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THE ROLE OF PERENNIAL GRASSES IN SUSTAINING PRODUCTION IN SEMI-ARID AREAS

by

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INTRODUCTION

In much of Africa, including large parts of Zimbabwe, the rainfall is too low and erratic to sustain successful agricultural cropping so that economic production depends upon using herbivores (e.g. cattle) to convert natural vegetation into products which are of value to man (e.g. meat, milk, hides). In Africa, significant and increasing human deprivation is occurring in these semi-arid savanna rangelands. Solutions to these problems are complicated as they involve interactions between socio-political, economic, financial and ecological factors, often operating under very different time scales.

In semi-arid rangelands ecological factors assume a greater relative importance than in most other agricultural systems. In arable agriculture the ecology is simplified, with one or a few species of plants being grown in an homogenous and highly controlled environment. The manager is in a strong position because he usually has a fair understanding of the production function and is able to manipulate inputs according to the outcome required. In contrast, managers of semi-arid rangelands have to contend with greater spatial and species heterogeneity, grossly unpredictable rainfall, production functions which are more complex and not well understood, as well as land of such low productivity that the financial inputs required to improve productivity are not viable (e.g. the costs of clearing bush encroachment are not covered by the increased productivity resulting from this action). Users of these drier rangelands are in a weak managerial position as most of the inputs into the production system (e.g. rainfall, soil) are outside their control.

In addition, ecological cause and effect relationships in such areas have little effect within the time frame of financial management, particularly as they are often subtle and hidden by variablility. As a result they do not receive adequate priority in decision making, although they may affect the livelihood of several generations to come.

The intensifying human deprivation in drier African rangelands is influenced by a number of ecological factors. The purpose of this paper is to emphasise:

1. that productivity in these rangelands is limited by the amount of water available for plant growth; and

2. that the presence of a vigorous sward of perennial grass is important in maintaining favourable soil-water relationships, thereby enhancing the efficiency with which the limited available precipitation is used.

SAVANNAS

Savannas are characterised by a continuous grass cover in which trees and shrubs usually occur, but these seldom form a continuous cover paralleling that of the grassy layer (Frost *et al.*, 1985). Savannas cover vast areas of the tropics and sub-tropics and are particularly prevalent in Africa (Lamotte and Hadley, 1984) (Figure 1).

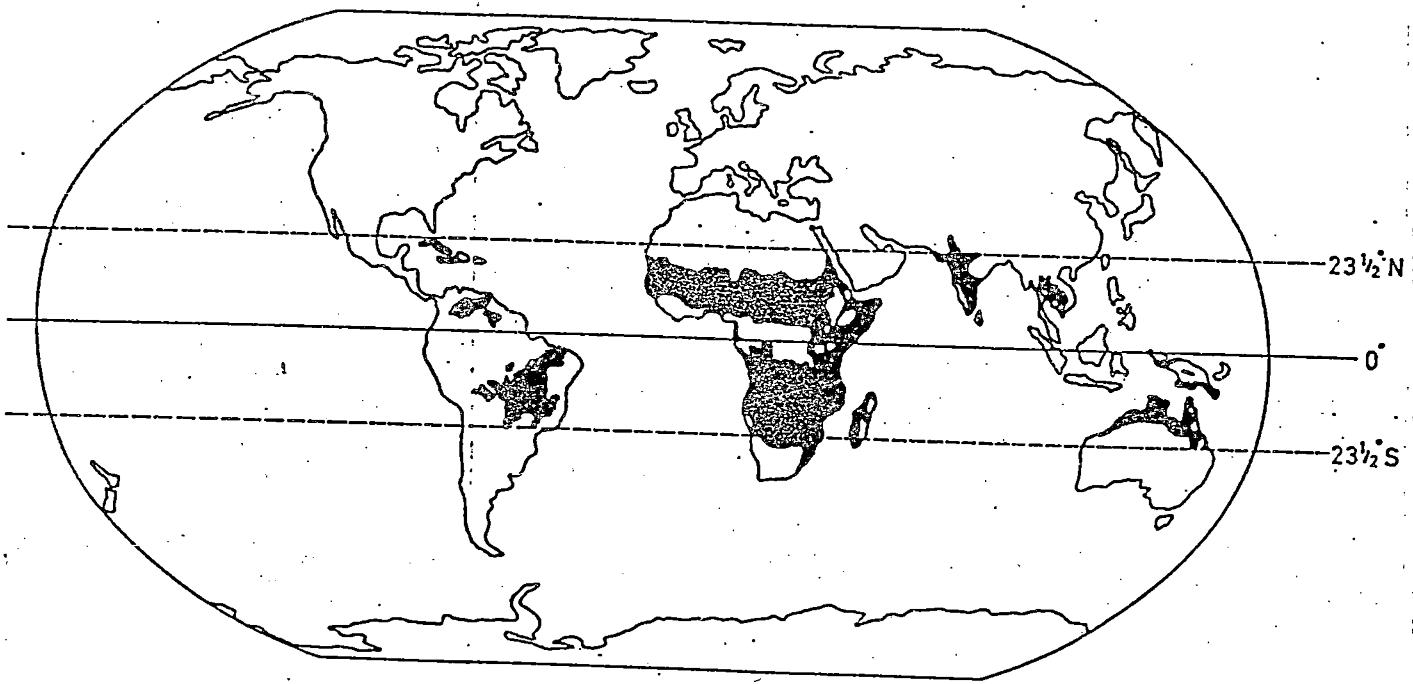
Zimbabwe is broadly characterised by two savanna types: dystrophic savannas with sandy, nutrient-poor soils associated with higher rainfall, and eutrophic savannas, with richer soils associated with drier areas. It is with the latter type of savanna that this paper is mainly concerned.

There is presently much concern about ecological degradation in Africa's semi-arid savannas and the effects of this on the people who live there. Many of the solutions suggested to combat this degradation aim at promoting trees while relatively little importance is attached to the grass layer. The grass layer is usually the main source of animal food and has a large influence on the soil surface, affecting soil structure, erosion, infiltration and organic matter content. It should be afforded a greater importance. at the same time it should be recognised that in some circumstances woody species are not a solution but may be a symptom of degradation. In much of southern Africa, particularly in those areas having less than 700 mm of annual precipitation, bush encroachment is a severe problem which reduces rangeland productivity considerably (West, 1965; Riney, 1963; Dye and Spear, 1982).

LIMITING FACTORS

In semi-arid environments, plant and animal production tends to increase as rainfall increases (Bate *et al.*, 1982; Coe *et al.*, 1976) because herbage production is usually limited by plant available moisture. In using these environments man has tended to modify the vegetation causing both reduced and more variable levels of plant available moisture, with similar effects on vegetation and animal production. It is likely that much of the recent human suffering in Africa's semi-arid savannas is a result

FIGURE 1: WORLD DISTRIBUTION OF TROPICAL SAVANNAS



Source: Lamotte and Hadley (1984)

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of such degradation, especially where the effects are exacerbated by climatic droughts or political turmoil.

Plant available moisture is, in part, a function of climate and climatic change has been blamed for this suffering. However, the evidence supporting this is inconclusive and, in any case, other factors affecting plant available moisture (e.g. infiltration/runoff) are probably more important because they are amenable to human management or subject to mismanagement. In practice the effect of man on vegetation, through his influence on ground basal and litter cover, infiltration, soil structure and soil nutrient status, is the crucial factor determining the efficiency with which precipitation is converted into plant available moisture and thereby into useful products.

The following discussion will suggest that semi-arid savannas are of most value to man where the herbaceous cover is good (and hence where perennial grasses dominate the sward), and where woody vegetation is not overly competitive. It is under these conditions that rainfall is used most efficiently in the production of commodities which are of value to man.

OPTIMAL VEGETATION COVER

There are three basic components of savanna vegetation namely perennial grasses, annual grasses and woody species. The characteristics of these components and their densities are a function of the environment, human management and competitive interaction between them. These factors have important implications for rangeland productivity and are elaborated upon below.

Perennial grasses are more robust, productive and provide better soil cover than annuals. The presence of root reserves and the ability to recommence growth when rain falls, following a dry spell, gives them a further advantage over annuals. Thus perennial grasses are less dependent on the growing conditions within a particular season. Because they also improve the status of the soil surface, making for more efficient use of available precipitation, production from perennials tends to be both higher and less variable than that from annuals.

While production from annuals might approach that of perennials in good years, differences can reach 300% or more in bad ones (Kelly and Walker, 1976; Barnes and McNeill, 1978). When annuals replace perennials productivity is lost, but the increased variability may be a more serious consequence. To cope with this increased variability producers, and subsistence producers in particular, may be forced into choosing less risky production strategies which are generally also less productive. With commercial cattle enterprises, profitability is reduced because ranchers destock in dry years when prices are low and restock in wet years when prices are high. In addition, ranchers are seldom able to match cattle stocking rates to the condition of the veld in a particular year so that herbage is wasted in good years and overused and degraded in bad ones.

Woody vegetation is a valuable, if unquantified, source of animal food in Zimbabwe. Under certain circumstances herbaceous production may be higher under a woody canopy (Bosch and van Wyk, 1970; Kennard and Walker, 1973; Barnes, 1982), perhaps because shading reduces evaporative losses or where trees improve the soil's fertility by recycling nutrients from underground ("nutrient pumps"). However, extensive stands have an overall suppressive effect on the herbaceous layer and may have reduced the productive capacity of large areas of rangeland in southern Africa.

The situation in more arid savannas, particularly where frequent light precipitation occurs, may be different as uniformly scattered trees may be able to concentrate precipitation, such as mists, which would otherwise be insufficient to support continuous herbaceous cover (Glover and Gwynne, 1962). Nevertheless good perennial grass cover has been reported in areas of very low rainfall, for example in the south western Kalahari where the annual rainfall is as low as 150 mm (Leistner, 1959; Child, Parris and le Riche, 1971).

Experiments in Zimbabwe have indicated that woody vegetation can reduce the sustainable carrying capacity of rangelands by two thirds (in areas where rainfall is in the range 400 to 850 mm per year) with effects being particularly severe in dry years (Ward and Cleghorn, 1964; Barnes, 1979; Dye and Spear, 1982; Gammon, 1983). With bush clearing, some less palatable perennials may become evident, but livestock carrying capacities are considerably increased. Gammon (1983) summarised twenty three years of experimentation in the semi-arid lowveld of south-western Zimbabwe. He concluded that on cleared veld, at stocking rates double those applied on uncleared veld, livemass gains were greater (in cattle) and livemass production per hectare exceeded that on uncleared veld by 115 to 143 per cent. Livemass gains per head were similar on cleared and uncleared veld when the stocking rate was between two and three times heavier on the uncleared veld. It was concluded that cattle carrying capacities could be increased two to three fold by bush clearing. This should be sustainable as it was noted that perennial grasses were predominant at all stocking rates on cleared veld and there was no evidence of deterioration 28 years after clearing.

Increased productivity probably resulted from reduced competition for limited soil-water by woody vegetation. Woody vegetation is a less efficient fodder producer than grass, because grasses cycle nutrients much more rapidly than when they are tied up in unavailable forms in woody tissues. Most importantly ground cover, and hence infiltration rates, are lower under a woody canopy.

However, optimal conditions include a certain proportion of woody species because they provide shade, out of season greenery and, in some cases, nitrogen and longer lasting humus. They may also act as "nutrient pumps" and some woody species favour more palatable grasses when not too dense (Kennard and Walker, 1973).

The conclusion is that agriculturally marginal, semi-arid areas are most productive when a good grass cover of perennial grasses is present. Better ground cover, particularly in the early growing season, when susceptibility to erosion is highest, reduces erosion and favours the retention of water which is the main factor limiting production. Herbage production is greater than where woody or annual species dominate and, in addition, is much less variable than with annual communities. Variablility has important ecological implications which are magnified by financial management systems.

DEGREDATION PATHWAY: A MODEL FOR RANCHERS

As stated previously, human welfare in semi-arid areas is related directly to sustainable plant productivity and hence to plant available moisture. The following explanation is based on theoretical models derived by Walker *et al.* (1981) and is designed to provide a model to which livestock producers can relate (Figure 2). The actual and relative availability of soil-moisture is central to the functioning of semi-arid ecosystems. Management decisions which affect plant/soil/moisture relationships are important, particularly in eutrophic savannas, as they can have major and irreversible effects on the ecosystem.

The optimal condition of the environment is illustrated by Figure 2a. Perennial grasses by providing a good ground cover, maintain a well structured soil, reduce runoff and minimise loss of soil and nutrients. Precipitation is retained in the surface soil horizon and is thus available for grass growth, so that nutrients are rapidly made available for animal production.

Misuse of fire and overgrazing, especially when selective, reduce the vigour of favourable perennials (Figure 2b). Ground cover and rainfall efficiency decrease, although annual grasses and woody species may become more abundant. With increased bare ground, soils become compacted and runoff increases, reducing infiltration and leading to accelerated soil loss. This situation is particularly relevant in eutrophic savannas as moisture is the major limiting factor and because the more finely structured soils (loams and clays) are more susceptible to compaction.

This situation is not necessarily reversable. Not only does less water infiltrate, but a larger proportion of the rainfall that does soak in reaches the subsoil, below the

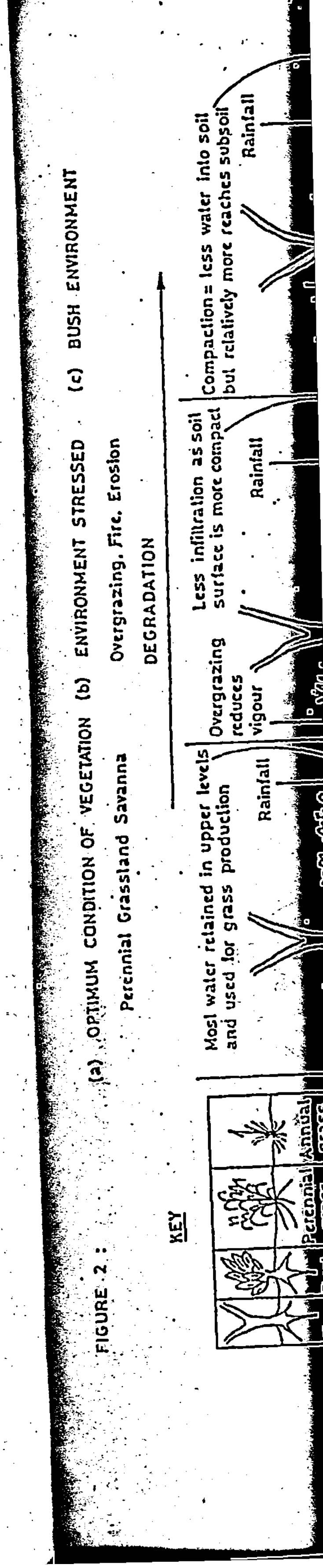

FIGURE 2 : (a) OPTIMUM CONDITION OF VEGETATION (b) ENVIRONMENT STRESSED (c) BUSH ENVIRONMENT

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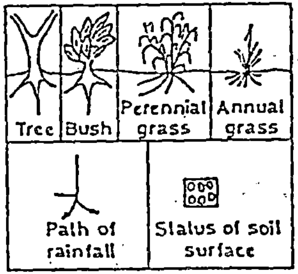
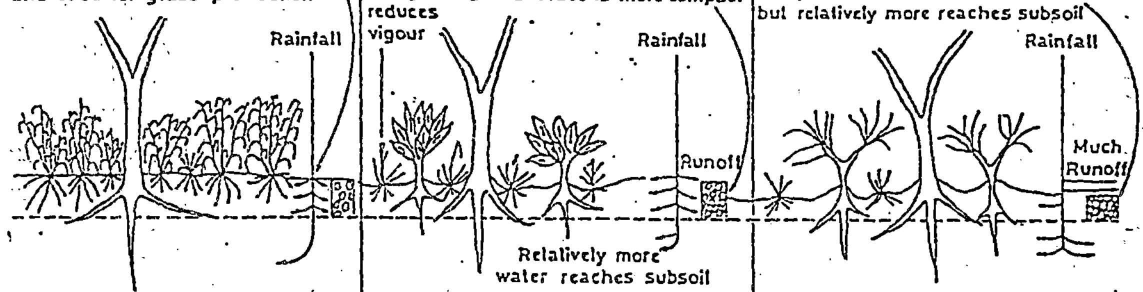
Perennial Grassland Savanna — Overgrazing, Fire, Erosion

DEGRADATION →

KEY





GROUND COVER	Good	Average	Poor
DOMINANT VEGETATION	Perennial grass	Annual grass / shrubs	Bushes
SOIL STRUCTURE	Good structure	Some compaction	Badly compacted
WATER AVAILABILITY	Most retained in topsoil Little available for tree growth	Some runoff, some water percolates below topsoil	Much runoff, little water available in topsoil; relatively more water reaches subsoil and this perpetuates tree domination as trees have longer roots
EROSION	Low	Medium	High
PRODUCTION	High	Medium	Low
WATER AVAILABLE FOR USEFUL PLANT GROWTH	High	Medium	Low
NUTRIENT AVAILABILITY	Nutrients cycled rapidly		Nutrients tied up in woody tissue. Less available as animal food.

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level of grass rooting systems (Figure 2c). The deeper rooted woody species then have a competitive advantage, which they are able to maintain at the expense of grasses. The system remains inefficient, with low levels of ground cover encouraging runoff and soil erosion. Productivity is reduced.

Child *et al.* (1971) recorded one such example of ecological decline in the Kalahari Gemsbok National Park in Botswana (Figure 3). Some 25 to 38 years after cattle ranching was abandoned in this region, the grass and wildlife biomass in the formerly ranched area was significantly less than that of an adjacent area where no cattle overgrazing had occurred.

There is also evidence that misuse of these semi-arid environments may degrade them beyond critical ecological thresholds from which recovery is slow even where it is possible (Figure 4). External energy, such as bush clearing, can sometimes be used to reclaim such land but this is seldom profitable.

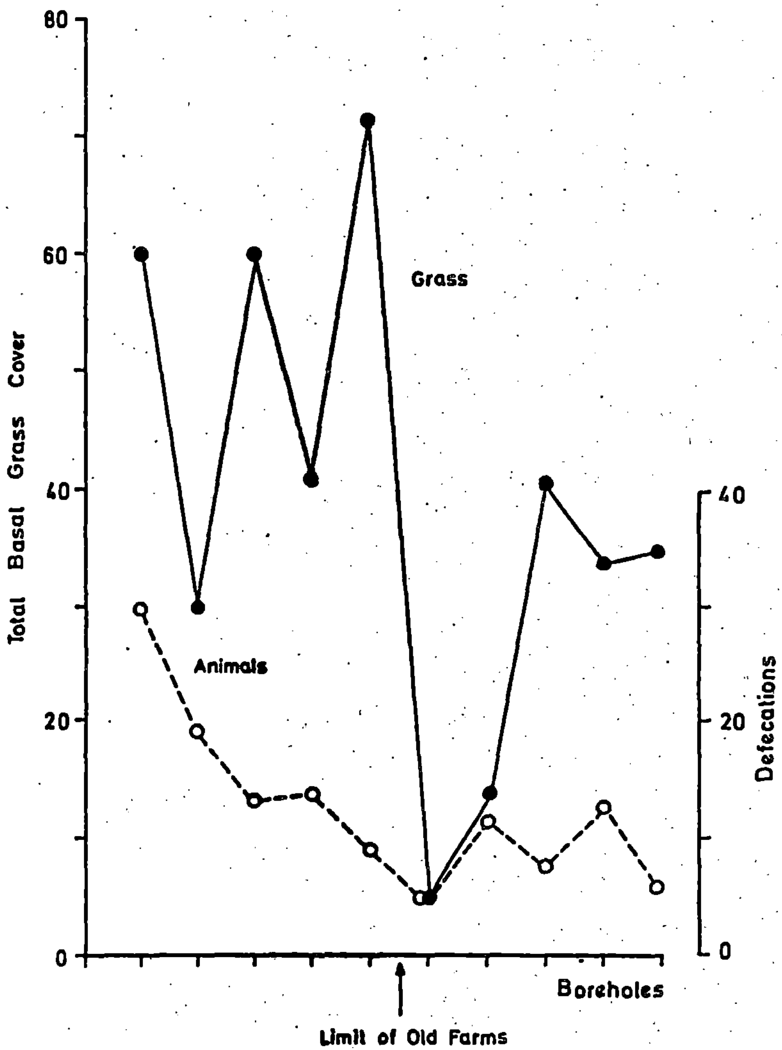
Child (1968) gives an excellent example of this situation in Botswana (Figure 4). Prior to the establishment of a cattle outpost at Bushman Pits in 1949 this area had been grassland with a carrying capacity of about one livestock unit per eight hectares and wildebeeste and springbok were common. Overgrazing by cattle degraded the system over a threshold, so that the vegetation became characterised by scrub encroachment which was kept in check by fire. With the reopening of a stock route through the area in 1956 the grass cover was further suppressed and fire could no longer control the growth of bush. As a consequence the scrub was able to grow and by 1965/66 had formed an impenetrable thicket. Productive grasslands were converted into useless thicket which could not be rehabilitated economically.

DISCUSSION AND CONCLUSION

The welfare of people inhabiting semi-arid savannas is inextricably linked with the ecological status of these environments and the status of the soil-water-vegetation complex. Hence welfare is related to the condition of the herbaceous, and particularly the perennial grass, cover because of its key role in this complex. The misuse of savanna grassland results in rapid, and usually irreversible degradation, with related losses in productivity.

The severe state of environmental degradation in Zimbabwe is illustrated in Table 1 where Whitlow (in press), using evidence derived from aerial photographs, indicated that severe soil erosion has occured on some 11% of Zimbabwe's agricultural lands (especially the Communal Lands), while some erosion is evident on 90% of farmland. These soil losses are extremely serious. However, they also indicate that a significant amount of the available

FIGURE 3: THE EFFECT OF PAST LAND USE ON THE FREQUENCY OF GRASS AND WILD LIFE POPULATION ALONG THE AUOB RIVER IN SOUTH WESTERN BOTSWANA



Source: Child et al (1971)

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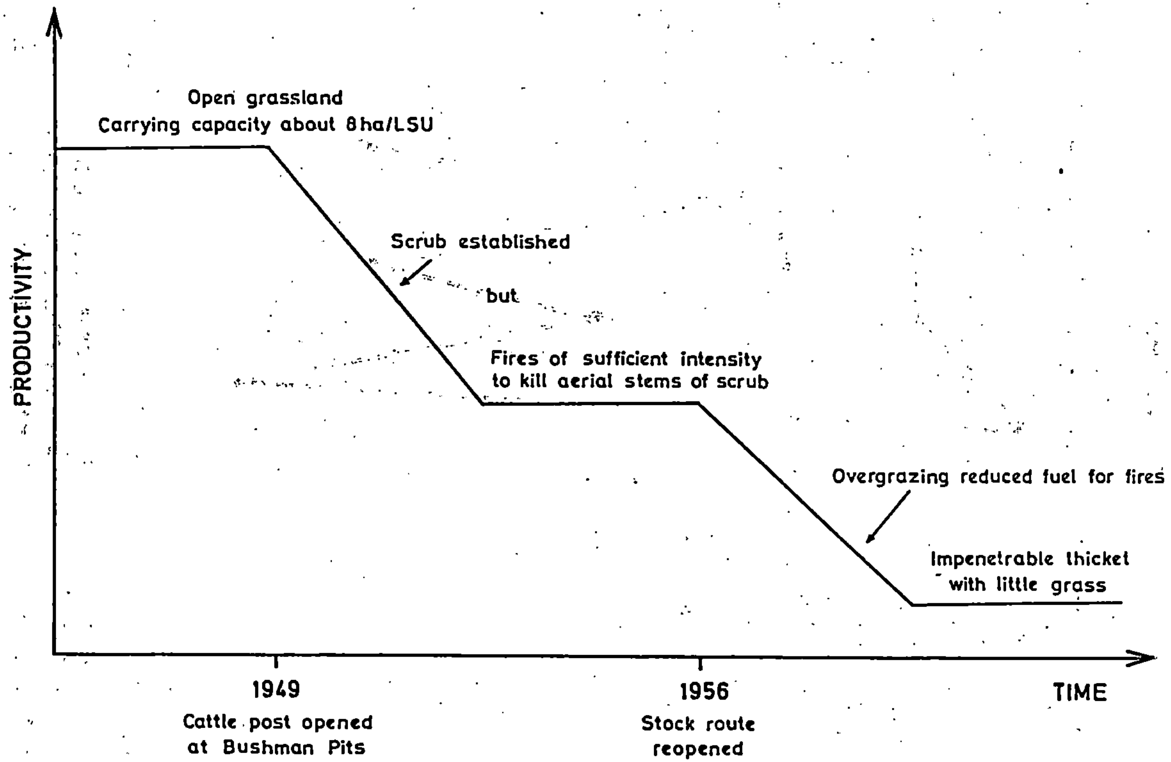
FIGURE 4: ILLUSTRATION OF THRESHOLD CONCEPT

An example from N.E. Botswana



Source: Child G. (1968)

TABLE 1: Extent of Erosion in Zimbabwe

Erosion class*			Zimbabwe	Communal Lands	General Land	Other Lands
1	Zero	not present	17,2	7,2	14,7	55,4
2	0,1 - 4,0	very limited	45,7	29,7	64,7	40,5
3	4,1 - 8,0	limited	16,0	20,3	15,9	3,2
4	8,1 - 12,0	moderate	10,2	19,6	3,4	0,6
5	12,1 - 16,0	extensive	5,6	11,3	1,2	0,3
6	over 16,0	very extensive	5,3	11,9	0,1	-
			100,0%	100,0%	100,0%	100,0%

* Percentage area of total erosion within grid cells.

SOURCE: Whitlow (in press)

precipitation is being wasted; water is the main factor limiting production.

Zimbabwe has a rapidly expanding human population and cannot afford to continue wasting vital resources. Present systems of rangeland use are neither sustainable nor conducive to development. They are unable to maintain existing, and in many cases inadequate, levels of human welfare despite being effectively subsidized by "environmental capital". In other words, present production is taking place at an opportunity cost measurable in terms of future welfare foregone. This degradation may well become self perpetuating as people, in an attempt to maintain their level of income, compensate for reduced productivity by overusing the resource. Not only do opportunities for range recovery become increasingly costly as degradation proceeds, but the people depending on the land become poorer and less able to afford reclamation measures.

Decision makers at all levels of society must recognise that this downward spiral exists and act to encourage the development of land use practices which are sustainable and in which the area concerned holds a comparative advantage. This requires improved land use technology and, more importantly, a system of incentives which encourage economically efficient land use. Here approprite institutions related to resource tenure and marketing are essential.

In semi-arid rangelands, land use systems which are financially viable, but which do not degrade the resource base on which human welfare depends, must be evolved. This paper suggests that the methods needed must be able to increase production without impinging on the health of the herbaceous cover. This can be achieved by diversifying into alternative or complementary enterprises (e.g. tourism on a cattle ranch) and by specialising to create a tiered rural economy. The former is an initial step in improving production, while specialisation (e.g. producers, distributers, suppliers) which depends on the development of exchange and trade, allows further improvements in efficiency.

Unless ecologically sustainable methods of generating increased incomes in semi-arid rangelands are developed, the people living there can only look towards a future of increasing misery.

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