig. 6). In the southern parts of the country, attempts to prohibit burning have been rather ineffective, but an early burning policy can take their place since early fires are less fierce and consequently cause comparatively little damage to the trees. In regions where water supply is inadequate, early burning also encourages a green flush of grass growth to help livestock tide over thirst for a longer period in their southward movement before they reach their watering centres.

The adaptation of cultivation to forestry reached its greatest development in the 'gerf' land and on the basins of the Blue Nile where the riverain *Acacia arabica* forests were worked by cutting immediately followed by resowing. Its cultivation as a 'taungya'[4] crop was greatly aided by the rise in the price of maize during the forties: the system is simple and beneficial especially where land hunger is acute—labour is employed to sow maize together with *Acacia arabica* seeds, and at the end of the production period the maize crop is shared between the labourers and the Forests' Department. Under this system the Forests' Department controls the whole operation and is able to obtain relatively cheap labour at a time when there is a general tendency for wages to inflate. In the basins along the main Nile contractors are permitted to sow and harvest a maize crop free in return for sowing the *Acacia* seeds with the crop; this practice can be adopted extensively in the Northern Province owing to the limited arable land. But to extend this system over other parts of the country, it is not necessary to specify the agricultural crops to be grown, but rather to leave the contractor or labourer to grow whatever crop he wishes, provided that this does not adversely affect the normal growth of the trees; this has now become quite feasible because experiments have shown that good results can be obtained from the sowing of agricultural crops with tree seeds. In other parts of the country where cultivable land is abundant, cultivators are reluctant to take part in the 'taungya' system because they have

4 It is a Burmese word denoting afforestation by sowing tree seeds with agricultural crops.

enough land which they can cultivate at will and without the restrictions necessary when trees are grown among their own crops.

This 'taungya' system not only ensures a rational utilization of land and conservation of soil, but also contributes to the country's production of subsistence and cash crops. It will help in the production of more food crops for the Nilotic and Beja people who are frequently swept by famines, and those who live along the main Nile (north of Khartoum) who often suffer from low floods and crop failures. Of equal importance is the effect of this system on the promotion of tree growth, as indicated by the results of experiments conducted during 1953.[5]

Besides these modifications, there is the legal element, the Central Forest Ordinance of 1932 declares that all rights are extinguished where central forest reserves are established, and no type of shifting cultivation should be practised except in the form of 'taungya' for regeneration of the forest. Under the Provincial Forest Ordinance the local government authorities may declare certain species of trees to be 'protected trees' and these should not be cut down or injured in any way without permission, even in the course of cultivation. In practice this provision is very difficult to enforce because of the scattered nature of the cultivation, lack of adequate forest staff and general unawareness among the people of the indirect values of the forest.

OTHER AGRICULTURAL ACTIVITIES

In agriculture, the nature of the shallow tropical soils and their relative poverty in nitrogen, as in most of the southern parts of the country, must be guarded with the greatest possible care; undulating terrain, like that of Equatoria Province, requires special treatment. The long dry season of the central zone of the country, which is accompanied by widespread fires and which is followed by torrential rains, is especially conducive to soil erosion.

In Equatoria Province many of the local inhabitants have been given plots for coffee plantation, but lack of control resulted in many people cultivating more land than they were originally allotted; most

5 J.K. Jackson and F.G.G. Peake, *Forestry Research in the Sudan,* 1950 to 1954, Forest Memoir No. 7, Agricultural Publications Committee, Khartoum, 1955, pp. 11–13.

of these extended agricultural lands are on steep slopes and often on the very edge of streams and 'khors'. This has resulted in the complete clearance of trees and bushes from the sloping terrain, which is cultivated without ridging. Some of these cleared areas contain some of the few remaining parts of the gallery forests. The situation is further aggravated by the fact that these areas are on marginal land for coffee production. Also the creation of tobacco farms in the same province has involved a great deal of deforestation of sloping terrain and along the streams, and erosion has started in these areas. Tobacco farms are small and so scattered that it is extremely difficult to control deforestation, and impracticable to arrange fuel plots on sustained yield basis.

It is absolutely vital under such conditions to include in the local standing orders provisions for the control of forest clearance for commercial agriculture on unsuitable sites.

In regions suffering from scarcity of arable lands, the limited alluvial soils found along edges of streams, foothills, and at the bottoms of wadis and depressions acquire a great significance for subsistance agriculture for local inhabitants as is the case in the mountainous regions of Equatoria Province and Jebel Mara. These vulnerable soils can be utilized with a fair degree of safety if conservation farming practices are adopted, such as contour ridging, crop stripping, terracing and mulching. In Equatoria Province coffee plantations can be established on contour strips, alternating with planted or natural forest strips or tea plantations on the higher altitudes, which would give the same protective effects on these slopes as the natural forests if given the necessary conservation treatments. The same also applies to fruit gardening on contour strips on the slopes of Jebel Mara.

GRAZING

Grazing has had a far reaching impact on the natural vegetation and the soils of many areas. Under natural conditions, before the intervention of man and his domesticated animals, there would have been a whole spectrum of wild grazing and browsing animals, each of which is a selective feeder, maintaining an ecological balance with the natural vegetation. When these wild animals are replaced by domesticates, the ecological balance is upset because there is

much greater pressure on certain vegetation species which are actively selected by the limited range of domestic animals. This pressure is minimal when grazing is light and controlled, but with heavier grazing, resulting from either large animal stock or use for prolonged periods, there will be a decline in the density of the more favoured species, and in consequence the value of the grazing land will deteriorate. Over-grazing will produce a serious reduction, if not a complete disappearance, of the vegetative mattress, which will in turn give rise to severe soil erosion.

During the fifty years 1917–1967, the total number of the four main domestic animals (sheep, cattle, camels and goats) increased from 3.7 to about 31.8 millions. The Government's policy till 1947 was, because of fear of the consequences of an undue rocketing of the animal population, to stabilize animal numbers, but afterwards, owing to better prospects of increasing water supplies by digging reservoirs, it decided to maximize the application of proved methods of disease prevention on the assumption that animals could be safely increased to support the growing human population and to create a surplus for export purposes. In 1961 the accepted animal numbers were [6]: 2.9, 8.5 and 6.5 millions for camels, cattle, sheep and goats respectively; in 1967 the approximate numbers were 2.9, 11.1, 10.4 and 7.4 millions respectively.

The tribesmen of Southern Sudan keep large numbers of cattle as a sign of prestige. The number of cattle is increasing at a high rate because very few are slaughtered or sold for cash, while neither the area of grazing land is increased nor the quality of the pasture improved. Grazing land is confined to areas above the flood level and to areas outside the domain of the tsetse fly. Reduction of the number, or at least lowering the rate of increase of cattle, extension of grazing land and raising of the quality of the pasture are urgent needs for the protection of the forest and the soil, especially since it has become evident that serious erosion has already started in the overgrazed northern parts of Bahr el-Ghazal Province and most of Equatoria Province. To reduce the number of cattle in this area by attributing economic significance to it, will be, at least at the present time,

6 A.R. Bayoumi, 'Some Problems of Land Use and Rural Water Development in the Republic of the Sudan', an unpublished report to the Ministry of Agriculture, Khartoum (no date), p.7.

fruitless, because cattle as a sign of prestige have long been rooted in their folklore and traditions, to the extent that the various aspects of their life are determined accordingly. It will be a long time before the spread of education and the economic development of their area alter their social structure and weaken these traditions. The extension of grazing land involves the eradication of the tsetse fly in the woodland savanna belt, and the provision of water points in ungrazed lands in the south-eastern extremity of the clay plain.

In Kordufan and Darfur Provinces, where the lack of water constitutes the main problem, the situation is no less drastic. The large number of animals here (cattle and camels) have a wide area to move over, but between Bahr el-Arab and the northern and western frontiers there is a general inadequacy, or even lack, of rich pastures. Early in the rainy season the nomads start their northern journey, the target for which is provided by the 'gizu' species on the southern fringes of the Sahara desert. They stay there until the 'gizu' grasses are completely grazed, with the result that the soil becomes exposed for almost the whole year, paving the way for desert creep. During the dry season large numbers of pastoralists stay with their animals around the comparatively few water supply centres in concentrations usually far above their capacities in view of grasses and water supply. So for many miles around these centres the land is overgrazed and exposed to wind erosion for most of the dry season. Some of the camel-owning tribes come in contact with the Hawasma and the Messeriya Zuruq during this dry season in the vicinity of Delling and Abu Zabad, an area which, according to Harrison,[7] is already over-grazed to the extent of twenty per cent.

The semi-desert grassland of the Butana, if not for the occupation of man and his domesticated animals, would have been covered by almost pure stands of *Blepharis* species, which are palatable to camels and sheep during almost the whole year, and to cattle during the rainy season.[8] *Blepharis,* if heavily grazed, cannot regenerate and may completely disappear, and indeed this is the case in almost all the over-grazed areas of the plain. *Blepharis* has disappeared

7 M.N. Harrison, *Report on Grazing Survey of the Sudan* (to the Ministry of Animal Production), Khartoum, 1955, Part III, p.26.

8 Lebon, *op.cit.*, 1965, p.160.

from the banks of the Atbara river for a width of about twenty miles. The provision of water points would release the pressure from the over-grazed centres, and would give *Blepharis* a better chance for regeneration; the new water centres should be confined to the western, central and south-eastern parts of the Butana, and should be reserved for the use of cattle and sheep only, leaving camels to feed on the drier areas.

For the alleviation of grazing pressure and improvement of grazing conditions in all these regions the following steps are necessary:
1 To conduct preliminary land capability surveys which are essential prerequisites to planning of the water provision programmes. Such planning should take into consideration the following aspects:
(a) Better distribution and convenient siting of the water points.
(b) Determination of the size of the water points based on the grazing potential and the carrying capacity of the range.
(c) Determination of the numbers and kinds of livestock involved.
(d) Controlled use of the water point, the time of the year it should be opened for use and for how long, etc.
2 Adoption of rotational grazing.
3 Trial on grass re-seeding from the air immediately before or during the rains to enrich the pastures, especially in over-grazed areas of poor rainfall, like the northern parts of the Butana plain.

Grazing by cattle and sheep can have serious consequences, but the effect of goats on the semi-desert vegetation is much more drastic. The main domain of goats is the semi-arid region extending roughly between latitudes 13°N and 17°N, and covering an area of about 200,000 square miles; this region is one of the most populous parts of the country; the natural vegetation comprises small trees and bushes which are within easy reach of man and his animals. The ecological balance has been tipped in favour of aridity and desert conditions in this region, which is over-used by man and over-grazed by his animals.

The goat was considered a problem after it had been realized that desert conditions had started to extend southwards. In this region about six million goats are kept for the provision of milk. Goats are ubiquitous feeders and can thrive on anything but absolute desert, and eat all the plants within reach, leading to the loss of practically all vegetation and the consequent prevention of regener-

ation. The situation is aggravated by the steady increase in the number of goats, because none enter the international trade of the country and very few are slaughtered. The various measures of control have been hampered by the social side of the problem: the goat is considered as the source of milk for the poor sector of the population. One of the measures attempted was the enclosure of the perimeters of towns and big villages to preserve the natural vegetation within them, but this enclosure system could not be carried out on a wide scale. In fact this system increased the concentration of goats in the unenclosed areas which constituted about eighty per cent of the total area, thus subjecting these areas to more severe erosive actions. Another measure was the allocation of certain areas for grazing, but this proved impractical because goats were very rarely confined to them. Taxation, as a measure to discourage people from having large numbers of goats, was attempted but did not give encouraging results. Another attempt in the Gezira Scheme was the treatment of foliage with repellents, but it proved fruitless because goats remained unaffected.

This problem is acute because through the activities of goats the threat of desert encroachment is becoming a reality. The most effective solution seems to be, as Ballal [9] has advocated, the complete extermination of goats from this region, despite the fact that they are a source of milk for the poor. Some individuals, encouraged by the state, have started dairy farming schemes near big towns to encourage the use of cows' milk instead of goats' milk, but the response was rather limited because the price of cows' milk was so high that the poor could not afford it. If such dairy farms are owned and efficiently run by the public sector or by co-operative societies formed and run by the people themselves and aided by the state, cows' milk can be made available in abundance and at a reasonable price; this will pave the way for the gradual extermination of goats and the conservation of the natural resources of the region.

Since the complete extermination of goats may well extend over decades, the following short-run remedial measures may be considered:

9 A. Ballal, 'The Goat as a Problem in the Semi-Arid Region of Northern Sudan,' *Sudan Silva* 12 (11), 1962, pp. 22–24.

(1) A culling process whereby all the undesired goats could be eradicated and only the good milkers kept.
(2) Introduction of high yielding breeds to help reduce the number of heads necessary to be kept by the poor man for his milk supply.
(3) Disposal of young, especially females, at the age of three to nine months for local meat consumption.
(4) Making available and encouraging the use of cheap dry feed, cakes, silage etc. to discourage out-of-pen feeding.
(5) The provision of improvement services and facilities for grazing land should always be made with a view to favouring cattle and sheep.

SETTLEMENT

Settlement will continue to be an important type of land use in the coming years because a large proportion of the population is now either semi-sedentary or without any definite form of settlement. The creation of permanent settlements for these people must be planned for with due regard to the complexity of the geographical factors involved such as climate, terrain, soil and water supply.

The inhabitants of Equatoria Province, to a large extent, have certain agricultural and social customs and practices modified by their environment and favourably accorded with these conditions; these practices include the spreading of the population thinly over the poor, shallow, tropical soils, and this has rendered shifting cultivation a relatively suitable form of land use. A newly introduced feature is the deliberate change of this mode of settlement by administrative arrangements to create dense concentrations of settlement along the main roads Another aspect of change in the mode of settlement in Equatoria Province is official encouragement of the downward movement of tribesmen from the hills and hillsides to form dense concentrations along valleys, as has been done by the Latuka in the Katire area of the Imatong Mountains. The positive effect of this new mode of settlement of the Latuka is that it terminates deforestation, overcultivation and over-grazing on the mountainous areas and eventually aids the regeneration and conservation of trees. But in the case of the Zande settlement the tropical soil is too poor to carry dense concentrations of agricultural and pastoral people. Settlement concentrations are also being created by the establish-

ment of 'peace villages' for southerners returning from the forest and from adjoining African territories in response to the new government policy to implement the democratic solution of the southern question; this must be undertaken with due regard to the carrying capacitites of the natural resources.

Similar concentrations of settlement have appeared in the western parts of the country where new points of water supply were provided to release the pressure on the already over-populated areas. Most of these new water points have meant new areas of denudation because of human and animal over-population of these water points provided in such an arid region. Here, as well as in the recently introduced types of settlement in the southern provinces, a healthy balance between the degree of concentration and the capacity of the areas must be maintained if the general standard of living of the local inhabitants is to be raised, without seriously endangering the natural vegetation and soils of these localities.

In Bahr el-Ghazal Province, the area within the domain of the tsetse fly is about 91,000 square miles in the vicinity of Wau. To exterminate the tsetse fly and render the area favourable for human and animal habitation, the Gogrial tsetse campaign, arranged by the Ministry of Animal Resources, has cleared off all trees and completely burnt an area of about 820 square miles north of Wau. The eradication of the tsetse fly is undoubtedly desirable, but it is unfortunate that this campaign was not referred to any land use or conservation authority to weigh and balance the costs and returns and to investigate if there were any other satisfactory solution. Such wholesale clearance of forest land not only initiates accelerated soil erosion and water dissipation, but also threatens to create sites for heavy concentration of cattle population with consequent overgrazing and further erosion, unless the situation is carefully guarded with provision of the appropriate balance between the requirements of the human and animal population and the capabilities of the area. This complete tree clearance also means that the newly created settlements will depend on other areas for the provision of wood fuel and all other forms of roundwood.

North of Er Roseires dam, the Kenana and Rahad agricultural schemes are about to be established. A primary aim should be that the agricultural village communities should get their wood require-

ments from within the schemes themselves. If each village consists of 200 families and each family of seven persons on the average, then such a community will need about 600 feddans of forest land for firewood and charcoal; an allowance of another 100 feddans should be made for the provision of other forms of roundwood. If the rotation system is similar to that of the Gezira scheme, then about eight to ten per cent of the total area of each scheme should be put under forests. The existing natural forests can be preserved, wherever possible, to meet the people's requirements before the forest plantations are ready for felling. The inhabitants will undoubtedly keep some domestic animals, particularly cattle, the pasture for which must be carefully considered.

FIRE

Some vegetation fires are due to natural causes, especially lightning, but the vast majority of these fires are started by man, who has long been systematically burning the natural vegetation of his environment. The causes behind this firing are many: to provide grazing when it is scarce; to clear the land for various types of cultivation and for easy movement; to drive game out of the forest in order to facilitate their capture; to kill certain parasites; to give room for settlement; and even to enjoy the sight of a good blaze, especially at night. So fire is not in itself a type of land use, but it has always been associated with some land management practices.

Fire severely damages many of the woody plants though it stimulates the growth of some savanna species. The degree of damage increases with the frequency of the burning and the intensity of the individual fires, which depend on the density of the vegetation cover and the time of year when burning is done. Early burning, at the beginning of the dry season when grasses are green and have a high moisture content, is estimated to consume twenty to thirty per cent of the herb cover, while late burning, at the end of the dry season when grasses are fully dry, may consume over ninety per cent of the grass mat. Wind, and the time of the day when burnings take place, also affect the severity of the fire.

The immediate effects of fire are:

(a) to kill tree seedlings;

(b) to kill some perennial plants and permanently destroy annuals;

(c) to burn up the vegetation debris;
(d) to destroy the humus, and
(e) to expose and dry the soil surface.

The secondary effects, according to Ferguson,[10] are as follows:

(a) by exposing the soil, rain will beat it into a hard surface layer, especially in clay soils, or wash it away, especially in sandy soils.
(b) by burning the ground vegetation and the debris there will be no effective barrier to running water;
(c) by burning the humus and humus-forming materials the absorptive capacity of the soil will be reduced and the physical structure upset, and the amount of plant nutrients will be diminished;
(d) by destroying tree seedlings vegetation will deteriorate and the grass/tree ratio will be increased; this increased grass/tree ratio will in turn increase the severity of fires and consequently their damaging effect;
(e) a long-term effect is that the diminished absorption of rain water and the greater run-off will cause a loss in the water supply which, coupled with a general reduction in trees, may cause permanent damage. This process is progressive and, if allowed to follow its irreversible course, the creation of desert conditions will be its ultimate end.

The economic effects of fire include the destruction of the actual and potential forest resources, reduction of the productive capacity of the soil, and consequently a permanent diminution of the natural wealth of the country.

The line running roughly along the 850 mm isohyet on sand and the 950 mm isohyet on clay, divides the country into two parts in regard to fire danger. South of this line the density of the grass mat renders annual grass fires highly probable. The frequency of fires in Southern Sudan is high, despite the fact that the early rains help to prevent the spread of fires originating from shifting cultivation areas. One factor contributing to this high fire-frequency is the considerable disarray of early burning times which may start as late as February because of the prolonged rainy season. Over the central parts of the country, the frequent spread of fires is mainly due to the inability of the authorities to complete fire-lining before early burn-

10 H. Ferguson, 'Deterioration of Soil and Vegetation in Equatoria' in *Soil Conservation Committee's Report,* Khartoum, 1944, p.139.

ings are started by the local people. Fires are also known to be started by herdsmen to enable new grasses to grow for their domestic animals; one such fire destroyed twenty-seven feddans of 'teak' and 'neem' in Equatoria Province in 1955. Cultivators and honey-collectors also start dangerous fires; in 1963 honey-collectors completely burnt 174 cubic metres of firewood in Upper Nile Province. A considerable part of the forest of Southern Sudan, especially in Equatoria Province, has been completely and deliberately burnt by the military forces in their fight against rebels and bush-fighters in 1955 and subsequent years.

With frequent fires the woodland savanna will degenerate to a tree savanna type and eventually, if fires are continued for many years, to scrub or grass savanna. Vidal-Hall[11] has studied the existing state of the high woodland savanna and the remnants of the tropical rain forest in Equatoria Province and Bahr el-Ghazal Province. He shows that the tropical rain forest has been retreating as a consequence of frequent fires, and that more open types of savanna have increased at the expense of the closed types. He also points out that the gallery forests which exist along the river courses extending from the forest zone into the savanna zone, exist only because the dampness of the valley bottoms limits the influence of fires, but where fires can spread annually in a thick mat of dried grass only fire-resistant tree species can survive and even so their growth is retarded. The effects of these burnings on the soil may well be disastrous, though no detailed studies have been undertaken in the Sudan. But the facts so far established indicate that soil is adversely affected by repeated severe burning because soil fauna and flora, organic matter, nitrogen content and general fertility will be diminished. These detrimental changes do not occur with light burning which may, to varying extents, actually increase soil fertility.

The country should aim at minimizing the frequency and intensity of fires. One reason for fire spread has been associated with fire-lines which have proved to be too narrow (about four to five metres) around some forest reserves in Kordufan and Darfur Provinces. Such fire-lines should be as broad as the unwanted land of

11 M.P. Vidal-Hall, *The Silviculture and Regeneration of the Forest Types of Equatoria and Bahr el-Ghazal Provinces,* Forest Memoir No. 4, Agricultural Publications Committee, Khartoum, 1952.

the country can permit, and mechanization needs to be used in fire-lining to ensure its completion before the big fires of the early burning threaten the forest reserves. It is not true that the working period of such machines would be so short that it does not justify the costs involved, because these can be simple and cheap machines attached to tractors which can go back to their normal agricultural processes after the completion of fire-lining, and so no problem of excess capacity will be involved. Secondly, these machines can work for six-to-seven months, starting in the north immediately after the rainy season in September or early October, and moving southwards following the end of the rainy season until they finish the southern areas where the rainy season extends to February or even March. Such a mechanized method reduces costs, economizes manpower, hastens the work and removes grass lumps more thoroughly. Other protective measures include an increase in the number of officials to promote control and supervision of forest reserves and natural unreserved forests. Heavy fines, and the long imprisonment of individuals starting fires have some effect, but they can never be satisfactory protective measures. A nationwide campaign to create a sense of conservation seems to remain the single most effective remedy. Until the fire-raiser is convinced that he is trying to get his immediate returns at the expense of the agricultural potentiality and the grazing qualities of the land to be used by the coming generation, and until there is fuller co-operation between officials and the public, fires will continue to be a serious threat to vegetation cover and the soils of the country.

II. EFFECTS OF THESE LAND USE TYPES

The various types of land use which have involved, and are still involving, forest clearance, have had adverse effects on the country's water supply and soil.

EFFECTS ON WATER SUPPLY

There is accumulating evidence that the water supply of the northern parts of the country has diminished in the last 400–500 years. Describing the Neolithic habitation in the Libyan Desert of the Sudan, Arkell[1] states that sherds and Neolithic axes have been found in a number of localities now without permanent habitation, in numbers and distribution which suggest permanent villages. It is thought that these people retreated to the south and the south-east; the evidence consists of the similar implements and pottery which have been found in the Nile Valley between Kerma and Shellal, and of the fact that the pottery now in use in the Nuba Mountains bears great resemblance to that of the Tama and Masalit who lived around Bir Natrun in the Neolithic age. Arkell also notices that there is a southward trend in the former sites of northern towns, and gives a number of examples: Uri near Jebel Matarrag (1500 A.D.) is now almost waterless, and Kobe, north-west of Fasher (1800 A.D.) is now without water supply; Turra, at the northern extremity of the Jebel Mara range, was densely inhabited about 1500–1600 A.D., but now the diminished water supply supports only a fairly thin population; in 1500 A.D. the main east-west route across Kordufan and Darfur Provinces ran through the sites of Kawa, Faragab, Bara, Uri, Wara and north of Lake Chad, but now it runs through Kosti, el-Obeid, el-Fasher, Abbeshe and south of Lake Chad.

Andrew[2] stresses that there is evidence of considerable Moslem pilgrim traffic across the Red Sea to Jeddah in the thirteenth century from a port afterwards abandoned for lack of drinking water. The

1 A.J. Arkell, A note to the soil conservation committee, Khartoum, 1944.

2 G. Andrew, 'The Climate of the Sudan' in *Soil Conservation Committee's Report*, Khartoum, 1944, p. 154.

pilgrimage in 1497 of the Emperor El-Haji Mahmoud to Mecca from Goa via In-Gades and Agades and Bilma (latitude 18°N – 17°N) with 800 people and numerous horses and donkeys, shows that this region must have been fertile and comparatively well watered at the time; now this region is a part of the desert. Large communities were living in permanent villages in the line Goa–In-Gades–Agades as late as the eighteenth century A.D., and the remains of these villages can still be seen in the sand. Andrew states also that Lake Undar was a permanent lake till 1913, but at the present time it is practically dry during the period from March till the rains commence in July or August.

This indicates that the water supply of these areas has diminished and that since about the fifteenth century A.D. the southern boundary of the Sahara appears to have advanced southwards and to be still advancing. Can this phenomenon be attributed to any major climatic changes which the country has undergone in recent geological times? The answer to this question may be sought in the soil succession, the fossil record, meteorological records, annual measurements of the river volume and the recorded history of the area. From the soil succession point of view, Andrew[3] argues that the uniformity, thickness and type of the silts of the Nile valley now being deposited show that the Nile regime has remained constant probably throughout the Neolithic to the present day, and from this a regional constancy of climate may be safely assumed. The soils of the Hashaba, Fatisa and Ed Dueim pump scheme areas were deposited under water, because fossil remains of the water snail are of general occurrence throughout the upper ten feet of the soil; the rarity of the fossil remains of the water snail in the surface layers indicates that since the drying out of this region the climate has never been wet enough to enable the water snail to flourish, indicating that no wide climatic fluctuations have taken place in recent geological times.

The record of the volume of water flowing in the main tributaries of the Nile kept by the Egyptian Irrigation Department since the beginning of this century, and the records of meteorological stations show that no major climatic change has occurred during this period.

The history of the northern part of the country, as known from

3 Andrew, *op.cit.*, 1944, p.5.

archaeological research, covers a period of more than 5000 years, and reveals nothing in the distribution or condition of buildings erected throughout the whole of this period, or of graves, to show that the climate was essentially different from that of today; the perfect state of preservation of the elaborate mural decorations in the Temple of Abu Simbel shows that the climate of this area has been as dry as it is today since the close of the reign of Ramses II in 1225 B.C. The fact that the flesh on bodies buried about 4000 years ago near Kerma was so well preserved as to enable sex determination to be made from it[4] also indicates that the climate of the area has not undergone any major change.

The fact that climate has not greatly changed for better or worse since the close of the last major wet phase in Pleistocene times confirms that the diminution of water supply and the southward creep of the desert over previously cultivable land has essentially been brought about by irrational land use practices, which involved the complete clearance of vegetation.

EFFECTS ON FORESTS AND SOILS

The deforestation and the destruction of the ecological balance associated with the different types of land use have adversely affected the soil cover over different parts of the country. In Khartoum and the Northern Province the harvest of wood from, and overgrazing in, the desert scrub forest have led to an increase in the frequency and intensity of sand storms and the formation of mobile sand dunes. Over the southern provinces increasing soil erosion and water dissipation have become the natural answer to the various types of land misuse. In Upper Nile Province, though characterized by its general flatness, tree clearance for irrigated agriculture is progressively expanding, wind and water erosion becoming more intense, and shortage in wood fuel and building poles impending. In Equatoria Province, where gully erosion is not extensive, sheet erosion is common and the ironstone plateau shows many areas of bare ironstone from which the surface soil has been completely washed away. The major factors contributing to the general erosion are over-grazing and grass fires.

Human activities in those areas have not given rise to consequences

4 Andrew, *op.cit.*, 1944, p.6.

as serious as in some parts of Blue Nile Province and Kassala Province, where the previous conditions, namely sparse population largely dependent on domesticated animals, and very extensive areas of woodland savanna, have not been conducive to the formation of a public conscience about the conservation of natural resources. Because of the combined effects of annual grass fires, uncontrolled grazing, extensive tree cutting for firewood and charcoal, shifting cultivation and pump schemes, woodland savanna has entirely disappeared from large areas like those round Sennar and Es Suki and the extensive areas of Luani and Singa. Erosion has become a serious problem in the Gezira area, northern Funj and Kassala, in such areas as Wad Medani, Hag Abdalla and Er Roseires on the Blue Nile, in the area of el-Gueisi on the Dinder tributary and near Showak-Butana ridge and Khashm el-Girba on the Atbara river.

In Kordufan and Darfur Provinces, deforestation, explosive rate of erosion and soil deterioration are attributed to grazing practices, creation of new water points without sufficient consideration to the carrying capacity of the surrounding land, and the rapid agricultural expansion allowed under indefinite crop rotation systems. Overgrazing has led to the disappearance of the three most favourable grazing plants (*Aristida plumosa, Blepharis* spp. and *Monsonia* spp.) from the vicinity of the water centres in the western parts of the region; these plants are also absent over much larger areas to the east where almost pure stands of the little-grazed *Cyperus conglomeratus* have taken their place. So severe and thorough has been the grazing near Bara that sand has become unstable, and is again forming moving dunes, which have begun to invade the cultivated zone. Deterioration of vegetation and soil is apparent in Khuwei and En Nuhud areas, and to a greater extent along the Kosti-el-Obeid and Babanousa-Nyala railway lines to which more and more people have been, and are still being, attracted by the bore wells drilled at the railway stations and the administrative centres. Here the savanna vegetation has been reduced to sparse stunted scrub.

The inhabitants of the Nuba Mountains, occupying the more accessible parts of the uplands, have reduced the woodland savanna to mere scrub in most places, and to eroded bare rocks or scree in some places, especially on the abandoned areas of terraced cultiva-

tion. The areas now under cultivation, namely the pediment and the clay plain, have been deforested. This large scale clearance of woodland, aided by fire action, has eliminated trees and accelerated erosion in the area. The provision of sunk wells on the gravels at the foot of the mountains, and the creation of reservoirs on the clay plain, have not helped the dispersion and increase of cultivated land to the same extent as the opening up of new areas to extend the attack on woodland and soil.

In Darfur Province the most outstanding examples of land misuse are found east and north of Jebel Mara, in the basins of Wadi el-Ku and Wadi Kaja. The occurrence of silt terraces and the availability of a reasonably adequate water supply throughout the dry season within a few feet in these basins have led to the rise of many permanent villages and an ever increasing number of cultivators. These favourable sites have also attracted many tribesmen and their herds from remote areas in the north and north-east, where the water supplies are seasonally available. All these factors have contributed to the present conditions where the human and animal populations are too dense, and the cultivated land too extensive for the available water supplies in these two 'wadis'. Over-population and overgrazing have seriously upset the ecological balance in the area, especially around the water centres. The creation of naked perimeters in this region has accelerated wind erosion and converted the stabilized sand dunes to a mobile state. El-Fasher is the most notable example of wind-eroded areas, especially the tract known as el-Fasher plain. An almost similar extent of erosion can be observed at Tawila, Mellit and el-Geneina.

In the Red Sea Hills and the Beja area, the eradication of some trees has been taking place for a long time. Andrew[5] quotes from Turner's report that the top of the hills above 6,500 feet were covered with forests mostly juniper; the old charred stumps in places where juniper has long died out show that it was once spreading over a much larger area than at present. He suggests that some time between twenty and fifty years ago extensive fires occurred over a period of years, probably deliberately started by the local people to kill weeds and juniper which were not palatable to goats and thus

5 G. Andrew, 'The Red Sea Hills' in *Soil Conservation Committee's Report* Khartoum, 1944, p.56.

to extend the grazing area for their animals. He estimates that in some places more than fifty per cent of trees of over forty years of age show fire damage. The resulting forests are so heavily exploited, and often completely destroyed, that severe soil erosion and rapid run-off have become a prominent feature of the area; now there is insufficient water supply for the juniper to regenerate, except on the most favourable localities such as the ravines. On the steeper slopes where the run-off is quick, old trees are slowly dying out and very few young trees are coming to take their place. The situation is aggravated by the enormous need of the local inhabitants for firewood, charcoal and timber; the monthly demand of Port Sudan town only has been estimated by Gleisberg[6] at about 23,000 kantars of firewood and about 570 tons of charcoal; to satisfy these requirements the people must monthly cut an area of about 10,000 feddans of natural forests. Another alarming fact is that the population of Port Sudan is expanding at a high rate.

In the Tokar area the results of irrational land use practices are more drastic. The present channel of the Khor Baraka is at least partly due, according to Kennedy-Cooke,[7] to deforestation and consequent erosion and sand storms so that the two previous channels of the Khor Baraka have been filled up with dust. Forest clearance in the area has been going on for a long time, reaching a climax in about 1860 A.D. when Mumtaz Pasha, Governor-General of the Sudan, ordered the clearance of trees to make room for the production of cotton; since then the rate of erosion and the intensity of sand storms have been magnified. Arkell[8] estimates that since the start of erosion, the scouring effect of the torrential rains on soil dried by summer heat and denuded of forests has carried away more than ninety per cent of the alluvial silt that supported forests on the banks of the 'khor'.

The relatively recent creation of the Tokar agricultural scheme has not only involved further devastation of woodland and destruc-

6 C.F. Gleisberg, 'Some Problems of Forestry at Port Sudan and Neighbourhood', *Sudan Silva* 8 (1), 1958, p. 25.

7 B. Kennedy-Cooke, 'Tokar and the Baraka Delta' in *Soil Conservation Committee's Report.* Khartoum, 1944, p. 61.

8 A.J. Arkell, 'Khor Baraka' in *Soil Conservation Committee's Report*, Khartoum, 1944, p.59.

tion of other vegetation types, but has also attracted human and animal populations in numbers far exceeding the carrying capacity of the land. The increasing over-grazing, especially by goats, and uncontrolled wood cutting, have rendered the remaining forests scattered, old, and unable to regenerate naturally. Increasing soil erosion has changed the nature of the Khor Baraka from a narrow 'khor' to a wide plain one. Formerly the forests were responsible for the fixation of the soil and had an important regulatory effect on the flow of the 'khor'.

High winds roar almost continuously over the area, raising extremely dense clouds of dust, except for the period when the 'khor' is actually flowing, from July to September, Only on the tops of the higher hills does any form of plant grow successfully; otherwise most of the vegetation is either dead or covered with dust. Apart from the actual bed of the 'khor' practically the whole area is wind-eroded. After the end of the rainy season in September or October, the north-east wind starts to blow over the dry bare surface, causing the sand dunes to move over the often unharvested fields; this violent, sand-laden wind tends to die out by mid-December, but may continue well into January. In April or May a more violent and a more heavily sand-laden southerly wind commences; it is so dense at its worst that it is practically impossible to see even a few yards ahead. The action of this wind has changed, and is still changing, the face of the delta by erosion and the piling up of dunes, though the two winds work counter to each other; but the action of the southerly wind is more dominant in shaping the landscape because, according to Kennedy-Cooke [9] if it has added ten feet to the height of the dune, the north-east wind will not remove more than three feet of it. Numerous irregularly-shaped sand dunes have become a feature of the delta and they are in constant motion when a wind is blowing. Their advance over the delta has been estimated by Kennedy-Cooke as ranging from two to five metres per annum.

What has happened to the Khor Baraka and Tokar town might soon happen to other parts of the eastern region, and in the near future similar dangers may arise at Suakin and Port Sudan towns and the Khor Arba'at.

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9 Kennedy-Cooke, *op.cit.*, 1944, p.62.

III. COMPARATIVE ASSESSMENT OF FORESTRY AND OTHER TYPES OF LAND USE

The Land Use and Rural Water Supplies Department Board has defined its task as promoting:

> 'the proper use of the land for the purpose of cultivation of crops, utilization and development of pasture land or forests, according to the capability and suitability of such land, in priorities demanded by the national needs and economy and in such a manner as to maintain such utilized land in good heart and perpetual productivity.'[1]

This definition was prescribed after the country had realized that the most outstanding problem confronting agriculture, which contributes over sixty per cent of the national income, is the irrational use of land, water, plant and animal resources.

The land capability classification used by the United States Department of Agriculture may be regarded as typical. It distinguishes eight classes of land ranging from class I which is 'very good land from all points of view' to class VIII which cannot be utilized for any purpose other than recreation, wildlife and similar functions.[2] The land classes I, II and III are suitable for cultivation though increasing care is required with the lowered quality of the land up the column, while class IV can be used for occasional cultivation or a form of shifting cultivation. The remaining classes, V, VI and VII can only be used for forestry and pastoral purposes.

Before the introduction of the development programmes in 1948, forests covered more and better quality land. Almost all the development between 1949 and 1963 was agricultural in nature and on former forest land ranging from classes II to IV. By the end of 1963 the area under irrigated agriculture had a total of about four million feddans, or more than double what it was in 1950: the area under

1 M.K. Shawki (1963): Integration of the Conservation and Development of Wild Resources with Programmes of Economic Development in Modern States', *Sudan Silva* 14(11), pp. 5–6.

2 J.K. Jackson (1962): 'Some Thoughts on the Place of Forestry in Land Use Planning', *Sudan Silva* 12 (11), p.17.

mechanized rain crop production has reached a figure of more than 1.5 million feddans, and is about forty times greater than in 1950; the railway network has increased by about three times during this period. New settlements have sprung up following these developments, making more and more forests accessible to irrational utilization. Out of the 157 million pounds of Sudan's own funds which were spent on these developments, only one million was devoted to forest land and water conservation. Between 1953 and 1963 the forested area has slightly more than doubled, increasing from 1,040,276 to 2,574,411 feddans. The estimate of the forests as occupying 9.61% of the total area of the Sudan (the 1961 Land Use Classification)[3] cannot be accepted because over ninety per cent of this area is unreserved and thus open for various agricultural and pastoral practices. Only the forest reserve estate, which amounts to less than 0.5% of the total area of the Sudan, can be considered as proper forests because only this area is subject to rational use.

The overwhelming agricultural expansion and neglect of forestry may be due partly to the assumption that a particular class of land should wholly be devoted to that particular use; for instance land classes I,II and III should be used for agriculture and nothing else. This is due to the negative attitude of such classifications in saying what should not be grown on a particular class of land, because it is beyond their scope to say what is the best type of land use to be practised on land which is suitable for multiple use, such as class I.

Forestry, the relatively undervalued type of land use, and agriculture, the most dominant and emphasized land use type, are comparable in many ways, and in some respects forestry has a more favourable impact on the economy:

(a) Forestry and agriculture are alike in the sense that they both encourage the rational development of the products of the soil, but they differ because the rotation of agriculture is usually a matter of years, while that of forestry is a matter of decades or even centuries. So while the cultivator is satisfied with a security of land tenure over a few years, a forester requires it in perpetu-

3 J.H.G. Lebon, *Land Use in Sudan* (Bude, Cornwall, Geographical Publications Limited, 1965), pp. 74–75.

ity.[4] So forestry has a greater magnitude of conservation of soil than agriculture.

(b) In contrast to agriculture, in which the land must be broken up and prepared before being brought under cultivation, and in which seed sowing must precede harvesting time, forestry has started almost everywhere with harvesting or exploitation; here the cost of production, reduced to felling cost only, is negligible if compared to that of agricultural crops. To Petrini[5] this forestry by exploitation has a 'dumping' effect compared with productive forestry, and it is always much cheaper to devastate existing forest areas than to create new ones for which interest must be charged on the various costs of establishments, and it has always been true that this destructive undertaking sells its timber with profit at lower prices.

(c) Forestry production is much less dependent upon unfavourable economic and environmental conditions than agriculture. In the case of forestry, weather cannot cause crop failure except in the case of young plantations, and cannot jeopardize the quality of the harvest by hard harvesting conditions. If at one time of the year the wood market prices are low, if the harvesting labour is scarce, or if labour is too costly, trees can be left to continue growing till more favourable conditions prevail. But agriculture, on the other hand, is not so adaptable to such unfavourable production and market conditions.

(d) In regions where the environmental conditions are not favourable and the soil is shallow, agriculture cannot be practised, while forests of one type or another can grow or be planted on almost all classes of land except for the true desert. Where agricultural crops cannot be grown, forestry gives the highest financial returns.

(e) There are many industries based on forestry, which can be established in rural areas to aid in minimizing the great socio-economic disparities between urban and rural societies; this is also the case for agriculture. Other forest industries, such as hunting

4 J.R. Ainslie, 'Forestry, the Father of Agriculture', *The West African Review* (September, 1953), p.13.

5 Sven Petrini, *Elements of Forest Economics* (trans. Mark L. Anderson) (T. and A. Constable Ltd., 1951), p.5.

and sport, can also be developed. Forest grazing is playing an immensely significant role in the life of the nomadic and semi-sedentary peoples. Other useful functions which can be attributed to forestry include the provision of various recreational facilities for both local people and foreign visitors.

FORESTRY AS A BRANCH OF THE ECONOMY

Under favourable conditions forestry can yield very high financial returns, as in the Po valley of northern Italy and the valleys of northern Iraq, where the most profitable form of land use is the cultivation of poplars. In the Sudan reluctance to devote more money and land to forestry is an indication of the assumption that forestry gives low financial returns. This under-appreciation of the importance of, and the role to be played by, forestry in the national economy has given birth to unbalanced and short-term planning systems in which forestry comes almost last in a long queue. But even under the present conditions (low expenditure and confinement to low-quality land) the contribution of forestry to the national economy is significant.

The production of forest produce, especially firewood and minor forest products can only be estimated on a very rough basis because local inhabitants all over the country collect considerable amounts to meet their requirements; so the figures given by the Forests' Department do not reveal the real picture of the total forest produce; this is true for forest products consumed within the country as well as, but to a lesser extent, for those entering international trade. Table II shows that the internally consumed forest products amount to over 22.5 million pounds in value according to the official figures; this does not include the considerable quantities used by people in their daily life, and apart from other products like 'Lulu' oil, palm oil, sawn timber used by local people for making furniture, doors, windows and ornamental works, and round timber for various purposes, and apart from the large range of manufactured articles like ropes, threads, mats, baskets and various containers. The total annual value of the internally consumed forest products may exceed forty-five million pounds. Forestry has already been able to satisfy the country's demand for railway sleepers, most of its needs of sawn hard timber and round timber and other minor commodities.

The export values of forest products (Table III) account for about ten per cent of the total value of exports of the country for the aver-

TABLE II: Values of some internally-consumed forest products per year (average 1961–1968)

Commodity	Approx. value in LS.
Railway sleepers	525,000
Sawn timber	318,200
Firewood and charcoal	21,350,000
Round wood	216,000
Bamboo (big towns only)	10,500
Dom nuts	38,100
Tanning material	98,400
Beeswax	27,700
Senna	31,300
TOTAL	22,615,200

Sources: (1) Forests Department, Annual Reports for the period July 1961 to June 1968.
(2) M.K. Shawki: *Forests in the Sudan* (in Arabic), (Forest Memoir No. 4,1961), pp. 6–7.

age of the ten years 1954–64. They amount to about twenty per cent of those of cotton, the single most important cash crop, for 1961, and to about eighteen per cent of its average export value for the period 1954–64. The contribution of forestry to the country's stock of hard currency is more significant than that of grazing; the export values of animals and their hides and skins amount to about seventy per cent of those of the forest produce.

Forestry, as a branch of the national economy, absorbs a large part of the otherwise unemployed labour force, and thus helps to increase domestic national production and offers labourers the opportunity to earn their living. Forestry can still offer further employment to more and more people since it is noted that some of its activities suffer from shortage of permanent or daily-paid labour. In 1963, for instance, it was reported that the number of permanent labourers in the Funj area was increased by fifty per cent and the number of man-days of daily-paid workers by fourteen per cent compared to 1962 figures. In almost all other parts of the country labour was scarce for one part of the year or another; in Khartoum, Upper Nile and Northern Provinces labour was short throughout the year, while in Jebel Mara area this labour shortage was acute during the cultivation and harvest periods. In Bahr el-Ghazal Province labour was severely short during the first and last quarters of the year,

TABLE III: Annual exports from forests, grazing lands and cotton (average 1954–1964)

Item	Export value in LS.
Forest lands:	
Gum Arabic	6,542,518
Senna	27,989
'Garad'	14,939
Beeswax	23,987
Dom nuts	13,160
TOTAL	6,622,593
Grazing lands:	
Camels	1,929,000
Cattle	816,856
Sheep	665,500
Hides and skins	1,139,336
TOTAL	4,550,692
Cotton	33,155,143
Sudan	63,523,258

Source: The Information Production Centre, *Agricultural statistics,* Ministry of Agriculture, Khartoum, 1964–1967.

while in the Zande area daily-paid labour was extremely scarce during the dry season when the local inhabitants usually leave their daily employment to practise their traditional hunting. This indicates that forestry can absorb more permanent and daily-paid labourers and thus help to modify the grievances of unemployment. During 1967 the number of permanent labourers employed was over 5,000 and the man-days of the daily-paid workers reached a figure of over eight million, giving a total for man-days of over ten million.

To those employed in forest activities should be added those who depend on gum Arabic in one way or another. Most of the semi-sedentary and some of the nomadic people occupying the gum belt of Darfur, Kordufan, Blue Nile and Kassala Provinces should be considered as getting their living, at least partly, from forestry since they are either gum tappers, collectors, dealers or merchants; they are dependent, to varying extents, on 'hashab' and 'talh' forests.

FOREST INFLUENCES

Forest influences constitute another equally significant aspect to be considered in the evaluation of the place of forestry, as a type of land use, in the national economic structure and land use planning. Forest influences, though they cannot be evaluated in monetary terms as forest products, possess economic bearings. An attempt to evaluate some of these influences is included later.

Influences on Climate

Wind velocity may be reduced by the forest stand by forty to eighty per cent.[6] The degree of reduction of wind speed inside the forest is directly proportional to the height, length, width and density of the individual crowns, and to the density of the forest stand. The thinning of the canopy increases evaporation, and thus it has a drying effect, especially in the relatively arid, hot parts of the country. The disappearance of forest stands has facilitated the free passage of wind and helped the prevalence of severe, damaging winds in Khartoum and Tokar areas.

Solar radiation is another factor of the forest microclimate. Sun rays do not only bring light, but also heat, and since the forest permits decreased light to penetrate, this must be accompanied by decreased temperatures. This admission of minimum heat and light, as in the remnants of the southern tropical rain forests which have not yet been widely interfered with, does not allow the dense growth of tall grasses which assist the spread of severe grass fires and hinder the free movement of man and game. Associated with this effect on solar radiation is the effect on air temperatures, the extremes of which are modified by the forest, rendering the climate more equable.

The relative humidity of the air inside the forest is higher than in the open, the increase being usually from four to ten per cent. [7] This is attributable to many factors: the mean temperature of air is lower inside the forest than in the open and hence a lower saturation point; the moisture content of the air inside the forest is increased by transpiration from the leaves; and the lower velocity of the wind inside the forest prevents water vapour from being carried

6 J. Kittredge, *Forest Influences* (New York, McGraw-Hill Book Company, 1948), p.71.

7 R.S. Troup, *Colonial Forest Administration* (Oxford, University Press, 1940), p. 22.

away rapidly. Closely connected with relative humidity and temperature is the effect of the forest on rainfall, which is a debatable topic; the increase of rainfall is only slight. Of more importance is that the action of the heavy, torrential tropical rains on the soil is reduced to a significant extent by the canopy of the forest, thus protecting the soil inside the forest.

Influences on Soil

Continuous cropping of land impoverishes the soil through the removal of nutrient substances, and fertility has to be restored by adding fertilizers and manures. The forest has an opposite effect; soils under forest cover are constantly enriched by the addition of organic constituents including nitrogen and inorganic material, all of which undergo progressive changes after leaf-fall, through the agency of a large population of bacteria, worms, fungi, insects and other animals. Another important aspect is the effect of the forest on the structure of the soil, rendering it more porous and deeper than soil in the open; this is due to the penetration, expansion and subsequent decay of the roots, thus creating channels and changing the structure of the soil. This greater porosity and the ability of the forest floor to retain from one to five times its dry weight of water, [8] account for the higher soil moisture in the forest than outside. There is a marked difference between the influence exerted by the forest on soil and that exerted by other plant covers, especially grass which when dense and unbroken provides effective defense against surface erosion. But it affects the soil nutrient status only in a comparatively thin layer, while the forest penetrates to a far greater depth. Also grass cover, because it is easily saturated with water, facilitates run-off while the natural forest tends to allow deeper infiltration and thus increased water supply.

If the vegetation cover is removed, the top-soil then exposed to the dessicating action of the sun and the violence of torrential rains or strong winds, may be swept away in the space of a few years. Although the main agents of erosion are water in the rainy season and wind during the dry period, there are other agents which have acquired a major significance since they harden the top-soil and involve a loss of nutrients and permeability; such agents include grass and bush fires, tree-cutting, heavy grazing and shifting cultivation.

8 Kittredge, *op.cit.*, p. 213.

The loss does not end by washing away the fertile top-soil because the addition of large quantities of sediment to the drainage features creates further severe problems.

It is true that erosion cannot be completely eliminated or avoided but the protective cover provided by the forest greatly reduces it. The forest not only acts as a defence against soil erosion but also provides protection for soil in the most sterile and the most unproductive areas and enhances their quality. To remove the forest or replace it by other unsuitable forms of land use can have disastrous consequences on the productivity of the soil and the rate of erosion over considerable areas of the country; this has resulted in the encroachment of desert conditions over some productive parts of Northern Sudan.

Effects of Shelter Belts

Since the various needs of the population for land make it impossible to re-establish vegetation cover on the whole of its potential area, means to recover the changed and disturbed ecological balance should be sought. One of the most effective methods is the planting of shelter belts; by means of tree plantation, the forest can be extended beyond the boundaries of its normal growth, for instance into the semi-arid areas. With the application of irrigation, ploughing and manuring, trees can be established in an environment normally inimical to their growth. Tree planting is thus essential in the northern belt of the country which is endangered by desert creep, and where natural tree growth is hampered by climatic conditions. The main problem, constituted by the inadequacy of irrigation water, may now be solved after the completion of the Aswan High Dam, and by the utilization of streams radiating from the limited hills and 'jebels' and by choosing less water-consuming species. Species poisonous to animals and species which spread easily into adjacent fields must be avoided, and root competition should be curbed as much as possible. Owing to the ever increasing need for mechanization, high growing species must be preferred for the protection of larger areas. Where cultivable land is limited, as in the Northern Province, species which will develop broad crowns may be selected. Species of such belts whether for crop land or pastoral land, should, wherever possible, be capable of the production of good timber because ultimately a time will come when it will be needed as a forest produce.

Shelters for crops have acquired paramount significance, and scheme-owners and farmers must be encouraged to introduce them because the profits to be derived therefrom are twofold; the tree plantations can provide timber, round wood and firewood, and in the meantime they shelter the field crop. No experiments on yields have been conducted in the Sudan, but Table IV gives a general idea about the effect of shelter belts on the yields of some crops in the steppe region of the U.S.S.R. Shelters can also prevent direct wind damage to rather delicate products like flowers, fruits and vegetables.

TABLE IV: Effects of shelter belts on the yields of some crops in the steppe region of U.S.S.R.

		Yield in kantar per hectar		Increase in yield in sheltered steppe	
Station	Crop	In sheltered steppe	In open steppe	kg.	%
Kamennaya Steppe	Winter rye	1630	1390	240	17
	Oats	1420	1380	40	3
	Alfalfa	3000	990	2010	203
	Grass (bromus)	1910	960	950	99
Saratow	Summer wheat	1540	930	610	66
	Winter rye	2380	1730	650	38
	Potatoes	10150	5970	4180	70
	Alfalfa	5170	2450	2720	111
Mariupol	Winter wheat	1710	970	740	76
	Barley	1520	1020	500	49
	Grass	2170	1560	610	39
Krasnokutsk	Winter wheat	1310	1180	130	11
	Summer wheat	1170	620	550	88
	Barley	2370	1850	520	28
Rostashi	Winter wheat	1430	1240	190	15
	Summer wheat	1280	1210	70	6
	Rye	1420	1180	240	21
	Potatoes	10250	6010	4240	71
	Hay (bromus)	1320	1160	160	14
Guselskii	Winter wheat	1120	910	210	23
	Summer wheat	1270	1230	40	3
	Oats	1480	1670	-190	-11
	Barley	1900	1630	270	17
	Hay	2130	970	1160	119
	Lentils	1690	1070	620	58

Source: J. Van Der Linde, 'Trees Outside the Forest' in F.A.O. (ed.) *Forest Influences*, Rome, 1962, p.145.

The other type of planted belt is shelter for pastures. This cannot be mentioned without stressing the necessity of improving grazing lands in the western and eastern parts of the country by the provision of adequate water points and the growing of grasses palatable to animals on a scientific basis, and above all, careful control of these pastures against over-concentration of animal population. A shelter 'provides earlier growth and therefore greater production of grass. Better strains of grass can be grown, and therefore more stock, and also better strains of stock can be kept'.[9] The shelter can also protect animals against high winds. If grazing land is limited, which is not the case in most parts of the country, the screen can be located in a place less suitable for grass growth. The Sudan, which has a large animal population grazing on an already overgrazed, exposed and erosion-threatened land, needs such belts to fix the soil, minimize erosion and help in providing adequate rich pastures.

Other Influences

The presence of forests and trees is recognized as being beneficial to the health of the people living in their vicinity. Many component factors contribute to this influence; the more or less complete drainage of swamps increases the healthiness of marshy localities, probably by destroying the breeding environment of malarial mosquitoes; another component factor is elimination of air pollution by the fixation of dust suspended in the air on the surface of the leaves. This is why an effort is always made to set aside parks inside towns and encircle the latter with green belts; woods or even groves of trees around habitations and settlements in otherwise bare landscape are of great value in relieving the monotony of the scenery; they provide recreational and leisure facilities. It is also for these reasons that attempts are made to plant trees in rows along both sides of roads.

The forest has a regulatory effect on stream flow by ensuring a higher degree of water infiltration during the rainy season to be liberated during the dry season; it also helps the prevention of silting behind dams and on the river floor by fixation of the soil. When forests are devastated, infiltration is reduced, and water runs off

9 J. Van Der Linde 'Trees outside the Forest', in *Forest Influences* (Rome, F.A.O. [ed]. 1962), p. 157.

rapidly during the rainy season carrying large quantities of sediments into the rivers; quite often these fine particles, together with nutrient material in solution are transported out into the sea and are thus lost, while the coarser fragments are deposited in the river beds. Thus deforestation involves a loss in nutrient materials and soils, a rise of the level of the river bed, and irregularity of stream-flow. The rising of the level of the river bed may hamper or halt navigation on the river itself and cause rivers to undercut their banks and change their courses, or else to overflow their banks and cause excessive damage by flooding or by the deposition of coarse sediments over agricultural land. The silting up of streams or depressions may also cause the formation of swamps or impervious pans. The irregularity of stream-flow may also cause floods, resulting in loss of crops, buildings, domestic animals and even human lives; floods may also jeopardize the health of the population. The irregularity of stream-flow is also accompanied by a high probability of crop failure in areas dependent on irrigation. This forest influence on streams is of great importance, which becomes greater not only with the steady rise in water requirements for industry, electricity, cultivation and grazing, but also because by the very reason of these requirements, the users of such waters settle near their source in ever increasing numbers, forming ever richer centres which are consequently liable to irregular water supply.

Tourism is one of the influences which are relatively ignored. Forests, which are considered in the less developed communities as being unsuitable for human habitation, now attract ever larger groups of people for more or less long stays, as people become crowded in urban centres and as communication facilities spread out and increase. The only counter-attractions to the forest are seas, lakes, beaches and resorts; places where the forest is combined with these attractions are preferred. Jebel Mara, the Red Sea and Dinder Game Reserve may provide popular tourist centres with more than one attraction. The preservation of wild game, which is another function provided by the forest, is important not only from a tourist point of view but also as a source of revenue. Rhinoceros, for instance, is worth the equivalent of LS. 7,000 in hard currency per head. Many wild animals now confined to forests in the southern parts of the country are known to have lived further north, but

started to migrate southwards with the increasing clearance of the forests of central and south-central Sudan. It is becoming more and more pressing to demarcate and protect forests necessary for the preservation of the precious game of the country.

Dune-stabilization is another forest influence the utilization of which is so common and worldwide that it needs no justification. Its significance is derived from the already stated fact that sand creep over some agricultural lands in the northern part of the country has already started.

The inspirational influence of forests has been realized throughout the ages, and poets, writers, painters and philosophers have derived inspiration from them. From the earliest times the forest has left a very deep impression on the minds of the people, and it is associated with religious beliefs among some of the Nilotic tribes. This finds expression in the veneration of certain kinds of trees, while the folklore of many southern tribes is bound up with the forest and the spirits that inhabit it.

RETURNS PER UNIT AREA

Is it absolutely true that forestry is a type of land use that gives low financial returns or can it compete with other forms of land use in this respect? For the discussion of the economics of the commodities which have an exchange value the cost/benefit ratio is important. The application of this indicator to agricultural production in the Sudan is made difficult by the fact that a great many agricultural processes are carried out by the farmers themselves who usually do not include the price of their own work in the cost of production; it is also hampered by the fact that land, as a factor of production, has no recognized value in most parts of the country. Though the returns of production can be calculated with a fair degree of accuracy, the cost of production can only be estimated on a rather rough basis. The determination of the net financial returns per unit area, to determine the type of land use which gives the highest financial returns, can only be done on rough estimates.

Forestry

(a) *Firewood*: firewood is the cheapest and most needed forest product. Its average annual production is over thirty per cent of the

total wood production. The revenue paid to the government for standing trees to produce firewood from outside forest reserves, i.e. the royalty value of firewood, is about LS.0.300 per cubic metre in most parts of the country, and this figure may be regarded as the average. Its average retail value is about LS.1.330. If a cubic metre of firewood is burnt into charcoal, the equivalent value of charcoal produced will be about LS.1.950. Firewood has no export value in itself, but its value in terms of foreign exchange can be determined by the calculation of the value of imported kerosene which would be needed to replace it, i.e. the cost of substitution, which is an important utility indicator. In calorific value one cubic metre of firewood is equivalent to forty-nine gallons of kerosene, and at a value of LS.12.000 per ton, this will be worth LS.2.000. The annual yield of firewood varies from one cubic metre in the drier savanna regions to about six cubic metres per feddan in the southern parts of the country, and an average of three cubic metres will not be more than expected. So firewood gives LS.0.900 per feddan on royalty value, LS.3.990 on retail value, LS.5.850 if burnt into charcoal and LS. 6.000 in equivalent value of kerosene. For firewood collected from outside forest reserves, i.e. from natural unreserved forests, the cost of production is negligible. If the lifespan of the forest is ten years, then the annual respective figures will be LS.0.090, LS. 0.399, LS.0.585 and LS.0.600.

If we assume that the per feddan other expenses till felling time is about LS.26.153, then the total per feddan cost of production will be LS.60.000. If we assume that the life of a forest plantation is forty years then the annual per feddan cost will be LS.1.500.

Plantation of quick-growing trees like *Eucalyptus,* established for the production of firewood, can yield as high an average as eight cubic metres per annum per feddan. Thus the gross per feddan returns will be LS.10.640 on retail value, LS.15.600 if converted into charcoal and LS.16.000 in equivalent value of kerosone. The net per feddan returns will be LS.9.140 on retail value, LS.14.100 if burnt into charcoal and LS.14.500 in equivalent value of kerosene. If the lifetime of the plantation is ten years, then the annual net per feddan respective returns will be LS.0.914, LS.1.410 and LS.1.450.

(b) *Timber plantation*: Jackson[10] estimates the yield of the con-

10 Jackson, *loc. cit.*

ifer plantation in the ImatongMountains as 10,000 cubic feet (about 300 cubic metres) in thirty years per feddan. This is equivalent to 333 cubic feet (10 cubic metres) per feddan per annum. If it is assumed that the standing value of this timber is LS.0.120 per cubic foot, this will give an annual financial return of LS.40.000 per feddan. This volume of wood (ten cubic metres) will produce about five cubic metres of sawn timber which, at a price of LS.19.000 per cubic metre, are worth LS.95.000. Thus one feddan of conifer can economize the equivalence of LS.95.000 in foreign exchange. So the net financial returns of conifer plantations will be LS.38.500 on wholesale price and LS.93.500 in foreign exchange equivalence per feddan.

Teak is expected to yield about 3,000 cubic feet (about eighty-four cubic metres) of wood per feddan in sixty years, or fifty cubic feet (about 1.4 cubic metres) per feddan per year. Assuming a price of LS.0.500 per cubic foot, the gross standing value of this will be LS.25.000 per feddan per annum; at a price of LS.3.000 per cubic foot, its gross import value will be LS.150.000 per feddan per year. The net financial returns will then be LS.23.500 on wholesale price and LS.148.500 in equivalence of foreign exchange per feddan per year.

(c) *'Hashab':* gum Arabic is collected from the 'hashab' trees. These naturally growing 'hashab' trees produce about one kantar of gum per feddan annually. At an average market price of LS.3.200 the annual per feddan returns will be LS.3.200 for the producer. At an average export price of LS.6.300, the per annum per feddan returns will be LS.6.300 in foreign exchange equivalence. Here the cost of production is negligible and so these can be regarded as the net figures.

In the case of 'hashab' plantations, the feddan can hold about 300 trees if the trees are planted or sown four metres apart; at an average annual production of 1.35 lbs of gum per tree, the feddan will produce about four kantars. The gross values will then be LS.12.800 at wholesale price and the gross export value will be LS. 25.200. The net values will be LS.11.300 and LS. 23.700 respectively.

These values for both planted and naturally growing 'hashab' trees would increase if we included the value of the wood when these trees are felled after their yielding age.

(d) *Forest influences:* here it is the forest influence, and not the forest itself, which is emphasized though the two are inseparable. The magnitude of the forest influence is not confined to forest soils, fields or crops, but extends beyond that to affect the combination of soil and water, factors upon which the entire economy of the country depends. To think that there is no relation between the economic value of a forest and the utilitarian value of its influences it false. It is of great importance to use these species which have the highest economic value and the most rapid growth for protective measures. This remains valid even if the required outlay must be higher than that required by a low economic value forest which can exert the same influences.

The application of utility indicators may better illustrate the economic significance of forest influences; if their utilitarian values could be expressed by sufficiently convincing indicators or index numbers, good progress would be made towards the creation and development of a consciousness of their socio-economic character. The comparative economic evaluation of forest influences is extremely vital since the lack of such utility indicators has hampered the steady development of forestry in the Sudan.

Cost and benefit factors are important in the economic evaluation of any output. Cost, which is a price or an exchange value, is only important when the produced commodity is marketable. Forest influences, though they are linked to the soil and cannot be transported, definitely have a market since any construction, e.g. a field benefiting from one influence or more has naturally a higher exchange value than a comparable asset not enjoying the same advantage or advantages created by the forest.[11] This difference in exchange values must naturally be attributed to the forest influences involved. The benefits derived would increase with a decrease in the cost of production of these forest influences; where the forest stand is already in existence, this cost of production may be considered as zero or very negligible, being confined to the cost of guarding the forest against devastation. For forests to be established we can consider the cost of production as that in Table V. The cost of production seems to increase with time since if a piece of land has passed the equilibrium point and is

11 T. Francois, 'Evaluation of the Utility of Forest Influences' in *Forest Influences* (Rome, F.A.O. [ed.] 1962), p. 250.

TABLE V: Average cost of silvicultural operations per feddan (1961–67)

Silvicultural operation	Average cost in LS.
Initial ground clearance	1.246
Preparation of land	1.952
Canalization and ridging	8.900
Planting or sowing	2.067
Broadcasting	0.993
Weeding	2.363
Watering	3.600
Closing of cracks	0.325
Cost of 1000 plants	7.100
Thinning	1.565
Fireling per km.	3.088
Timber cutting	0.648
TOTAL	33.847

Source: Forests Department, Annual Reports for the period July 1961 to June 1967.

not left to revert to forest cover, it will continue to deteriorate, which will in turn involve an increasing cost of afforestation. The problem is that the cost of establishing a forest is the cost of production of the overall forest influences and it is not possible to determine the part of this cost which is attributable to the individual forest influences.

Benefits derived from forest influences are difficult to assess because they frequently refer to values which cannot be adequately expressed in monetary terms. The annual appropriations required to repair the damage resulting from the devastation of a forest, i.e. the cost of substitution, can be regarded as benefits which were formerly being derived from a forest influence. Here again since it is difficult to determine the overall benefits derived from a forest stand, it is more difficult to determine the benefits which can be attributed to the individual forest influences. It is intended here to give rough estimates of the possible values attributed to the overall forest influences in selected areas of the country.

The ribbon along the line joining Merga, Abu Tabari, Bir Natrun, Jebel Rahib and Jebel Tageru used to be permanently inhabited. If we assume that the type of land use practised was one which gave the lowest financial returns, i.e. grazing, then the land must have yielded at least LS.0.070 per feddan per annum; if we assume that the area extends for about seven miles in width and four hundred

miles in length from west to east, then the annual financial returns will be about LS.160,000. If we accept that the present state of aridity has been brought about, even partly, by the devastation of the natural vegetation, then at least a part of these returns can be considered as the annual financial return of the forest influences. When we take into consideration the cost of houses and various social services and institutions, the commercial transactions which were in operation and the social cost paid by the inhabitants when they were forced by increasing aridity to migrate, these returns will greatly increase. Now if it is ever possible to re-establish permanent settlements on these sites, the cost of establishment will be immensely high; the cost of substitution can also be regarded as financial returns which were derived from the forest influences before the devastation of the natural vegetation.

The deforestation of the banks of the Khor Baraka and the wholesale clearance of trees over the entire scheme have changed the nature of the river bed itself, and accelerated erosion at a frightening rate. This has resulted in severe winds which have in turn led to the formation of sand dunes within the delta and over the former productive land. The rate of sand creep is two to five metres per year in the delta and into Tokar town; about twenty-five per cent of the delta area has been covered with sand dunes and a great part of the canalization system has been abandoned owing to changes of the 'khor' flow. If we accept that the cotton area would have been increased by twenty-five per cent had it not been for the formation of sand dunes, then the annual financial losses will be over LS.600,000 at an average yield of 2.2 kantars per feddan and a net per feddan export value of LS.20.330. The greater part of these losses can be considered as the annual financial returns of the forest influences. If we took into consideration the cost of the abandoned system of canalization and the inconveniences caused by severe winds, the annual financial returns of the overall forest influences would increase considerably.

In ten years and at annual creep of four metres of sand dunes along one hundred miles of land, more than 1,500 feddans of productive land will be covered with sand dunes. This will then involve an annual financial loss of about LS.30,000. The establishment of a forest belt along this area can reduce this annual creep by about seventy-five per cent, if it could not totally prevent it; then the gross

annual benefits derived from this belt will be about LS.22,000. This shelter belt will be equivalent to about fifty feddans in cost, about LS.75.000, and the difference may be regarded as the net annual financial returns of the created forest influences. The afforestation of the 'khor' banks will regulate its flow, fix the soil on the banks and will eventually stabilize the position of the cultivated land. This will lessen erosion too and economize the cost of the canalization system which is usually abandoned whenever the 'khor' starts to change its course or even to fluctuate considerably in its annual flow.

The influence of the forest on regulating the flow of streams is of vital importance in a country like the Democratic Republic of the Sudan, where a major problem is constituted by the lack of water supply especially during the dry season. The 'khor' Arba'at radiates from the Red Sea Hills and is responsible for the entire fresh water supply of Port Sudan town, the only sea port of the country. If devastation of the forests on the catchment area and the slopes continues, the 'khor' may change its course further away from the town or its flow may be greatly diminished. By then the town may find itself compelled to depend for its water supply on the purification of sea water, a process which involves at present a greatly higher cost of production than fresh water. The cost of substitution may be considered as the financial returns derived from the regulatory effect of the forest on the 'khor' Arba'at. The fact that human and industrial requirements for a fresh water supply in the area are continuously increasing necessitates not only preservation of the remaining forest land but also immediate re-afforestation of the denuded areas.

The effect of shelter belts on the quality and quantity of agricultural crops has been established in many parts of the world. Table IV shows that sheltered agricultural fields give yields about fifty per cent higher on the average than those of similar unsheltered fields per unit area. If the water requirements are available, such a system of shelter belts can be introduced, after necessary experimentation, in the various agricultural schemes. The annual quantitative increase in the per feddan output will then represent the annual returns of the forest influences exerted by the created shelter belts.

Wildlife is appreciated by increasing numbers of people, both from within and outside the country, who visit Dinder Game Reserve and the natural forests of the southern parts of the country. The

creation of many other game reserves, especially in Equatoria Province, will ensure the preservation of a large number of tropical wild animals which are now retreating fast in the face of forest devastation. This has become particularly necessary after the recognition of the fact that quite a number of the country's rare game may well cross the borders into Kenya, Uganda and Ethiopia.

There are two types of value attributable to wildlife in a forest: commercial values and aesthetic and moral values. The commercial values, or the income which can be derived from forest wildlife, include income from sales of hunting and fishing privileges and the returns of all other privileges, like camping, photography, foods and drinks, enjoyed by forest visitors as long as they are attracted by wildlife in the forest. The output (satisfaction) of the forest's commercial values can be calculated in monetary terms, but it is difficult to measure the output of the aesthetic and moral values, but it is fair to assume that the output is at least equal to the input, because people will not go on spending their time and money in this form of recreation unless they are getting returns as satisfactory as they would get through some other use of their time and money.

Agriculture

(a) *Cotton*: for the cost of production, Table VI has been drawn to give an average picture; it represents the average of nine ten-feddan cotton fields in each of the Gezira, White Nile area and the Gash delta for the period 1961–1968. The work of the cultivator has been priced at the prevailing prices and included in rough estimates.

For the period 1961–1968 the average per feddan production of irrigated Egyptian cotton was 4.6 kantars in the Gezira, 3.62 in the White Nile schemes and 4.16 in the private estates of the Blue Nile Province. For Egyptian cotton grown by flood in the Gash delta the figure is only 2.08 kantars; the average per feddan production of this type of cotton for the whole Sudan is 4.25 kantars. The average share of the Egyptian cotton grower is LS.7.200 per kantar. This gives gross per feddan returns to the grower of LS.33.120 in the Gezira, LS.26.064 in the White Nile schemes, LS.29.952 in the private estates of the Blue Nile Province, LS.14.976 in the Gash delta, and LS.30.600 for the country as a whole. The net per feddan financial returns will be LS.22.210 for the Gezira, LS.16.232 for the White Nile schemes, LS.19.526 for private estates in the Blue

TABLE VI: Average cost of production of cotton
(1961–68)

Operation	Cost
Initial preparation of land	LS. 4.000
Sowing	3.000
Resowing	1.500
Weedings	20.000
Waterings	6.000
Picking	1.000 per kantar
Transport to nearest station	0.100 per kantar
Clearance of field	19.000
Incidental expenses	5.000
Total expenses per ten feddans	58.500+picking and transport costs (1.100 x output)
Total expenses per feddan	5.850*+picking and transport costs (1.100 x output)

* This is surely lower than the average for the last three years.

Nile Province, LS.6.838 for the Gash delta and LS.20.075 for the whole country. The net per feddan export value of irrigated cotton is LS.55.330 for the Gezira scheme, LS.42.296 for the White Nile schemes, LS.49.478 for private estates, LS.21.814 for the Gash delta and LS.50.675 for the whole country.

American cotton is grown by irrigation in the Blue Nile Province, the Zeidab pump scheme, the Berber–Shendi reach and Dongola–Merowe reach of the Nile in the Northern Province, by flood in the Tokar delta in Kassala Province and the 'khor' Abu Habl in Kordufan Province, and by rain in the Gedaref area, the Nuba Mountains and in Equatoria and Upper Nile Provinces. The average export price is about LS.13.000 per kantar, of which about fifty per cent goes to the producer. Under irrigation the per feddan production is 5.67 in the Gezira scheme and 2.2 kantars in the Northern Province. This gives a gross per feddan financial return to the producer of LS.36.855 in the Gezira and LS.14.300 in the Northern Province; this gives a net per feddan return of LS.24.768 and LS.6.030 in the two areas respectively. For the per feddan export values, the gross figures are LS.73.710 for the former and LS.28.600 for the latter; the net figures will be LS.61.623 and LS.20.330 for the Gezira and the Northern Province respectively.

The average per feddan production of American cotton grown by flood is 2.2 kantars in Tokar area and 3.1 kantars in the 'khor' Abu Habl. This gives the grower a gross financial return of LS. 14.300 and LS.20.150 and a net return of LS.6.030 and LS.10.890 for the two areas respectively. The gross per feddan export values are LS.28.600 and LS.40.300, and the net export values are LS. 20.330 and LS.31.040 respectively.

For rain grown American cotton the average per feddan output is 2.376 kantars of unginned cotton for the Gedaref area, 2.75 kantars in the Nuba Mountains, 2.09 kantars for Equatoria Province and 2.486 for Upper Nile Province. A rain-cotton grower in the Gedaref area said that in 1966 he was given LS.50.000 for his thirty-one kantars of unginned cotton. If we accept this as the average then a wholesale price of LS.1.613 per unginned kantar of cotton, gives a gross per feddan return of LS.3.833 for the Gedaref area, LS.4.436 for the Nuba Mountains, LS.3.371 for Equatoria Province and LS.4.010 for Upper Nile Province. It is difficult to determine the cost of production in this case because rain-cotton growers do not usually employ paid labour except sometimes for picking. A rain-cotton grower in the Gedaref area estimated the cost of production on his nine-feddans field at LS.9.000; if this is accepted to be the average production cost, though it is too low to be true, then the net per feddan returns will be LS.2.833, 3.436, 2.371 and 3.010 for the four areas respectively. At an average export price of LS.180.000 per ton of ginned cotton, the average export price of the unginned kantar will be about LS.3.000. This gives a gross per feddan export value of LS.7.128 for the Gedaref area, LS.8.250 for the Nuba Mountains, LS.6.270 for Equatoria Province and LS.7.458 for Upper Nile Province. The net export values will be LS.6.128, 7.250, 5.270 and 6.458 for the four areas respectively. Here it must be noted that these figures are for the crop of one year, but cotton grown under rain conditions is not usually grown year after year on the same piece of land without a fallow period; if we accept that for half the time the land will be left to retain fertility under bush fallow, then the actual figures will be half of those calculated above; the net per feddan returns will be LS.1.417 for the Gedaref area, LS.1.718 for the Nuba Mountains, LS.1.186 for Equatoria Province and LS.1.505 for Upper Nile Province at the

wholesale price; at the export price the net figures will be LS.3.064, 3.625, 2.633 and 3.229 respectively.

For the country as a whole the net per feddan wholesale value will be LS.17.787 for irrigated cotton, LS.8.860 for cotton grown by flood and LS.1.457 for cotton grown by rain. The net per feddan export values for cotton grown under these different conditions will be LS. 45.826, 25.685 and 3.138 respectively.

(b) *'Dura':* It is grown on extensive areas all over the country and under quite different environmental conditions for both domestic consumption and export. The average per feddan yield for the period 1961–1968 is 12.96 kantars under irrigation, 7.48 under rain conditions and 8.56 under flood conditions. The wholesale price varies considerably from place to place, from year to year, and from one time of the year to another, but LS.0.700 can be taken as the average per kantar price. After the transportation of 'dura' to the nearest market or consumption centre and after grinding it into flour, its average retail value will be LS.1.400 per kantar. The average export price for the same period is about LS.30.000 per ton.

Under irrigation the per feddan gross returns will be LS.9.072 on wholesale price, LS.18.144 on retail price and LS.19.440 on export price. The average per feddan cost of production is about LS.3.720 (the average for thirty tenants in three different parts of the Gezira scheme is LS.18.600 per five-feddans field for the period 1963–69). Thus the net per feddan returns will be LS.5.352 on wholesale price, LS.14.424 on retail price and LS.15.720 on export price.

For 'dura' grown under rain conditions, the average gross per feddan return to the grower is LS.5.236, and the retail and export values are LS.10.472 and LS.11.220 respectively. The average per feddan cost of production is about LS.1.700 (the average cost of production for ten growers in the Nuba Mountains and eight in the Gedaref area is about LS.8.500 per five-feddans field for the period 1967–69). So the net per feddan returns will be LS.3.536, LS.8.772 and LS.9.520 on wholesale, retail and export prices respectively. But 'dura' is not grown by rain on the same piece of land every year; so if we assume that for half the time the land is left fallow to retain its fertility, the net per feddan wholesale value will be LS.1.768, the net retail value LS.4.386 and the net export value LS.4.760.

For 'dura' grown by flood, the gross per feddan wholesale value is LS.5.992, the retail value is LS.11.984 and the export value is LS.12.840. If we accept the average per feddan cost of production as LS.2.300 (for eight growers in Tokar delta the average cost of production is LS.11.500 per five-feddans field), the net per feddan wholesale, retail and export values will be LS.3.692, LS.9.684 and LS.10.540 respectively.

(c) *Ground-nuts:* the yields of ground-nuts differ greatly due to the great variety of conditions under which it is grown. For the period 1961–1968 the average per feddan yield for ground-nuts grown by irrigation is 11.308 kantars, 6.226 kantars when grown under rain conditions and 4.4 kantars when grown by flood. The average wholesale price is LS.1.000 and the retail value is LS.1.400 per kantar. At an export price of LS.50.000 per ton, the export value of the kantar will be LS.2.270.

For ground-nuts grown by irrigation, the per feddan gross returns to the grower will be LS.11.308, the gross retail value will be LS. 15.831 and the gross export value LS.25.669. For ground-nuts grown under rain conditions, the gross per feddan wholesale, retail and export values will be LS.6.226, LS.8.716 and LS.14.133 respectively. For ground-nuts grown by flood, these per feddan gross values will be LS.4.400, LS.6.160 and LS.9.988 respectively. The per feddan cost of production varies considerably, but the following figures may be accepted as averages: LS.2.480 for irrigated ground-nuts (in the Gezira scheme the average cost is about LS.6.200 per a 2.5 feddans field), LS.1.500 for ground-nuts grown under rain conditions (in the Gedaref area the average cost is about LS.7.500 per five-feddans field) and LS.0.900 for ground-nuts grown by flood. This will give net per feddan returns of LS.8.828 on wholesale value, LS.13.351 on retail value and LS.23.189 on export value for irrigated ground-nuts. The net values for ground-nuts grown under rain conditions will be LS.4.726, LS.7.216 and LS.12.633 respectively; and those for ground-nuts grown by flood will be LS.3.500, LS.5.260 and LS.9.088 respectively.

(d) *Wheat:* wheat is grown by irrigation mainly in the Northern Province, Blue Nile Province and Kassala Province, and by flood in the Northern and Kassala Provinces. It is not grown by rain and

does not enter the export trade of the country. The average per feddan output is 15.1 kantars when irrigation is used, and 18 kantars when grown by flood. The average wholesale price is about LS.0.850 per kantar, and the retail value–after transportation to the nearest consumption centre and after conversion into flour–is almost double this figure. Wheat in itself has no export value, but in terms of foreign exchange equivalence and at an average world price of about LS.40.000 per ton, the export value of wheat will be LS.1.820 per kantar. The irrigated wheat will thus have a gross per feddan wholesale value of LS.12.835, a gross retail value of LS.25.670 and a gross export value of LS.27.482. Wheat grown by flood will have a gross per feddan wholesale value of LS.15.300, a gross retail value of LS.30.600 and a gross export value of LS.32.760.

The average cost of production for ten growers in the Northern division and the Messelamiya division of the Gezira scheme is LS.18.500 per a five-feddans field; this gives an average cost of LS.3.700 per feddan. If we accept this as the average, then the net per feddan value of irrigated wheat will be LS.9.135 on the wholesale price, LS.21.970 on the retail price and LS.23.782 on the export price. For wheat grown by flood the same values will be LS.11.600, LS.26.900 and LS.29.060 respectively. This will be the case if we assume that wheat is grown on the same piece of land year after year, though in many places there is a short fallow period.

Grazing

Grazing is a type of land use which gives very low financial returns per unit area. The carrying capacity of typical grazing land in Kordufan Province may be estimated at thirty cattle per square mile, with an annual take-off of 7.5%. This can be taken as the average figure for the average grazing land in the country. With this same annual take-off the carrying capacity of the average grazing land may be estimated at about a hundred sheep or about forty camels per square mile. The average wholesale prices of sheep, cattle and camels may be taken as LS.4.200, LS.12.000 and LS.21.600 per head respectively. This will give wholesale financial returns of LS.31.500 per square mile in the case of sheep, LS.27.000 per square mile in the case of cattle and LS.63.000 per square mile in the case of camels.

TABLE VII: Net per feddan returns for some types of land use (LS.)

Type of land use	Wholesale value	Retail value	Export value
Forestry:			
Firewood (natural)		0.399	0.600
Firewood (planted *Eucalyptus)*	0.914	1.450	
Conifer plantation	38.500		93.500
Teak plantation	23.500		148.500
Hashab (natural)	3.200		6.300
Hashab plantation	11.300		23.700
Agriculture:			
Irrigated Egyptian cotton			
Gezira scheme	22.210		55.330
White Nile schemes	16.232		42.296
Private estates (B.N.)	19.526		49.478
Gash delta	6.838		21.814
SUDAN	20.075		50.675
American cotton			
(i) By irrigation:			
Gezira scheme	24.768		61.623
Northern Province	6.030		20.330
SUDAN	17.787		45.826
(ii) By flood:			
Tokar	6.030		20.330
Khor Abu Habl	10.890		31.040
* (iii) By rain:			
Gedaref area	2.833		6.128
Nuba Mountains	3.436		7.250
Equatoria Province	2.371		5.270
Upper Nile Province	3.010		6.458
(iv) SUDAN:			
by irrigation	17.787		45.826
by flood	8.860		25.685
by rain	2.914		6.276
Dura			
(i) by irrigation	5.352	14.424	15.720
(ii) by flood	3.692	9.684	10.540
* (iii) by rain	3.536	8.772	9.520
Ground-nuts			
(i) by irrigation	8.828	13.351	23.189
(ii) by flood	3.500	5.260	9.088
(iii) by rain	4.726	7.216	12.633
Wheat			
(i) by irrigation	9.135	21.970	23.782
(ii) by flood	11.600	26.900	29.060
Grazing			
Sheep	0.52	0.068	0.086
Cattle	0.044	0.066	0.089
Camels	0.103	0.123	0.189

* If we assume that for half the period the land is left fallow then these figures must be divided by two.

The per feddan returns will be LS.0.052 for sheep, LS.0.044 for cattle and LS.0.103 for camels. At average per head retail prices of LS.5.500, LS.18.000 and LS.25.000 for sheep, cattle and camels respectively, the per square mile annual retail values will be LS. 41.250 for sheep, LS.40.500 for cattle and LS.75.000 for camels. The annual per feddan retail values will then be LS.0.068, LS.0.066 and LS.0.123 for sheep, cattle and camels respectively. At per head export prices of LS.7.000 for sheep, LS.24.000 for cattle and LS.38.500 for camels, the per square mile annual yield in foreign exchange will be LS.52.500 for sheep, LS.54.000 for cattle and LS.11.500 for camels. The per feddan annual export values will thus be LS.0.086 for sheep, LS.0.089 for cattle and LS.0.189 for camels.

So forestry can compete quite successfully with these types of land use in terms of financial returns even if we drop from our consideration the significance of the various forest influences. This must be reflected in land use planning.

APPENDIX 1

Legend for Figure 4 (vegetation)

Main divisions	Sub-divisions
I Desert	
II Semi-desert	(a) *Acacia tortilis-Maerua crassifolia* desert scrub. (b) Butana semi-desert grassland. (c) Semi-desert grassland on sand. (d) *Acacia mellifera Commiphora* desert scrub. (e) Semi-desert scrub of southern Red Sea Hills.
III Woodland savanna	A. *Low woodland savanna* 1. On clay soils (a) *Acacia mellifera* thornland (i) On dark cracking clays, alternating with grass. (ii) On hill soils formed *in situ.* (b) *Acacia seyal-Balanites* savanna, alternating with grass areas. (c) *Anogeissus-Combretum* woodland savanna 2. On stabilized sand dunes and archaean outcrops (a) Gum Arabic scrub belt. (b) Low woodland savanna of south-western Kordufan and south-eastern Darfur. (c) *Terminalia-Sclerocarya* woodland savanna. 3. Special areas (a) Toposa area type. (b) Hill catena type. (c) Baqqara catena type. (d) Raqaba catena type. B. *High woodland savanna* (a) Deciduous high woodland savanna. (b) Modified tropical rain forest.
IV Seasonal and permanent swamps region	
V Mountain vegetation zone	

APPENDIX 2

Legend for Figure 7 (land use)

Symbol	Type of land use
1	Settlement (towns).
4a	Perennially irrigated cropland.
4a'–6a	Intermittently cultivated flush irrigated cropland, with grazing.
4b–6a(7c)	Land rotation (undifferentiated local types), with grazing, in low savanna or woodland savanna.
4b'–6a(7c)	Land rotation (embanked fields [4b ^{it}], and small areas of flush irrigation [4b ^{if}]), with grazing, in semi-desert or low savanna.
4b ^{ii}–6a(7c)	Land rotation (northern clay plain, including grass firing), with grazing, in low savanna.
4b^{iii}–6a(7c)	Land rotation (sand zone types), with grazing, in low savanna.
4b$^{iv'}$–6a(7b)	Land rotation (Nuba Mountains terraced type), with grazing, in woodland savanna.
4b$^{iv''}$–6a(7b)	Land rotation (Nuba pediments and clay plains), with grazing, in woodland savanna.
4b ^{v}–6a(7b)	Land rotation (Jebel Mara terraced type), with grazing, in mountain woodland savanna.
4b^{vi}–6a(7b)	Land rotation (Wadi Azum type), with grazing in woodland savanna.
4b^{vii}–6a(7b,7c)	Land rotation (Nilotic type), with grazing, in woodland savanna, or 'high' land of Southern clay plain.
4b^{viii}–6a(7b)	Land rotation (terraced upland and piedmont types of Equatoria), with grazing, in woodland savanna.

6a–(7b)	Used unimproved grazing, in woodland savanna.
6a(7c)	Used unimproved grazing, in low savanna.
6a(8)	Used unimproved grazing, in semi-desert grasslands.
6a(8')	Used unimproved grazing of seasonally wet grasslands.
6a(8")	Used unimproved grazing of perennially moist riverain grassland of southern clay plain.
6a(9)	Used sparse semi-desert grazing, alternating with desert.
6b(7b)	Unused unimproved grazing, in woodland savanna.
6b(7c)	Unused unimproved grazing, in low savanna.
6b(8')	Unused unimproved grazing, in seasonally wet grasslands of southern clay plain.
7a–e	Evergreen tropical rain forest.
7a–e(m)	Mountain evergreen tropical rain forest.
7a–e/sd	Semi-deciduous high woodland savanna, with closed forests.
7b–d	Deciduous high woodland savanna.
7f(i)	Tropical rain forest or high woodland savanna, with shifting cultivation.
8	Permanent swamps.
9	Unproductive desert.
W	Water area or principal perennial rivers.

APPENDIX 3

VERNACULAR AND BOTANICAL PLANT NAMES

Acacia arabica	Siha
Acacia mellifera	Kitr
Acacia senegal	Hashab
Acacia seyal	Talh
Acacia tortilis	Samr
Anogeissus schimperi	Sabaha
Azadirachta indica	Neem
Aristida spp.	Gao
Balanites aegyptiaca	Heglig
Blepharis spp.	Bogheil
Combretum hartmannianum	Subagh
Combretum cordufanum	Umm dajog
Commiphora africana	Gafal
Maerua crassifolia	Sarha
Mansonia senegalensis	Guru
Sclerocaryea birrea	Humeid
Tectona grandis	Teak
Ziziphus spinachristi	Sidr

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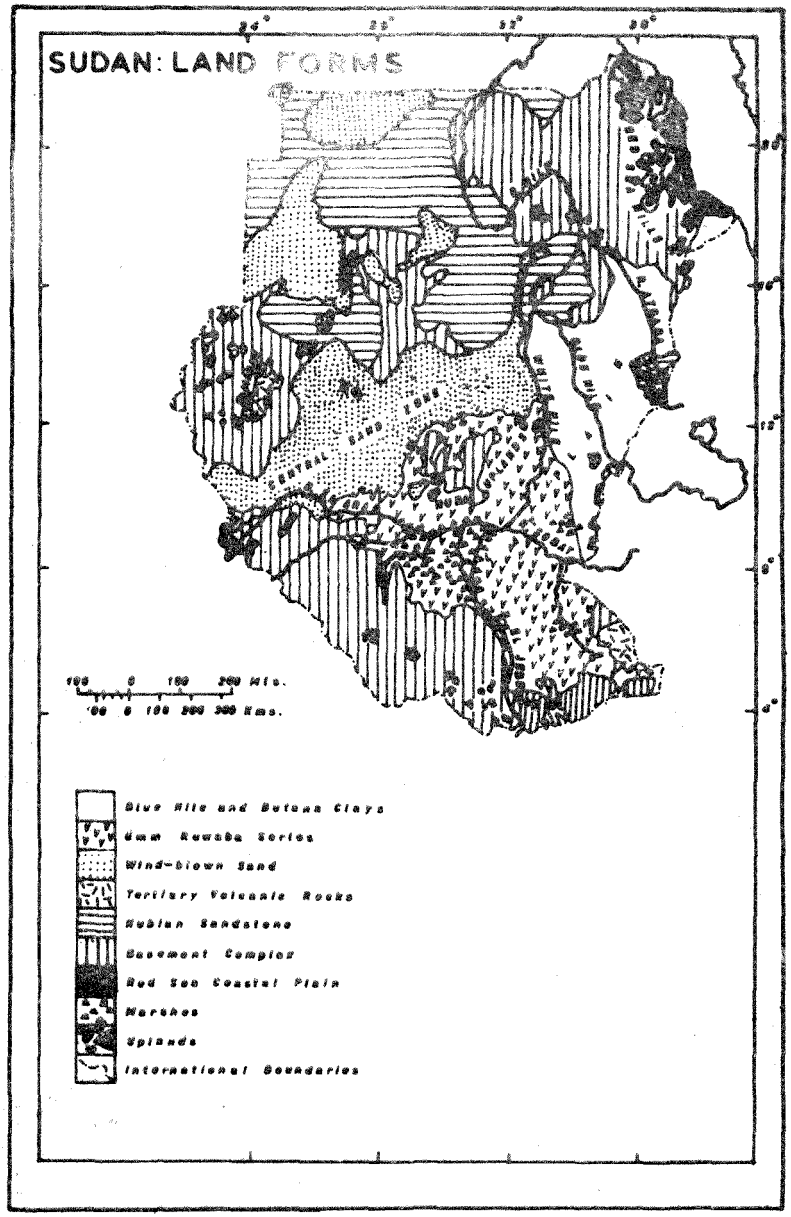

Fig. 1: SUDAN: LAND FORMS

Redrawn with amendents from J.H.G. Lebon, *Land Use in Sudan*, Geographical Publications Limited, Bude, Cornwall, 1965, p. 4.

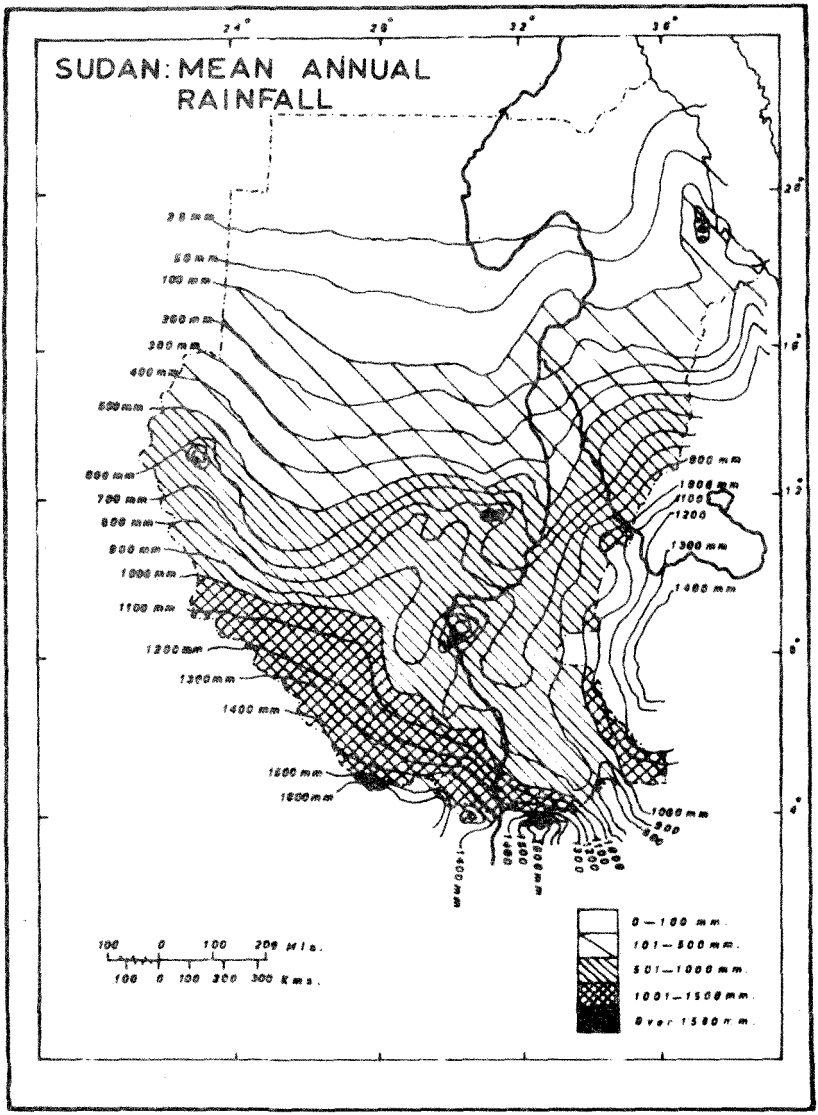

Fig. 2: SUDAN: MEAN ANNUAL RAINFALL
Compiled from *Climatic Normals* 1930–1960, 1961.

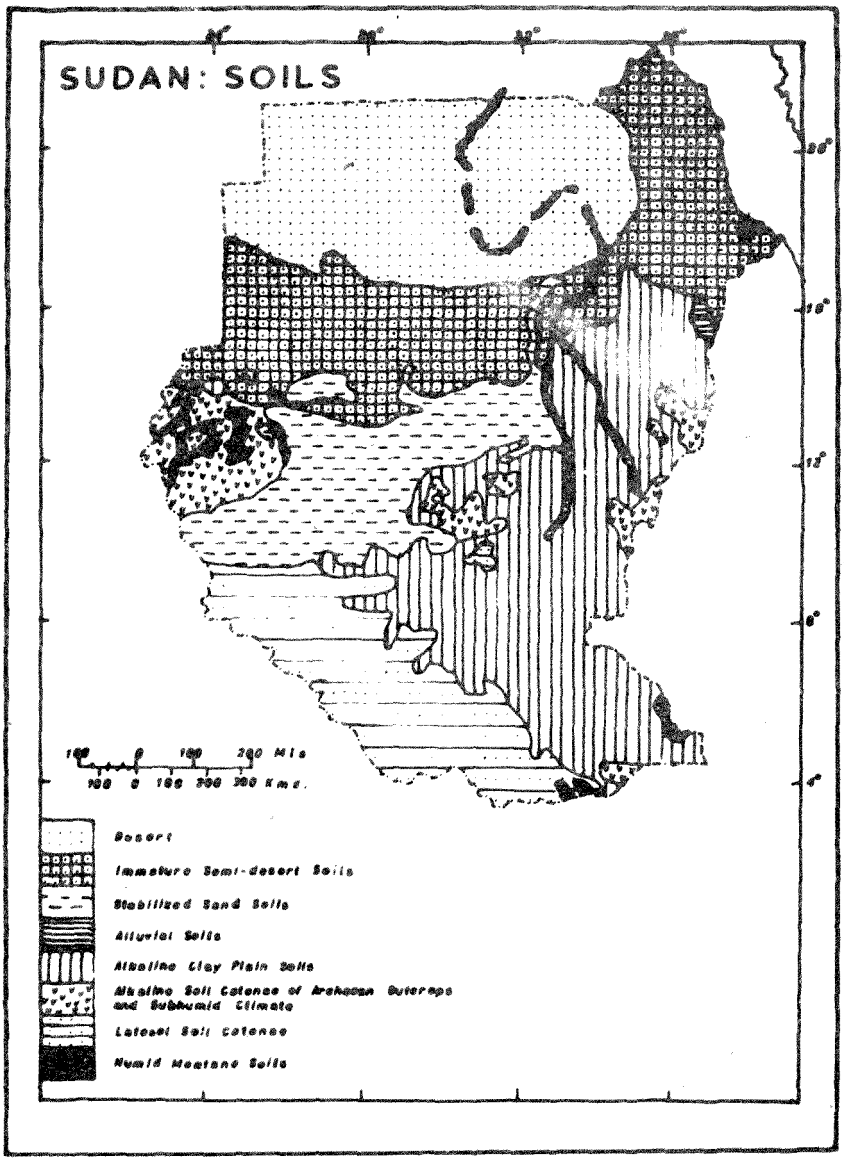

Fig. 3: SUDAN: SOILS
Redrawn with amendments from Lebon, *op.cit.*, p.44.

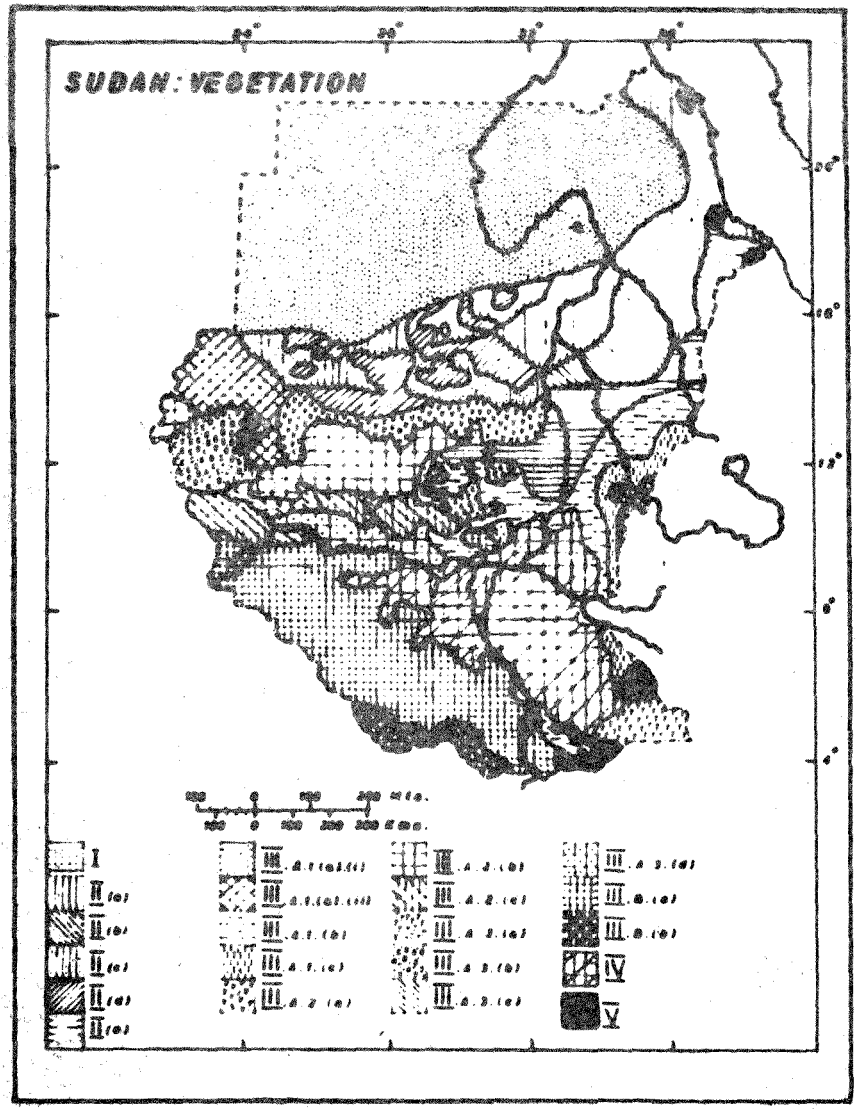

Fig. 4: SUDAN: VEGETATION
Redrawn with amendments from M.N. Harrison and J.K. Jackson, *Ecological Classifications of the Vegetation of the Sudan*, Forest Bulletin No. 2 (New Series), Agricultural Publications Committee, Khartoum, 1958.
The symbols correspond with those in Appendix 1.

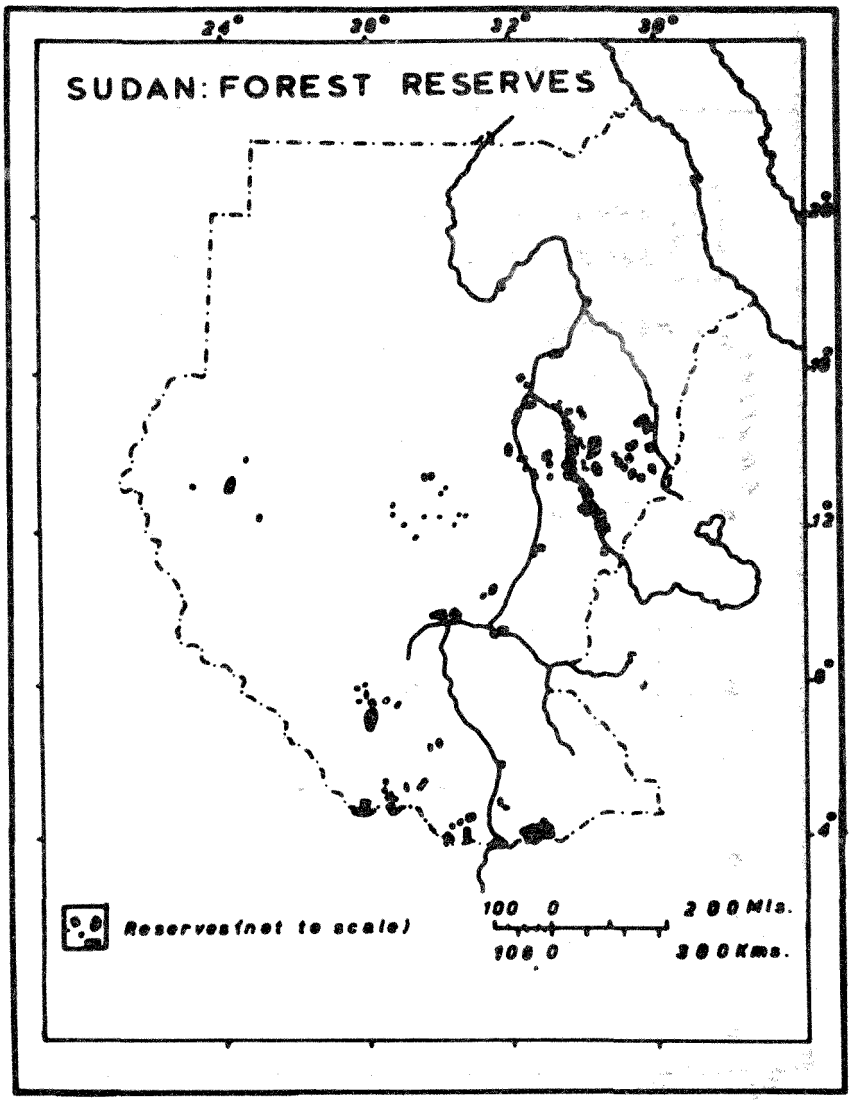

Fig. 5: SUDAN: FOREST RESERVES
Compiled from data of *Forests Department Annual Reports* for the period July 1962 to June 1968.

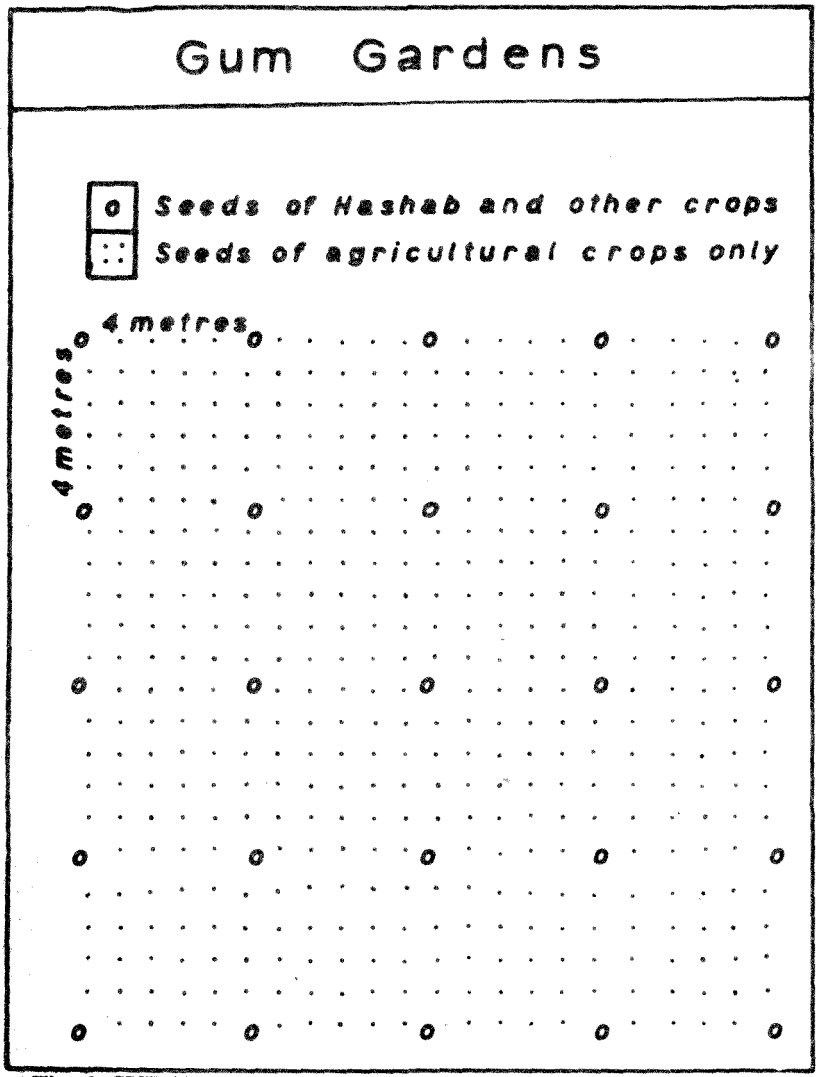

Fig. 6: SUDAN: GUM GARDENS
Redrawn from Forests' Department's *Improvements of Gum Gardens and Establishment of New Ones* (in Arabic) Leaflet No. 4, Khartoum, 1961.

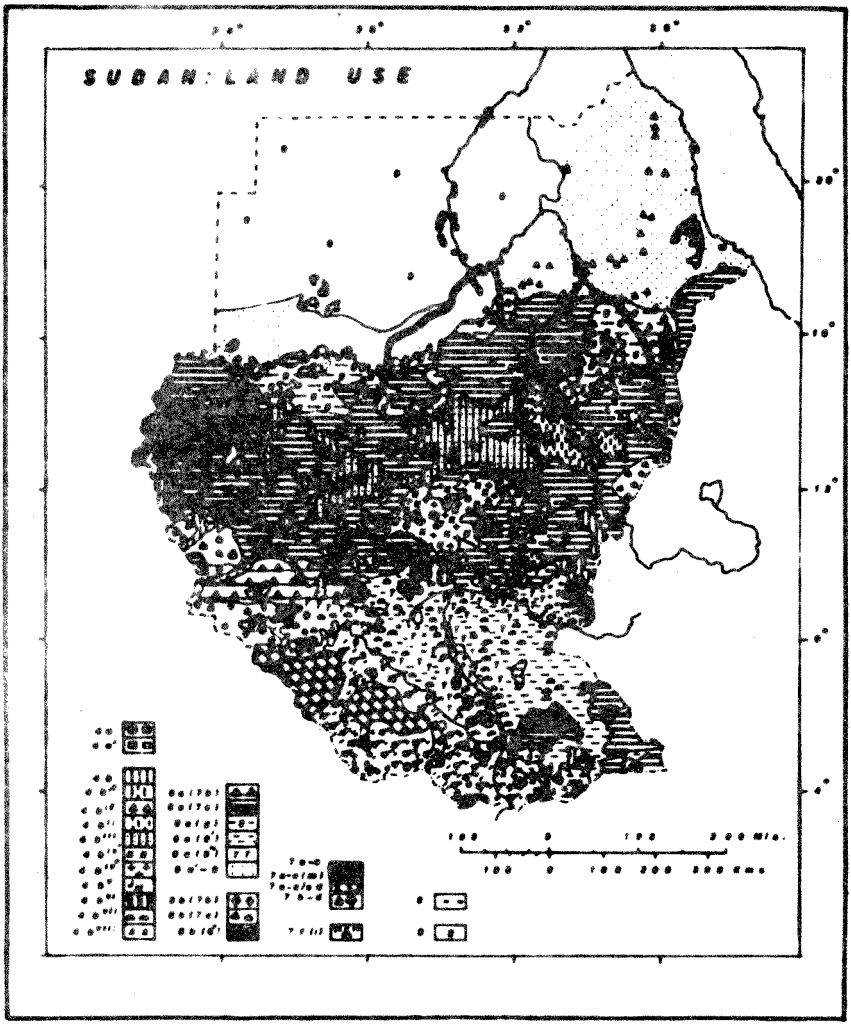

Fig.7: SUDAN: LAND USE
Redrawn from Lebon, *op.cit.*
The symbols correspond with those in Appendix 2.

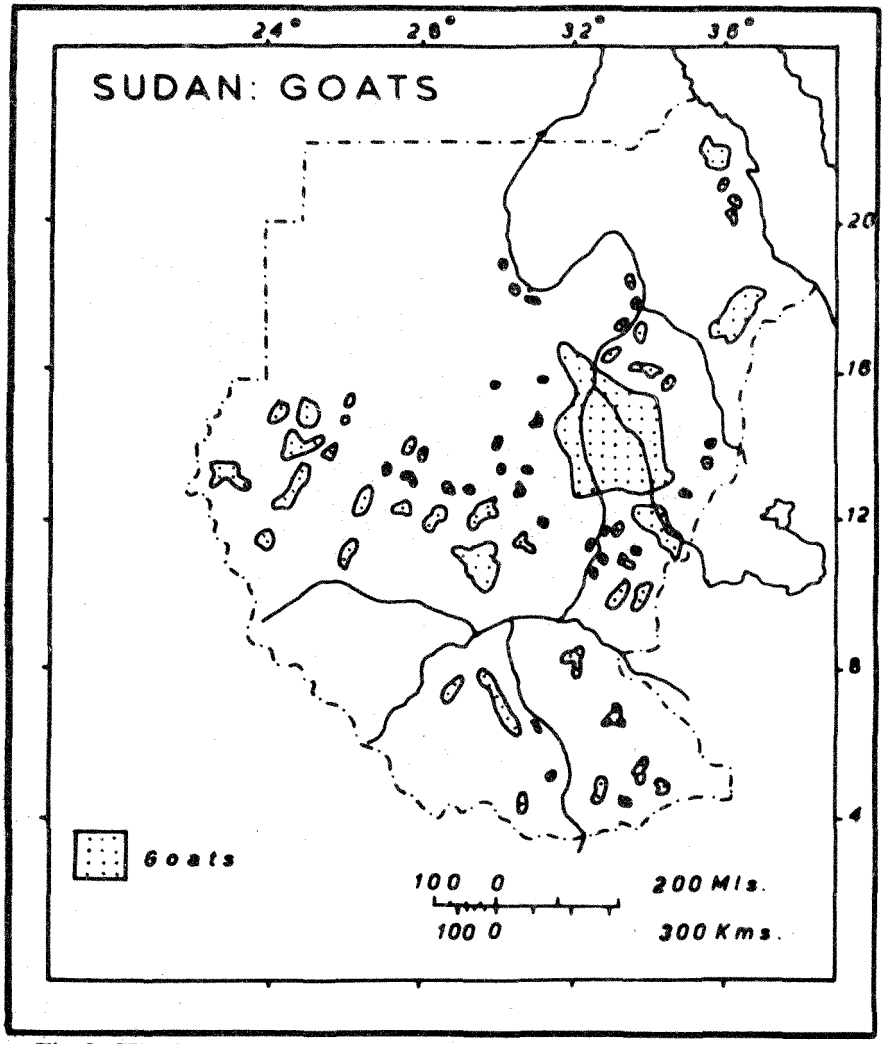

Fig. 8: SUDAN: GOATS
Redrawn with amendments from K.M. Barbour, *The Republic of the Sudan,* University of London Press Ltd., 1961, p. 90.

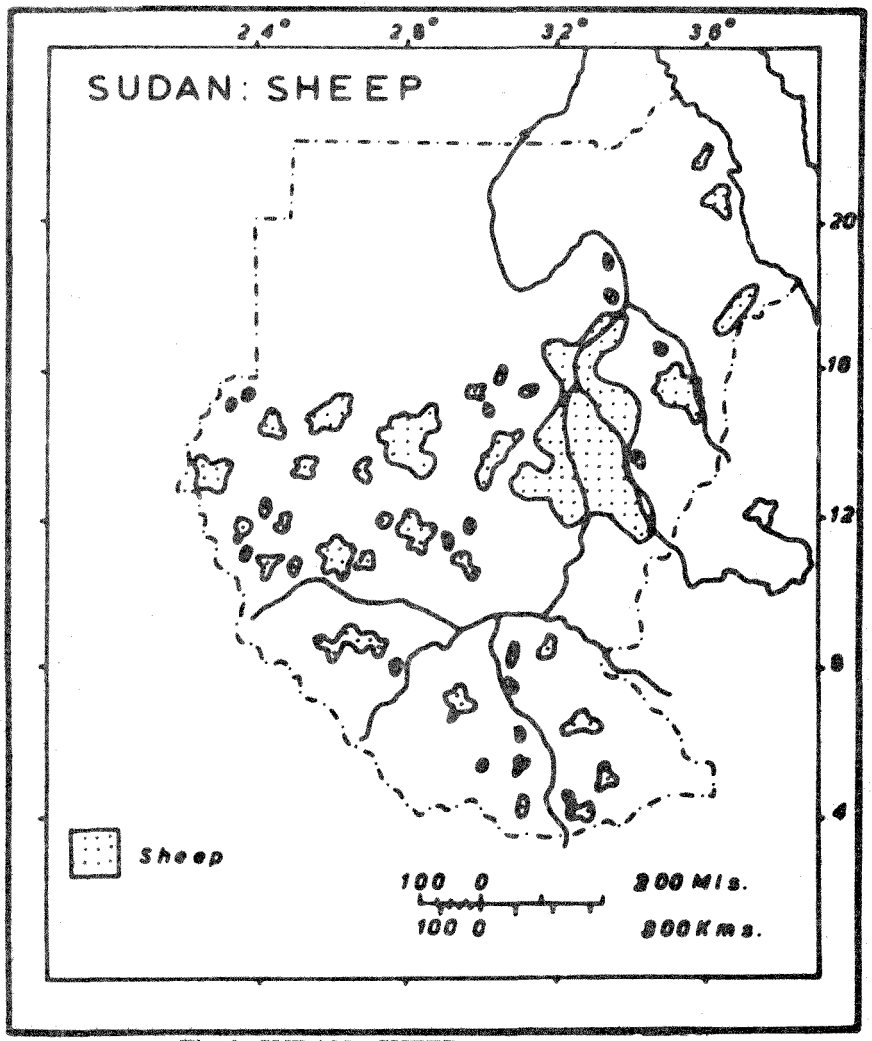

Fig. 9: SUDAN: SHEEP
Redrawn with amendments from Barbour, *op.cit.*

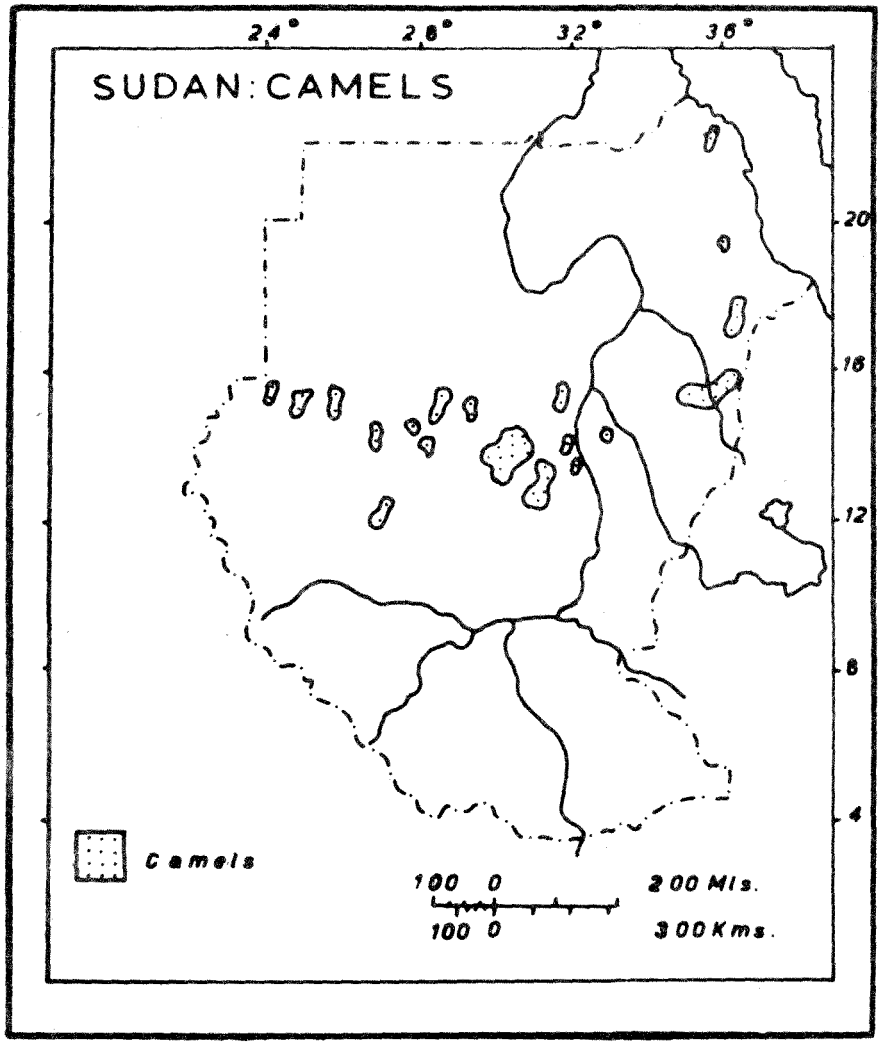

Fig. 10: SUDAN: CAMELS
Redrawn with amendments from Barbour, *op.cit.*

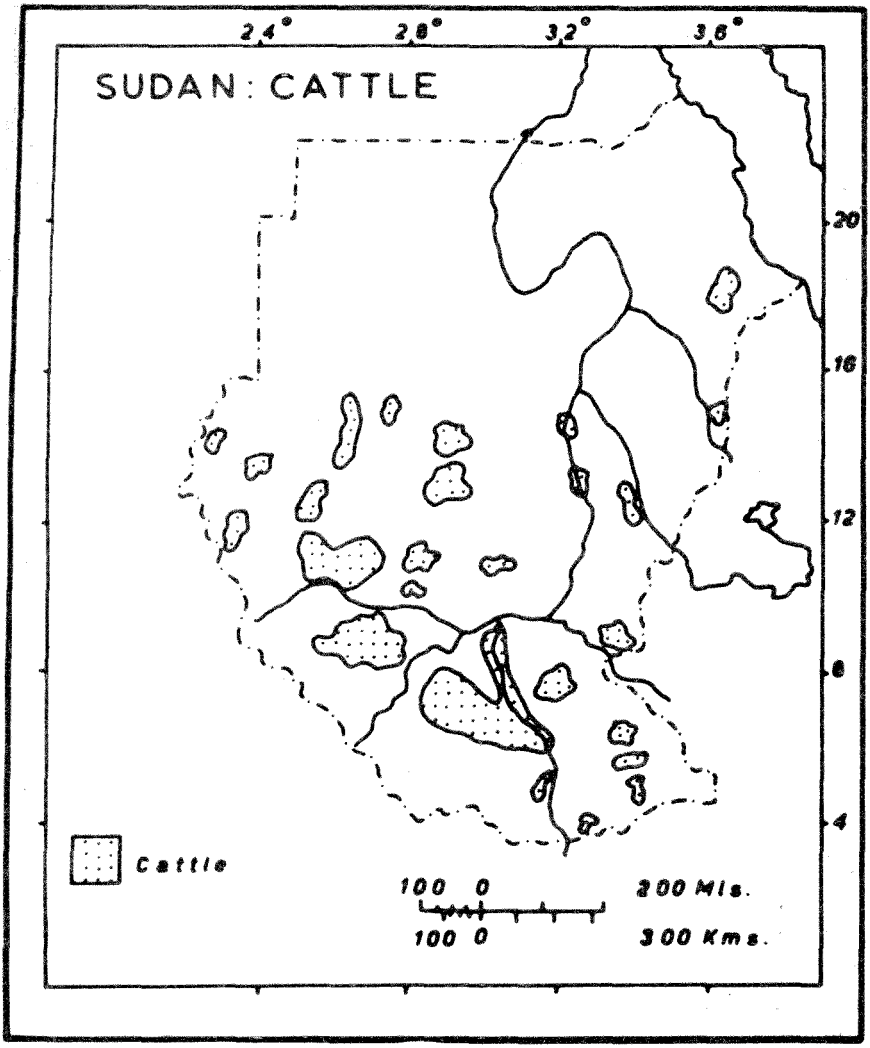

Fig. 11: SUDAN: CATTLE
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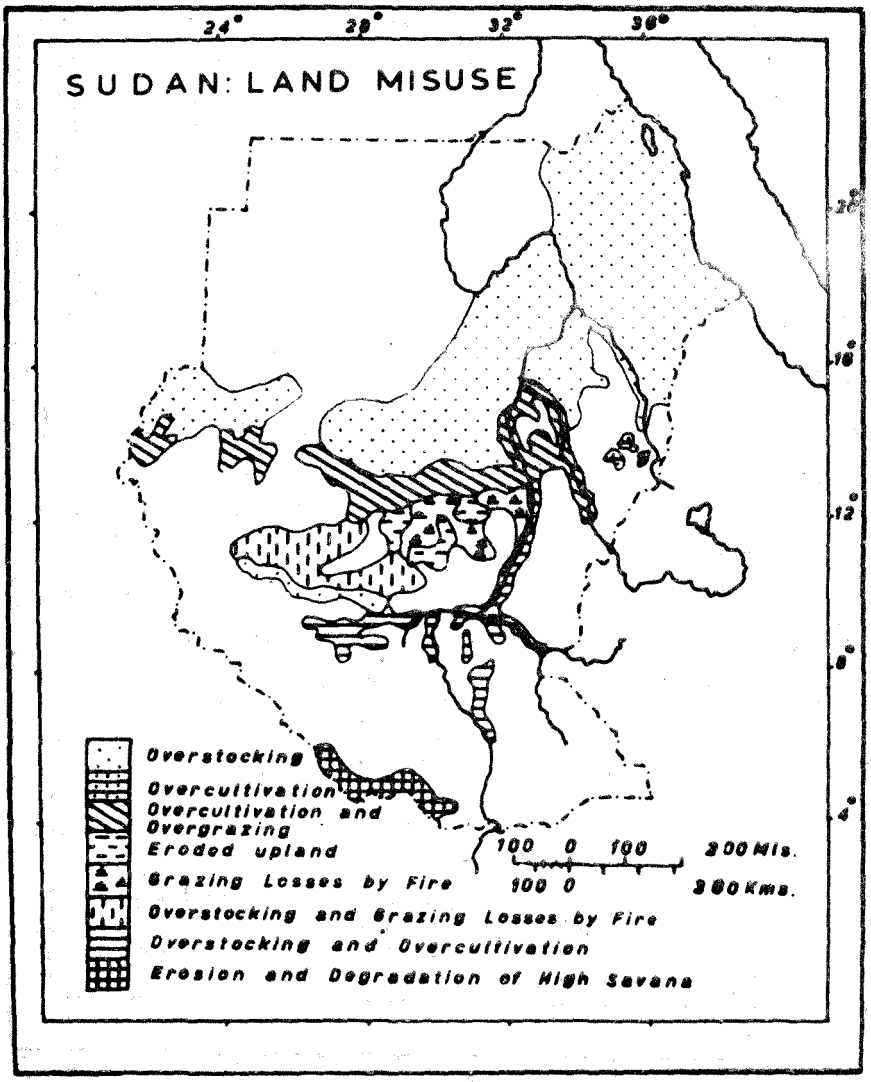


Fig. 12: SUDAN: LAND MISUSE
Redrawn with amendments from Lebon, *op.cit.*, p. 169.

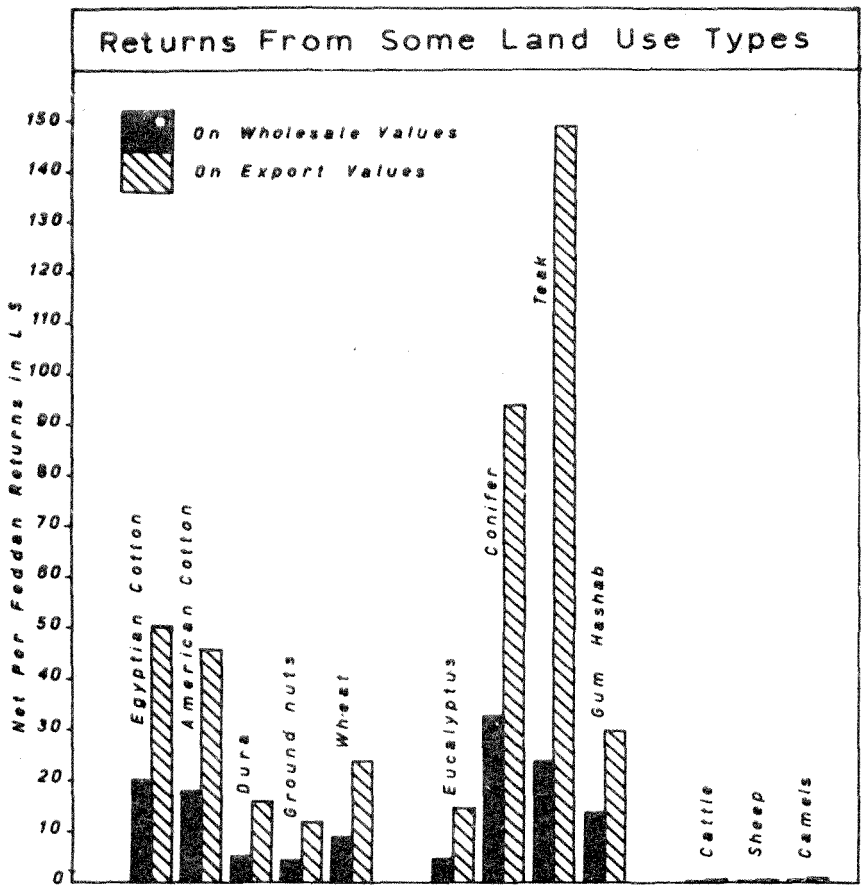
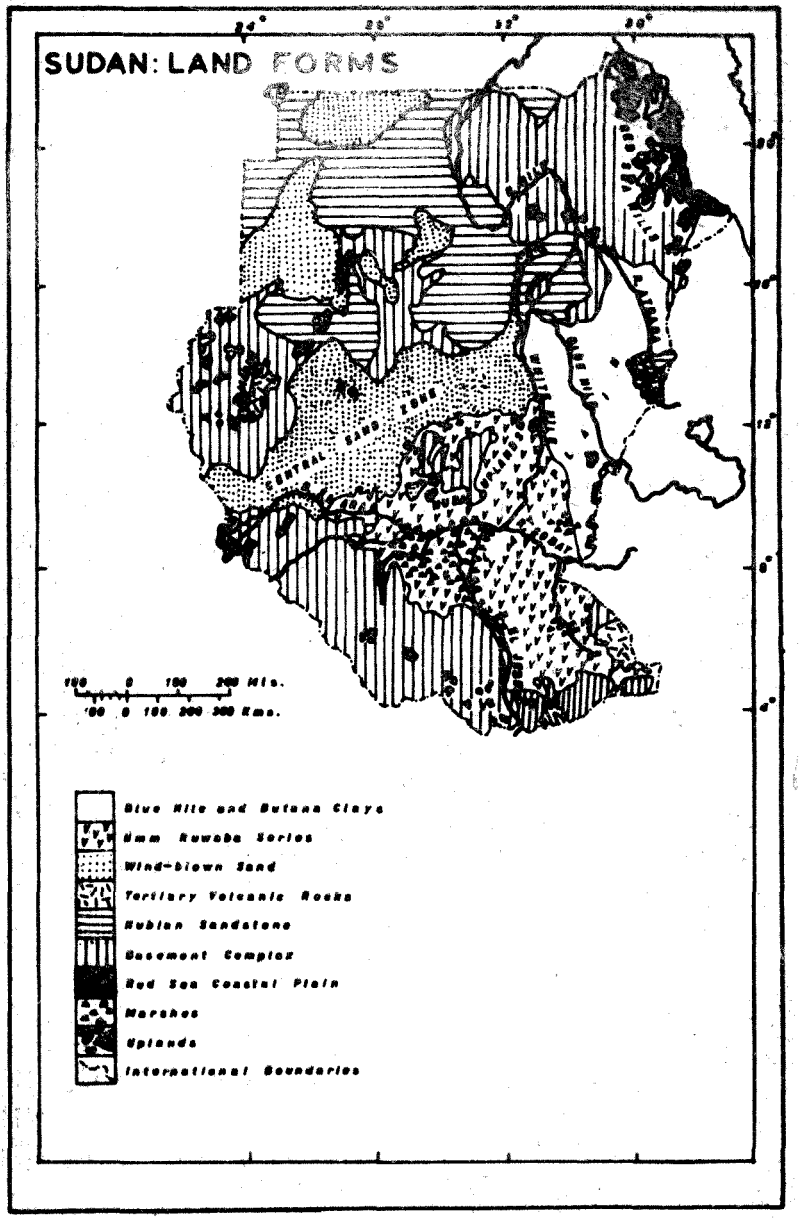


Fig. 13: RETURNS FROM SOME LAND USE TYPES
Compiled from Table VII, p. 51.


SUDAN: LAND FORMS
24°
28°
32°
36°
20°
16°
12°
8°
4°
CENTRAL SAND ZONE
WHITE NILE
BLUE NILE
ATBARA
100 0 100 200 Mls.
100 0 100 200 300 Kms.
Blue Nile and Butana Clays
Umm Ruwaba Series
Wind-blown Sand
Tertiary Volcanic Rocks
Nubian Sandstone
Basement Complex
Red Sea Coastal Plain
Marshes
Uplands
International Boundaries