THE INFLUENCE OF AGRICULTURAL PRACTICES ON SOIL EROSION PROCESSES IN CENTRAL TANZANIA

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Introduction

The problem of accelerated soil erosion in central Tanzania is chronic and there does not seem to be a straight-forward answer. Prospective solutions to the physical problem are made difficult by the fact that land use alternatives are limited by the socio-economic infrastructure. Associated processes of erosion and disposition remain part-and-parcel of an established 'conservative' social system operating on a relatively unflexible natural physical system. The two systems are not in harmony to maintain a desirable equilibrium. This paper outlines firstly the geomorphic setting of Kondoa, a district in central Tanzania threatened by accelerated soil erosion. The physical characteristics of the area are then related to the occurrence of erosion. A brief review of agricultural development during the colonial period is made in relation to measures taken to accommodate the problem and these are contrasted to current erosion control measures. Finally, suggestions for the future are made. The main emphasis is on establishing harmony among ecological systems.

Kondoa is a district in Dodoma Region covering an area of about 13,200 sq. km. To the east, Kondoa shares a boundary with Kitete district, Arusha region while to the north it shares a boundary with Hanang district, Arusha region. It is bounded by Singida and Dodoma districts to the west and south, respectively.

The district lies within the central rift zone, i.e. the southward extension of central Tanzania's eastern rift and is, therefore, characterised by block faulting topography. The mean altitude of Kondoa Highlands is about 1550 m.a.s.l. (metres above sea level). Kondoa is drained in a greater part by ephemeral rivers and streams and lies within the Bubu river catchment. In addition, there are various internal drainage basins with Lake Haubi in the north-east, Lake Biacha Sese swamp and its basin at the southern tip of Chivi river being the most conspicuous.

The climate is semi-arid with a mean annual rainfall of between 600-800 mm. The climate permits the growth of dry montane forest, open woodlands and bushed grasslands. Most of the natural vegetation has been cleared for cultivation but has also changed as a result of overgrazing. Consequently, extensive gully erosion has developed dramatically; 29.5 per cent of the total district area is eroded (1,256 sq. km. or 125,599 ha).

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Factors Influencing Soil Erosion

Topography

Slope angle and slope length influence conditions under which surface runoff is likely to initiate sheet and gully erosion. It is generally assumed that the steeper the slope, the greater is surface runoff velocity and volume and so the higher the erosion risk, with other variables held constant. In reality, this is not found as the variables change.

Kondoa district can be described as generally undulating, although the degree of slope and slope length at given locations depict considerable variations. Two distinct escarpments, associated with the central rift zone, can be observed together with a number of residual hills (inselbergs), alluvial flats and floodplains relative to the existing drainage systems. The western escarpment rises to the north of Kondoa town and extends to the west of the Great North Road northward of the upper course of the Bubu river in a north-south alignment. The escarpment is dissected by numerous ephemeral streams such as those separating the Tura and Burku hills, which rise to a level of about 1500 m.a.s.l. The escarpment is eroded along footslopes where grazing is, or used to be, the main activity. Another escarpment of a higher elevation rises to the east of Mondo in a south-west to north-east direction following the Dalai river floodplains. From this escarpment, hill systems rising to about 1800 m.a.s.l. can be observed and include the Congo, Usiria and Mokami hills. These hills are, in fact, inselbergs, the most distinctive topographical feature in the district. These are probably remnants of earlier processes of geologic erosion. Others include the Gai, Itiga, Mangwe and Chanjai hills separating the Mkuku flood plains from the main Kondoa floodplain. To the west of the Mondo-Haubi road more inselbergs, such as the Manki, Mlungia, Bangana, Suruma and Kalamba, occur. Most of these hills are eroded at the footslopes, between areas of cultivation and the steep slopes. Where the vegetation cover has been wholly or partly removed exfoliated granitic rock is exposed.

Most of the severely eroded parts in the district include the areas overlooking Lake Haubi basin, the pediments facing Sese swamp and its adjacent river flood plains and the escarpments bordering Kondoa and Mkuku floodplains. In these areas the slope gradients range between 6 degrees (13 per cent slope) and 15 degrees (33 per cent slope). Well-developed gully systems occur, some having incised 15 m. or more. While topography interacts with other factors for erosion to occur, the relative steepness of the area and the relative lengths of individual slopes have mutually influenced other factors to play their roles in erosion. The occurrence of gullies on relatively gentle slopes suggests that, in this case, slope angle is not the major influencing factor.

Where topography is the main influencing factor ameliorative measures effectively attempted include strip-cropping and terracing. Strip-cropping is especially applicable on slopes too steep for terracing. In soils with high intake, the strip width depends upon slope gradient, as shown below:

Per cent slop	Slope in degrees	Strip width
2—5	1—3	30—33
6—9	3.5—5	24
10—14	5.5—8	21
15—20	8.5—11	15

(Source: Cooke & Doornkamp 1974)

Terracing involves the making of an embankment parallel to the earth contours. It reduces slope gradient, breaks the original slope into shorter units, conserves soil moisture and removes runoff in a controlled fashion. This method has been applied in central Tanzania and its effectiveness is discussed later.

Vegetation

Vegetation cover protects the soil from direct rainfall impact. The roots of vegetation hold the soil together creating a sod, reducing the effect of concentrated runoff upon the formation of rills and gullies. At the same time, root penetration into the soil increases infiltration and reduces runoff and, hence, the erosion potential. However, decayed vegetation also increases the humus content of the soil, which act as a binding agent for individual soil particles. In each case, vegetation improves the structure of the soil retarding the impact of both surface runoff and rain splash.

In Kondoa district, the vegetation types can be categorised as dry montane forest, woodland, bushland, bushed grassland and grassland. Dry montane forests cover the highlands north of Lake Haubi. Woodland is limited to the escarpments between Kolo and Pahi, on isolated inselbergs and the 'Kibawi' areas ('Kibawi' is a traditional circumcision area. Since the areas are reserved for ritual ceremonies they cannot be cultivated on, not grazed regularly, as in other areas). As a result the vegetation in these areas tend to assume natural conditions. 'Miombo' woodlands, especially the normal *Tulbernadia Brachystegia* woodland, occur on inselbergs and other uncultivated slopes. Bushlands, the most extensive vegetation type, is dominated by the deciduous bushland and is reverting back to cultivation. Although the vegetation on the hillslopes is mainly thornbushes, the bushlands in the hills around Gobali and Haubi are dominated by *Dodonea viscosa* interspaced by *brachystegia* and *acacia* bushes. Bushed grassland and grassland occur in pockets unevenly distributed in the area. The mbuga floodplain can be distinguished from areas that are seasonably inundated and permanently wet areas around Lake Haubi, Lake Bicha and the Bubu floodplain (Banyikwa et al. 1979). Though vegetation types can be distinguished, in many cases the zonation is not clear due to overlap.

Judging from the 'Kibawi' vegetation it can correctly be inferred that people's activities have been influential in the present structure and distribution of vegetation in the district. Historical records have indicated that vegetation was cleared during the German

period for land reclamation aimed at removing tsetse flies from the area. Wooded grasslands, ideal for both domestic and wildlife grazing, usually attract tsetse flies. To protect the limited livestock against tsetse infection there was indiscriminate clearing of vegetation. Available documents indicate extensive clearing, especially in the Serya swamp areas and towards Kwamtoro. Other areas included the Chemchem area to the south-west of Kondoa town extending to the Chasinge-Kelema-Chambalo areas, the highlands overlooking the Masai steppe (west of Busi), and the area east and north of Bubu valley. Given the available climatic conditions of low precipitation the original vegetation could not regenerate quickly. During the periods that the land was void of vegetation cover, much of the soil was gradually eroded and it became increasingly difficult for the vegetation to re-establish itself. It should be noted also that clearing provided additional land for occupation by people from areas which already had elements of soil erosion and were considered overpopulated. To provide for their needs, more land had to be opened up and this meant more clearing of vegetation for crop cultivation and animal grazing. With limited land suitable for productive activities, a tendency to concentrate in the few suitable areas led to over population of both humans and bovine after the vegetation was cleared. Vegetation clearing induces soil erosion as long as the land is left bare as this allows soil particles to be carried away by water or wind. Vegetation characteristics of the area are influenced by climate and the two elements together determine the erosion potential of an area.

Climate and Soil Conditions

Of the climatic factors influencing erosion, rainfall seems to be the most dominant, especially in tropical environments. As noted above, rainfall intensity affects vegetation characteristics over an area. The kinetic energy of rainfall (implicit in rainfall intensity) influences rainsplash impact, while rainfall intensity determines the volume of water available as surface runoff affecting erosion. The seasonal distribution rainfall in an area will influence the availability of soil moisture. A single rainfall event is capable of generating the requisite surface flow (runoff) depending upon existing moisture conditions. In tropical environments most of the surface runoff is a result of rainfall which makes it an important element in analysing the erosion probability. Rainfall has to be analysed in terms of specific rain events to evaluate the raindrop impact and the total contribution towards runoff volume and velocity. Furthermore, the seasonal distribution and variation of rainfall influences vegetation cover. Prolonged drought causes vegetation desiccation while the impact of intense rainfall on bare ground is usually erosive. Such data for the study area remain to be collected and analysed and, therefore, only general statements can be made at this stage.

Kondoa district is semi-arid with a mean annual rainfall ranging between 600-800 mm. Semi-arid areas have a high erosion potential in that rain usually occurs after a long, dry season when most of the land is bare and the soil is loose. Rainfall in Kondoa is distributed between November and April but the most frequent rainfall events occur in January and are of high intensity causing rapid runoff capable of creating flushy floods in

streams and rivers. The climatic conditions in general explain the occurrence of ephemeral (influent) streams. In January the rainfall has the most erosive potential. At this time of the year much of the agricultural land area has been prepared and is ready for planting. The soils are, therefore loose and erodable.

Soil characteristics usually vary greatly over short distances due to local conditions. It is unrealistic to make generalisations of soils over a large area, such as a district. However, for working purposes average conditions are usually assumed to apply. In Kondoa, the soils are characterised by truncated soil profiles usually missing the 'A' horizon. They are generally shallow and friable. That they are normally coarse and permeable makes their erodibility potential very high. They have a massive structure and rarely do they have organic matter layers. The lack of a well developed 'A' horizon is a point of concern here. Organic matter in this horizon influences soil particle aggregation and, under normal circumstances, is a source of the plant nutrients released after decomposition. Particle aggregation and porosity influence detachability of the particles and soil permeability. These characteristics in turn affect infiltration capacity, an important factor controlling rate of runoff and influencing erosion. In this area most soils can be generalised as being dark reddish-brown, coarse, sandy loams and dark yellowish-brown, loamy sands (Conyers 1971). It is worth noting however, that a combination of factors comes into play to ascertain the erodibility characteristics of the soils. More data is required in this regard. The important soil characteristics relate to infiltration capacity versus runoff plus aspects of particle aggregation and size related to detachability.

Land use

Land use is the most important factor explaining the distribution of accelerated soil erosion in Kondoa. Land use explains the ingenuity of people in dealing with ensuing problems given specific technological options and operating under specified environmental constraints.

The Irangi people are primarily pastoral-agriculturalists growing maize and millet as staple foods while sorghum and oilseeds (groundnuts, castor oil, sunflower and sesame) are essentially cash crops. Their system of farming utilises family labour for all purposes of production using the hand hoe as the main implement to work the land. Only on a few individual plots, and occasionally on ujamaa farms, is the plough used. The agricultural cycle is such that planting of crops is done very early during the onset of the rainy season and most of the crops are harvested at the beginning of the dry spell. Land preparation, which entails clearing of bush and other vegetation, is normally done during the dry season and by the end of the season the farmland is clear. At the advent of the rains a period is allowed for the soil to soften before planting. At this stage, the soil is fairly loose and, with the intensification of rainfall, both rainsplash and sheetwash intensify. Rainsplash is the most important factor responsible for particle detachment while sheetwash, which eventually turns to channelled runoff, is responsible for entrainment and eventual transportation of the soil particles. Most of the top soil is eroded in this way. The Irangi also keep livestock in varying quantities. To keep abreast with dwindling vegetation resources

seasonal migratory grazing is practised within the region and in neighbouring regions. During the dry season the herders walk long distances looking for rich pastures. Most of the land, however, is very dry and there is hardly any grass. Due to frequent trampling, soil particles along the cattle tracks are loosened. At the onset of the rains the soil is washed away creating gullies along the cattle routes. In both cases of crop cultivation and animal grazing human activities create conditions under which natural factors are changed leading to land degradation.

In the past, food crops were grown under a system of shifting cultivation but, with the introduction of cash crops, 'permanent' settlements and farms to grow the crops effectively had to be established. With the system of shifting cultivation there was ample time for nutrient recycling within the natural system. Clearing of vegetation was selective leaving trees which did not affect the crops. The level at which the soil was disturbed was minimal given the tools available; with permanent farms and settlements the fallow period was either completely eliminated or was shortened. Vegetation clearing became more deleterious to allow room for extensive farms, housing units and cattle sheds. The expansion was limited to areas where the natural endowment was relatively high and tsetse free. This situation led to the creation of pressure on land and other resources within the highlands thus creating conditions suitable for soil erosion. In this way erosion was localised and limited to the few settled areas.

The eroded area in Kondoa has a human population density of 59 per sq. km. and a bovine population density of 68 per sq. km. (or 1.5 ha. per animal). This is a very high population density relative to the carrying capacity of the area as well as the average district population density. The district bovine carrying capacity is 2 ha. to 1 animal, although the recommended carrying capacity is 4 ha. to 1 livestock unit. The local population, in search of more land for agricultural expansion, cleared the vegetation and, for several reasons, did not apply proper farming methods, hence contributing towards land degradation. Vegetation clearing, as noted earlier, upsets the balance in the recycling of nutrients provided to the plants through the soil and returned as a result of vegetable matter decomposition. Vegetation is also cleared for energy requirements. Given the poor soils and lack of an even distribution of soil moisture conditions in a year, intensification of agriculture is limited and reliable crop rotation is minimal, if at all. The browsing bovine population leaves the soil bare of grass cover and renders the area susceptible to erosion with grass flourishing only during the rainy season. Trampling animals loosen the already bare soils which are eventually eroded through pluvial or sheetwash at the onset of intense rainstorms. With this topography and the nature of the soils, concentrated runoff leads to rill erosion.

In central Tanzania, land use had often complicated processes of soil erosion due to the fragility of the physical environment. To remedy the situation a rational balance has to be struck between feasible land use alternatives and environmental characteristics. Early attempts to come to grips with environmental degradation in the area were based on the physical assessment of land use practices.

Soil Erosion and Agricultural Development

Early in the 1930s, accelerated soil erosion was already a common phenomenon along the Irangi highlands as a result of vegetation clearing and poor land management. Severely eroded areas were normally referred to as 'bad lands' and the colonial government in the then Tanganyika introduced measures to alleviate the problem. As noted before, small-scale agricultural production and livestock rearing are the predominant activities in central Tanzania. To cater for the two land use practices, most of the woodlands were cleared as a measure against tsetse flies which cause *trypanosomiasis* among livestock and sleeping sickness among humans. Deleterious clearing of bush and other trees had been in practice since the 1920s and had influenced soil erosion in so far as other conditions permitted. To abate land degradation and yet sustain the population in these areas, conservation measures had to be undertaken. One such measure was to prohibit cultivation along steep slopes. It was assumed that in so doing soil characteristics within the areas would remain stable and the effect of surface runoff on slopes would be limited. This was a relatively effective measure considering the nature of the topography. However, it did have shortcomings.

By restricting cultivation along slopes, less land was available for agricultural production and this may have contributed towards food shortages especially since the whole area, because of its soil characteristics and limiting climatic conditions is marginally productive. At the same time, the restrictive system encouraged concentration of both human and bovine populations on specific locations, promoting over-use of the already limited resources within these localities. In this way land degradation was exacerbated rather than improved where land use practices were intensified. In contrast, however, limited cultivation on steep slopes might have led to quick regeneration of the vegetation as the areas were aready cultivated. Consequently, the tsetse flies were re-attracted to the production areas and livestock grazing became difficult to carry out. Crop production and livestock rearing were now both constrained at the same time. Eventually the measure was relaxed and, instead, people were made to plant trees and other vegetation species to check erosion.

Afforestation was also forced on people by the colonial government, especially on the hillsides, in order to create fuel reserves in valleys. A good example is Busi area, where such attempts were intended to make the indigenous people appreciate the various advantages of trees for both domestic uses and erosion control measures. The afforestation schemes, however, did not appeal to the local people because they were accompanied by coercive measures on default and this affected the majority of the population. Eventually, the schemes failed. Inhibiting factors to the programmes included a shortage of enlightened foremen to supervise the extensive work; inadequate funds to cover the conceived projects; and reluctance on the part of the local people towards the schemes since forest expansion limited availability of grazing pastures. To the people of central Tanzania, cattle ownership has always symbolised social status and any step that directly or indirectly undermined this status is not taken favourably by them.

Currently, reafforestation is being encouraged following the damage caused by

previous land use practices, which lacked essential elements of conservation. To ensure grassroot participation, some planning is done at the lowest levels possible for people to understand and implement the programmes. Comparative achievement can be said to have taken place but there is still room for improvement. More documentary evidence is essential before comprehensive appraisal can be made.

Rotational grazing schemes were introduced by the colonial government for better management of pastures. Over-grazed pasture lands were put to rest during the rains to allow vegetation regeneration and were grazed during the dry season only. Various subchiefdoms were identified for the schemes but these measures were short-lived. The indigenous people could not uphold the discipline of restricting livestock movement given the number involved relative to the grazing area. 'Trespassing' in any case was inevitable. At the same time, the newly-established grazing plots did not have water points, causing over-grazing in these areas and trampling livestock increased the erosion potential. Due to the indifference of the local people, either as a lack of enlightment or in protest against deployment of excess labour time in programme already failing, together with problems of implementation, erosion control measures did not promote agricultural development qualitatively or quantitatively. The imbalance between the agricultural system and environmental characteristics remained.

Settlement Schemes

In a bid to limit the rate of soil erosion people have been moved by the government from denuded hillsides to lowlands, such as Kelema on the Bubu floodplain.

Historically resettlement in central Tanzania was directed at over-stocked areas which were cleared during the anti-tsetse fly campaigns. Over-population created conditions conducive to soil erosion in newly-settled areas, making it necessary to clear new lands for other settlements. The main focus in such moves was to cut down the number of people per unit areas and to assume that all the areas had an evenly distributed natural resources endowment. This lack of settlement planning unveiled ecological problems related to land devastation. For example, there were no soil surveys to establish the productivity of land for a given period of time under anticipated land use practice. Land suitability for various land uses, or the suitability of land for given crops under alternative land management practices was never ascertained. There was no consideration of water supplies relative to the human and bovine populations nor were requirements of fuel wood and other energy needs established though it was obvious that such needs had to be met by the available resources—building material supplies, health facilities, schools and other social amenities including accessibility were rarely given enough consideration. The new settlements did not reflect an appreciation of the long-term implications of the interaction of people with the physical environment. The serious lack of foresight in establishing new settlements increased pressure on land, reducing fallow periods and necessitating cultivation of otherwise marginal lands before land fertility was fully restored. These forced population movements by the colonial government and the established settlements diversified the soil erosion problem in central Tanzania and induced resentment among the

local people. Cases of resistance by the indigenous population have been documented (Illife 1979).

After independence, agricultural development planners in central Tanzania did not consider the erosion problem in agricultural advancement. Early party policy tended to denounce conservation measures as being part of the bad colonial policies (Christiansson 1981) in order to gain the confidence of the people. However, over time and after some serious thought it was deemed necessary to revive some of the conservation measures, albeit within a different administrative structure.

Villagisation, a political move whereby people in rural areas were made to live together in villages on the assumption that water supplies, schools, health services and other social amenities would be made available, was not able to overcome the problem of unplanned settlements as it was carried out too quickly. Some of the short-comings in earlier settlement schemes can be identified though the soil erosion problem is now tackled in a different way.

One major short-coming of the villagisation programme was the lack of foresight in allocating land relative to the critical density of population, especially in a fragile environment as in central Tanzania. Allan (1965) defines the critical density of population as "the maximum population density the system can support permanently in that environment without damage to land". Relative to the environment some of the villages were too large and were likely to cause ecological disasters. In many villages, for example, there were no firewood allotments. This necessitated over-use of the available vegetation resources in the vicinities to the extent that desert-like conditions developed (cf Darkoh 1979). Similarly, as no soil surveys were undertaken, the production capacities of the villages can be questioned, especially since no remarkable improvement in the agricultural techniques were employed. However, nucleated settlements have the advantage of being able to carry out conservation measures that cannot be implemented by smaller, more dispersed communities.

Current Conservation Measures

Soil conservation is emphasised in many parts of the country because of the evidence of ecological crises which are manifest in the extension of desert-like conditions—droughts and famines and extensive land masses carved in gullies. Severity of the problem in central Tanzania has prompted the inauguration of a government institution charged with the responsibility to reclaim land in Dodoma region where the problem is very severe. This is HADO (Hifadhi ya Ardhi Dodoma) — Land Reclamation and Rehabilitation in Dodoma. It was established under the Ministry of Natural Resources and Tourism to cater for the conservation of soils in Dodoma region. The project was launched in 1973 with the following objectives:

(a) to try and conserve the soils, water and reclaim land already destroyed;

(b) establish fuelwood and timber plantations to ensure that Dodoma peasants are supplied with sustained forest produces;

(c) encourage and assist ujamaa villages in their afforestation programme; and

(d) educate people on the importance of soil conservation and village afforestation.

To accomplish these objectives, the project has established various tree nurseries in Dodoma region. Villages and institutions are encouraged to make use of the nurseries in establishing fuelwood lots and reclaiming eroded land. By 1979, the project was maintaining about 1,500 hectares of fuelwood and timber, and had reclaimed 7,535 ha. of land. The emphasis has been on levelling-out affected areas and establishing vegetation cover on prospective grazing land. In selected areas terracing is attempted to lower the degree of slope and in each case the terraces are stabilised with vegetation cover. Grass is allowed to grow on its own in most cases, though exotic tree species are planted on particular sites. Common tree species include the *eucalyptus*, *dodonea viscosa* and some pine species. A deliberate attempt to provide for surface runoff drains is made in reclaimed areas. Miniature dams have been constructed in some areas to control free running water. Many villages have been assisted in ridge construction and stabilisation of ridges with the planting of sisal, grass and other xerophytic plants, especially in areas of severe erosion.

Afforestation programmes in the area and in the country in general, are supported by the mass media through structured radio programmes and adult education study groups. Through the radio, people are informed about techniques and procedures of tree planting while study groups in adult education centres are supposed to physically participate in tree-planting following guided texts in their primers. In many cases, however, there are insufficient books for manageable working groups. This is a serious drawback yet to be resolved.

HADO, together with supporting institutions, in addressing the issues of degraded land have encountered numerous problems including the constraint of water supply. In central Tanzania, which is semi-arid, the distribution of water sources had remained variable and unreliable for raising the necessary seedlings and nurturing to bush stage. The survival rate of seedlings and trees usually declines relative to effective precipitation, thus exacerbating the problem.

At one stage, it was practically impossible to transport seedlings to their destined sites due to lack of vehicles, scarcity of gasoline and the general problem of trafficability. Initially, most of the seedlings were raised at regional and district headquarters but, due to problems, villages have been encouraged to raise their own seedlings where possible. The main barrier has been the apparent lack of manpower to supervise the work in all affected areas, but more villagers have been 'trained' in an effort to overcome this problem.

A major issue that remains to be tackled is related to the bovine carrying-capacity of land. The maximum stocking density to allow for an economy based on cultivation for subsistence with an additional small income from sale of livestock without destructive effects on the environment averages 1 lu per 3.5 ha. Based on this estimate, HADO, with the assistance of village authorities, has encouraged people to destock as the bovine carrying capacity was higher than 1 per 2 ha. (1 cu (Livestock Unit) (LU = 1 head of cattle

= 5 small stock). It refers to the optimum number of cattle which an area can carry comfortably through an average year allowing a margin for drier conditions (Christiansson 1981). It was difficult to accomplish this because livestock owners failed to deal effectively with the excess cattle. Animals could not be kept away from reclaimed land without reducing the livestock numbers. As a result, some villagers grazed their animals on "forbidden" grounds at night. Campaigns towards destocking are still in force though many households still resist and further education is still required.

Efforts by HADO are supported by village authorities in the incorporation of conservation measurers in village land use practices. A traditional method of ridge farming included the construction of contours (locally known as 'konduas') in elevated areas. The 'kondua' system has been preserved and is put into practice in many parts of central Tanzania. Similar practices are effectively used in other countries (Chakela 1981) and, therefore, need to be encouraged.

For a long time HADO has worked without adequate quantitative data on which to base its operations. Estimates or measured quantities of suspended and dissolved load transported by streams, rates of soil creep, surface runoff, rainfall intensities and their specific relations to existing soil conditions are still vague or unknown. The project proceeds through an appreciation of the observable physical damage on various locations. It is obvious that for a project of this magnitude it is not enough. In addition, the project is seriously constrained by a lack of adequate technological capacities to manage its task. At present, some data on which the project can base its rehabilitation measures are included in works by Temple (1972), Christiansson (1981), and research undertaken by the author in the district. Parallel studies have been done in other parts of the country and elsewhere in Africa under comparable conditions (Rapp et al. 1972; Temple 1972; Lundgren 1980; and Chakela 1981). Further research in this area is necessary and efforts are required to develop a reliable data base.

Soil Erosion Control: Past, Present and Future

Soil erosion is a naturally occurring geologic process responsible for the modification of landforms. In central Tanzania the process is a problem since the 'accelerated' erosion caused by the action of people upon the physical environment has disturbed the natural equilibrium. Among the important activities influencing the problem have been the clearing of vegetation for various purposes. Taking the 'Kibawi' areas as having representative natural vegetation it can be assumed that the ideal vegetation for these areas is savanna woodland. Given the physical conditions of the area it could be expected that indiscriminate clearing of bush or vegetation in general would have an adverse impact on the environment over a long-term period. Colonial policies are partly responsible for the current situation and can be criticised for implementing short-term measures to tackle the problem. In the case of tsetse infected areas it was considered most appropriate to clear the vegetation en masse. There was no consideration made of the type, distribution and nature of the successive vegetation after clearing. Nor was a consideration made of the vegetation's ability to provide the appropriate organic matter for soil development, the

ability to support bovine as well as human populations or for its own survival.

In the establishment of rotational grazing schemes it was assumed that vegetation regeneration would always take place within the 'fallow' period. The rate of increase in bovine population was not considered and, therefore, the carrying capacity of the identified plots was under-estimated. The same argument applies to measures prohibiting cultivation of steep slopes. Intensive cultivation on flood plains exhausted the soil without provisions for its replenishment. That some parts were prohibited for cultivation without alternative working zones highlights the failure of the policies to include long-term objectives for rural settlements in this area. There was encouragement of shifting cultivation but this system can only work in areas of very low population density. In Kondoa, land was already limited by restrictions on where to cultivate. This was an opportune moment for making arrangements for permanent settlements but this did not happen. Decisions regarding the location and dispersion of settlements with feasible land use alternatives should have been made with data derived from relevant resource surveys.

A further inadequacy was that the peasants were not educated on how best to conserve the environment nor involved in effective decision-making regarding land degradation. In this way, whatever measures were proposed by the colonial authorities were alien to them. To enforce the measures the authorities resorted to the 'stick' method as opposed to the 'carrot' method and in so doing caused resentment among the peasants. The structure of the government did not allow participation in decision-making at the local level. Peasants were only considered as inept farmers who caused soil erosion and were, therefore, compelled to 'help themselves'.

These colonial policies on erosion control were imposed at a time when 'badlands' already existed; when the administrators should have had foresight on policy issues and their relative consequences. However, there was a lack of appreciation of ecological balances between what the land could provide at one point in time and what proportion of it could be reaped under natural conditions. The whole problem in the area has evolved over the failure to recognise the significance of carrying capacity of land as a basis of establishing long-term proposals for the district. The need to create more revenue for the government during the 1931 depression, for example, resulted in a campaign to plant more crops for export regardless of the ecological implications. The price was environmental degradation manifest today in rows of gullies where export crops were cultivated (Illife 1979).

HADO has inherited far-reaching problems, but one of the areas where it has to be commended is in the appreciation of the fact that land carrying capacity in the eroded areas has been exceeded and that whatever solutions are reached, they will be based on this assumption. Land carrying capacity caters for one balance between the physical environment and its interaction with the social system. This is manifest in the reduction of grazing stock in the affected area and sometimes in shifting people and livestock from the worst affected areas. The question arises, however, as to how long the populations will remain excluded from these areas without raising problems of a similar nature to newly-established settlements. More data is needed to establish how well these new settlements are doing and how long they will remain unaffected.

A second commendation is that the project appreciates the effectiveness of maximum possible participation by the people for any erosion control measure to be successful. HADO has had to collaborate with the party and government authorities to mobilise self-help labour in villages to create ridges and contour terraces and to plant trees wherever appropriate. This step is backed by various campaigns through the party, social gatherings, the mass media and the establishment of demonstration plots within the affected areas. For some time, coercion has been kept to a minimum and it is anticipated that this exercise will, therefore, succeed.

A fact which has to be conceded is that 'badlands' have already extended very far. Considering the constraints on the resources of manpower, equipment and finance it is commendable that HADO concentrates on severely affected areas and those unaffected (so that they remain unaffected) and move gradually into areas that are moderately affected. The situation will not improve immediately but with time. Though reclamation is costly it cannot be ignored.

At this stage, the improvement of the existing 'badlands' is essential. As discussed above, relative increases in human and bovine populations aggravate the problem of soil erosion. Some social values which work against maintaining the requisite ecological balance have to be discarded to minimise chances of environmental degradation. The next step will be a re-examination of the entire agricultural system and development of methods which have conservation measures embedded in them. Such methods include ridging and terracing in relation to slope characteristics. In a situation like this such systems have to be encouraged. An improved system of shifting cultivation could work where land is available. Given the nature of the soils, climate and the agricultural techniques more emphasis has to be given to drought-resistant and moisture-preserving crops; the planting of crops such as maize, causes further problems under such soil moisture constraints and therefore, should not be grown despite their popularity.

Crop rotation is limited under such restrictive conditions of agriculture. Instead, interplanting of crops such as sweet potatoes, pulses and water melons can help increase infiltration of the soil and reduce erosion, especially during intense storms. In any case, adequate fallow periods have to be allowed by restricting cultivation in sub-marginal land.

Future developments in agriculture will depend, *inter alia*, on the conservation of available land. Agricultural systems depend on the vagaries of nature but, with some insight, certain elements of nature can be manipulated to the benefit of the people. For an ecological balance to be maintained there has to be harmony between the physical and the social environments. Accelerated soil erosion is, in essense, a manifestation of the conflict between these two environments which need mutual adjustment.

In order to assess the extent to which disequilibrium is occurring within the physical environment as a result of human activities, it is essential that active monitoring systems be established alongside reclamation schemes. Since the primary objective is to have more land available for development activities, farmers and all those working on the land need to be educated on the significance of keeping the social and physical systems in harmony. Where adult classes exist, aspects of environmental management should be made part of the curriculum while efforts are made to diffuse relevant ideas within the formal school

system. With an enlightened audience it is expected that much more care will be taken to manage the environment. For long-term developments there is a need for clearly formulated land use plans to be used in villages.

Conclusion

Agricultural development in central Tanzania has been constrained by processes of accelerated soil erosion. The colonial government failed to contain the situation by imposing inappropriate measures or by wrong tactics. In this fragile environment, attempts to rehabilitate the 'badlands' are constrained by unplanned settlements and land use practices. For the problems to be overcome, the peasants require to be educated about environmental management and its application to alternative land use practices.

REFERENCES

Allan, W. 1965 *African Husbandman* New York

Aitken, W. G. 1950 "Geomorphology of Parts of Kondoa District" *Tanganyika Notes and Records* No. 29

Banyikwa, F. F. et al. 1979 *Studies on Soil Erosion and Land Reclamation in Kondoa District An Evaluation of the HADO Project* Dar es Salaam

Berry, L. and Kates, R. W .1972 "Views on Environmental Problems in East Africa *"The African Review* Vol 2 (3)

Chakela, Q. K. 1981 *Soil Erosion and Reservoir Sedimentation in Lesotho* Uppsala

Christiansson C. *1981 Soil Erosion and Sedimentation in Semi-arid Tanzania: Studies of Environmental Change and Ecological Imbalance* Sweeden.

Conyers, A. 1971 *"Agro-economic Zones of Dodoma and Singida"* BRALUP Research Report Dar es Salaam

Cooke, R. U. and Doornkamp, J. C .1974 *Geomorphology in Environmental Management: An Introduction* Oxford

Illife, J. A. 1979 *A Modern History of Tanganyika* London

Jacks, L. 1974 Environment and Styles of Development Environment *Africa* 1

Kjekshus, H. 1977 *Ecology Control and Economic Development in East African History* London

Lord Haley 1957 *An African Survey*

Lundgren, L. 1980 *Compasiron of Surface Runoff and Soil Loss from Runoff Plots in Forest and Small-scale Agriculture in the Usambara Mountains Tanzania* Stockholm

Mushala, H. M. 1980 *"Soil Erosion and Control: Lessons from Kondoa"* Geography BRALUP Seminar paper (mimeo) University of Dar es Salaam

Stebbings, F. P. n.d. "The Man-Made Desert in Africa" *Journal of Royal African Society*

Stockdale, F. 1937 "Soil Erosion in the Colonial Empire" Emp Jnrl Expt Agr

Swai, B. 1980 Matuta: The Political Economy of Soil Erosion in British Tanganyika (mimeo) University of Dar es Salaam 1980

Temple, P. H. 1972 "Runoff and Soil Erosion at an Erosion Plot Scale with Particular Reference to Tanzania" *Geogr Ann* 54 A

Thompson, T. D. 1953 "Soil Conservation— Some Implications" Jnrl Afrm Admn 5 No 2

United Nations 1977 *Desertification: Its Causes and Consequences*