# RESOURCE MANAGEMENT IN SUKUMALAND, TANZANIA

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## 1. INTRODUCTION

The attention that has been devoted to Sukumaland, Tanzania, by development specialists has been attributed by De Wilde (1967) to the rapid expansion of livestock and cotton production in ways which have been the despair of professional agriculturalists and veterinarians. Cycles of drought, famine and disease have recurred at intervals of five to seven years while soil erosion has been an ever present phenomenon. Administrative responses to these problems have followed a cycle of education, persuasion, resettlement and coercion, to little avail. A number of studies, spanning many scientific disciplines, have sought to understand, change, or merely criticize, the existing state of affairs.

One school of thought, applied generally to the semi-arid ecosystems of the world, is expressed thus:

> The semi-arid ecosystems have, therefore, often been managed by a segment of the population which constitutes the least capable, least innovative group, often disinterested in what they are doing, but not capable of changing their circumstances (Walker, 1979).

Such generalizations display little insight into the complexity underlining human affairs and offer no solution to the dilemma which faces peoples like the Sukuma.

An alternative viewpoint would be to assume that the Sukuma, as individuals, are as rational in the management of their own resources as any of us. In order to examine this view in detail it is necessary to enquire, first, whether there are constraints imposed on the Sukuma which may help to explain their behaviour and, second, whether there are fundamental differences in their perception of what constitutes a resource. As O'Riordan (1971) has emphasized,

> A resource can no longer be conceived as a tangible object, but a functional relationship that exists between man's wants, his abilities and his appraisal of his environment. The definition of a resource is a culturally defined, abstract concept which hinges upon man's perception of the means of attaining certain socially valued goals by manipulating selected elements of the biophysical environment.

O'Riordan suggests that the role of resource management research is to attempt to improve the efficiency and accuracy of resource allocation between groups and individuals in space and time and to analyse the various forces and influences acting upon the process of choice and upon the decision makers themselves. This is the context in which I wish to discuss soil erosion.

Resource exploitation is a complex economic phenomenon. Resources are not generally depleted in the manner that Malthus suggested. Rather, as Ricardo and Mill proposed, resources are infinite but vary in quality and availability. Thus, resources are combined with labour and capital in the process of production and a law of diminishing returns should ensure substitution and more efficient use as they become scarce (Barnett and Morse, 1963). Technology increases the relative abundance of a resource and the efficiency of resource exploitation. However, technical innovation may not occur automatically as capital becomes available (Pepalasis, 1961); knowledge and availability of technology may diffuse outwards

relatively slowly. Furthermore, innovations often do not originate in peasant societies but are imposed from outside to satisfy a range of development objectives. They are often not determined by individual needs, which may attempt to balance relative risk and profitability (Hawkins, 1970). Individual and collective needs may conflict where the resource is common property and intervention may be necessary to reconcile such conflicts.

One of the goals of human societies is to buffer the effect of natural environmental hazards (Kates, 1970). These include not only extreme events, disasters, which are apparent because they exceed the reflective or absorptive capabilities of a society, but also those events to which there has been a continuous process of adjustment. The latter may be less apparent and may only be observed indirectly; for example, by the degree of occupancy of different zones, the perception of hazards and the range of damage-reducing adjustments practised.

In their resource management practices the Sukuma people mediate between a series of conflicts of an economic, cultural and ecological nature. In order to understand their predicament, in particular the causes for soil erosion in Sukumaland, three perspectives must be examined and synthesized: historical, economic and ecological. The historical perspective reviews what is known of a series of disasters which overtook the Sukuma people at the beginning of the twentieth century, as well as the administrative policies pursued in the following decades. The economic perspective examines the spatial and temporal dimensions of risk and the behaviour of the people as farmers and cattle herders. The ecological summarizes the ecology of two important disease vectors – tsetse flies and cattle ticks – and demonstrates how ecological studies contribute to an understanding of the other two components. As part of this synthesis a number of models are assembled, each of which may illuminate aspects of the problem, suggesting future approaches towards the planning of research and development policy in Sukumaland and elsewhere.

## 2. THE HISTORICAL PERSPECTIVE

While our knowledge of Sukuma history is relatively sparse, we may note that resource conservation and natural-hazard buffering activities have long been in conflict. Successive administrations appear to have ignored this conflict and, as a result, they have either destabilized the system or their policies have had unexpected consequences. The sequence of natural catastrophes and government interventions which have dominated recent Sukuma history are summarized in Table 1, from 1858 when the first written records were made, until 1967, which is a convenient stopping point (Iliffe, 1971, 1979; Cliffe, 1964, 1972; Ford, 1971; Kjekshus, 1977; De Wilde, 1967; McLoughlin, 1970).

In the 1860s and 1870s Burton, Speke and Stanley travelled through the area and commented on its wealth and peace: grassy plains (in the wet season) filled with cattle and intersected by hedges between well-cultivated fields (Stanley, 1961). These plains were separated by open woodland (bush) which was inhabited by tsetse flies. The Sukuma people understood that the fly lived in the bush and carried a disease fatal to cattle. There was an 'agro-horticultural prophylaxis' (Ford, 1971) with the bush left ungrazed until the risk of death by starvation was greater than the risk of the disease carried by the fly. Wild game were rare wherever there were

people, and people abounded throughout many areas of Sukumaland. Warfare and slavery, according to one recent view, had minimal impact (Kjekshus, 1977). Yet by the turn of the century the peace so vividly described by Stanley had all but disappeared.

TABLE 1. *Chronology of some relevant events in Sukumaland*

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|---|---|
| 1858 | Speke's record of traversing Sukumaland from Tabora to Lake Victoria. |
| 1875 | Stanley's record. |
| 1889 | Stanley and Emin's record. |
| 1890– | Rinderpest pandemic, 90% cattle mortality. Smallpox epidemic. Jigger flea epidemic. |
| 1893–95 | Red locust plague. German procurement and pacification. Famine. |
| 1900 | Tsetse fly and trypanosomiasis epidemic and epizootic. |
| 1914–18 | First World War. Transfer to British rule. Relapsing fever epidemic. |
| 1918 | Trypanosomiasis epidemic in Maswa. |
| 1924 | Tsetse belt had overrun three quarters of Sukumaland, bush clearance organized. |
| 1927 | East Coast Fever epizootic. |
| 1929 | Tsetse Research Station established in Old Shinyanga. Famine and drought. |
| 1930 | Heavy rain. Human population increasing. |
| 1931–32 | Drought. Rinderpest epizootic. |
| 1934–36 | East Coast Fever epizootics. Control of Rinderpest, Pleuropneumonia, tick and worm infestations was lost. |
| 1942 | Famine. Relapsing fever epidemic. |
| 1943 | Rinderpest under control. |
| 1944 | Famine and drought. East Coast Fever epizootic. |
| 1945 | Pleuropneumonia. Peak of relapsing fever epidemic. |
| 1947 | Sukumaland Development Scheme (cotton). Tsetse belts receding. |
| 1949 | Famine and drought. East Coast Fever. Human expansion into Geita accompanied by sleeping sickness epidemic. |
| 1955 | New development policy announced. |
| 1955 | Rinderpest epizootic. |
| 1957–60 | East Coast Fever. |
| 1961 | Independence, development projects. |
| 1962–64 | East Coast Fever. |
| 1965 | Cattle density low. |
| 1967 | Arusha declaration. East Coast Fever. |

In the 1890s a series of important ecological disasters overwhelmed the population. First, there was a pandemic of Rinderpest, a contagious viral disease of cattle which is thought to have been reintroduced by European activities. This reduced the cattle population by as much as 90% and undermined the entire economic, social and political framework. An epidemic of smallpox swept through the human population and then, weakened, they were beset by an epidemic of jigger fleas which often crippled their feet, undermining their labour and mobility. Then there were the red locust plagues of 1893–95 and, as the century drew to a close, the impact of German pacification and procurement policies was felt and contributed to a growing famine.

The people died, the grassy plains were deserted, the bush regenerated, bringing in its wake the tsetse fly and the wild game. Epidemics of trypanosomiasis broke out among man and beast. By the 1920s inhabited Sukumaland had shrunk to around a quarter of its previous size. A series of German and then British Colonial Commissions were charged with the control of these epidemics. Their policy was to move people from infected areas, establishing permanent population concentrations and clearings. This effectively surrendered more land to the bush, the animals and the fly. Wildlife eradication was suggested as a remedy but this was disregarded

Kjekshus analyses the settlement failure in terms of the administration's negative attitude towards the people. There was a tendency to 'save the African from himself'. Forced resettlement and villagization was started as a health measure. Later it was seen as having the advantage of providing centres for education, medical care and water. It also provided the opportunity to impose major changes on the peasant agricultural system – to regulate cattle, rotation and tillage. In addition the settlements were seen as a way of protecting wildlife, preventing soil erosion, providing cheap labour and forming the basis for the 'development' of the territory.

After the First World War the British encouraged cotton growing as a cash crop, and Swynnerton set up the first tsetse research station and undertook control operations (Wood, 1924; Peat, 1946; Purvis, 1951; Swynnerton, 1922, 1924, 1925, 1936; Glasgow, 1960). Population pressure and tsetse control both contributed to bush clearance, which removed the threat of trypanosomiasis. Bush clearance created new problems. The remaining trees were lopped and destroyed for firewood and building materials, while grasses were grazed to the roots. The dry season winds lifted the soil and wet season rains created gullies unhindered by windbreak or ground cover. The first administrative concern about soil erosion was voiced in 1929 (Berry and Townshend, 1972). The source of the problem was felt to be overstocking. During the 1930s demonstration plots were set up and efforts made to persuade the native authority to adopt conservation measures. The people resisted them. The area became known as the 'cultivation steppe' and took on the treeless, overgrazed appearance so characteristic of central Sukumaland today. For the peasant cultivator, 'occupation means elimination of tsetse fly, reduction of game and vermin and reduction of ticks by keeping the grass short. In so many words, this means making the country bare of all that shelters the above enemies of man' (Rounce, 1949).

Malcolm (1953) proposed to decrease population density by moving people and stock into new areas and providing water supplies. The objective, according to Rounce, being 'the improvement of the standard of living of the African peasant, by giving him . . . new capital in the form of land, on the condition that he only lives on the interest and maintains the full capital value'. In 1947 the Sukumaland Development Scheme was launched with a large injection of capital, accrued from marketing cotton. Its objectives were to provide the British Empire with much-needed cotton, to modernize agricultural practices and to prevent soil erosion. A gradual change in agricultural practices was envisaged with integrated pasture care and adequate rotations, promoted by education and demonstration. It was intended to preserve and protect the indigenous system of communal land ownership and communal labour. New watering points were set up and the overpopulated areas were resettled at carefully controlled densities (strikingly similar to the post-independence villagization policy). Cotton production boomed because of the high post-war market for cotton. The soil-conservation measures, at first promoted by voluntary means, were enforced by legislation. The people were still resisting them and many of their objections had an interesting ecological flavour.

The legislation covered every aspect of agricultural life, including tie-ridging, the planting of trees, contour banking and hedging. Stock could not be moved without permission and stock reduction was mandatory. The people accepted some of the conservation measures at first, because they could see the rationale. They rejected

others which interfered with their normal agricultural practices or required arduous labour which they believed more profitably employed elsewhere (Iliffe, 1971). Cliffe suggests that the rules challenged the peasant's economic security and his culture. There were insufficient administrators to enforce these measures or to adapt them to the local culture and customs, as Malcolm (1953) and Cory (1953) wished. The impetus, rationale and direction of agricultural and political reform came as usual from the bureaucracy rather than the people (Finucane, 1974). The objections of the people were based on their own understanding of the environment: for example, that planting trees encourages graminivorous birds, manuring encourages weeds, contour banking encourages rats and, as discussed later, long grass fallows encourage ticks which harbour cattle diseases. But perhaps the destocking measures caused the most resentment. Cattle, as in other parts of Africa, are associated with bride-wealth and are an insurance against famine. The manager of a cattle herd has relatively little managerial control: there is multiple ownership of each animal; contingency or reversionary rights; and actual or potential lien. The only cattle that could easily be sold were those that had been bought rather than inherited, and even some of those had to be kept against the possibility of a 'childbirth blood-price' (compensation for illegitimacy). Cattle were also lent to other herders in order to spread the risk of disease, make use of better grazing, prepare for migration into tsetse inhabited bush, or simply to conceal the true wealth of the cattle owner and thus reduce his social obligations.

A long-term, compulsory policy which ran contrary to local economic forces was not practicable in the changing political mood of the 1950s (Iliffe, 1971). The resentment of conservation measures grew, fanned by the flames of the national independence movement. A Sukuma politician was quoted as saying 'destocking has taught every African that it is Government's purpose to make the African beggars'. By 1958 there was widespread civil disobedience and the entire legislative package was dropped. But even by 1955 there had been a change of policy towards what has become known as the 'transformation approach'.

The keynote of this approach to development, as stated in the Report of the Royal Commission on Land and Population in East Africa, was the individualization of land tenure. The commission recognized that this would lead to the development of inequalities of wealth, landlessness, exploitation and debt, but believed that individualization was the only method of promoting soil conservation, economic growth and cash cropping. Concentrating on progressive farmers would replace the policy of regulating agriculture by legal sanctions. It was a policy of 'betting on the strong'.

The transformation approach was criticized by Nyerere at the Annual Conference of the Tanganyika African National Union, as emphasizing dependence on external markets coupled with internal inequalities, and elsewhere (Anon. 1955). Iliffe concludes that the transformation approach did mean short-term economic growth but its long term structural effects were not fully appreciated until after independence. It intended that there would be capital-intensive Village Settlement Schemes managed by foreign experts for the few, plus gradual improvement for the many. It was sanctioned by the World Bank in 1960 and carried into the post-independence era.

During the 1960s there was a renewed emphasis on micro-economic investigations

and farm surveys which pointed to the complexity of subsistence agriculture (Von Rotenhan, 1968; Hulls, 1971; Collinson, 1972; Hankins, 1974; Anthony and Uchendu, 1974). These studies are of seminal importance and their findings will be described later. The national policy pursued since 1967 explicitly emphasizes the need to increase social welfare at the same time as economic output. It rejects the 'transformation approach' in favour of the 'improvement approach'. An attempt was made to stop imposing solutions solely from above, to use persuasion instead of force, to help people towards the self-management of their own communities. However, the attitudes of the bureaucracy have been slow to change, for there is still a tendency to regard development as a purely technical problem and the importance of local environmental differences and conflicts has largely been ignored (Finucane, 1974; Cliffe, 1972).

## 3. A SOCIO-ECONOMIC PERSPECTIVE

In their resource management practices the Sukuma must mediate between a series of conflicts, some common to all mankind, others special to the Sukuma predicament. These include: productivity and equality; cash and subsistence; cropping and grazing; cultivation and fallow; opportunity and security; individual and communal property right. Some of these conflicts affect common property resources and their resolution may exacerbate soil erosion.

### 3.1 *Common property resources*

When a resource is publicly owned it is in the interest of the individual to maximize his share of it. Thus, when grazing common land, it is sensible to own the largest herd and, in the absence of communally accepted restrictions, to consume all the grazing before others can do so. Societies may develop co-operative traditions which restrict this free economic behaviour, but they may develop slowly and may be easily disrupted.

There were a number of co-operative traditions in Sukuma society (Malcolm, 1953; Cory, 1953; Welch, 1974). The community was organized into societies by age and sex. These performed communal tasks such as hoeing or house building and were rewarded on a reciprocal basis. There was equal access to uncultivated land for grazing, water supplies for domestic consumption, and products like thatch, poles, firewood and manure. Ownership of trees, cultivated fields and water holes was recognized and vested the individual with special privileges. Village headsmen controlled dry season water tanks and were responsible for their maintenance.

The basis of traditional land tenure was 'usufructuary right of occupancy' so a holder could not be deprived of his land as long as he occupied it and used it. The local authority allocated available land to those who wanted it and land could not be bought or sold or arbitrarily assigned to others. New land could be cleared from the bush by anybody, providing that it was not near cultivated plots. Thus control of the land was vested in the local community and not in the individual. Malcolm's discussion of land tenure illustrates the dilemma of managing a common property resource.

According to Malcolm, the explicit objective of the colonial government was to raise the standard of living of the people. A land ordinance required administrators

to 'assure, protect and preserve' the land rights of Africans. At the same time it was clear that pressure from human and livestock populations was leading to soil erosion and loss of fertility. A more intensive system of cultivation was required with land improvement and conservation measures. The system of land ownership would influence this process. Malcolm discussed the advantages and disadvantages of individualization of tenure in some detail. It would act as an incentive for land improvement, giving the individual a vested interest in its continuing fertility and providing a security against which credit could be raised. On the other hand the community would lose control as the individual would have the right to transfer ownership. There would be, he felt, a progressive acquisition of larger holdings by smaller numbers, fragmentation of small holdings, the appearance of a landless labouring class, high rents, insecurity of tenure, absentee landlordism and 'all the familiar attendant evils'.

Malcolm argued strongly in favour of retaining village control over the land along co-operative lines and he thus anticipated Ujamaa. The major problem, as he saw it, was to enable individuals to profit from permanent improvements such as trees planted for fuel, windbreaks or food. The village co-operative would have to pay the individual for such permanent improvements.

> While, as a result of this study, I am deeply impressed with the immense value of existing land tenure, particularly from the point of view of assuring beneficial land utilization, yet the problems attendant upon any attempt to graft on to it provision for compensation for unexhausted improvements may well prove insoluble and, in default of far-sighted and determined leadership, an increasing measure of individualization appears inevitable.

One path out of this dilemma appeared to be an intensive farming system, based on a cash crop such as cotton.

### 3.2 *Cotton production*

Cotton was established as a cash crop in Sukumaland by German settlers in the early 1900s. The crop was adopted by the peasants and production increased substantially after the First World War. During the 1930s, for example, production increased fivefold. However, the real impetus for cotton production was the Sukumaland Development Scheme of 1947. In the fifteen-year period following this scheme cotton production increased a further sevenfold without soil-conservation measures or destocking being much affected. Von Rotenhan (1968) has suggested a number of factors which increased the peasant cultivators' interest in cotton, including: high world prices; access to marketing facilities; provision of high-yield varieties; and promotion by traditional and political leading figures. However, the increase was not due to higher yields per acre or better husbandry, but rather a consequence of a reduction in fallow and the cultivation of hitherto unused land both within the area and in new areas.

De Wilde (1967) suggests that cotton ought to act as a stabilizing factor in the Sukuma economy, providing a cash income for investment and thriving well under relatively dry conditions when other crops fail. However, increased cotton production appears to have introduced new and accelerating problems of soil erosion and exhaustion (see Fig. 1). More cotton is today being grown on more land at the expense of grazing land and fallow. Profits from the sale of cotton are being invested

in cattle. More cattle than ever before are concentrated in higher densities on less land and overgraze and trample the soil. Erosion increases, cattle quality decreases and cotton yields are reduced by soil exhaustion.

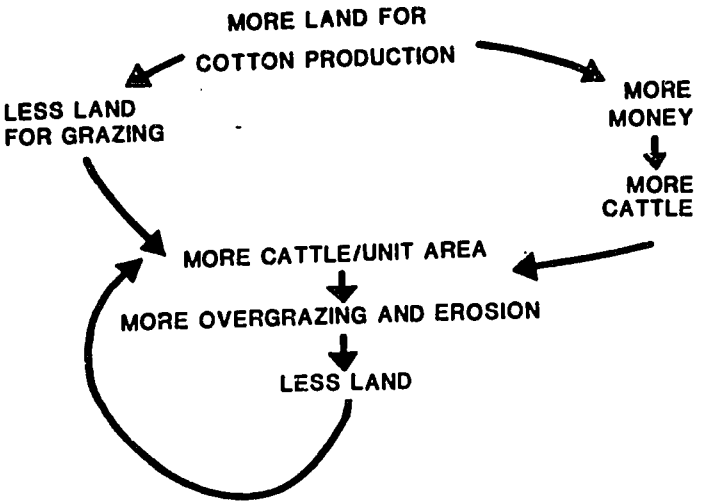


Fig. 1 *Positive feedback between cattle and cotton production which may contribute to the destabilization of Sukuma agriculture (after Von Rotenhan, 1968).*

The technical problems of cotton production in Sukumaland have been studied since at least 1924, when the Empire Cotton Growing Review was first published. The crop is subject to devastating pest attack by, for example, cotton stainers, bollworms and jassids. Application of insecticide has been hampered by the small scale of individual plots and the lack of water. Lack of water also prohibits irrigation. Land fertility is low and neither natural nor artificial fertilizers are generally applied. Planting is staggered and suboptimal in order to fit in with the cultivation of food crops and to offset the risk of drought. Rotations are inadequate and cultivation practices are labour-intensive, using the simplest implements. However there have been widespread changes during the last decade including the increased availability of tractors. De Wilde emphasizes that within their own time-horizon the Sukuma have generally considered labour rather than land as the scarce production factor. Consequently they are unlikely to adopt cultivation techniques which raise yield per hectare if these simultaneously raise labour requirements which are already scarce.

Hulls (1971) and Collinson (1972) have emphasized that Sukuma farmers distribute the risks of cultivation, or buffer the effect of natural hazards, by mixed farming and staggered planting. While Ukuriguru Research Station recommended planting in December, the farmers stagger planting between November and February. An analysis of the coefficient of variation of rainfall over a nineteen-year period suggests that they may be rational to do so (Collinson, 1972). Furthermore, production is not uniform throughout Sukumaland but varies along a moisture gradient, from the more extensive practices of the drier (700 mm rainfall), underpopulated areas far from the Lake Victoria, to the more intensive practices of the wetter (1000 mm rainfall), and more highly populated areas near the lake.

There have been many attempts to separate Sukumaland into distinctive zones, some like Conyers *et al.* (1979), appearing to ignore the ecological factors on which such a zonation must depend. Hankins (1974) delineated two zones on the basis of drought experience and perceived risk. Von Rotenhan (1968) observed that cultivation practices tend to be more intense in areas with higher rainfall and population densities, as might be expected. The most striking example is Ukara island, where heavy applications of cattle manure are combined with a green leguminous mulch and cattle are permanently stalled (Upton, 1973). In higher rainfall areas cotton production and cattle health are more stable and more diverse crops are grown (McCulloch, 1965). In areas of lower rainfall and population density more food crops are grown, cotton production is more variable, planting is more staggered, epizootics are more frequent and the return on land and labour is higher, indicating relatively low levels of intensification (Von Rotenhan, 1968; Ruthenberg, 1968). The inhabitants report that hunger due to drought is a common experience and they plant cassava as a famine crop (Hankins, 1974).

However, the most interesting zonation in Sukumaland coincides with the distribution of livestock.

### 3.3 *Cattle ownership*

The Sukuma are primarily agriculturalists rather than pastoralists. In earlier times wealth may have been represented by iron hoes and small stock. However, by 1875 cattle had become a major source of wealth. They represented a system of exchange, insurance and investment in an economy without money, central government or banks. Their importance in connexion with bridewealth, and so with social reproduction in general, has already been noted.

Sukuma cattle are beset by numerous diseases, some of which are contagious and others, even more important economically, borne by tick and tsetse vectors. Rinderpest, a contagious viral disease, breaks out at irregular intervals. Trypanosomiasis, caused by protozoa and carried by tsetse fly vectors, was conquered by banishing the fly to the edges of Sukumaland, where it remains important. By 1965 it was possible to control most epizootic bacterial and viral diseases by prophylactic vaccination, hygiene and quarantine (McCulloch, 1965). Sporadic outbreaks of blackquarter, anthrax and haemorragic septicaemia were under control. Vaccines were available to control tick-borne diseases such as anaplasmosis, babesiosis and rickettsiosis, but had not been introduced because of handling difficulties.

The most serious threat is theileriosis, East Coast Fever (ECF), carried by cattle tick vectors. There are no curative drugs and immunization techniques, developed in the late 1960s, are difficult to apply on a large scale (Wilde, 1976, FAO, 1977). Epizootics occurred in 1957/8, 1960/1 and 1962/3 which killed between 50 per cent and 100 per cent of the cattle in infected herds.

Hutchinson (1965 a,b) discussed the age and sex structure of Sukuma cattle herds in some detail. He estimated that stocking levels in Sukumaland were approximately 35 per cent higher than recommended for maximal sustainable yield, and herds contained a disproportionate number of old, unproductive animals. Although the Sukuma own 36 per cent of the cattle in Tanzania, they were and are contributing only 3–15 per cent to the national cattle market (Hutchinson, 1965; Hankins, 1974).

The cattle herds are not of equal size; it has been estimated that 30–40 per cent of Sukuma own 60–70 per cent of the stock (McLoughlin, 1970). Overstocking is principal cause of soil erosion and there is much debate as to the conditions under which stock reduction, destocking, may be expected to occur (Yeoman, 1964, McCulloch, 1965, Hutchinson, 1965, Von Rotenhan, 1968). According to McCulloch destocking will not be feasible until cotton production and cattle diseases have been stabilized, reducing the uncertainty from year to year. Von Rotenhan suggests that attitudes towards cattle will change when the demand for meat and milk increases as the result of greater purchasing power from the sale of cash crops. A village grazing committee may then be established to manage grazing guards. The alternative that he proposes has long been suggested in Sukumaland – the individualization of land ownership.

However, the Sukuma people deliberately overstock their land in order to combat disease. To understand why, it is necessary to examine the ecology of their diseases in some detail.

## 4. THE ECOLOGICAL PERSPECTIVE

The vegetation in Sukumaland is so managed by the people as to exclude two principal pests – the tsetse fly and the cattle tick. This they achieve by removal of woodland and intensive grazing of grassland, creating as a result ideal conditions for soil erosion by wind and water. In order to understand the importance of these pests and the conditions necessary for their control it is necessary to examine their ecology.

Nash (1969) has suggested that the economic and political development of much of Africa has been hindered by the tsetse fly, which denied man access to animal transport and ox ploughs, forcing him to rely on head porterage and hand hoes. However, the cattle tick may have had an equally important role. Tsetse fly feed on wild hosts, deny large tracts of woodland to access by cattle and are readily removed by destroying their woodland habitat. Ixodid ticks, on the other hand, do not thrive in unstocked country. Rather, they occur in areas from which tsetse have been excluded and cattle introduced. Thus the tick problem advances as the tsetse fly retreats. Yeoman (1964) points out that in spite of this fact none of the special research and control organizations instigated for the fight against tsetse had their parallel in organizations for the fight against the tick. He speculates that this may have been because the importance of tsetse is apparent from the blank spaces on the map while ticks just indicate the presence of yet another cattle disease. Ford (1971) suggests that the colonial administrations believed, misguidedly, that the presence of tsetse had prevented indigenous African peoples from developing a proper animal husbandry. If tsetse were removed cattle would flourish and their owners would eat them instead of using them as a symbol of wealth. In Ford's view this hypothesis cannot be correct as most of the cattle in East Africa live out of contact with tsetse. Nevertheless, it may explain the effort which was devoted to tsetse research.

### 4.1 *Tsetse fly ecology*

Four species of tsetse fly (*Glossina*) are found in Sukumaland, with specific, but overlapping, preferences for woodland habitat and mammalian blood. They are adapted to living in hot dry places by searching for cooler, more shaded patches and

heir peculiar biology makes them especially vulnerable to control by habitat manipulation. A single egg is produced and retained in the uterus where the larva is nurtured on milk-like secretions. It is thus protected from a hostile and desiccating environment. When mature, the larva is deposited on the ground in favourable sites where there is plenty of shade and loose soil or litter. It burrows rapidly downwards and becomes a hardened puparium which is resistant to desiccation and predation. Micro-climate is an important determinant of its survival. At temperatures above 30°C, for example, fat metabolism exceeds development rate. After a month in the ground the adult emerges. Both sexes feed exclusively on blood, and mating often takes place in the vicinity of the host. The female mates only once and then produces two to three offspring per month for two to three months.

Tsetse flourish within a relatively small temperature range, 21–28°C (Glasgow, 1963), and are found in deciduous woodland. As the dry season progresses the woodland loses its leaves and the flies retreat into denser patches seeking shade and cool spots. Their pupae are then highly aggregated, whereas in the wet season they are scattered widely. Under moderate conditions they prefer to rest in intermediate shade. Although strong fliers, they disperse slowly and seldom venture far onto the plains. Infestation of new woodland proceeds slowly, the population advancing like a wave about 1 km per generation.

The preferred mammalian hosts of tsetse are Suidae (warthogs) and Bovidae (giraffe, buffalo, cattle, bushbuck). They feed for one to ten minutes, then fly sluggishly to the nearest tree to rest. They feed in shade but hunt by sight in open places.

The blood of many of these wild hosts contains a protozoan parasite, genus *Trypanosoma*, which lives in its host almost as a commensal. These multiply in the gut of the tsetse fly and migrate to its mouthparts from whence they infect a new host during blood-feeding. The species *T. vivax*, *congolense* and *brucei* cause nagana disease in cattle. The species *T. rhodesiense* is extremely virulent to humans, in whom it has not yet adapted the ability to coexist. The incubation period in the fly varies with species, being longer for *T. brucei* and *rhodesiense*, and infection rates are correspondingly lower. Rhodesian sleeping sickness has symptoms of fever, headaches and swelling; death may occur within months. The principal hosts are bushbuck, which tend to live in thickets. The disease is a zoonosis spread by tsetse fly to rural man (Apted, 1970).

Infections of cattle with *T. congolense* or *vivax* vary greatly in their severity, duration and outcome (Fiennes, 1970). Symptoms typically include emaciation, fever and weakness, and death may occur within ten days. Alternatively the cow may appear to recover while remaining infected. This state is referred to as premunity – the host is refractory to fresh infection with the same species and strain of trypanosome, yet liable to a recrudescence of the disease if subject to stress. Therefore the cattle herd may be maintained in the vicinity of tsetse country if provided with good grazing and not required to work. According to Fiennes it is the practice in many parts of Africa to deliberately take cattle into lightly infested tsetse country at certain periods in order to expose them to infection and allow the development of premunity. Cattle mortality is then often highest at the end of the dry season when nutrition is poor and the herd is stressed. It was the custom in Sukumaland to graze the cattle in woodland at that time, for the threat of further

infection in the premunized herd would be smaller than the threat of recrudescence due to nutritional stress.

Nineteenth-century Sukumaland may be pictured as a state of dynamic equilibrium (see Fig. 2). Grassy plains and grazing cattle were contained by woodland with wild game, trypanosomes and tsetse fly. Where woodland invaded the plains it was cleared by man; where cattle invaded the woodland it was attacked by tsetse. The rinderpest pandemic of 1891 destroyed this equilibrium (Ford, 1971): both cattle and wild game died in large numbers; the tsetse fly, deprived of woodland game, disappeared. The catastrophes which struck man and cattle on the plains enabled the woodland to regenerate. The plains shrank and were replaced by woodland free of tsetse. People and cattle, concentrated into a smaller area, reproduced rapidly and began to expand outwards into the woodland until, during the 1920s, they collided with the recolonizing tsetse fly and wild game. Epidemics of trypanosomiasis resulted. This picture is, of course, overschematic, since trypanosomiasis epidemics were found in discrete foci rather than a broad front.

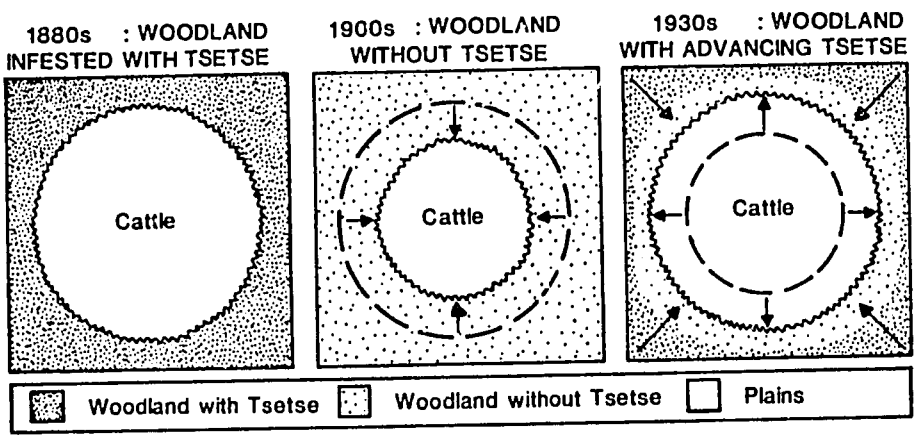


Fig. 2. *Woodland, cattle and tsetse 1880s–1930s.*

The first epidemic of Rhodesian sleeping sickness occurred around the north shore of Lake Victoria at the turn of the century and has been attributed to the European invasion. As it spread south around the Lake the mortality rate was very high, and this probably initiated the intense scientific effort devoted to sleeping sickness in the succeeding half century. However, later epidemics have occurred in restricted foci and affected much smaller populations. Whereas many millions of people are potentially exposed to the parasite there are generally less than 2000 cases per year. Apted (1970) attributes the low case rate to the constant vigilance of medical authorities. Partially effective drugs were introduced as early as 1905 and the epidemic died out by 1914. A natural focus of infection appears to have been established around the Simiyu river, near Maswa. An epidemic occurred in the woodland villages there and reached its peak in 1922. The British administration reacted by resettling the population on the plains and the epidemic died out. It was not until later that it was fully appreciated that the disease was a zoonosis and the strategy of resettlement was replaced by bush clearance. This focus is now attributed

to the proximity of the Serengeti Game Reserve with its large herds of wild animals (Ford, 1977). Another epidemic started in Southern Tanzania in 1930 and spread north to Mwanza (Duggan, 1970). A focus was established in Geita district, to the west of Mwanza. In the 1930s this area was heavily wooded with a small human population largely confined to the shores of Lake Victoria. The epidemic was controlled by resettlement and aerial surveys were undertaken with a view to developing the region. The Sukuma began settling this area from the mid-1930s in response to population pressure in central Sukumaland. After 1947, settlement was encouraged by the Sukumaland Development Scheme, as previously described. Under this scheme settlement was to have occurred at carefully controlled densities in order to conserve natural resources. An epidemic of Rhodesian sleeping sickness occurred among the van of the settlers which led to increased concentration of settlement and more systematic bush clearance. The planned settlement densities were not maintained and Geita district developed a thriving cotton industry and cattle population similar to older parts of Sukumaland (Anthony and Uchendu, 1974). The threat of sleeping sickness was removed with the woodland.

After the 1920s the tsetse belt restricted available grazing and the cattle population density began to increase. Ford graphed the subsequent growth of the cattle population in Sukumaland between 1913 and 1957. While the general trend is upwards, the curve is not concave as would be expected with a population growing without limit, but rather convex as would be expected by a population nearing the limits of its carrying capacity. The growth of the cattle population appears to have followed a classical logistic curve but two separate mechanisms were probably involved. In the centre of Sukumaland the cattle population was limited by starvation. At the periphery there was contact with tsetse fly and growth was limited by trypanosomiasis. In the conflict between people and fly it was the people who were winning, by bush clearance and cattle premunity. The periphery expanded and the cattle population increased at a rate controlled largely by the available grazing area. This model of the dynamics would predict that there was an area between centre and periphery where herd growth-rate was not restricted by either nagana or starvation, and it would be to the advantage of the individual to ensure that his herd grazed here. However, this advantage may be masked by the effect of drought and tick-borne disease which would be important to the individual but only causes a ripple on Ford's graph of the total cattle population.

Moreover, Sukumaland is not encircled by woodland but forms a corridor (Fig. 3) hemmed in by tsetse-infested bush. To the west *G. morsitans* inhabits the tall, open-canopied, *miombo* woodland (Buxton, 1955). To the east *G. swynnertoni* is found under the drier and smaller *nyika*, 'thorn bush', woodland. This bush exerts an 'ecological pressure': woody vegetation and tsetse fly tending to recolonize the open plain wherever human activity is diminished.

There are, of course, more subtle ways by which to control tsetse other than the wholesale destruction of woodland. However, complete destruction is not without merit (Ford, 1970). It is easy to accomplish without expert assistance, is an effective anti-tsetse measure, opens the land up for farming, improves the quantity and quality of grass for grazing, and may even raise the water table. A good grassland is at least as effective as woodland at preventing soil erosion – unfortunately it also creates a new disease hazard as described in the next section. An alternative to total clearing

is partial clearing (Welch, 1970). It is usual to distinguish selective and discriminative partial clearing. Selective clearing alters the shade available to adults and puparia by removal of either the understorey or upper canopy. Discriminative clearing is small-scale total clearing of woody vegetation at the boundary between woodland and grassland. The main problems associated with partial clearing are organizational and financial, as discussed by Welch. A high standard has to be maintained in order for the clearing to be cost-effective. In practice it is often either badly organized or too expensive. Partial clearing could help to solve the resource-management problems in Sukumaland by reducing soil erosion and providing fuel and building material.

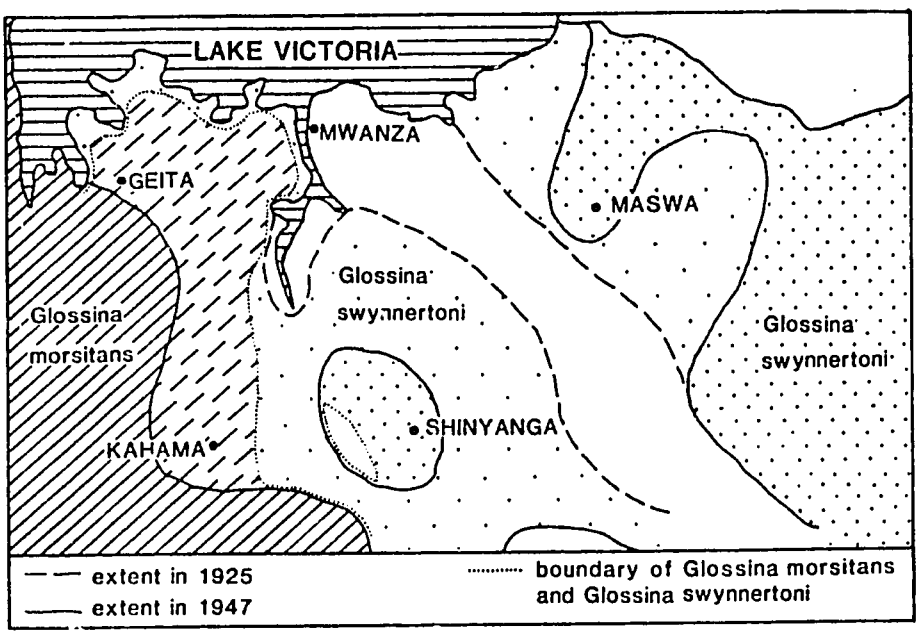


Fig. 3 *Tsetse-infested bush in Sukumaland (Ford, 1971).*

Other methods of tsetse control include destruction of wild game, biological and genetical control and the use of insecticides. Many of these measures have been tried in Sukumaland, as reviewed by Glasgow (1960) and Ford (1971). Ultimately it was the large-scale destruction of woodland by an expanding population which drove out the tsetse and it is only the continual agricultural activities of the populace which maintains this condition. If the bush were allowed to regrow and, in the absence of effective and expensive chemical control, the fly reinvaded, the cost of new trypanosomiasis epizootics would be difficult to bear.

### 4.2 *Tick Ecology*

Ticks surpass all other arthropods in the number and variety of diseases which they transmit to humans and domestic animals, and a selection of these are prevalent in Sukumaland, as Table 2 indicates (Arthur, 1962; Yeoman, 1964; Walton, 1964; Hoogstraal, 1967). Ticks feed exclusively on blood and often live in the open field,

yet – paradoxically – they have neither wings nor other means of rapid movement with which to locate a host. Control of ticks and tick-borne diseases depends, as does tsetse control, on an understanding of their special habitat requirements and feeding strategies. Four groups of ticks may be distinguished.

TABLE 2 *Some tick-borne diseases in Sukumaland*

| *Clinical conditions* | *Disease organism* | *Tick vector* | *Tick habitat and habit* |
|---|---|---|---|
| Human Disease | | | |
| Relapsing Fever | *Borrelia duttoni* (Spirochaete) | *Ornithodorus moubata* s.l. | African dwellings |
| Tick Typhus (importance unknown) | *Rickettsia conori* | *Rhipicephalus appendiculatus* etc. | field |
| Cattle Disease | | | |
| Redwater Fever | *Babesia bigemina* (Sporozoa) | *Boophilus decoloratus* | one host |
| Anaplasmosis | *Anaplasma marginale* | *B. microplus* | |
| East Coast Fever | *Theileria parva* (Sporozoa) | *Rhipicephalus appendiculatus* | three hosts |
| Heartwater | *Rickettsia ruminantium* | *Amblyomma variegatum, gemma* and *lepidum* | three hosts |

Soft ticks have adopted the strategy of living in their hosts' dwellings: animal burrows, hen coops and human housing. They hide in cracks and crevices or earth floors and venture forth at night to feed rapidly on sleeping hosts. The species *Ornithodorus moubata s.l.* infests about 90 per cent of traditional housing in Sukumaland and transmits a spirochaete which causes relapsing fever (Walton, 1964). This is a serious disease although immunity may be acquired and treatment with antibiotics is effective (Manson-Bahr, 1966). The nuisance value and disease association of this soft tick are widely known among African peoples. Walton has suggested that several cultures have evolved housing designs which reduce tick incidence. Some are known to carry soft ticks with them on long journeys, reinoculating themselves at intervals and thus ensuring that they do not lose their immunity. Epidemics have occurred during the twentieth-century owing to large-scale population movements, associated particularly with the two world wars (Good, 1977). These are attributed to the lack of cross-immunity between local populations of the spirochaete. Good suggests that the epidemic which occurred in Sukumaland between 1953 and 1955 may be explained by the large-scale purchase of bicycles by peasants benefiting from cotton production. In the earlier parts of the century relapsing fever was prevalent along migrant-labour routes, severely affecting the economic benefits that peasants might gain from migrant labour.

The remaining three groups of ticks are all hard ticks, the family Ixodidae. Their habitat is the open field and they are predominantly pests of livestock and domestic animals. They may be distinguished by their life-cycles. The hard tick life-cycle comprises an egg, larva, nymph and adult with one blood-meal generally required

between each moult. The feeding tick remains attached to its host for periods of several weeks, inserting its barbed mouthparts into the skin and often causing mechanical injury as well as inoculating the host with pathogens. After feeding the immature stages moult either on the host or among pasture vegetation. If they moult among the vegetation then they seek a new host for their next blood-meal. The three groups of hard ticks are distinguished by their need for one, two or three hosts on which to complete the life-cycle. The gravid adult always oviposits among pasture vegetation, laying one large batch of eggs in the soil before dying.

Clearly, the different feeding strategies evolved by ticks have important implications for disease transmission and tick control. A tick which remains attached to its host for most of its life may be controlled most readily by applying pesticide to the host, for example by dipping. Very few of the population will be in the pasture at any time. A one-host tick (*Boophilus* spp.) cannot transmit pathogens acquired while feeding to a new host during a subsequent blood-meal. Pathogens can only be transmitted transovarially. At the same time the one-host tick is less exposed to the vagaries of the environment (and thus less susceptible to control by environmental modification) but more exposed to natural enemies, such as birds which consume ectoparasites from cattle hides. The two- and three-host ticks (e.g. *Rhipicephalus* spp.), by contrast, may acquire pathogens from one host and transmit them during a subsequent meal on another host. There will be a larger reservoir in the field and a smaller percentage of the population will be destroyed by chemical dipping. They are more exposed to the hazards of host finding and more easily controlled by environmental modification.

Field survival by hard ticks depends on a complex response to light, temperature, humidity, gravity, vibration and so on. The tick must seek out a relatively humid micro-climate in which to moult and then a relatively high point in the vegetation on which to await a passing host. The ability to attach rapidly to a passing host must be matched by the ability to remain alive and capable of activity in a relatively exposed position for considerable periods. They seek strong stemmed vegetation and shelter from sunlight and wind. Despite their hardiness, high temperatures and drying conditions must eventually exhaust their food and water reserves. The general appearance and physiognomy of the vegetation, especially the close ground cover, is an important determinant of micro-climate, mitigating extremes and serving as a substrate for the condensation of dew, which is probably a vital factor in the survival of ticks under arid conditions (Yeoman, 1967 (3) ). The grass also provides the bait which lures grazing ruminants to where the ticks lie in wait. Therefore tick control can be achieved by environmental sanitation through the reduction of ground cover.

East Coast Fever (ECF), caused by *Theileria parva*, is economically the most important cattle disease in Sukumaland (Yeoman, 1964). Mortality rates among fully susceptible animals are very high, but those which recover tend to be immune and to transmit partial immunity to their offspring. The pathogen can be destroyed in the tick by starvation for more than 266 days, or temperatures above 33°C, and the tick cannot thrive at temperatures above 30°C or relative humidities below 80% (Arthur, 1962, Yeoman, 1964; Radley, *et al.*, 1978; Branagan, 1973). The tick tends to discharge its entire burden of parasites at one blood-meal. *T. parva* infections of African cattle appear to be of ancient origin and there is a wild-host reservoir (of at least one sub-species) in the buffalo *Syncerus caffer* (Purnell, 1977). The organism

cannot be transmitted transovarially and the principal vector is the [illegible] *Rhipicephalus appendiculatus*.

Yeoman, in a series of classic papers (1966–67), examines the correlation between tick species, cattle density, climate, ECF epizootics, vegetation and soil type on a transect through Sukumaland from, roughly, Lake Victoria to Shinyanga. His study was partially prompted by the observation that ECF epizootics occurred in a restricted zone in a region of fairly uniform cattle density. On one side of this zone ECF was enzootic, on the other side it was absent. Large-scale attempts to persuade the Sukuma to dip their cattle in any zone had failed and improved management would clearly depend on a more detailed understanding. McCulloch, *et al.* (1968) enlarged on Yeoman's study and the combined results demonstrate both the complexity of the region and the ecological insight of the people.

Malcolm (1953) has already recorded the Sukuma practice of deliberately overstocking (*kutobanga*) in order to induce a short, sweet herbage inimical to ticks (*peupe*), and that this is associated with dry season hardship but freedom from disease. Yeoman (1967 (3) ) describes how, on hardpan soils, the natural vegetation, when ungrazed, forms a stand of medium height perennials which survive the dry season as standing hay. With overgrazing these are replaced by short annuals, surviving the dry season as seeds, forming an attractive green sward during the early rains but without a mat of humus and roots. In the dry season this is quickly wilted and grazed leaving a bare hard or powdery earth with a scattering of chaff. Small areas of taller vegetation are left on '*mbuga*' soil, associated with the soil catena, but these are not central to the main discussion.

Yeoman's diagrammatic summary of the transect is reproduced in Fig. 4. This demonstrates that the enzootic ECF zone near Lake Victoria, where rainfall is higher, is associated with tall perennial grasses while the clean, ECF-free zone in the hinterland is associated with short annual grasses. In the intermediate zone the height and constitution of the grasses is determined by grazing pressure and this, in turn, determines tick population density. Cattle movement introduces ticks and *T. parva* infection into this zone when conditions are right, leading to an epizootic of ECF. Yeoman and McCulloch's interviews with the local people indicate that they are conversant with the correlation between changing vegetation and ECF. Yeoman points out that several years' delay may occur between the initiating factor leading to a change of grass cover and the actual ECF epizootic. He suggests that the initiating factor is probably not directly climatic but rather a reduction in grazing pressure as a result of drought, rinderpest and other diseases or deliberate destocking measures. It is salutary to consider that 'well-intentioned efforts to reduce stock numbers on the grounds of good-husbandry and pasture and soil conservation, in the absence of measures to control tick numbers could lead to an outbreak of disease' (Yeoman, 1967 (3) ). Three final points from Yeoman's study should be noted: firstly, he suggests that biological control methods could be especially useful at the edge of a pest's range, where slightly tipping the balance may be sufficient; secondly, he suggests that a hay-mowing strategy could both conserve pasture and control ticks; and, thirdly, he observes the interesting anomaly that ECF epizootics can occur at surprisingly low tick densities, where the infestation rate can be overlooked by veterinarian and owner alike and where dipping tanks would only remove one or two ticks per animal.

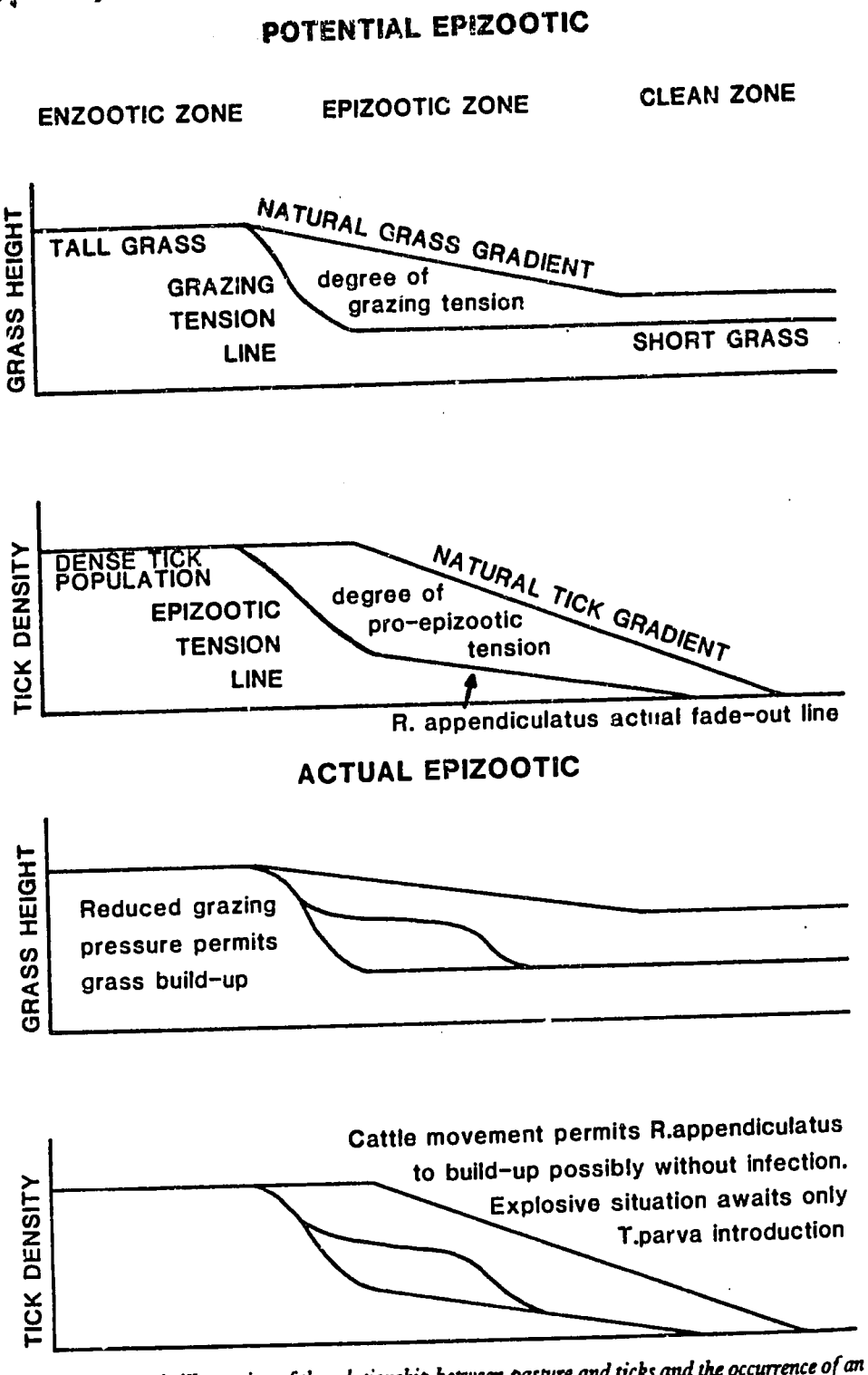


Fig. 4 *Schematic illustration of the relationship between pasture and ticks and the occurrence of an East Coast Fever epizootic (Yeoman, 1967 (3) ).*

McCulloch *et al.*'s studies between 1965 and 1968 trace the boundaries of the epizootic zone in successive years and these are reproduced on a sketch map of Sukumaland in Fig. 5. It is interesting to note that the epizootic zone has completely overrun the 1957–60 boundary and this was confirmed by an FAO survey in 1974–75 (FAO, 1977). It appears that *R. appendiculatus* is extending its range in a number of African countries and it has been suggested that an increase in dry-season rainstorms may be responsible. McCulloch *et al.* also made a detailed record of the mortality and movement of cattle from selected farmsteads in each zone and the highlights of that research are listed in Table 3. There was evidence of high calf mortality from ECF in the enzootic zone and from starvation in the clean zone. However, the most important observation was the high annual turnover of herd composition.

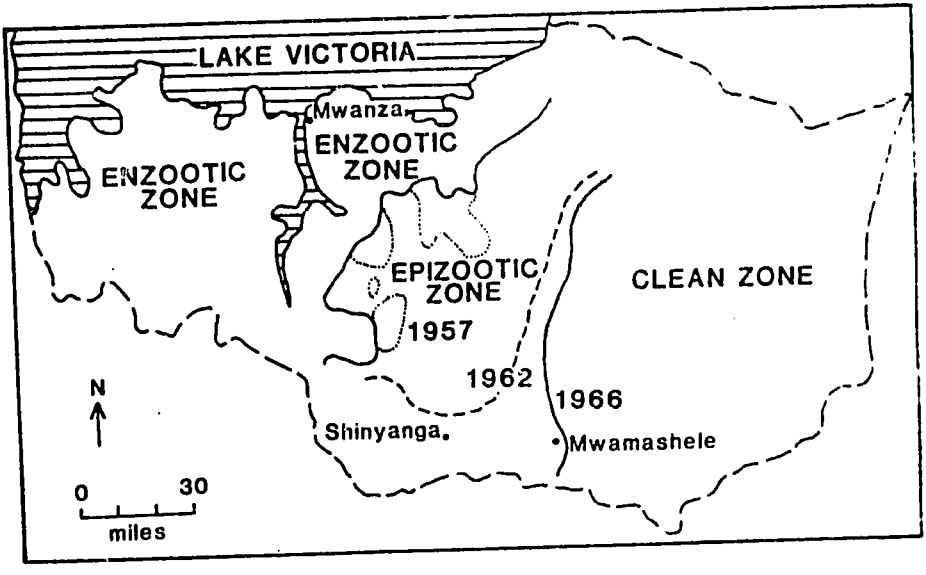


Fig. 5 *Sketch map of east coast fever zones in Sukumaland, Tanzania. (McCulloch* et. al. *1968).*

TABLE 3 *McCulloch* et al.*'s record of annual cattle herd changes in all three ECF zones of Sukumaland.*

| *Source of change* | *Enzootic zone* | *Epizootic zone* | *Clean* |
|---|---|---|---|
| Percentage death from ECF Adults | 9 | 15 | 5 |
| Percentage death from ECF Calves | 46 | 46 | 4 |
| Total deaths from starvation | 0 | 5 | 73 |
| Percentage in herd composition (Percentage inwards + percentage outwards) | | | |
| Bride-wealth | 14 | 14 | 17 |
| Purchase | 13 | 11 | 16 |
| Sale | 10 | 16 | 16 |
| Gifts | 5 | 2 | 10 |
| Loans | 1 | 1 | 13 |
| Inheritance | 3 | 0 | 8 |
| Total | 46 | 44 | 80 |

The composition of the cattle herds changed by an average of 58 per cent each year while only 1.2 per cent, representing excess of sales over purchases, actually left the community. Cattle movements appeared to occur in all directions and over large distances, with susceptible cattle moving into enzootic zones and infectious cattle, with their ticks, moving into clean zones. A large proportion of this turnover was due to the payment of bride-wealth. This would be most difficult to control, owing to the social importance of bride-wealth in the community, and therefore a continual mixing of cattle from the three zones may be expected. This is probably one of the major driving forces behind the re-occurrence of epizootic ECF in Sukumaland as Yeoman, in his earlier study, has suggested.

These studies emphasize the importance of ECF in regulating the decision-making behaviour of the Sukuma people with regard to cattle and grazing land management. The picture of Sukumaland as a corridor bordered by tsetse-infested bush may therefore be enhanced by the addition of tick-infested grassland pressing down from the north. The composite image is illustrated diagrammatically in Fig. 6. The northern boundary is Lake Victoria, there is tsetse-infested bush to east and west and a moisture gradient leads to more arid conditions in the south. Central Sukumaland is envisaged as bounded by diverse ecological pressures which constantly tend to diminish the economy. The people combat these pressures using the only technique which is both readily available and guaranteed to succeed.

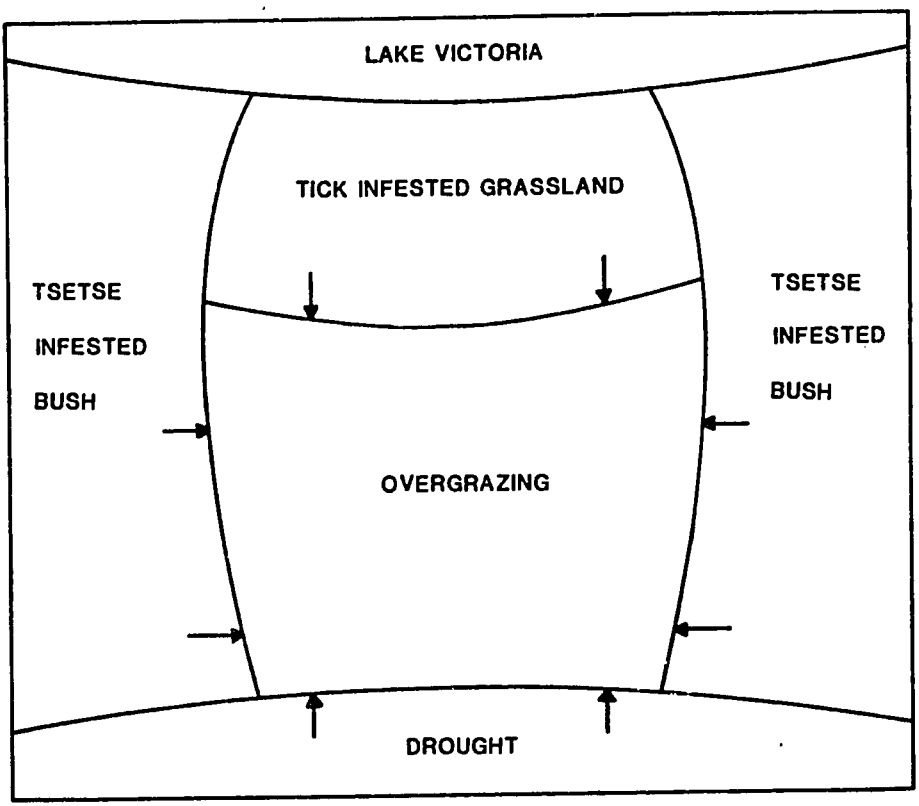


Fig. 6 *Schematic representation of Sukuma ecological dynamics.*

By maintaining large cattle herds and old animals the Sukuma combat tick-borne disease in two ways. First, overstocking and overgrazing destroys the tick habitat. Second, old animals are largely immune to ECF when constantly challenged and ticks lose their entire parasite burden at each blood-meal. Therefore, old animals dilute the challenge experienced by the herd and reduce the total number of infected ticks which feed on calves. Herd size and composition may appear sub-optimal when the objective is profit maximization, but could be optimal when the objective is risk minimization.

Cattle dipping provides an alternative to overstocking as a method of preventing tick-borne cattle diseases, but dipping schemes have rarely met with success. Yeoman (1964) describes a number of problems associated with dipping schemes. These include persuading people to travel 16 km or more to a dip over difficult terrain. In the wet season this could involve swimming torrential rivers which are hazardous and also wash off the acaricide. In the dry season cattle may already be stressed by long marches in search of water or there may be insufficient water to maintain the dip (FAO, 1977). In the enzootic zone for ECF calves encounter the disease early in life. The survivors are reasonably immune, if stunted, and immunity is reinforced by natural challenge. Dipping removes the challenge and may render the herd susceptible. The tick must then be permanently eradicated or the risk of an epizootic is enormous. Under enzootic conditions calf mortality is 10–30 per cent from all causes including starvation. Under epizootic conditions it is 30–70 per cent. It is, therefore, rational for a Sukuma farmer to resist dipping.

Effective new methods of ECF control are urgently required. Research has aimed at the development of a suitable form of immunization. A method has been developed at Muguga, Kenya, which involves the simultaneous injection of several strains of *T. parva* and of antibiotic. This has been tested in the field and found to be efficacious (FAO, 1977). However, strains vary over relatively small distances. Improvement in cattle dipping would be necessary before ECF could be controlled on a scale large enough to convince the Sukuma people to abandon their policy of overgrazing. Studies by FAO (1977) have demonstrated that the concentration of active acaricide, especially gamma BHC, in dips is not being maintained at an effective strength. A change to the more long-lasting acaricide 'toxaphene' has been recommended. Yet already there are reports of tick populations resistant to this acaricide in West Lake region.

The FAO report has recommended a strategic dipping programme based on detailed surveys of: (1) the serological evidence for the occurrence of ECF; (2) the presence of acaricide resistant ticks; and (3) the areas where the tick breeds seasonally or all the year round. In order to eradicate ECF it would be necessary to dip all cattle once a week in specified months of the year while ensuring that each dip manager maintained adequate supplies of acaricide and water, monitored the concentration of acaricide and tested for the presence of resistant ticks. Such a policy would clearly be impractical at present, owing to the limitations on transport and communication which prevail throughout much of East Africa. A more limited approach must be adopted. Economically important losses occur when improved cattle are distributed from ranches with good tick control to villages where control is generally inadequate. Further losses occur when susceptible cattle are marched through enzootic zones to a railhead or kept in holding grounds at the railhead

awaiting shipment. For example, 17 per cent of all cattle purchased for shipment and slaughter in Dar es Salaam die of tick-borne disease between purchase and slaughter. These losses could be prevented by a combination of dipping with long lasting residual acaricide and immunization.

## 5. A BREAKPOINT MODEL OF RANGE MANAGEMENT

By their resource management practices the Sukuma attempt to hold four interacting biotic populations in dynamic equilibrium. These are the populations of cattle, disease vectors, disease-causing pathogens and pasture vegetation. If effective techniques for controlling vectors and pathogens other than by pasture management were introduced then alternative objectives for cattle management could be considered. The regional planning objective is relatively clear: to increase meat production and decrease soil erosion, thus promoting the long-term prosperity of the region. In order to achieve this objective the cattle management practices of the people may have to be replaced by modern cattle-management technologies. This would probably mean changing from extensive rangeland grazing to ranching and the regional administration could attempt to promote this change by persuasion, legislation or force. The new management strategy would then be to maximize sustainable yield.

The present management objectives of the cattle herders are more complex, as demonstrated above. These objectives pertain to survival in the immediate future and a suitable descriptive shorthand may be risk minimization. At present Sukuma cattle herds are not optimal in size, sex ratio or age distribution, when measured in terms of the regional objective. They may, however, be optimal when measured in terms of the cattle herder's own objectives and bearing in mind his management constraints.

In order to change from the old to a new system it might be supposed, and has often been suggested, that destocking is the principal requirement. It is, perhaps, implicitly assumed that there is a smooth continuum between two separate states of cattle management. I speculate that rather than a smooth continuum there is a series of discontinuities. I suggest that these discontinuities may well be perceived by the Sukuma, as part of their own folk-ecology, more readily than by the Western-trained veterinarian. The modern theoretical understanding of such discontinuities is a recent development (Holling, 1973). This speculation may be developed further by using a simple theoretical model proposed by Noy-Meir (1975) which considers the dynamics of cattle-grazing pasture vegetation.

This theoretical model attempts to highlight certain characteristics of a grazing system by ignoring others. For example, it ignores the specifics of cattle husbandry, the nutritional status of different grasses and the effect of competition by wild herbivores. The plant community is lumped together in a single variable representing the density of edible biomass available to a single species of herbivore. The herbivore population is also lumped into a single variable representing the density of grazing herbivores. The rate of change of plant biomass is then equal to the rate of growth less the rate of consumption and the rate of growth depends only on the plant biomass present. The relationship between plant growth rate and plant biomass in the ungrazed system is illustrated in Fig. 7a. At low biomass growth rate

increases as leaf area increases. At high biomass growth rate falls as shading, competition and woody vegetation increase.

a. *Growth rate of ungrazed vegetation as a function of edible biomass.*

b. *Consumption rate of grazed vegetation as a function of edible biomass.*

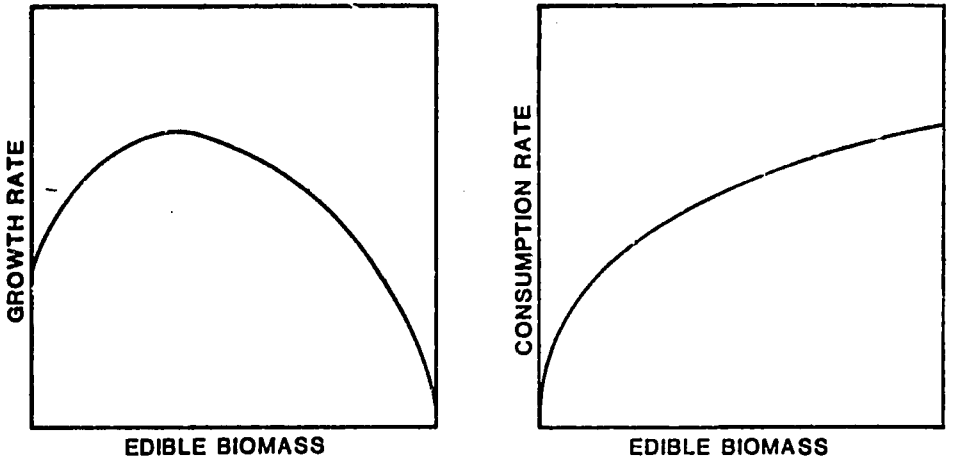


Fig. 7 *Plant–herbivore relationships (Noy-Meir, 1975).*

Similarly, the rate of consumption of plant biomass per animal unit depends only on the quantity of vegetation present (see Fig. 7b). At low plant biomass intake is limited by foraging ability, and at high biomass a saturation level is reached depending on the animal's digestion rate. Consumption is used both for maintenance and for reproduction. When Figs. 7a and 7b are combined a series of intersecting points may be obtained which depend on herbivore density or stocking rate. Each intersection represents an equilibrium point and these points form a continuous line (see Fig. 8), when stocking rate is plotted against plant biomass. Steady states are represented by a solid line and unstable states, or breakpoints, by a dotted line. The steady states are conditions of dynamic equilibrium and, at fixed stocking rate, a perturbation in available biomass is followed by a return to equilibrium along the direction of the arrows. At certain stocking rates there are two stable equilibria. At the lower equilibrium plant biomass is scarce, the herbivores are malnourished and spend much effort locating food which barely sustains them. At the higher equilibrium there is ample vegetation, the herbivores are well-nourished and highly productive. A constant removal rate of herbivores is required to prevent the stocking rate from increasing.

This theoretical model can be used to consider the possible consequences of destocking. If the grazing land is initially overstocked, at equilibrium point (a) on Fig. 8, an initial reduction in stocking rate will promote a smooth transition until point (b) is reached, with only slight improvement of either the vegetation or the stock condition. As the stocking rate is decreased still further a sudden change will occur, the vegetation will grow faster than the consumptive capacity of the stock, becoming rich and lush while the stock become fat and productive. If the herd is not culled the stocking rate will increase, from point (c) to (d), and grazing pressure will

improve the quality of the vegetation, reducing shading and leaf area. At point (d) the stock will provide maximum sustainable yield but only a slight increase in grazing pressure will lead to overgrazing, a sudden decrease in available plant biomass and a return to condition (a).

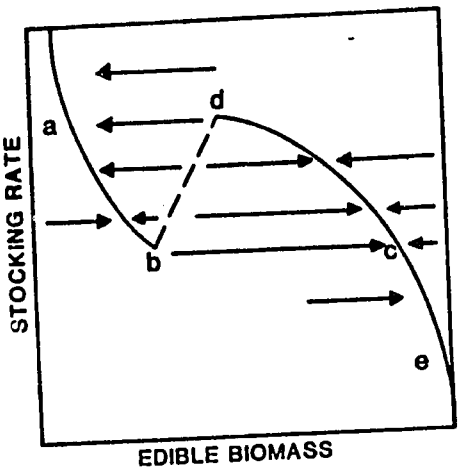


Fig. 8 *The isocline of vegetational equilibria of a plant-herbivore grazing system at various stocking rates (Noy-Meir, 1975). Arrows indicate direction of change following perturbation. The broken line is the breakpoint.*

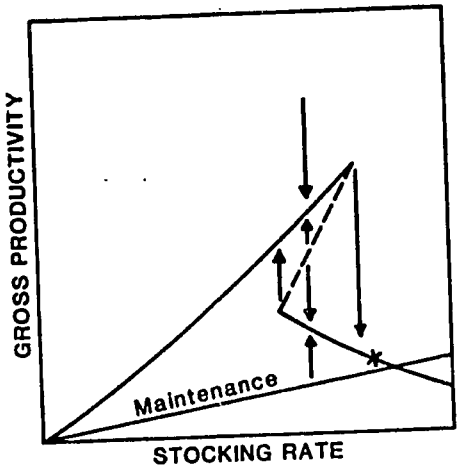


Fig. 9 *Herd productivity and maintenance requirements as a function of stocking rate and at equilibrium vegetational states (May, 1977). Arrows indicate direction of change following perturbation. The broken line is the breakpoint. The cross marks the approximate condition in Sukumaland, with 35% overstocking and 3% net yield.*

Figs. 7 and 8 should now be compared with Yeoman's schematic illustration of changing grazing pressures in the epizootic zone of Sukumaland (Figs. 4 and 5). Clearly, Yeoman and Noy-Meir are describing the same kinds of phenomena. In the enzootic zone the grass is tall and lush while heavy calf mortality, together with sufficient rainfall, maintains the system between points (c) and (d) of Fig. 8. In the epizootic zone grazing 'tension', or pressure, maintains the system near point (b), rather than (c), until a perturbation (e.g. high rainfall or loss of stock) flips it to point (c). At point (b) cattle ticks cannot thrive, for there is inadequate ground cover. At point (c) the tick population increases and an epizootic of ECF occurs following a chance introduction of *T. parva* infections. If destocking continues (as a result of ECF) below point (c) and towards point (e), I speculate that the grassland vegetation would be replaced by a succession of woody plants culminating in open woodland. The tsetse fly would then invade and the cattle would be beset by an epizootic of trypanosomiasis. In the hinterland, or clean zone, the short grass and high grazing pressure maintain the system near point (a).

The plant-herbivore model has been elaborated by Caughley (1976) and May

(1977). May's graphical representation of gross animal productivity as a function of stocking rate is especially apposite (see Fig. 9). The higher curve represents the well managed, productive herd. The broken line represents the transition zone between the two equilibria. The point of maximum productivity is a knife-edge on which balance can only be maintained by rapid response and sophisticated management methods. As that knife-edge is approached the broken line becomes closer to the solid line: high productivity is accompanied by high risk as smaller perturbations are capable of flipping the system to its lower productive state. The straight line represents the animals' maintenance requirement, net yield being the difference between gross production and maintenance. Hutchinson remarked that the Sukuma cattle are 35% overstocked so that the gross productivity is only 3% above the maintenance requirements. The approximate position of Sukuma cattle management can therefore be marked on Fig. 9.

A number of further elaborations of this model are possible and field studies are required to test its validity. For example, separate isoclines could be constructed for each rainfall zone and an isocline of cattle equilibria superimposed (Noy-Meir, pers. comm.). It would then be possible to consider whether regular cyclic phenomena could occur. Vector and pathogen population dynamics could also be introduced, with their associated time-lags. Further questions might include the effect of increasing cotton production. Would the associated vegetational enrichment lead, paradoxically, to additional destabilization (Rosenzweig, 1971)? The objective of such speculative models is not to provide detailed tactical answers for the daily management of Sukumaland. The objective, rather, is to point out strategic management issues which may require attention before interference with the Sukuma way of life. These models illustrate that there may be ecological pitfalls unknown to economists and regional planners which seriously challenge our ability to promote economic development.

The most general feature of the ecological process illustrated here may be the influence of grazing herbivores on the micro-habitat requirements of haematophagous arthropods, which are their potential disease vectors. Similar examples are expected to occur in a diverse range of equivalent circumstances and could explain the incidence of other epizootics.

## 6. PLANNING AND MANAGEMENT

Soil erosion is an important and urgent issue in many semi-arid regions. The conditions under which it occurs, its causes and effects, are numerous and complex, as the present study has tried to demonstrate. Consequently, indigenous populations face a predicament in their management of biotic resources compounded of economic and ecological actuality. Their management decisions are constrained by limited access to capital, labour, technology, communication and suitable land in ways which prescriptions for solving their problems often appear to overlook (Pratt and Gwynne, 1977; Walker, 1979). They respond to such constraints by adopting management practices which may appear 'minimal' (Barnes, 1979) to the outside observer.

Before proposing new management plans for such regions it may be crucial to

determine the cardinal objective. While this is a matter of policy and the prerogative of the state we may, perhaps, ask whether an outside observer could perceive which objectives are more appropriate for the long term survival and development of peoples like the Sukuma. One basis for such a choice might be to consider whether a proposal would improve the structural development of a region or create new disequilibria and inequalities. When a suitable policy has been determined some means must be found to translate it into strategy: how can an indigenous population with a traditional management system, whose objectives, perceptions and constraints are largely unknown, be persuaded to change their management practices in order to meet new objectives? Strategy may depend on additional understanding of the existing system and require multidisciplinary research.

Sukumaland has been relatively rare among the regions of Africa regarding the amount of sustained scientific effort devoted to it. Much of the research was, perhaps, piecemeal and this may be appropriate in the early stages. The Sukumaland Interdisciplinary Rural Research Project, undertaken by Finucane, Hankins, Hulls and others between 1968 and 1970, tried to adopt a broader view. It examined spatial variations in drought and the perception of drought, risk and staggered planting of cotton and food crops. It also examined the structure of the administration, its response to change and the problems of communication. Additional research is needed to draw together all the key economic and ecological components of the system. A general procedure for conducting such research has been proposed by Walker, Norton, Conway, Comins and Birley (1978). This procedure recognizes that while complex systems provide infinite scope for enquiry, an understanding of a few key processes and the links between them may suffice for management. The objective of such research is 'optimal ignorance' (Chambers, 1974).

It is imperative to emphasize the need for dialogue with the indigenous population. While the less productive ecosystems of the world are urgently in need of improved management, they are already full of people who actively manage them. Their cultures are often little understood by the onlooking scientist or even the regional planner. They may live in areas where communication is conspicuously poor and field staff of all specialities are sparse. In seeking to understand their economy and ecology there may be no more cost-effective source of information than the occupants themselves. A procedure which fails to make full use of such a database or fails to involve the occupants in designing new management schemes would be dangerously elitist. However, to elicit collaborative responses from the people is a difficult task, calling for a 'sophisticated simplicity' which may not normally be part of a scientist's training (Chambers, 1974); Richards *et al.* (1975) forcefully argue the same case.

Sukumaland is again fortunate that implicit acceptance of this view is evident in the approach of the Interdisciplinary Rural Research Project as well as in the work by Ford (1971) on trypanosomiasis, Yeoman (1967) and McCulloch *et al.* (1968) on East Coast Fever, and earlier work by Malcolm (1953). The government of Tanzania, under the leadership of President Julius Nyerere, is well known for the policies that it has adopted in this respect. It is accepted that the approach has not yet been successful, but this is hardly surprising considering how little is known of the ecological conditions which determine the pattern of human settlement and enterprise.

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*Résumé*

## La gestion des ressources au pays des Sukuma

Dans la gestion de leurs ressources les Sukuma s'interposent entre une série de luttes économiques, culturelles et écologiques. Pour bien comprendre leur situation, en particulier les causes de l'érosion du sol au pays de Sukuma, on examine la question de trois points de vue: d'un point de vue historique, d'un point de vue économique et d'un point de vue écologique. L'étude historique traite non seulement ce que l'on sait d'une série de désastres qui ont surpris les Sukuma au commencement du siècle mais aussi la politique administrative pratiquée au cours des décennies suivantes. L'examen économique considère les dimensions spatiales et temporelles des risques et la conduite des gens en tant que fermiers et bouviers. L'examen écologique résume l'écologie de deux porteuses de maladies importantes – les tsé-tsés et les tiques – et démontre comme elles sont importantes si l'on veut comprendre les deux autres aspects de la question. On fournit plusieurs modèles dont chacun peut éclairer certains aspects du problème, suggérant des façons dont on pourrait aborder à l'avenir l'organisation des recherches et la politique d'aménagement au pays des Sukuma et ailleurs.