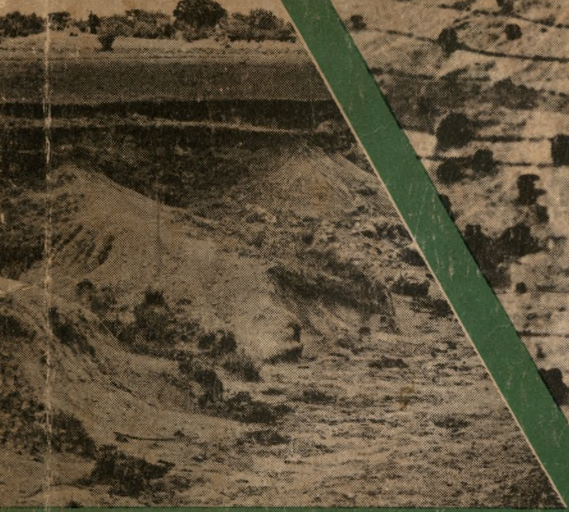

LAND DEGRADATION IN ZIMBABWE

A Geographical Study

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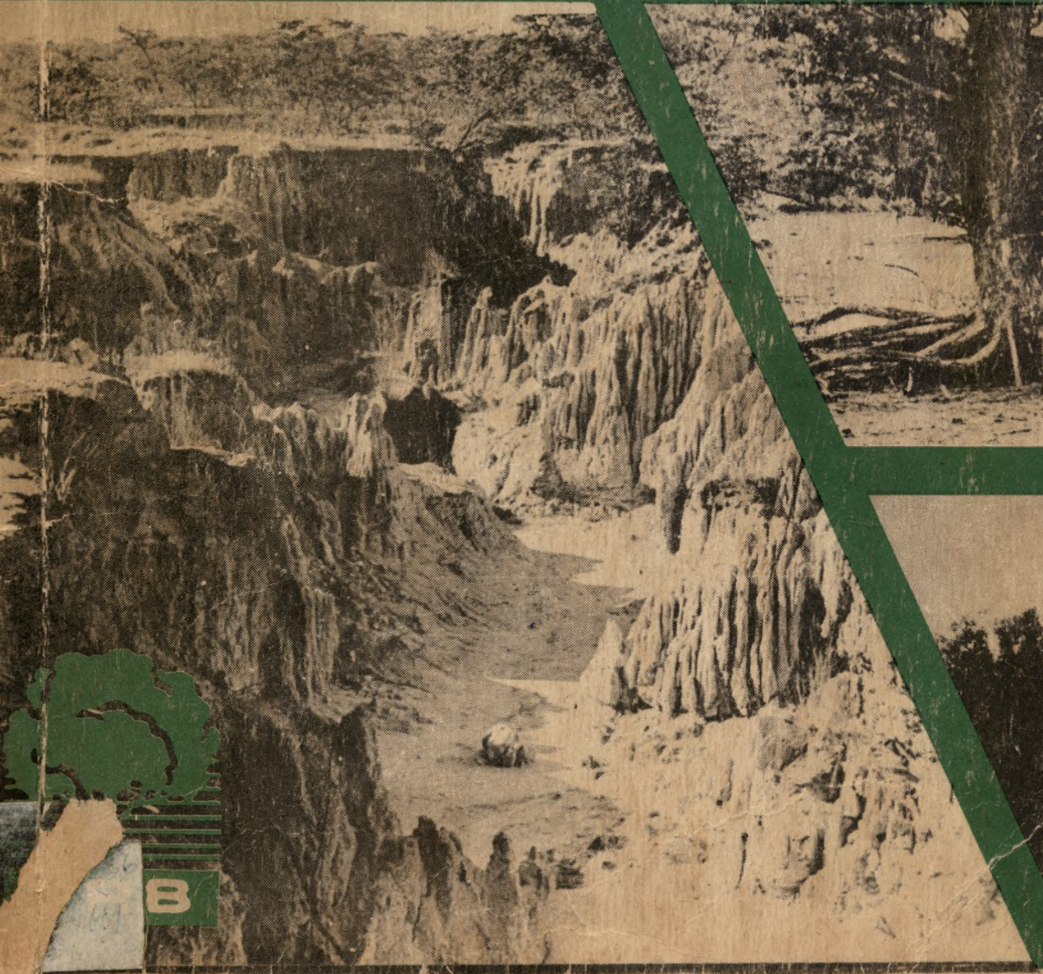

Land Degradation in Zimbabwe
A Geographical Study

Report prepared on behalf of the Department of Natural Resources

by
Richard Whitlow
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1988

SUMMARY OF REPORT

The *terms of reference* for the national erosion survey of Zimbabwe were as follows:

- — the survey method should be simple, systematic and quantitively based.
- — the survey should have potential for monitoring changes in erosion patterns;
- — the survey should generate information on the extent of erosion in both map and statistical forms at scales appropriate for national and regional planning;
- — the survey method should be economic in terms of financial and manpower inputs.

Research was initiated during 1984 to develop a suitable method for extracting information on erosion from 1: 25,000 aerial photographs. A technique involving sampling of 1,000 grid cells per aerial photo within a grid framework was developed. The main national survey was carried out in late 1985 using this technique and involved detailed examination of nearly 8,500 aerial photographs, representing a 22% areal sample of the country. The data from this survey, combined with previous scientific research and government reports, forms the basis of this study.

The main report covers the following aspects of land degradation:

1. causes and consequences of erosion
2. history of the erosion problem
3. distribution of erosion
4. influence of physical factors on erosion
5. influence of human factors on erosion

The erosion problems are *immensely complicated* involving the interaction of many political, social, economic and environmental factors. It would be *unrealistic* to expect anyone to gain a reasonable familiarity with these problems from reading this brief summary alone.

1. CAUSES AND CONSEQUENCES OF EROSION

- — the erosion system is extremely complex comprising the interaction of energy forces (e.g. rainfall intensity), resistive forces (e.g. stable soil aggregates) and protective forces (e.g. plant cover).
- — where protective and resistive forces are low in relation to energy forces, as occurs in the Communal Lands, then high rates of erosion are common; where the protective and resistive forces are high as in areas of good management and low population pressures, then erosion is localised.
- — rates of soil formation in Zimbabwe are very slow (e.g. 400 kgs/ha/year), whereas rates of soil erosion are very much greater; estimates for average soil losses on croplands and grazing areas on commercial farms are 15 tonnes/ha/year and 3 tonnes/ha/year respectively; the equivalent averages for Communal Lands are 50 and 75 tonnes/ha/year.
- — expressed in terms of soil life span, for the Communal Lands in the upper Sabi Catchment cultivation of maize may only be possible for another 10 years before soils become too shallow for crop growth; sorghum cultivation may be impossible within 30 years.
- — the removal of nutrients in eroded soils amounts to estimated financial losses of $2 540 million each year when converted into the cost of replacing lost nutrients with chemical fertilizers.
- — the consequences of this erosion are seen in general declines in crop yields and very high rates of siltation of reservoirs, especially of the smaller dams used for rural water supplies; such small dams are likely to fill with sediment within 15 years of construction and even the larger irrigation schemes are being affected adversely by siltation problems.
- — soil erosion is clearly an important problem in Zimbabwe, especially within the Communal Lands; it is essential that conservation measures be included as a central and key part of development strategies in these areas rather than being treated as a token appendage.

2. HISTORY OF THE EROSION PROBLEM

- — an understanding of the history of the erosion is necessary to account for the present patterns of land degradation and to assess past successes and failures in tackling resources deteriation, so that more effective plans can be developed to overcome soil erosion and related problems.
- — the review of erosion focuses mainly on the large-scale commercial farming areas and the Communal Lands, the former characterised today by high standards of conservation and localised erosion and the latter by generally poor standards of conservation and widespread erosion; distinct, but not necessarily discrete, historical phases can be identified for these two main farming areas.
- — the phases in the *large-scale commercial farming areas* are as follows:

Phase 1: Trial and error — pre-1931
a combination of ignorance and neglect resulted in widespread erosion and limited progress was made in promoting basic mechanical protection of arable lands.

Phase 2: Erosion awareness — 1931 — 1948
farmers began to realise the need for soil conservation; continuing erosion on many European farms and, even more so, within the 'native reserves' prompted an official Commission of Enquiry in 1938; the outcome of this was the passing of the Natural Resources Act (1941) the establishment of the Natural Resources Board and the creation of Intensive Conservation Area (ICA) committees to encourage and, where necessary, enforce conservation measures.

Phase 3: Conservation farming — 1948 — 1965
the establishment of the Department of Conservation and Extension (1948) and the introduction of farm planning (1956) improved greatly the general standards of conservation; along with mechanical protection, for which subsidies were given, better husbandary practices were seen as vital in conserving soil and water resources for increased production.

Phase 4: Mixed fortunes — post 1965
farmers were forced to diversify and intensify production due to difficult political and economic circumstances following the illegal declaration of independence; despite growing security problems, general awareness on conservation remained at a high level, although the need for constant attention of basic anti-erosion works was stressed.

the phases in the *Communal Lands* were as follows:

Phase 1: Creation of the reserves — pre-1926
the first 'reserves', the Gwaai and Shangani, Reserves were declared in 1894 and, following pressure from the British government, additional areas of land were set aside for the exclusive use of the indigenous population. By 1911 these "native reserves" comprised about 8,5 million hectares, barely one fifth of the country; land degradation was not a problem at this stage since population densities were low.

Phase 2: Centralisation — 1926 — 1951
spatial re-organisation of arable and grazing lands and settlements was initiated in this phase as a basis for improved farming and conservation. Despite these efforts extensive erosion took place. The Natural Resources Act (1941) was intended to overcome this degradation which was seen mainly as a product of poor farming methods. Manpower and financial constraints preventing the proper implementation of this resource legislation and destocking measures which were carried out were very unpopular, compromising future conservation efforts.

Phase 3: Agrarian reforms — 1951 — 1962
compulsory conservation measures were introduced by agrarian reforms as dictated by the Native Land Husbandry Act (1951); although considerable progress was made in mechanical protection of arable lands, the enforcement of such measures was unpopular and became a major political issue; in addition, the attempt to change from a tribal communal system to an individual system of land tenure was opposed.

Phase 4: Uncertainty — 1962 — 1969
with the abandonment of the Native Land Husbandry Act and the changing political circumstances in the country, there was a period of uncertainty in the 1960's; some progress was made in improving farming and conservation through the efforts of the Department of Conservation and Extension who had become responsible temporarily for the reserves, now referred to as Tribal Trust Lands. In the face of growing population pressures, land degradation became widespread.

Phase 5: Growing pressure — post 1969
with their political and economic aspirations being blocked by the government the peasant farmers turned increasingly to supporting the guerrilla forces intent upon taking control of the country; with the deterioration in security during the civil war, conservation was neglected and this exacerbated an already serious problem. Since independence some progress has been made in resolving the conservation problem by, for example, afforestation and resettlement schemes.

3. DISTRIBUTION OF EROSION

— it was estimated that there were just over 1,8 million hectares of eroded land in Zimbabwe, that is 4,7% of the country. Most of this eroded land, some 1,5 million hectares were located in the Communal Lands. 271,000 hectares of eroded land were recorded in the General Lands and only 35,200 hectares of eroded land were observed in non-agricultural areas (e.g. national parks, forest reserves).

erosion was recorded as negligible in just under two fifths of Zimbabwe and about one quarter of the country had very limited erosion (under 4% of the land in a given area being eroded); a further one fifth of the country had limited to moderate erosion (between 4,1 — 12% of the land eroded); in the remainder of the country (13,2%) erosion was rated as being severe to very severe, that is, over 12% of the land being eroded in a given locality.

— the most extensive erosion was recorded in the Communal Lands, especially within Natural Regions IV and V, but also within the higher rainfall areas where nearly one tenth of the land was eroded. The General Lands were less affected by erosion, the most extensive erosion in these areas being in Natural Regions III and IV.

— the area of eroded cropland in Zimbabwe was estimated at 842,400 hectares and for non-cropland, mainly grazing areas, the figure was 992,400 hectares. In the Communal Lands there were 768,200 hectares of eroded cropland and 760,300 hectares of eroded non-cropland. In the General Lands there were 65,900 hectares of eroded cropland and 205,200 hectares of eroded non-cropland.

4. INFLUENCE OF PHYSICAL FACTORS ON EROSION

— high intensity rainstorms, shallow and/or unstable soils and steep slopes combine to create serious erosion hazards in some parts of Zimbabwe; about one third of the country is characterised by high risks of erosion, mainly in the northwest and north of the country; however, most of this land is set aside for wildlife reserves so, despite these risks, limited erosion has occurred; where farming takes place very rapid degradation is not uncommon.

— comparing potential erosion, as defined by the hazards survey, with actual erosion, as determined from aerial photo analysis, it was discovered that areas of high risk are not necessarily areas of extensive degradation; population density and land use systems were more important influences on erosion than the environmental factors; for example, in the densely settled Communal Lands there was widespread erosion even in areas of low erosion hazards with respect to slope, soil type (etc).

— erosion problems are more acute in areas of granitic domes which are characteristic of the broad arc of Communal Lands centred on Masvingo and extending north-eastwards into the Mutoko district; rock outcrops may occupy up to one third of the land in a given locality and high rates of runoff are generated from these hills; where the land is cleared right to the bases of the domes, excessive sheetwash and gullying is common.

— in central and western Zimbabwe there are large areas characterised by sodic soils; these soils have high levels of sodium which disperse soil particles and result in very unstable soil aggregates; such soils are affected by serious sheetwash erosion and, in some areas, very large gully systems have developed partly due to processes of subsurface tunnelling.

5. INFLUENCE OF HUMAN FACTORS ON EROSION

— the most important factor which accounted for statistical variation in erosion was population density; that is, there was a direct positive correlation between increases in population density and increases in the extent of eroded terrain; this relationship was valid for the Communal Lands, but not for the General Lands where high population densities are associated normally with intensive farming and, with high standards of conservation, erosion is minimal in such areas.

— relatively localised erosion was recorded within croplands on commercial farms; it is likely that the aerial photo survey under-estimated the extent of sheetwash erosion in these areas; but, in general, high standards of conservation measures have managed to reduce the extent of soil loses on the croplands, although further improvements are possible by, for example,. modifying tillage practices.

— erosion on croplands in the Communal Lands was more widespread and severe; much of the erosion seems to date mainly from the 1960's period when population pressures were increasing and conservation measures were neglected; a combination of late planting, shallow ploughing and limited ferti lizer or manure application, contribute towards the high rates of soil erosion on these croplands.

— wetland areas (vleis, matoro, bani) which characterise the headwater valleys of the rivers draining the central plateau of Zimbabwe are estimated to cover some 1,28 million hectares; these wetlands act as sponges regulating streamflow, especially in the dry season and for this reason are protected areas; in the General Lands, where most wetlands occur, there is very little erosion since such areas are used mainly for grazing; in the Communal Lands, however, there are enormous pressures on the wetlands for grazing and cultivation; locally, this has resulted in serious and very rapid gullying.

CONCLUSION

From this survey and, indeed, the repeated warnings given by the Natural Resources Board over the last twenty five years of so, it is clear that Zimbabwe has a serious erosion problem, particularly within the Communal Lands. Resolving this problem will require massive financial and manpower inputs beyond the present means of the country. Technical solutions to the problem are available already. The problem lies in integrating these solutions effectively with the socio-economic circumstances with the rural areas.

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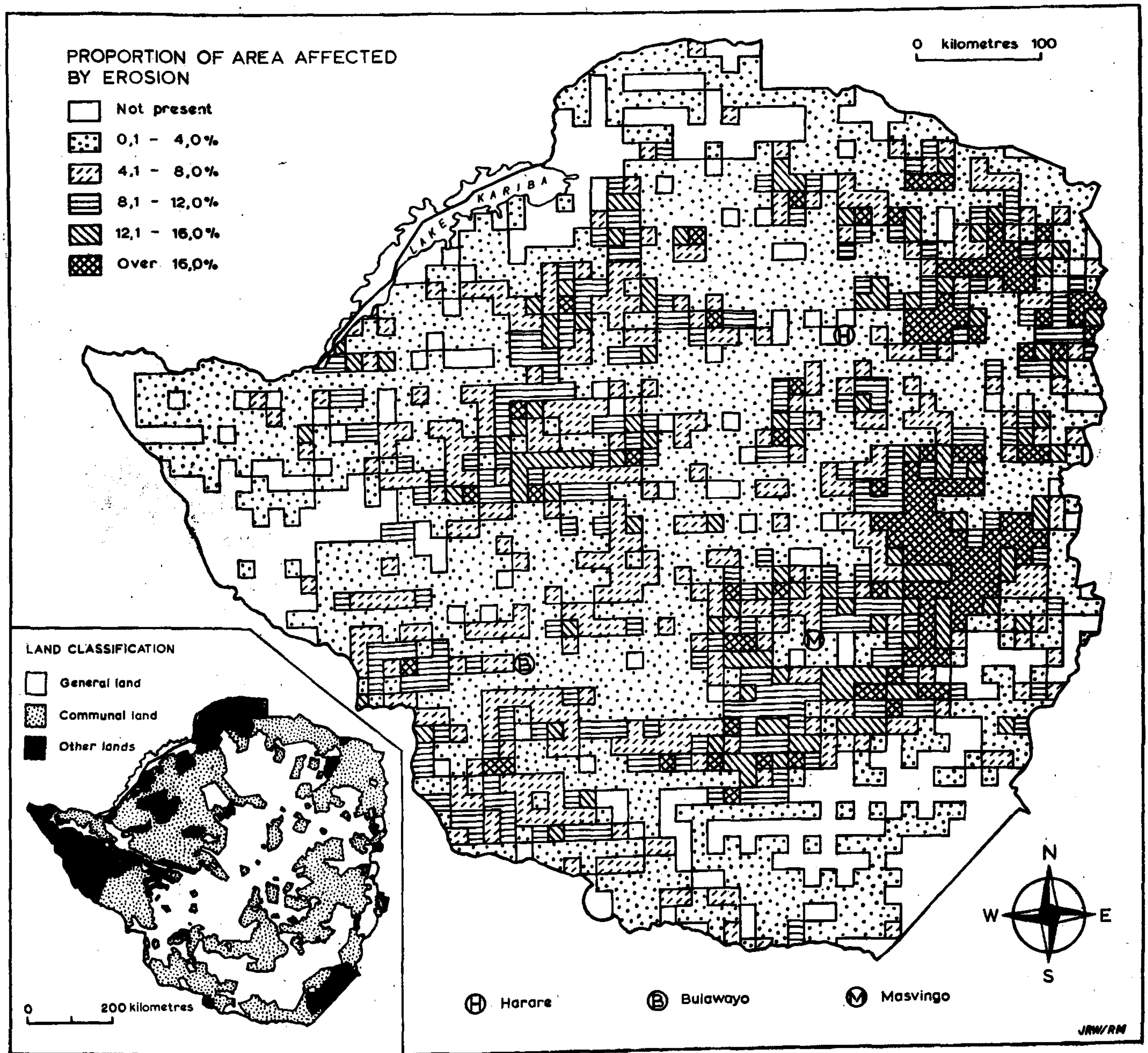
JRW/MS
November 1986



National land degradation survey.

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Many individuals and organisations were involved directly in this research and I would like to thank them for their contributions, however big or small.

In particular, I would like to thank the following:

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Aerial photograph extracts in this report are reproduced with permission of the Surveyor General.

In addition, I would like to thank Dr B. Campbell of the University of Zimbabwe for carrying out the statistical analysis of the erosion data. The main report draws, at times extensively, on the research of Henry Elwell (Institute of Agricultural Engineering, Hatcliffe) and Dr. Michael Stocking (University of East Anglia, Norwich); their work has contributed enormously to our understanding of erosion in Zimbabwe and has been acknowledged fully in this report.

Finally, I would like to thank my wife and baby daughter for putting up with some 40 days (and nights) when I was closeted firmly in my study, only to emerge for food and sleep!

I enjoyed doing this study and learned a great deal in the process which I hope will be of benefit, via this report, in tackling the erosion problem in Zimbabwe.

Richard Whitlow
November, 1986.

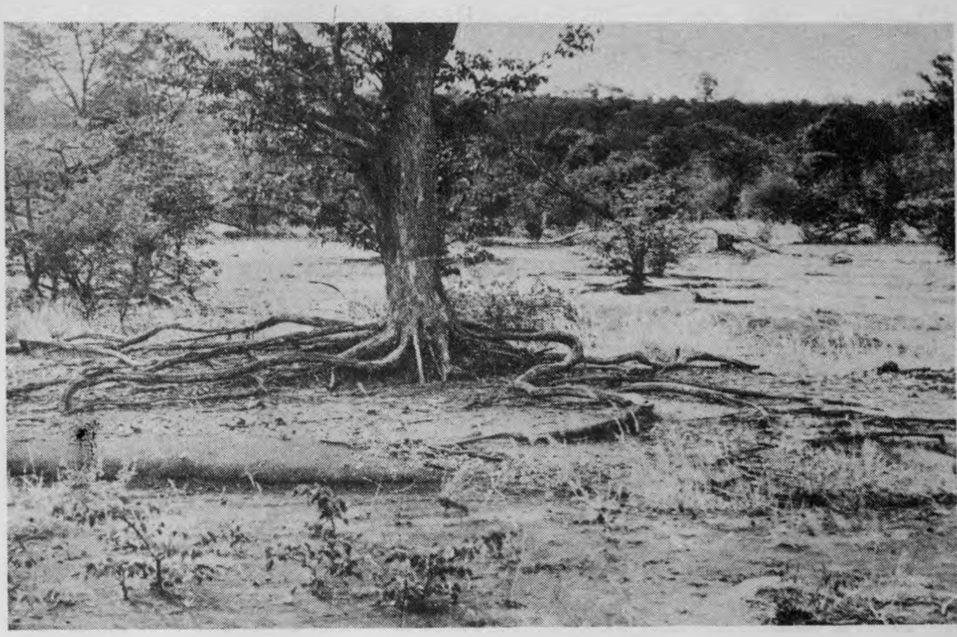
LAND DEGRADATION IN ZIMBABWE - A GEOGRAPHICAL STUDY

Gully erosion in a wetland area in Mangwende Communal Land

(Source: author).

Sheetwash erosion exposing tree roots

(Source: H.A. Elwell).



Alluvial infill resulting from erosion in the headwaters of a river basin

(Source: author).

1. INTRODUCTION

The basic terms of reference for the national erosion survey of Zimbabwe were as follows:

- the survey method should be simple, systematic and quantitatively based;
- the survey should have potential for monitoring changes in erosion patterns;
- the survey should generate information on the extent of eroded terrain in both map and statistical forms at scales appropriate for national and regional planning;
- the survey method should be economic in terms of financial and manpower inputs;

In accordance with these objectives a pilot survey was undertaken to develop and test a method for carrying out a national survey during 1984 (Whitlow, 1986). Subsequently, the Department of Natural Resources indicated that it wished to proceed with a countrywide survey which was initiated in the latter part of 1985 with the support of the Department of the Surveyor General. The main data collection was completed by the end of February, 1986. During the analysis and evaluation of these data it became apparent that a report based solely on the aerial photo assessment of erosion would not do justice to the complex problems of land degradation in Zimbabwe. A more comprehensive study which incorporated previous scientific research and historical records was deemed necessary, especially for the benefit of decision makers and planners who, by virtue of their background, know very little about the causes and consequences of soil erosion.

This report covers five main aspects of the erosion survey of Zimbabwe. Firstly, the history of the erosion problem is examined with respect to the large and small scale commercial farming areas and the Communal Lands. This historical review is essential to understand how the present circumstances of soil conservation land degradation evolved.

Secondly, the methods of the national survey are described and the relative advantages and disadvantages of these methods are discussed. There were no precedents for this survey in Africa or elsewhere and given that the study may well attract a great deal of attention and, perhaps, criticism, a full account of this pioneering methodology has been given.

Thirdly, the general distribution of erosion in relation to land tenure types, natural regions and occurrence within croplands and non-croplands is discussed. The focus in this section is more on defining the magnitude and spatial dimensions of the erosion problem, the basic causes of which are explored in the remaining sections.

Fourthly, the influence of physical factors on erosion is examined with respect to rainfall characteristics, soil types and terrain. The significance of granitic domes and sodic soil is discussed in greater detail because areas with such features are especially vulnerable to degradation.

Fifthly, the influence of human factors on erosion is evaluated with respect to the importance of population density as a measure of pressure on the land, erosion resulting from cultivation and grazing and finally, the degradation of wetlands.

To place this survey in perspective it is useful to outline briefly the basic causes and consequences of soil erosion. There is a substantial scientific literature on this topic (e.g. Hudson 1971; Morgan 1979; Blaikie 1985) where more detailed information can be obtained.

a) Causes of Erosion

Erosion involves the detachment of soil particles from larger aggregates (or peds) and the removal of the particles by flowing water and wind. In the sub-humid climatic conditions which prevail throughout most of Zimbabwe fluvial erosion is dominant, that is the effects of rainsplash and run-off, both surface and subsurface. Aeolian or wind erosion is more localised. However, the presence of fossil sand dunes in the dry south-west of the country is indicative of more active aeolian processes in the recent geological past (Thomas 1985); consequently, fears that man-induced desertification could result in the reversion of these areas to desert-like conditions are, perhaps, justified.

Soil erosion is an extremely complex phenomenon, varying both spatially and temporally. Consequently, scientists have developed a variety of models to assist in identifying critical components and interactions within the soil erosion system. Stocking (1980) has presented one such model which is useful for describing an erosion system (Fig. 1). Within this model, erosion is seen as a function of energy, resistive and protective forces.

Energy forces are those which determine how much energy is applied in the process of detaching and transporting soil particles. For example, high intensity rainstorms result in greater detachment of particles from peds than low intensity storms, whilst high rates of surface runoff on steep slopes result in greater removal of soil than occurs where runoff is limited and there are low angle slopes. Resistive forces are those which help overcome the applied energy forces and relate mainly to soil properties. For example, where soils have a high organic matter content and have stable aggregates they are able to withstand the effects of raindrop impact more readily than soils with low organic matter content and unstable aggregates. Protective forces are those which neutralise energy forces. For example, a good plant cover will intercept raindrops and dissipate their

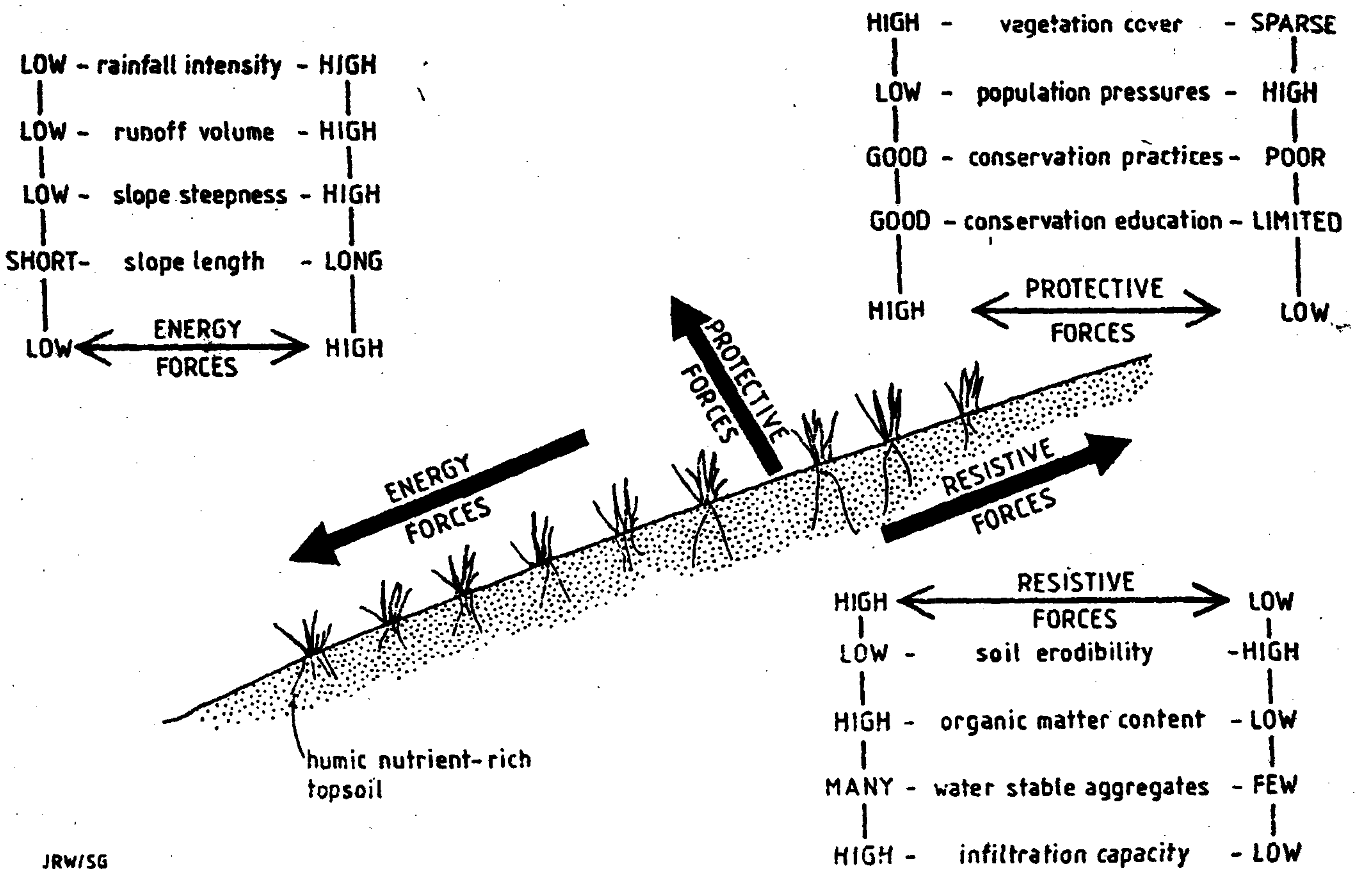


Figure 1 – Model of an erosion system.

energy before they reach the ground. Protective forces, however, include a variety of human factors such as soil conservation practices and population pressures which may promote or reduce erosion depending on their presence or absence.

Bearing in mind that this model is a simplification of reality, it is clear that erosion is the product of a large number of interacting variables. Different combinations occur within different areas and even within the same area at different times. This means that it is unwise to generalise since this could be misleading and obscure the diverse dimensions of erosion, especially when practical solutions to reducing erosion are being sought.

In the Zimbabwe context it seems that variations in erosion are a function mainly of the protective forces outlined in Figure 1, albeit that the effects of these may be enhanced or reduced depending on the nature of energy and resistive forces. For example, in the Communal Lands there is widespread and locally severe erosion due to the inadequacy of the protective forces. This inadequacy is the product of excessive population pressure and the associated socio-economic stresses, as well as limited conservation education. The result is that soil conservation measures are not sufficient to counteract erosion.

In contrast, within the largescale commercial farming areas there is a much greater level of conservation awareness and soil conservation measures, generally, are of a high standard. Moreover, there is less pressure on the land as far as human and livestock populations are concerned. Erosion, therefore, is much more localised than is the case in the peasant farming areas. Where limited protective forces combine with situations where naturally high rates of erosion occur or could occur where biotic disturbances are introduced, then one has the makings of accelerated land degradation. Examples of this include the densely settled Communal Lands in areas of granitic domes and sodic soils as discussed later in this report.

b. Consequences of Erosion

The consequences of erosion can be outlined in terms of the effects upon source areas from which soil is removed and sites where soil is deposited as sediment.

With respect to on-site effects it is useful to think in terms of a soil balance equation comparing rates of soil formation and erosion. A detailed study on granitic rocks in the high rainfall areas in eastern Zimbabwe has demonstrated that rates of weathering and soil formation are in the order of 150 to 400kgs/ha/year. Over a 1000 year period this would produce a soil depth of between 4 to 10 millimetres (Owens and Watson, 1979). In the lower rainfall areas rates of weathering and soil formation are somewhat lower and soils, typically, are relatively shallow (Thompson and Purves 1978). Potentially, this makes these areas more vulnerable to the adverse effects of accelerated erosion.

Stocking (1986) has computed the following average rates of soil loss for agricultural lands in Zimbabwe making use of the model developed by Elwell (1978):

commercial grazing lands — 3 tonnes/ha/year
communal grazing lands — 75 tonnes/ha/year
commercial arable lands — 15 tonnes/ha/year
communal arable lands — 50 tonnes/ha/year

These estimates relate only to soil removed by sheet-wash process. It is abundantly clear that rates of soil loss are many times greater than the rates of soil formation, especially in the communal farming areas. Taking the highest estimated erosion rate on communal grazing areas, that is 75 tonnes/ha/yr, this converts to the stripping away of some 20 centimetres of soil over a 1000 year period. Field evidence shows that locally much greater rates of erosion occur and a single intensive rainstorm may result in the removal of several millimetres depth of soil within a few minutes. Elwell (1975) indicates that a practical target figure for conservation measures on sandveld soils might be 4 tonnes-ha/year, but even this means that farmers are losing soil at a rate which exceeds soils formation by at least a factor 10.

Recognising that rates of soil loss are not easily translated into practical implications for human activity, Elwell and Stocking (1984) have proposed that erosion be expressed in terms of soil life span. This can be determined from the following equation.

$$Lf = \frac{(De - Do)\,M}{Z - ZF}$$

where

Lf	=	soil life – span in years
De	=	depth of available productive soil (metres)
Do	=	minimum soil depth for a particular crop (metres)
M	=	bulk mass of soil (tonnes/ha/metre depth of soil)
Z	=	predicted rate of soil loss (tonnes/ha/year)
Zf	=	estimated rate of soil formation (tonnes/ha/year)

The equation has been applied to peasant farming areas in the upper reaches of the Save catchment, areas long recognised as having high rates of erosion (Du Toit, 1985). It was estimated that in these Communal Lands the soil depth could be insufficient to grow maize within ten years and sorghum production would be impossible within 30 years. Even if these estimates of soil life span are conservative they show that certain areas in Zimbabwe are on the brink of collapse, with all the socio-economic hardships that will follow.

An alternative measure of the consequences of soil loss is to express the volume of soil removed annually in terms of the amount of fertilizer needed to replace the nutrients in the eroded soil. On the basis of ten years of experimental plot data from Henderson Research Station, Stocking (1986) has estimated the following values of nutrient losses due to soil erosion in Zimbabwe:

Nitrogen — 1,60 million tonnes/year
Phosphorus — 0,24 million tonnes/year
Organic carbon — 15,60 million tonnes/year.

Converting the nitrogen and phosphorus losses into the equivalent costs of fertilizer at 1985 prices, Stocking (1986) calculated that this 'erosion costs' amounts to some \$2 540 million per year. For arable lands alone the loss was estimated at over \$140 million or twice the value of the fertilizer used on croplands during the 1984/85 season. These losses do not take into account the nutrients leached out of the soil and removed from farming areas in solution form. The loss of organic carbon is important since there is a strong correlation between organic carbon levels and soil aggregate stability (Elwell, personal communication); the removal of organic carbon results in decreased aggregate stability and favours accelerated erosion. Clearly the unseen economic burden of soil erosion is enormous and, with continued degradation, is going to have a severe impact on the viability of both commercial and communal farming.

One obvious manifestation of the removal of soil and the nutrients within it is the decline in productivity of the land. Given the problems of maintaining soil fertility in the Communal Lands (Grant, 1981), combined with widespread erosion, one might expect that there would be marked decreases in crop yields in these areas. Analysis of crop data for the periods 1951-55 and 1976-80 show that this is true for some crops but not others (Tattersfield, 1982). For example, between the early 1950's and the late 1970's, the average yields of maize, a staple crop on peasant farms, actually doubled from 342 kgs/ha to 695kgs/ha; this increase is attributed partly to better husbandry and partly to use of higher yielding hybrids.

On the commercial farms average yields for the same period were 1,421 kgs/ha and 4,726 kgs/ha. The higher yields and the 3,3 times increase were attributed largely to applications of nitrogenous fertlizers (Tattersfield, 1982). Farmers in the Communal Lands are not in a position to use as much fertilizer as those in the commercial sector; hence their overall yields and increases in yields over the last thirty years are not as high. Nutrient depletion as a result of erosion is obviously not assisting in efforts to improve maize yields in the Communal Lands. Other crops reported to have increased yields in the peasant farming areas include sorghum and groundnuts, the improvements being brought about mainly by use of high yielding hybrids (Tattersfield, 1982). One suspects that where these are grown as cash crops fertilizer inputs are offsetting, at least to some degree, the nutrient losses caused by erosion.

The trend of declining yields is shown more clearly in the case of munga and rapoko, traditional small grain crops amongst peasant farmers. Since these are not grown commercial virtually no research has been carried out on these crops; hence there has been little improvement in, for example, development of hybrid varieties (Tattersfield, 1982). Crop yield averages for munga for the early 1950's and late 1970's were 531 kgs/ha and 385 kgs/ha respectively, whilst the comparable figures for rapoko were 605 kgs/ha and 493 kgs/ha. Increases in overall production of these two crops have been brought about by extension of cultivation, typically into more marginal lands which are less fertile and more prone to erosion. In the case of these crops and indeed the better yielding crops such as maize, one must bear in mind that average data obscure considerable variations in yields. It is not uncommon to find adjacent fields where in one plot there is a fine stand of maize and little erosion while in the other there are scattered stunted and yellowing plants and excessive erosion. There is, therefore, no doubt that erosion has had a negative effect on crop yields in the Communal Lands, more so on some farmers than on others.

A large proportion of the soil eroded from hill slopes enters the main river systems. A recent survey of sediment yield of African rivers indicated that in Zimbabwe up to 100 tonnes/km^2/year is lost in the form of suspended sediment or dissolved load (Walling, 1984). This only accounts for a fraction of the eroded material. Most of the sediment is stored within the river channels or is trapped in reservoirs. In the former situation this encourages the growth of aquatic plants such as reeds which effectively block rivers when they grow in dense stands. This may cause localised flooding of the areas adjacent to rivers during high discharge events. The siltation of dams is probably a more serious issue. Elwell (1985), for example, reports on a detailed survey of 132 dams in the Masvingo area. Of these 132 dams over half were more than 50% silted and 16 were completely silted.

The smaller, and hence low capacity, dams within or draining the Communal Lands are especially prone to high rates of siltation. Magadza (1984), for example, shows that small reservoirs have an effective life of under 15 years before being filled with sediment. However, as the reservoirs fill progressively with sediment their value diminishes in terms of water storage. Recognition of the widespread occurrence of reservoir siltation prompted a special sedimentation study by Interconsult (1985) in the preparation of the National Master Plan for Rural Water Supply and Sanitation.

It is clear from this brief outline of the consequences of erosion that land degradation has important environmental and economic impacts. To ignore these impacts would be foolish and to take token conservation measures as an appendage to development programmes is not much better. Erosion is not a problem of the future, it is here now and must be tackled now, at least while there is still soil to conserve.

2. HISTORY OF THE EROSION PROBLEM

A review of the history of soil erosion and past conservation measures is necessary for two reasons. Firstly, to account for how the present patterns of land degradation evolved and secondly, so that past successes and failures can be assessed as a basis for future plans. The period under review dates from 1890 to the present, just under one hundred years. Consequently only key issues and events will be discussed. A more comprehensive account has been given elsewhere (Whitlow 1987a, 1987b). Various scientific papers and government reports were used to compile this review. The annual reports of the Natural Resources Board (NRB) were especially useful, providing a chronological record of soil erosion and related environmental problems since 1942.

Political, economic and environmental factors have interacted in many complex ways to bring about the current situation of resource degradation in Zimbabwe (Whitlow, 1985a). A central part of the problem is the issue of land tenure and the division of land on racial lines. This is a complex topic in itself (e.g. Kay, 1970; Palmer, 1977; Bannerman, 1982), so only general comments of direct relevance to erosion will be given here, especially with respect to the Communal Lands. The focus in this review is on the farming areas, notably the large scale commercial farmlands and the Communal Lands. The small scale commercial farmlands are commented upon briefly below to complete the picture on the history of erosion and conservation measures. The non-agricultural lands such as national parks and forest reserves are not discussed since erosion is very localised in these areas.

The small scale commercial farming areas were established as Native Purchase Areas (NPA's) within the context of the Land Apportionment Act of 1931. Some 3,3 million hectares of land were set asided for division into small farms (c.90ha) to be held under freehold title.

The idea was to encourage the more successful peasant farmers to leave the 'native reserves' to pursue farming independent of traditional tribal tenure. This had a negative impact on the reserves since many of the more able farmers took up this opportunity, hence their potential role as a good example to other peasant farmers was lost. Although many farms were occupied in the NPA's, large areas were under a more communal form of land use. Such areas were transferred to what had become the Tribal Trust Lands in 1969 and by the time of the Land Tenure Act in 1970 the area of small peasant farms (referred to as African Purchase Areas or APA's since 1964) was reduced to just under 1,5 million hectares (Christopher, 1971).

Throughout their existence these Purchase Areas suffered from lack of financial and manpower support for basic construction and maintenance of conservation measures. For example inadequate water supplies and dip tanks involved trekking of cattle along roads and access routes through strips of state land separating blocks of farms. The resultant degradation was difficult to deal with since neither the farmers nor the government would take action on these public areas. By 1955, partly at the insistence of some of the farmers, conservation groups were established in the form of Agricultural Committees of Native Councils. Very few committees were established in the 1950's and it was only in 1961 when these were given a similar status to the Intensive Conservation Area committees in the European farming areas that greater support was forthcoming (See Fig 2 later). Thereafter, conservation efforts made greater progress and, given the much lower population densities in these areas, land degradation never became as widespread and serious as it did in the Communal Lands. Nevertheless, in relation to the large scale commercial farming areas, the state of resource conservation still leaves considerable room for improvement.

a) Large Scale Commercial Farmlands

Four main historical phases can be identified in these areas. These phases are as follows:

Phase 1 — Trial and error: — pre- 1931
Phase 2 — Erosion awareness: — 1931 – 1948
Phase 3 — Conservation farming – 1948 – 1965
Phase 4 — Mixed fortunes – post – 1965

Selected aspects of the history of the NRB are included in this discussion since this body has been involved intimately with conservation efforts on commercial farms more so than in the other farming areas.

Phase 1 – Trial and Error : Pre – 1931

The early decades of this century were very much a case of trial and error as the European settlers established farms in the 'virgin bush'. Soil erosion was just one of many environmental hazards to be faced along with the logistic and financial difficulties of pioneer farming. Few precautions were taken to protect arable lands and farmers, especially on the red 'goldbelt soils', seemed to regard the fertility of the soil as being inexhaustible. Yields soon declined with continuous cropping and excessive erosion (Jennings, 1921), forcing farmers to open up more land for cultivation (Aylen, 1939).

It was recognised at an early date that intensive tropical rainstorms could cause serious sheetwash erosion on exposed soils (Cripps, 1909). Despite advice and warnings from irrigation engineers, few farmers recognised the hazards of erosion let alone did anything to protect the soil (Haviland, 1928; Jennings, 1923). By 1921, the government irrigation engineer reported that soil washing was one of the most important problems facing farmers (Jennings, 1921). Two years later, however, some farmers prompted by declining maize yields sought his advice and subsequently installed what might be considered the first scientific anti-erosion works on commercial farms in Zimbabwe (Haviland, 1927). Progress in the adoption of basic conservation measures was slow, however, and it was not until 1929 that an appreciable amount of protection work on some 923 hectares of cropland was carried out (Aylen and Roberts, 1937).

General degradation of the veld due to uncontrolled fires and overgrazing was also a recognised problem on commercial farms (Haviland, 1927). The first specific anti-erosion legislation was in fact the Herbage Preservation Ordinance of 1913 which sought to prevent indiscriminate veld fires (Natural Resources Board, 1966). Degradation of roads and cattle tracks was a locally serious problem (Haviland, 1925, 1928). Of greater concern was bush clearance to provide firewood for tobacco curing and the limited measures to protect abandoned tobacco lands (Haviland, 1927). In addition, efforts to drain vleis by means of ditches to enable maize and wheat production had resulted in widespread gullying in these wetlands (Jennings, 1923; Haviland, 1927). As a result of this erosion, legislation was passed in the Water Act in 1927 to restrict the uses of these hydromorphic soils (Whitlow, 1983a).

Phase 2 – Erosion Awareness: 1931 – 1948

During the 1920's there was a growing awareness of the evils of soil erosion and a resolution on the problem of 'soil wastage' was discussed at the 1931 Congress of the Rhodesia Agricultural Union. A soil erosion committee was appointed to determine the main causes of erosion and to suggest remedial measures.

Following the recommendations of this committee the Minister of Agriculture in 1934, approved the establishment of two Soil Conservation Advisory Councils, one in Mashonaland and one in Matabeleland (Anonymous, 1935). This provided the first formal framework for communication between farmers and government officials on the erosion problem. Farmers soon came to accept the need for mechanical protection of arable lands and many, with the assistance of irrigation engineers, undertook the construction of ridge terraces in their croplands during the 1930's (Table 1). By 1938 some 27% of arable lands had been protected mainly in the Harare, Lomagundi and Mazowe districts. There were still large areas of poorly protected or unprotected croplands elsewhere in the country.

TABLE 1: CONTOUR RIDGING ON COMMERCIAL FARMS 1929–1939

Year	Length of ridge terracing (km)*	Area of land protected (ha)*
1929	122	923
1930	166	1250
1931	241	1821
1932	174	1311
1933	212	1603
1934	203	1530
1935	592	4468
1936	861	5413
1937	1633	10269
1938	2803	17624
TOTAL 1929–1938	7007 kms	46212 ha

Sources: Commission of Enquiry (1939) p.18.
* *original units in miles and acres so metric values have been rounded off.*

Continued soil erosion on commercial farms, but even more so within the 'native reserves' (discussed later), resulted in the appointment of a special commision in 1938 to assess the state of resource degradation in the country and to advise on measures to overcome these problems. The commission found that extensive areas in the maize growing regions "had been impoverished by erosion and some of it ruined beyond repair..." (Commission of Enquiry, 1939, p16), whilst serious erosion was observed on tobacco farms where the farmers were reluctant to construct ridges lest these impede soil drainage and encourage eelworms.

The Commission of Enquiry recommended that there was a need for specific legislation governing the uses of natural resources, the establishment of a Natural Resources Board to ensure compliance with this legislation and, finally, the appointment of local conservation committees to gain the support and co-operation of farmers in conservation measures. Following the acceptance of the commission report, parliament formulated and passed the Natural Resources Act in 1941. This act provided for the setting up of the Natural Resources Board (NRB) and determined its functions in ensuring effective implementation of the new legislation.

There was a very mixed response to these developments. Some farmers strongly approved of the legislation but some were openly hostile, regarding the new act as unwarranted interference in their affairs. Many farmers considered the principles were sound but had reservations about the wide powers of the NRB (views expressed in newspapers in 1941; see National Archives Reference S991).

The first Natural Resources Board assumed duties in November 1941 under the chairmanship of Sir Robert McIlwaine who had led the Commission of Enquiry a few years earlier. The Second World War was still in progress so there were severe financial and manpower shortages during the early years of the Board's existence. However, it also "laboured against apathy and a measure of suspicion on the part of the major section of the (European) farming community" (NRB 1966: p4). One of its major tasks, the establishment of local conservation committees, faltered badly.

Only two committees had been formed by 1944, but with the end of the war in 1945 the situation improved. In the years which followed there was a steady increase in the number of conservation committees, officially referred to as Intensive Conservation Area committees or ICA's (Fig. 2). Similar types of committee were established in the African farming areas but at a much later date, as shown in Figure 2. The ICA committees proved to be a powerful force for promoting conservation methods in the commercial farming areas.

During the 1940's the NRB was instrumental in obtaining government approval for subsidies on conservation works, financial assistance for ICA's to purchase earthmoving equipment, and the introduction of price incentives on crops to encourage the adoption of anti-erosion measures. The NRB also accepted the establishment of a Natural Resouces Court to enable farmers to appeal against orders issued by the Board. This appeased the recalcitrant farmers and gradually more and more farmers began to realise the benefits of co-operation via the ICA system.

This set the stage for more positive actions to prevent erosion and encourage better land husbandry (Kennan, 1971).

Phase 3 — Conservation Farming: 1948-65
In 1948 the Department of Research and Specialist Services (R and SS) was created to pursue studies on improved farming and to provide services such as soil analyses for farmers. A Conservation and Extension Branch (Conex) was incorporated in R and SS, but became a full department by 1950 (Kennan, 1971). Its main functions were to advise on basic soil and water conservation measures and to translate agricultural research into practice amongst the commercial farmers. Previously these functions had been carried out as peripheral duties by irrigation engineers and research staff. The establishment of Conex coincided with a general appreciation that both mechanical protection

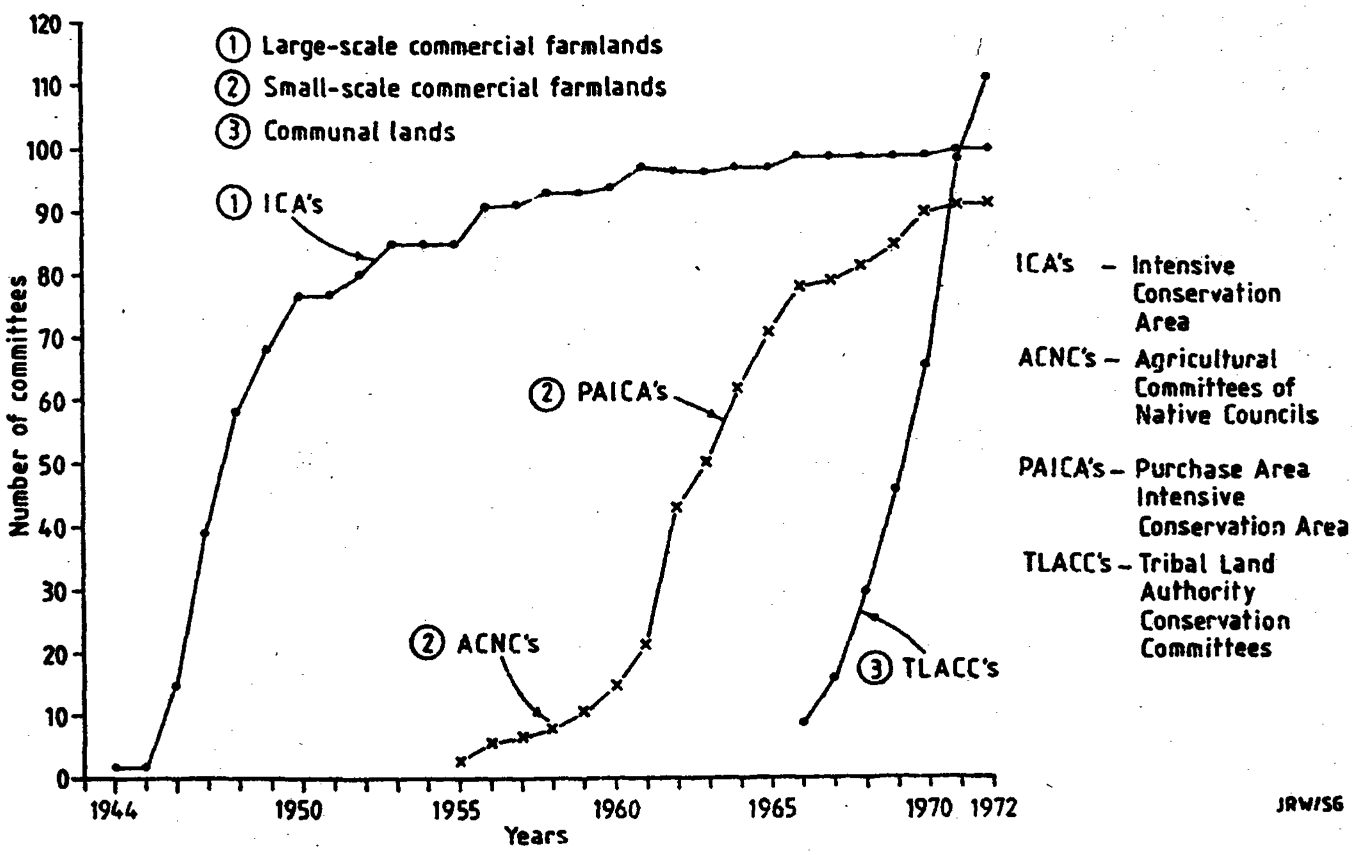


Figure 2 – Conservation committees in commercial and peasant farming areas, 1944–1972.

and improved husbandry were needed to prevent erosion.

Following the establishment and fairly rapid growth of Conex (Kennan, 1971), several factors promoted improvement in conservation measures. Firstly, there was the co-operation between the growing number of ICA's and Conex staff. Secondly, formal experimenal work on erosion was initiated on Henderson Research Station providing a more scientific basis for conservation measures on arable lands (Hudson, 1963, 1971). Thirdly, by the mid-1950's the extension of aerial photography and contour mapping provided a sounder basis for planning. Fourthly, in 1956, following the example of the United States extension service, Conex adopted a system of farm planning. This was regarded as "one of the most progressive and important steps taken for the improvement of conservation farming throughout the country" (NRB annual report, 1959, p8). Continuation of subsidies on conservation works and, in addition, assistance in construction of dams also promoted better soil and water conservation on commercial farms.

Despite the perennial problems of financial constraints and manpower shortages, along with disagreements over responsibilities between the Federal and Territorial Governments and the loss of experienced staff on the dissolution of the Federation of Rhodesia and Nyasaland in 1963 (Whitlow, 1987a), considerable progress was made in conservation. Conservation farming became the norm. This laid firm foundations for the subsequent intensification and diversification of commercial faming.

Phase 4 — Mixed Fortunes: Post- 1965

The illegal declaration of independence in 1965 precipitated growing political, economic and security pressures on the country. Commercial farmers, especially those producing tobacco, were forced to diversify. Thus economic sanctions promoted a trend of intensifying and broadening the base of the commercial farms. This, combined with the harnessing of water resources for irrigation, actually strengthened the commercial agricultural sector in the long term (Kay, 1970). Soil erosion was a minor problem in comparison with other difficulties faced by farmers. Judging from the NRB annual reports, land degradation issues did require attention from time to time.

Successive droughts in the mid 1960's, for example, brought about an awareness of deterioration of the veld in the main ranching areas in the south and south east of the country. The NRB responded by setting up a Marginal Land Use Committee to reassess land use policy in these areas. Farmers were encouraged to re-evaluate the carrying capacity of their ranches and to adjust livestock numbers accordingly. The Marginal Land Use Committee report (1968) reiterated the need for proper livestock and veld management, such as rotational grazing, to avoid degradation of the plant and soil cover. More innovative farmers, meanwhile, were experimenting with game ranching. Wild animals were thought to be less destructive on the habitat than cattle and had the advantages of being less susceptible to drought and disease. In time game ranching became more widely accepted as a sound conservation strategy in the drier regions.

By 1970 the NRB was expressing concern over the increasing incidence of erosion on arable lands in the higher rainfall areas. Reduced profitability of farming had led, seemingly, to neglect of conservation measures and a general survey of croplands indicated that, despite mechanical protection, some 12% of cropped areas were moderately to seriously affected by erosion (Elwell, 1974). This had resulted in a decline in yields and hampered operations on degraded lands, increasing production costs. Renewed efforts were made to promote basic conservation measures and research on erosion, especially sheetwash erosion, was initiated at Hatcliffe Research Station near Harare. Regrettably this research, despite its potential practical value (Elwell, 1978 and 1980a; Stocking, 1981), has suffered from inadequate financial and manpower support and has not been promoted actively through the extension services.

Deterioration of security conditions in the latter part of the 1970's greatly hampered farming operations. Many farms were abandoned and those near congested Communal Lands were claimed by peasant farmers in a spontaneous, but illegal, 'land grab'. Indiscriminate felling of trees and cultivation of streambanks were commonplace (NRB annual report, 1980). The problem persisted through the early years of independence, hampering the progress of more formal resettlement programmes in some areas (Zinyama and Whitlow, 1986). Despite these difficulties, commercial farming survived and since 1980, with the stimulus of new export markets, production activities have expanded. Moreover, Zimbabwe's assumption of food security in the SADCC groups rests fairly heavily on the commercial sector (Whitlow, 1985a). The high standards of conservation and husbandry which prevail in these areas today are the product of many years of investment and effort on the part of farmers and extension staff, assisted by the ICA committees and the NRB.

b) **Communal Lands**

The history of soil conservation and land degradation in the peasant farming areas is associated very closely with land alienation policies during the colonial period (1890 – 1980). A persistent theme in this history is the gradual deterioration of man-land relationships as population pressures, both human and livestock, increased. This is explained in greater detail in Section 6 of this report.

Five main historial phases can be identified in these areas as follows:

Phase 1 — Creation of reserves — pre- 1926
Phase 2 — Centralisation — 1926-1951
Phase 3 — Agrarian reforms — 1951-1962
Phase 4 — Uncertainty — 1962-1969
Phase 5 — Growing pressures — post- 1969

Phase 1 — Creation of reserves: pre- 1926

At the time of European occupation in 1890 there were an estimated 400 000 people in the country (Floyd, 1962). Although extensive areas were sparsely populated or uninhabited, all of the land was claimed by at least one tribe or another (Kay 1970). This situation changed radically within the first few years of colonial rule. Following the unsuccessful Ndebele uprising in 1893, the Gwaai and Shangani Reserves were created to the north west of Bulawayo to accommodate the 'defeated people' as their land was taken over by European settlers (Fig 3; Christopher, 1971).

Following a similar uprising by the Shona in 1896-97, it became apparent that the African people were in danger of being dispossessed of a large portion of their land. Consequently, the British government insisted that the British South Africa Company (which came under its jurisdiction) set aside land for the exlusive use of the indigenous population. This initiated the legal designation of what were termed 'native reserves.'

By the end of the second decade of colonial rule nearly 8,5 million hectares of land, just over one fifth of the country, had been declared 'native reserves' (Fig 3). Generally the reserves were demarcated in areas where Africans were living at the time, particularly the more densely settled areas, and little account was taken of the population displacements that had occurred during the rebellions. European farms tended to be concentrated in the central watershed region, especially following the construction of the railway lines between Mutare, Harare and Bulawayo. This effectively left the more peripheral parts of the country free for creation of reserves.

By 1911 the African population was estimated to be about 700 000 people of whom some 60% were within reserves (Fig 3; Beach, 1984). The colonial authorities regarded the reserves as more than ample to meet the present and future land needs of the African population (Palmer, 1977), and there were no further additions to the 'official' African areas until 1931. The implications of this initial phase of land alienation became obvious when African families on what had become settler farms were faced with the dubious prospects of becoming labourers, rent paying tenants or moving, voluntarily or otherwise, into the reserves.

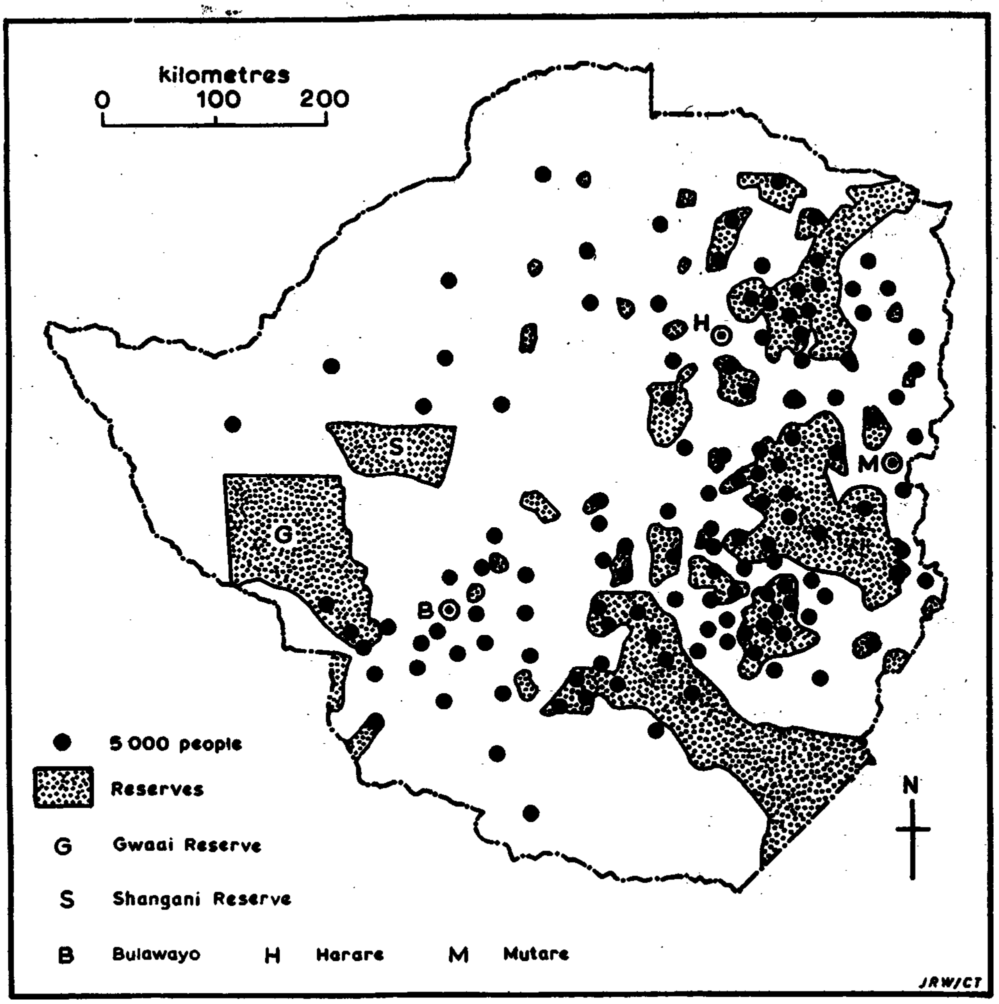


Figure 3 - Early native reserves in Southern Rhodesia (1911).

The concentration of people in the reserves did not lead to soil erosion initially since population densities were low, with an average of 5 person/km² in 1911 (Zinyama and Whitlow, 1986). However, as the reserve population increased partly from natural growth and partly from in-migration of displaced families, so conditions for resource degradation developed. It was not long before the District Native Commissioners responsible for administering the reserves began to express concern over the deterioration of plant cover and soils. The cause of this deterioration was seen as the " 'wasteful, slovenly and ineffective' methods of land usage employed by the tribesmen" (Kay, 1970, p84), rather than population pressure.

Factors which contributed to the deterioration of man-land relationship at this time included the widespread adoption of maize growing and the use of ploughs (Kay, 1970). Maize, for example, had become a staple subsistence and cash crop by the late 1920's. Arable lands were extended to produce more and more maize, partly to supply an expanding market in the towns and mines and partly to counter the lower, less reliable yields of maize. This extension of cultivation was facilitated by the use of ox-drawn ploughs which increased in number from around 3,400 in 1902, the earliest date for which figures are available, to nearly 94,000 by 1938 (Commission of Enquiry, 1939). Ploughing required complete clearance of woody vegetation, unlike hoe cultivation, so it had a more lasting impact on the physical environment. The common practice of ploughing up and down slopes favoured erosion, especially the initiation of gullying (Bond, 1948).

The welfare of the people in the reserves was a very low priority as far as the colonial administration was concerned. The reserves were regarded more as potential 'competition' for the newly established commercial farmers and the administration was keen to get Africans to enter wage employment rather than farming independently (Palmer, 1977). Consequently, little support was forthcoming for general development in the reserves, especially after the country became self governing in 1923 and the interests of the European population prevailed. It was not until 1924 that measures were taken to assist African farmers by means of agricultural demonstrators.

Phase 2 — Centralisation: 1926-1951

The need for some form of extension in the reserves was recognised during the early 1920's and in 1926 a man called Alvord was appointed as the Agriculturalist for the Instruction of Natives. Gradually Alvord built up a team of agriculturalists and African demonstrators to assist peasant farmers and by 1945 he had a staff of 349 men (Kay, 1970). At an early stage Alvord recognised that prevailing land use patterns within the reserves were inefficient in terms of labour and land. With limited manpower and funding, he decided that the best way to improve farming and conservation was to consolidate arable holdings, separate these from grazing lands by perimeter fencing and to locate villages along the margins of the cultivated areas. This strategy became known as centralisation. It was initiated in Selukwe reserve in 1929 where 'after much persuasion' the people agree to reorganise the croplands and grazing areas (Bond, 1948). By 1946 over 3,8 million hectares, mainly within densely settled reserves, had been centralised.

Basic conservation measures were included in the centralisation process, notably contour ploughing and inclusion of grass strips in the arable lands (Aylen, 1942). A soil conservation scheme was introduced in 1936 to promote construction of contour ridges and stormwater drains. This work was supervised by a Soil Conservation Officer and a team of Native Erosion Control Demonstrators who were appointed in the same year. Within two years over one thousand kilometres of ridging had been constructed protecting some 6,510 hectares of arable land, a remarkable effort when compared to similar measures initiated on European farms in 1929 (Table 1).

However, there were some 1,6 million hectares of arable lands in urgent need of protection in the reserves. It was estimated that it would take nearly 250 years to complete anti-erosion works on these lands, although plans were in hand to increase the rate of ridging to cover 32,000 hectares annually (Commission of Enquiry, 1939). In addition, it was not until 1944 that conservation measures were extended to grazing areas and roads, the latter being especially vulnerable to erosion because of the widespread use of sleighs.

By 1937 it was estimated that over 600 000 hectares of reserve land were badly eroded and over half the terrain in five densely settled reserves was subject to severe gullying and sheetwash (Commission of Enquiry, 1939). An equally serious erosion problem existed outside the reserves on African-occupied European lands, mostly owned by absentee landlords and companies who exacted rent from their tenants. Outside the jurisdiction of the Native Department and lacking security of tenure, these tenant farmers indulged in what was referred to derogatorily as 'Kaffir farming' (Bannerman, 1982). Despite legal measures to end the practice of renting land to Africans, it was estimated that there were 164,000 people living under these conditions in 1938. The areas of tenant farming were recognised readily on the ground because of the denuded and gully-scarred terrain (Commission of Enquiry, 1939). The growing problems of erosion associated with African farmers within and outside the reserves were a major reason for the establishment of the Commission of Enquiry referred to earlier.

Whilst the government saw the degradation as a product of indiscriminate cultivation, uncontrolled grazing and a lack of conservation awareness, the peasants saw the problems as symptoms of the need for more land. There was, however, a reluctance to grant additonal land for the reserves. The Land Apportionment Act of 1931 effectively enshrined legally what was a *fait accompli*, the inequable racial division of land (Bannerman, 1982). The area of the reserves remained at 8,5 million hectares as it was in 1911, but the European lands were extended to cover nearly 20 million hectares, just over half the country. It was not until 1950 that more land was added to the reserves in the form of Special Native Areas which are discussed later. The answer to conserving resources and improving farming was thought to be in a more determined resource policy, this being provided for in the form of the Natural Resources Act of 1941.

Specific legislation was incorporated in this act to deal with the native reserves. In particular provisions were directed at the following issues:

- the reservation of degraded lands against further use by people or domestic animals;

- the reduction of livestock numbers where there was evidence of overgrazing leading to resource deterioration;

- the obligatory maintenance of such soil conservation works carried out for the benefit of Africans by those people whose land was directly protected by these works.

Kay (1970) described this act as 'a declaration of intent rather than a blueprint for immediate action" (p.86). The NRB had neither the funds nor the manpower to implement the legislation. In practice, the only measures taken were to destock overgrazed reserves (Bond, 1948). This proved extremely unpopular, partly because of the manner in which destocking was done (Kay, 1970). More crucial was that reduction in livestock numbers was not combined with improved pasture management so that the benefits of reduced pressure were, at best, short-lived. Equally, the bitter resentment of peasant farmers to forced reduction of cattle numbers hardly provided a sound basis for encouraging participation in future conservation programmes.

With growing population pressures and land degradation in the more densely settled reserves, the government eventually agreed after prolonged debate to extend the area available for peasant farmers. In 1950 the Special Native Areas (SNA's) were created, these comprising about 1,7 million hectares taken mainly from hitherto unsold European areas and unassigned land (Christopher, 1971). The SNA's, however, were located in the arid south and tsetse infested west of the country (Fig 4), rather inhospitable areas for settlement and unlikely to absorb many people to relieve pressure in congested

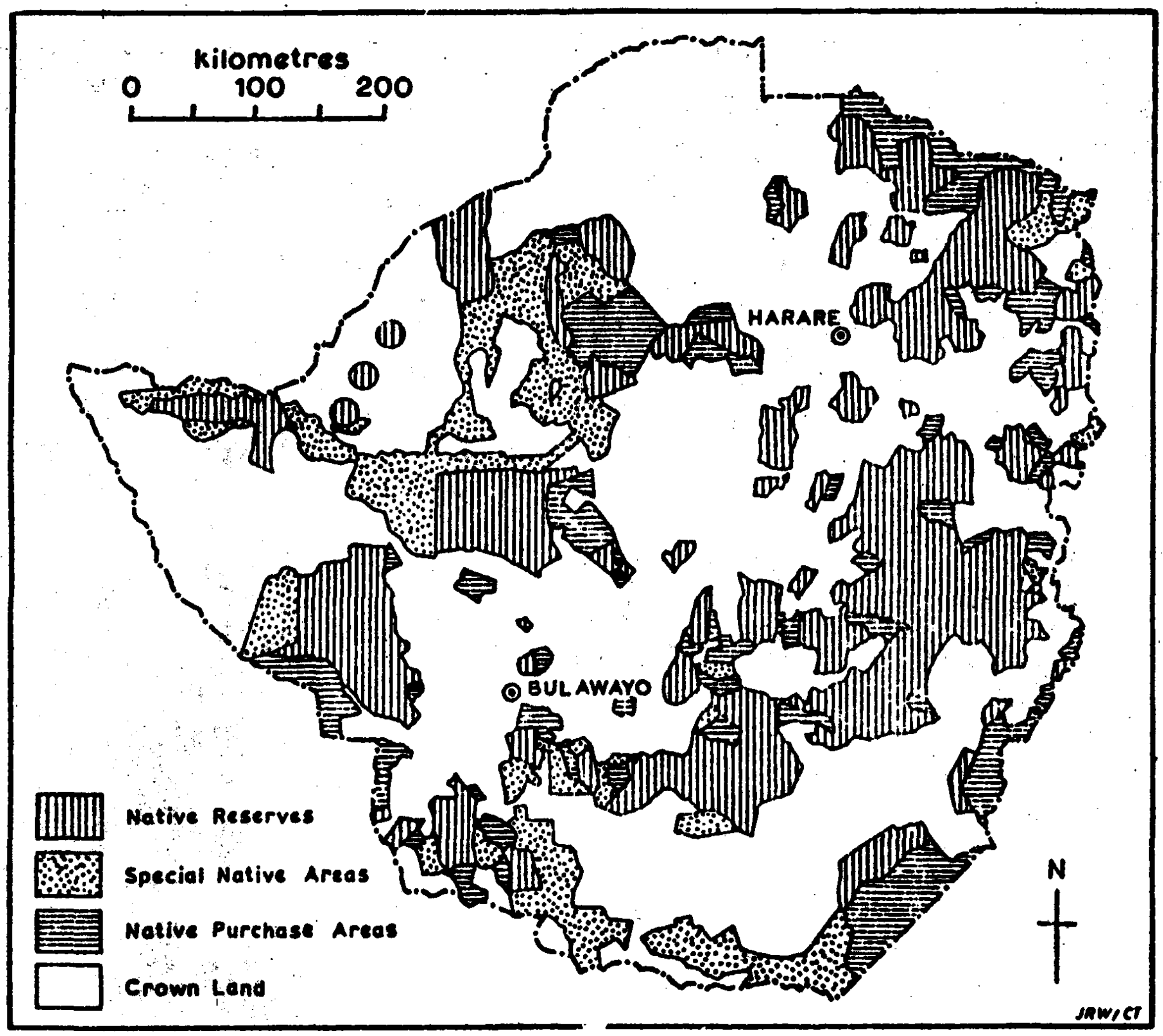


Figure 4 - Native reserves and Special Native Areas (SNA's) in 1950.

reserves (Floyd, 1962). The reserve population by 1950 was estimated at 1,25 million people giving an average density of just under 15 persons/km² (Roder, 1964). Barely 20% of the arable lands had been protected adequately and widespread degradation had occurred within the grazing areas. There was a growing sentiment amongst the administration that much firmer actions were needed to implement agrarian reforms and conservation measures in the reserves. Alvord's centralisation scheme which had operated, at least in principle, in persuading farmers to adopt such reforms gave way to an approach based on legal compulsion (Whitlow, 1985a).

Phase 3 — Agrarian Reforms: 1951-62

In 1951 the government agreed to a comprehensive programme of compulsory agrarian reforms via the Native Land Husbandry Act (NLHA). There were three main components in the NLHA. These were legal backing for the enforcement of conservation measures, the adoption of good farming practices and the replacement of the traditonal land tenure system with one based on individual rights. The philosophy behind the introduction of individual land rights was that farmers would be more inclined to effect improvements on land when they had security of tenure and, at the same time, could be held accountable for any mismanagement of their land (Kay, 1970). Whereas centralisation had upset the balance of the traditional system of land tenure to a minor degree, the NLHA threatened to dislocate it completely. Officially the NLHA was seen as "a most advanced piece of legislation which, if wisely administered, will be of material benefit" (NRB annual report, 1951, p8) in conserving resources and improving agricultural production in the reserves.

Technical details of the NLHA and its implementation are given by Floyd (1961), Johnson (1964), Kay (1970), Hughes (1971) and others. The focus here is on conservation aspects but some comment on land tenure is unavoidable. The NRB felt that individual land rights would motivate farmers to take greater responsibility for soil conservation and, if they failed to do so, then legal pressures would ensure compliance. Conservation of arable lands in terms of the NLHA relied, as in the past, on the use of contour ridges and grassed waterways. By 1957 over 200 000 hectares of arable land had been protected and proper conservation plans had been drawn up for nearly two thirds of the reserves by 1961 (Johnson, 1964), albeit only about 6,5 million hectares of arable and grazing land had been demarcated on the ground (Kay, 1970). During the period 1955 to 1962 over $3,4 million was spent on conservation works in the reserves and SNA's, some 9,8% of the total NLHA budget (Kay, 1970). Overall this was a remarkable conservation effort given the previous lack of progress.

This progress, however, has to be accepted cautiously. In the arable areas, for example, poorly designed ridge layouts were not uncommon since the surveying teams

Plate 1 – Contoured arable lands in a peasant farming area south of Harare (Source: author).

responsible for pegging ridges and plot boundaries were under enormous pressure to cover large areas quickly. Construction of ridges was left, invariably, to the women already overburdened with farming and domestic chores. Consquently construction and maintenance of ridges were not universally of a high standard. Locally, as described by Stocking (1972a) for the Mutoko area, contour ridges concentrated runoff and actually caused widespread gullying. On balance, however, there was a general improvement in the mechanical protection of arable lands, evidence of which is still present in the peasant farming landscape today (Plate 1).

Registered grazing rights were given to farmers to regulate livestock numbers and thereby avoid overstocking. Despite the controversial and unpopular destocking in the mid 1940's and early 1950's many reserves were found to be overstocked; hence compulsory reduction of cattle numbers was instituted yet again. An added complication was that the maintenance of soil fertility in arable holdings was based on the principle of one head of cattle to supply manure for 0.4 hectares of cropland. On this basis few of the reserves had enough cattle to cope with planned areas of cropland. In Chiweshe Reserve, for example, there was a ratio of one animal per 1,25 hectares of arable land in 1957 (Hamilton, 1964). Although rated as slightly overstocked, to maintain fertility this reserve required at least three times the number of cattle present in 1957. This situation persists even today where farmers lack sufficient cattle for manure and draft power. There seemed to be very limited efforts to improve grazing management and to increase carrying capacities; the emphasis remained on destocking as the best way to stop degradation of grazing areas.

Various criticisms have been levelled at the NLHA (e.g. Yudelman, 1964; Kay, 1970). The key factors, however, were the disruption of the traditional system of land tenure and the creation of a landless class which could not be absorbed easily into other sectors of the economy. There simply was not enough land for everyone to have a viable, although very small, land unit. By 1959 there were 102,000 families entitled to land in the reserves but who could not be accommodated in these areas (Kay, 1970). There was growing political opposition to the NLHA as people, especially young men, realised that they no longer had free access to land (Hughes, 1971). This coincided with a growing tide of African nationalism which saw the NLHA as an obvious political target (Whitlow, 1985a). The NLHA was abandoned largely because of this political discontent in 1962.

Phase 4 — Uncertainty: 1962-69

This was a very fluid period when the "virtual suspension of the implementation of the Native Land Husbandry Act, reorganisation of administrative and technical services..... and review of policies (with the impending dissolution of the Federation)......... all contributed towards a period of uncertainty" (NRB annual report, 1962, p20). Against a background of growing opposition to the NLHA detailed investigations were carried out to assess the political and economic problems in the reserves (e.g. Mangwende Commission, 1961; Phillips Committee, 1962). Acknowledging the contentious issue of the racial division of land, the government introduced reforms designed to eliminate land apportionment in the long term (Christopher, 1971). Amid fears that this would undermine the security of the European population, a more conservative government was elected and vowed to retain past discriminatory legislation. Whilst the other members of the Federation were on the brink of full independence under black rule (i.e. Zambia and Malawi), the prospects for greater political freedom and socio-economic advancement were bleak for the African people in this country.

Conservation measures, consequently, had to be pursued within the Native Reserves and SNA'S, collectively known as Tribal Trust Lands (TTL's) from 1963, in a distinctly unfavourable political atmosphere. Moreover, the "grassroots extension workers who had been used in a mandatory role of extension by compulsion (during the NLHA phase) had to re-establish the confidence of their clients" (Kennan, 1980, p184). Responsibility for the TTL's extension was taken over by Conex for most of the 1960's and it took a long time to regain the support of the peasant farmers. General government policy was to allow the traditional tribal authorities to deal with local tenure matters whilst continuing efforts to improve conservation and agricultural output (Hughes, 1971).

During the 1960's there were growing human and livestock population pressures within the TTL's. Between the official censuses in 1962 and 1969 the African population in the country as a whole increased by 1,228,700 people to reach nearly 4,85 million in 1969. Nearly three quarters of this increase had to be absorbed by the TTL's. With the cessation of destocking in 1961, there was an increase of over 0,5 million cattle by 1969. This placed enormous pressures on an economic and conservation system already strained to its limits (Kay, 1970). There was a widespread trend of encroachment of cultivation into grazing lands, sometimes into areas of infertile and unstable soils (NRB annual report, 1967) and commonly with limited, if any, mechanical protection. This trend placed even greater pressures on the grazing lands as more animals had to be supported on a diminishing area.

Various efforts were made to contain the steadily deteriorating problem of land degradation in the TTL's. For example, conservation courses were held to enlighten and educate tribal leaders on the need for conservation from 1965 onwards (NRB annual report, 1965). A 'type peasant farm' was established at Henderson Research Station to demonstrate to tribal leaders the ways in which simple reforms could improve farming output and living standards (Rodel and Hopley, 1973). Tribal Land Authority Conservation Committees (TLACC) were initiated in 1966 (see Fig 2) to facilitate communication between the NRB, extension staff and the rural people. By 1969 there were 46 such committees some of whom were "enforcing conservation regulations with a strictness which would have been considered unrealistic previously" (Hughes, 1971, p70). A Lands Inspectorate Service was established in 1963 to assist in persuading farmers to adopt and maintain basic conservation measures. This service, along with Conex, launched a major drive in 1967 to improve mechanical protection of arable lands.

These efforts were successful to varying degrees, but overall the trend of degradation continued. Resource deterioration, in turn, resulted in a lowering of productivity and living standards such that some TTL families were reduced to a sub-subsistence level (see local studies described by Kay (1970, p92)), barely able to meet their daily food needs. The situation was especially critical in Mutoko TTL which was described as the "largest single conservation problem in the country" (NRB annual report, 1966, p21) mainly because of excessive population pressures. The serious position in this area was likely to "develop into a major sociological and rehabilitation problem" (NRB annual report, 1967, p17), if actions were not taken promptly to alleviate the degradation of resources. The same was true of many of the densely settled TTL's where farmers were struggling to eke out a living on marginal, extensively eroded land. Politically, the ground was fertile for support for forces intent upon overthrowing the government (Ranger, 1985).

Phase 5 — Growing Pressures: Post-1969

Throughout the 1970's there were growing political, economic and security problems within the country The TTL's in particular, bore the brunt of the protracted civil war which escalated at this time. This turbulence had a serious impact on conservation efforts disrupting farming operations and hampering the work of government officials to such an extent that they ceased to function in many areas. Responsibility for peasant agriculture returned to the Ministry of Internal Affairs, partly due to disagreements between this ministry and Conex staff (Kennan, 1980).

Further changes in land policy were undertaken in the form of the Land Tenure Act of 1970. This act was drawn up on the basis of an equal division of land between Europeans and Africans in what was referred to as the 'concept of parity' (Christopher, 1971). This parity was more cosmetic than real since it took no acco[illegible] quality or population size. The African [illegible] and APA's) were barely altered in ext[illegible]

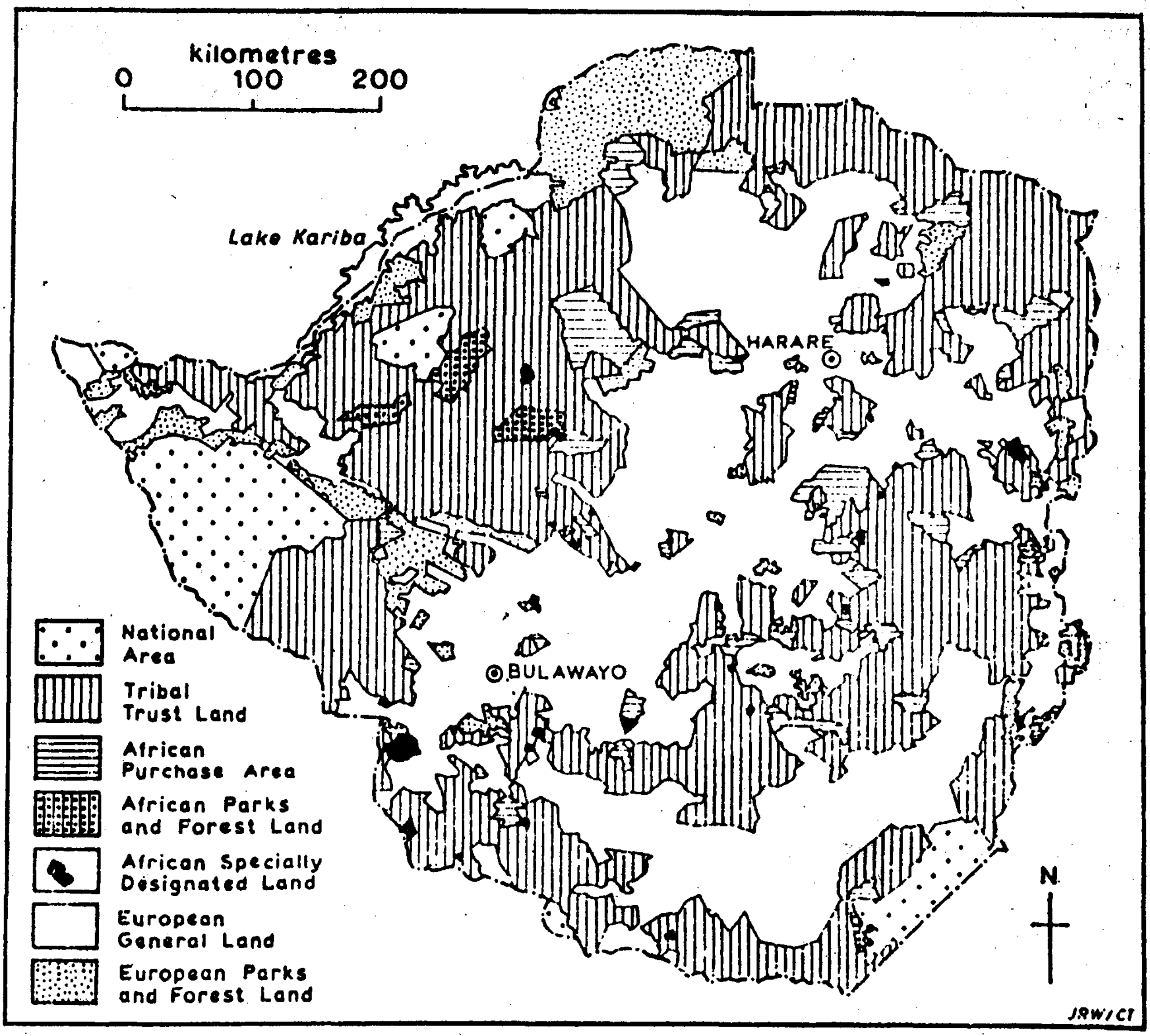


Figure 5 - Land tenure in 1970 showing Tribal Trust Lands and African Purchase Areas.

and the better agricultural terrain remained firmly in European control (Fig.5).

The new act had important implications for the TTL farmers. Firstly, it gave stronger legal support to the tribal authorities in their tasks of allocating land and determining how it should be used (Murton, 1971). Secondly, it ruled out the option of further land acquisition from European areas since government policy was that the socio-economic and environmental problems in the TTL's should be resolved by agrarian reforms not more land. Politically, the legislation was a clear signal that the economic advancement and land aspirations of the African population were going to be blocked as long as the government remained in office. The frustrations of peasant farmers manifested themselves in the lack of co-operation with government officials and growing sympathy for the guerilla forces.

In 1970 a joint committee of the NRB and the Ministry of Internal Affairs decided that a new conservation policy was needed in the TTL's. Three main priorities were identified. These were the mechanical protection of arable lands, the implementation of veld management and the restoration of soil fertility. These had, in various ways, been important in conservation efforts for years so could hardly be regarded as 'new priorities.' The main changes were that they were seen as interdependent in the farming system and farmers had to be persuaded rather than forced into accepting these priorities. The focus of attention shifted to community level development. Traditional extended family groups ('musha' in Mashonaland and 'isigaba' in Matabeleland) were to be the target for extension work and grazing schemes (NRB annual report, 1973). Theoretically a sound strategy, in practice it failed due to the lack of staff and funding and the escalation of the civil war.

During the early 1970's conservation efforts initiated in the previous decade continued to make progress. For example, by the 1971-72 rainy season nearly 80% of the 2,28 million hectares under the plough was protected adequately by contour ridges. Similarly, grazing schemes, some initiated through the TLACC's (which had increased to 90 by 1970 as shown in Fig 2), were introduced in many areas to number over 500 by 1973. Some of these were very successful (Froude, 1974), but many were not managed properly and there was little improvement in veld condition or the livestock. As the civil war intensified, so it became increasingly difficult for extension staff to supervise conservation measures and for farmers to comply with these measures. Conservation works in arable lands were neglected and most of the grazing schemes collapsed.

Political fortunes in the late 1970's shifted in favour of greater and more significant African participation in governing the country. The critical conditions of population pressure, poverty and environmental degradation within the TTL's were given as much attention as limited funds and manpower would allow. The Department of Agricultural Development (Devag) was established to co-ordinate a broad based programme of development within the TTL's especially within what were termed IRDA's (Intensive Rural Development Areas; see Ministry of Finance, 1978). Under peaceful conditions, with a massive input of manpower and funding and full support of the rural population, fulfillment of these ambitious programmes would have been difficult (Whitlow, 1985a). Under wartime conditions they could barely be initiated, let alone completed. It was very much a case of too little, too late and at the wrong time! Political events soon overtook these plans and Zimbabwe had a new majority government in 1980.

In its first post-independence report the NRB commented that during the late 1970's and especially in the 1980-81 rainy season "there was a significant increase in the area of unsuitable, unplanned and unprotected land being used for crop production. In addition, there was large scale uncontrolled cultivation of wet areas, streambanks and even water courses" (NRB annual report for 1980-81, p1), mainly in the TTL's known now as Communal Lands, but also on abandoned commercial farms occupied by squatters. There was considerable apprehension within the NRB as to the response of the new socialist-orientated government to these trends. This apprehension proved to be unfounded. In an address to the First National Conservation Congress of the NRB in September 1980, the Prime Minister pledged full support for the conservation movement in Zimbabwe, stressing in particular the need for extending efforts into peasant farming areas (Zimbabwe Science News, 1980). At this time, however, there were more pressing and sensitive political issues to be resolved and conservation was a low priority.

Subsequently, the problem of land degradation has been recognised clearly in national development plans (Republic of Zimbabwe, 1982, 1986). Recognition of a problem, however, is not the same as taking effective actions. Some of the more positive measures taken to ameliorate the conservation problems in the Communal Lands to date include the following. Firstly, the initiation of a pilot afforestation programme following a series of surveys since 1978 (Whitlow, 1980; Whitsun, 1981; Du Toit et al, 1984); secondly, a resettlement programme was initiated soon after independence to relieve pressure in the Communal Lands and is to be continued at a rate of 15,000 families per year during the 1986-1990 national plan; thirdly, reorganisation of administrative structures has taken place to enable local communities to have a greater role in decision making via their village development committees (VIDCO's); fourthly, there has been widespread improvement of infrastructural facilities in the peasant farming areas.

Undoubtedly, all of these efforts will assist in counteracting and rehabilitating the natural resource base of the Communal Lands. The task, however, is an enormous one. A proper conservation programme, which is long overdue, is going to be extremely costly. Zimbabwe's national budget is already heavily committed in sectors such as education and defense so there is a danger that, as in the past, conservation will be financially compromised. One obvious solution is to seek massive international aid for rural development within which conservation has a central, not a peripheral, role. The alternative is to see the problems and neglect of the colonial past perpetuated at the expense of both the people and the land.

3. METHODS OF EROSION SURVEY

Ultimately the method developed for the national erosion survey represented a compromise between what was *scientifically desirable* (i.e. accuracy) and *logistically feasible* (i.e. time, available manpower and funding). Insofar as the method employed has never been used for a countrywide survey in Zimbabwe or elsewhere, it is useful to discuss how the basic survey procedure was devised.

Initially, past methods of erosion assessment were evaluated to determine whether they were suitable in whole or part for carrying out a national survey in accordance with the terms of reference given earlier. Two main approaches have been used in Zimbabwe notably general ground or aerial reconnaissance and mapping by means of earial photography. For example, the 1939 Commission of Enquiry team travelled some 8,530 kilometres and interviewed over 200 individuals in their assessment of the state of natural resources, especially soil. More recently, Elwell (1974) used a questionnaire technique to obtain information on the extent of erosion on arable lands as well as the main causes of such erosion in the commercial farming areas. Low level aerial reconnaisance has been used in this country for many years by the Lands Inspectorate staff and ICA committees to gain an impression of the nature of erosion in various regions and to identify local areas in need of urgent attention. Whilst such methods may reveal the general nature and extent of erosion, they are all extremely subjective and do not enable accurate quantification and mapping of erosion. Their only relevance to the present survey is as a means of verification of erosion pattens in the field, an issue which will be returned to later.

One of the earliest attempts at systematic mapping of erosion by means of aerial photographs was carried out by Keech (1968). The method involved measuring gully lengths within 400 hectare grid squares marked on aerial photographs and generating data on gully density.

Although a method for mapping at 1:50,000 scale was outlined by Keech (1968), it was never applied to a systematic regional or national survey. This method was unsatisfactory for the present survey since it was too detailed and time consuming for mapping large areas and it ignored sheetwash erosion, a widespread form of land degradation in certain parts of the country. Nevertheless, the notion of quantifying erosion within grid cells proved to be very useful in developing a more appropriate method of survey.

An alternative way of erosion assessment is to delimit and classify 'erosional land units' on aerial photos according to the SARCCUS procedure described by Ivy (1979). This method was tested in 1984 in a survey of the Lake Kyle catchment and was applied to several smaller river basins as part of a siltation study (Interconsult, 1985). This revealed that the method had at least four major limitations. These related to the subjectivity of delimiting and classifying erosional units, the excessive time involved in mapping, the problem of effective reduction of detail from 1:50,000 base maps to small scale maps for national coverage and finally, the necessity of deriving area estimates from laborious and time consuming planimeter measurements. Consequently, this method was regarded as unsuitable for a national survey.

An entirely different approach towards erosion assessment was adopted by Stocking and Elwell (1973). Their study was based on the evaluation of five main factors known to affect erosion in Zimbabwe. These factors included erodibility of soils, slope, rainfall erosivity (a function of intensity), plant cover and human influences in the form of land use systems and population density. These factors were given numerical ratings according to the risks of erosion they presented. Mapping was based upon grid cells equivalent to one quarter divisions of a standard 1: 50,000 topographical map. Although the factor scoring system used in this survey can be criticised (Morgan, 1979), the study did enable the definition of the varying degrees of erosion risks on a national scale. Moreover, the mapping procedure employed has numerous advantages, in the extraction and presentation of data on erosion within a grid framework.

It must be stressed, however, that this survey gave information on *potential erosion hazards* and that this is not necessarily the same as the *actual erosion* which might occur in a given area. Indeed, as will be discussed later, erosion risks do not always correspond with the extent of land degradation; hence the 'hazards map' of Stocking and Elwell (1973) should be used as it was intended, that is a guide to areas where conditions are particularly conducive to high rates of erosion.

The evaluation of previous methods of erosion assessment in Zimbabwe revealed that a new procedure had to be developed to carry out a national erosion survey. In this regard three inter-related issues had to be faced. These were what data sources were available, how could the data be extracted conveniently and in what formats could these data be presented?

a) **Data Sources**

Zimbabwe if fortunate in having extensive 1:25,000 scale panchromatic aeriol photo coverage. There is piecemeal photography of varying scales for the period 1935 to 1962, but since 1963 systematic 'blanket photography' has been flown at approximately five year intervals over the entire country. This is an invaluable data source for monitoring changes in the landscape since for most areas it is possible to obtain up to five different dates of photography. This can be extremely useful in, for example, observing extensions of gully systems and reconstructing changes in land use which may have promoted or resulted from erosion, as demonstrated later in this report. The documentation of changes in erosion and land use patterns does require, however, very detailed mapping so of necessity can only be carried out for selected local areas.

The main focus of the present study was to carry out a baseline survey of the present state of land degradation in Zimbabwe. Most of the aerial photography available for this survey had been taken during the period 1980 to 1984, but some parts of the country had older photos dating from 1979 (see Appendix for details). This means that it is impossible to get a standard time base for a national survey which utilizes this photography. However, the inherent generalisation in small scale mapping would mask temporal variations over such a short period.

Alternative data sources considered for this study were the 1982 Canadian aid photography and satellite imagery. The former was rejected since firstly, the photography is at scales of 1:65,000 and 1:80,000, too small to identify erosional features easily and secondly, the photo prints were not readily available for analysis in Zimbabwe. Similarly satellite imagery was rejected because of the high costs (including foreign exchange) of obtaining image tapes, the coarse effective scale of the imagery in comparison with blanket aerial photos and the lack of facilities and expertise locally to analyse such imagery. However, the possibilities of using satellite imagery for national monitoring of resource degradation in the future should not be ruled out entirely (Millington and Townshend, 1984).

In selecting the blanket aerial photos for the national survey it is important to note the relative advantages and disadvantages of this photography for erosion assessment.

The main advantages included free access to the aerial photo collection housed in the Surveyor General's Department (a vital factor given the lack of funds for the survey), a good indexing system based on 1:250,000 maps and the fact that severely degraded terrain and linear erosion forms (e.g. gullying) can be identified easily on 1:25,000 prints. The main disadvantages concern the difficulty of detecting sheetwash erosion in areas where the plant canopy is sufficiently dense to obscure what the ground surface looks like. This is especially a problem in cultivated lands where during the dry season, when aerial photography is flown, there is crop stubble and trash in the fields. Consequently, sheetwash which may have occurred during the rainy season is not visible although accumulation of sediment along fields margins may indicate the presence and severity of this type of erosion.

Another problem relates to the appearance of erosional features on photos. Severely degraded areas tend to show up with pronounced tonal and textural variations, but where erosion is only slight then it is very difficult to identify since photo contrasts are limited. Observer experience, in terms of familiarity with aerial photos and knowledge of erosion on the ground, is another facet of this problem and will be returned to later. Given these limitations it is likely that the present survey *underestimated* the extent of erosion in Zimbabwe.

b) Data Extraction

Assuming one was to examine all the 1:25,000 photography covering the country it would be necessary to study about 53,000 prints, obviously an unmanageable and unrealistic task! Some form of sampling clearly was needed bearing in mind two of the key objectives, to map and quantify the erosion. In previous national surveys of cultivated lands and wetlands (Whitlow 1979a, 1984), a stratified random sampling procedure was employed successfully. In these surveys stratification was based on grid cells of about 45 square kilometres equivalent to 1/16 divisions of the standard 1:50,000 maps. The aerial photograph closest to the centre of each grid cell was selected for observation as shown in Figure 6A. The features of interest were recorded by means of their presence (or absence) for 25 randomly located points within the central portion of each photo. This method enabled derivation of numerical data in a grid format which facilitated representation of features in both statistical and map forms, hence it was well suited for a national survey. The method reduced the number of photos analysed to about 8,500, a more realistic target for a rapid reconnaissance survey.

However, since erosion tends to be rather patchy and localised it was thought that 25 random sample points per photo would not be sufficient to obtain accurate data. This was confirmed in a pilot study of five areas with contrasting erosion patterns (Whitlow, 1986). It was discovered that estimates of eroded land area varied enormously depending on the size and number of sample squares, partly because of differences in the spatial occurrence of the erosion features. The most accurate and consistent estimates were obtained from observing 1,000 one hectare grid squares on each photo, this providing a basis for detailed recording within a large contiguous area (Fig 6B).

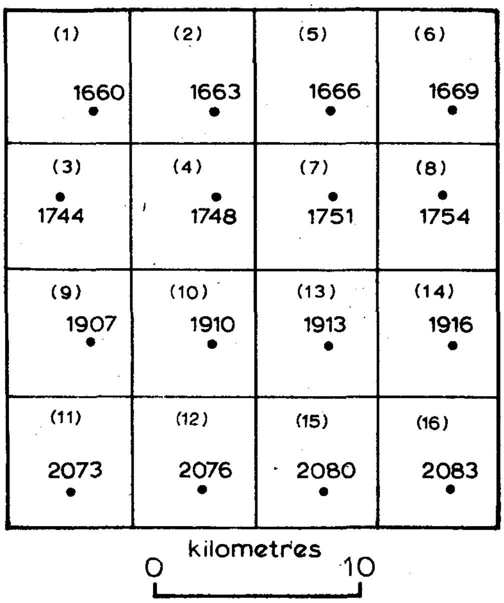
The method involved marking a rectangular area (10 x 16cm) on a transparent acetate sheet and dividing this into 0,4 x 0,4 cm grid squares, each square being equivalent to one hectare on the ground at a photo scale of 1:25,000. The presence of erosion within each grid square can be marked on the template whilst observing the aerial photos under 3 x magnification using a mirror stereoscope. Different symbols were used to distinguish between gully erosion, sheetwash and rilling (often occurring together) and streambank degradation (Fig 6C). In addition, the erosion types were classified according to their presence in cropland, non-cropland and wetland. Once a template had been annotated in the manner indicated by the example in Figure 6B it was photocopied to provide a permanent record of the erosion patterns on each sample photograph.

This technique has several advantages for data extraction off the aerial photographs. Firstly, it enables rapid coverage of large areas with sample observations covering just over 22 percent of each grid cell, that is 1,000 hectares in a 45 square kilometre cell. Secondly, through restricting interpretation decisions to observing the presence and type of erosion within discrete grid squares, it improves the accuracy of identifying erosion patterns. Thirdly, the method enables generation of numerical data by summation of grid squares within which symbols have been placed; for example, for the template shown in Figure 6B 168 squares were marked as having some form of erosion present, which in turn represents 16,8 per cent of the area affected by erosion. Fourthly, the grid cells serve as a basic map unit so there is no need to transfer any boundaries to a base map as, for example, is the case in the method outlined by Ivy (1979). This last aspect will be elaborated upon later.

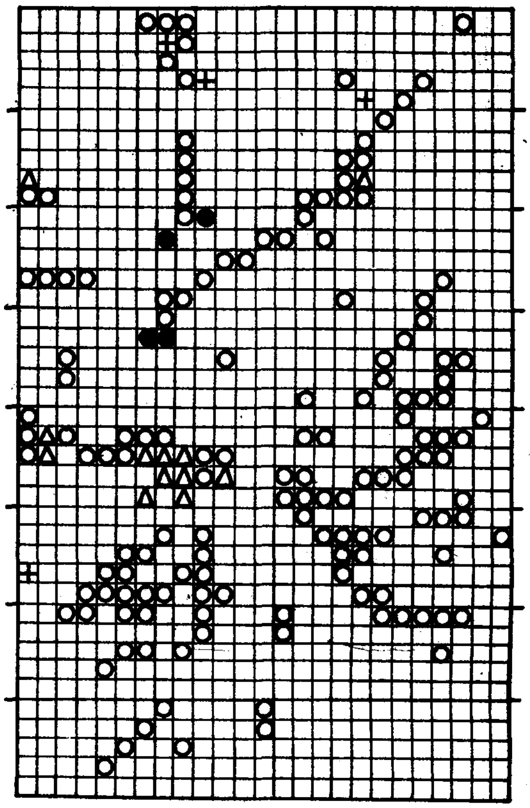
One must also be conscious of the disadvantages of such a method. For example, the wide spacing of the 1,000 hectare sample blocks means that inevitably some eroded patches could have been missed or even overemphasised. However, given that observations covered over one fifth of each grid square and the emphasis was on regional and national patterns of erosion, this problem was regarded as being of minor significance.

More important was the ability of the observers in distinguishing between the main erosion types. In practice, during the survey it was discovered that although identification of erosion on cropland and non-

Ⓐ Division of 1 : 50 000 map



Ⓑ Grid template (1 000ha)



Mutoko 1981 Strip 2 No. 78 1731B1-1

Ⓒ

Erosion type	Cropland	Non-Cropland	Dambo
gully	▲	●	–
sheetwash & rilling	△	○	N/A
stream - bank	×	+	N/A

Ⓓ Total erosion % - 1/16 grid

16,8	0,3	0	0	0	0	2,2	5,6	1,8	0
2,2	0,5	0	0	0,7	0	4,0	3,6	3,1	1,6
3,4	12,0	6,6	0	0	0,2	7,4	4,4	1,4	22,0
0	0	0	0	0,8	6,1	0	3,3	0	22,6
0	0,9	2,4	0	14,8	13,3	0,9	2,6	3,7	12,7
0	0	0	3,1	5,8	3,3	2,6	5,9	7,7	6,6
2.5	0.8	12.8	3.0	8.7	7.3	2.9	8.3	5.1	4.4
1,4	2,0	4,7	7,3	3,3	4,0	0	0	0	1,7

Ⓔ Total erosion % - 1/4 grid

5,0	0	0,2	3,9	1,6
3,8	1,6	1,8	3,8	11,5
0,2	1,4	9,3	3,0	7,7
1,7	6,9	5,8	2,8	2,8

JRW/RM

Figure 6 – Procedure for assessing the extent of erosion on aerial photographs.

croplands was reasonably reliable, wetlands tended to be grouped with non-cropland and gullying was grouped with the sheetwash and rill category. The reason for the latter error relates to the fact that a gully rarely occupied more than a small portion of a 'one hectare grid square' and given the bare areas often associated with gully margins, the observers opted to classify the squares according to the most extensive erosion type. Thus, while the pilot survey carried out in the Mutoko area (Whitlow 1985b) enabled generation of data in accordance with the classification mentioned earlier (Fig 6C), the national survey data could only be classified in terms of *total erosion, erosion on croplands* and *erosion on non-croplands.*

c) **Data Presentation**

Erosion information was required in both map and statistical forms. The grid cells obviously dictated the format of the maps which could be generated. For example, the regional variations in erosion were revealed from plotting values of percentage area of eroded terrain using the 1/16 divisions of the 1:50,000 maps (Fig 6D). Alternatively, the values could be aggregated to generate data for a map based on 1/4 divisions as shown in Figure 6E. Inevitably the coarser grid size involves a greater degree of generalisation and the averaging process used in producing such a map conceals extreme values. However, the coarser grid was very useful for presenting erosion patterns on a national basis and has been used for the map of total erosion (see Fig 9) included in this report.

Six erosion classes were defined for the erosion maps mainly on the basis of the frequency distribution of percentage total erosion values for the 8,496 sample grid cells (see Fig 8), but taking into account the mean erosion values for Zimbabwe (4,69%), the General Lands (1,77%) and the Communal Lands (8,43%). The six classes are as follows:

Class 1	zero — not present/negligible
Class 2	0,1-4,0% — very limited
Class 3	4,1-8,0% — limited
Class 4	8,1-12,0% — moderate
Class 5	12,1-16,0% — severe
Class 6	over 16,0% — very severe

The zero categoy does not literally mean that there was no erosion present; rather it means that erosion could not be detected using aerial photography and was less severe, therefore, than in those areas where erosion was visible on the photos. The verbal descriptions of the classes are for discussion purposes only.

Statistical data from the survey are presented in three ways. These are in terms of frequency distributions with the six erosion classes, as mean erosion values expressed in percentages and finally, as estimates of hectares of eroded land. There are three points to note in relation to the results presented later. Firstly, they are based on computer analysis of 8496 grid cells rather than the aggregated values used to produce the national maps and in the preliminary analyses of the erosion data reported by Whitlow (1987c); consequently the values cited here may differ from those based on the coarser scale of analysis. Secondly, the data from the grid cell format differs slightly from the official figures on, for example, areas of natural regions and land tenure categories. However, these differences in percentage terms are very low and do not detract from the main arguments concerned with gross differences within and between different parts of the country. Thirdly, erosion patterns in the small scale commercial farming areas, the former African Purchase Areas, are more akin to the conditions in the Communal Lands than in the General Lands, so such areas have been grouped with the former in the results.

Two outstanding issues remain in this survey, these being the *verification* of the aerial photo analysis and the *monitoring* of erosion changes. Since the basic recording unit comprised a block of 1,000 one hectare grid squares per grid cell, it was not practicable to field check the erosion estimates. Indirect validation was necessary in response to two questions. Do the results reflect realistically the situation known to occur on the ground and do the results conform sensibly with other forms of environmental and social data? The results reported below suggest one can give a qualified affirmative response to the questions, bearing in mind the inherent limitations of using aerial photos to detect erosion. On balance the results appear to be a realistic assessment erring, if anything, on a *conservative evaluation* of erosion in Zimbabwe.

As well as information on the present extent of erosion, it would be desirable to obtain data on erosion changes. The grid sampling method used in this survey may not, in fact, be sufficiently sensitive for this task unless the time interval between aerial photography is in the order of fifteen to twenty years. During the Mutoko pilot survey (Whitlow 1985a) the exact locations of the 1,000 hectare sample blocks were marked on 1:50,000 base maps; there are plans to compare the results of this 1981 survey data with information from photography done in the early 1960's for these same locations. Until this is completed the feasibility of using the grid method to monitor erosion remains a theoretical rather than practical issue.

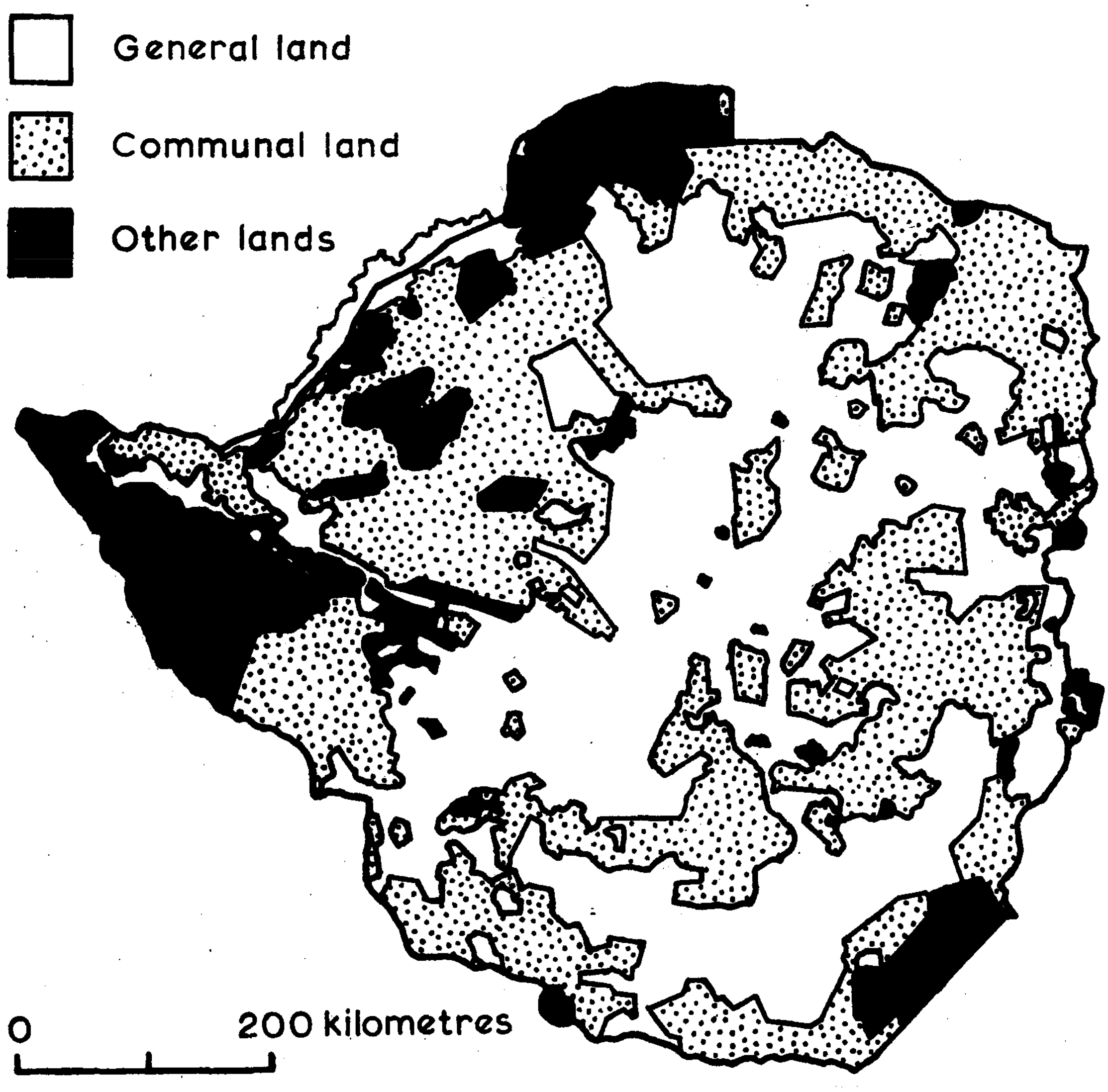
At this stage it is likely that a more profitable approach would be to select particular problem areas for detailed mapping of erosional features at, for example, 1:20,000 scale or larger. By utilising several dates of aerial photography from the 1950's, or even the 1940's, it would be possible to reconstruct changes in erosion patterns and associated land use reasonably well. An example of this type of mapping is discussed later (see Fig 19). Insofar as extensive land degradation has occurred in many areas during the last 35 to 40 years, this type of mapping would be more informative on longer term rates of erosion that comparing data from the present survey with information derived from aerial photos taken in say 5 to 10 years time.

Part of the reason for this is that in very badly denuded areas the rates of erosion may be relatively low given that much of the soil material has been stripped away. In terms of rates of erosion such areas would have low priority but in terms of reclamation may need urgent attention. It must be stressed that *monitoring of environmental change* is much more complex than doing a baseline survey and, by definition, may require greater inputs of skilled manpower and funding. Certainly, it would be desirable to develop a systematic national programme of field monitoring to complement information obtained from aerial photography or satellite imagery.

Standard scientific procedures for erosion monitoring already exist (e.g. Dunne, 1977); it is more a matter of whether such monitoring is seen as desirable and whether it is given adequate logistic support.

To conclude this discussion of methods it is useful to outline the basic details of the survey. A pilot survey was carried out in the latter part of 1984 to test the survey method and determine the manpower and time inputs necessary for the main survey. On the basis of this exercise it was estimated that it would require 500 man-days for a national survey or about 16½/weeks for a team of 6 research assistants. The final survey was carried out between late September 1985 and the end of January 1986, that is about 20 weeks allowing for leave etc.

The survey team comprised seven men from the Lands Inspectorate staff of the Department of Natural Resources. Prior to doing the main survey they underwent a 3 week intensive training programme on aerial photo interpretation (under the guidance of the Planning Branch of Agritex) and a further one week of training on the grid method. Thereafter, the four best interpreters were selected for the photo analysis. Two of the team were involved in initial processing of the annotated templates, that is, copying and recording the frequency of erosion symbols for each template. In addition they plotted a series of compilation maps on the 1/16 and ¼ grid formats using 1:1 million base maps. The seventh member of the team acted as co-ordinator which involved photo selection and monitoring the progress of the survey. Two of the survey team were involved in computer coding of the data during February. The data set was analysed by Dr. B.M. Campbell (Department of Biological Sciences, University of Zimbabwe), using the computer facilities at the university.



4. DISTRIBUTION OF EROSION

The general results of the survey are presented in this section in terms of the distribution of total erosion according to the main land tenure systems (Fig 7), natural regions and erosion on cropland and non-cropland. The results are elaborated upon with respect to particular physical and human factors influencing erosion in subsequent sections. A more detailed statistical analysis of the data has been presented by Whitlow and Campbell (1988).

a) Total Erosion and Land Tenure

There are three aspects that need stressing with respect to these results (Table 2). Firstly, there is the marked concentration of erosion in the Communal Lands which constitute 46,4% of the nation's land but have over four-fifths of the erosion. Secondly, the grid sampling method necessitates that each grid cell be classified by the dominant land tenure type. Consequently, some of the erosion recorded for the General Lands or non-agricultural areas was contributed by degraded peasant farmlands on the periphery of such areas; in addition, illegal squatting within these areas has resulted in locally serious erosion. Thirdly, the mean erosion figures, for example, of 4,7% for Zimbabwe seem to suggest that erosion really is not a problem. In this regard it must be

TABLE 2: TOTAL EROSION ACCORDING TO TENURE

Eroded Lands	Communal Lands	General Lands	Non Agri cultural Lands	Zimbabwe
Area (1,000 ha)	1528,5	271,1	35,2	1834,8
% of eroded land	83,3	14,8	1,9	100,0
% of tenure type	8,43	1,77	0,62	4,70
% of country	3,91	0,69	0,09	4,70
Total area (1,000 ha)	18133,8	15277,9	5661,4	39073,1
Total area (% of country)	46,4	39,1	14,5	100,0

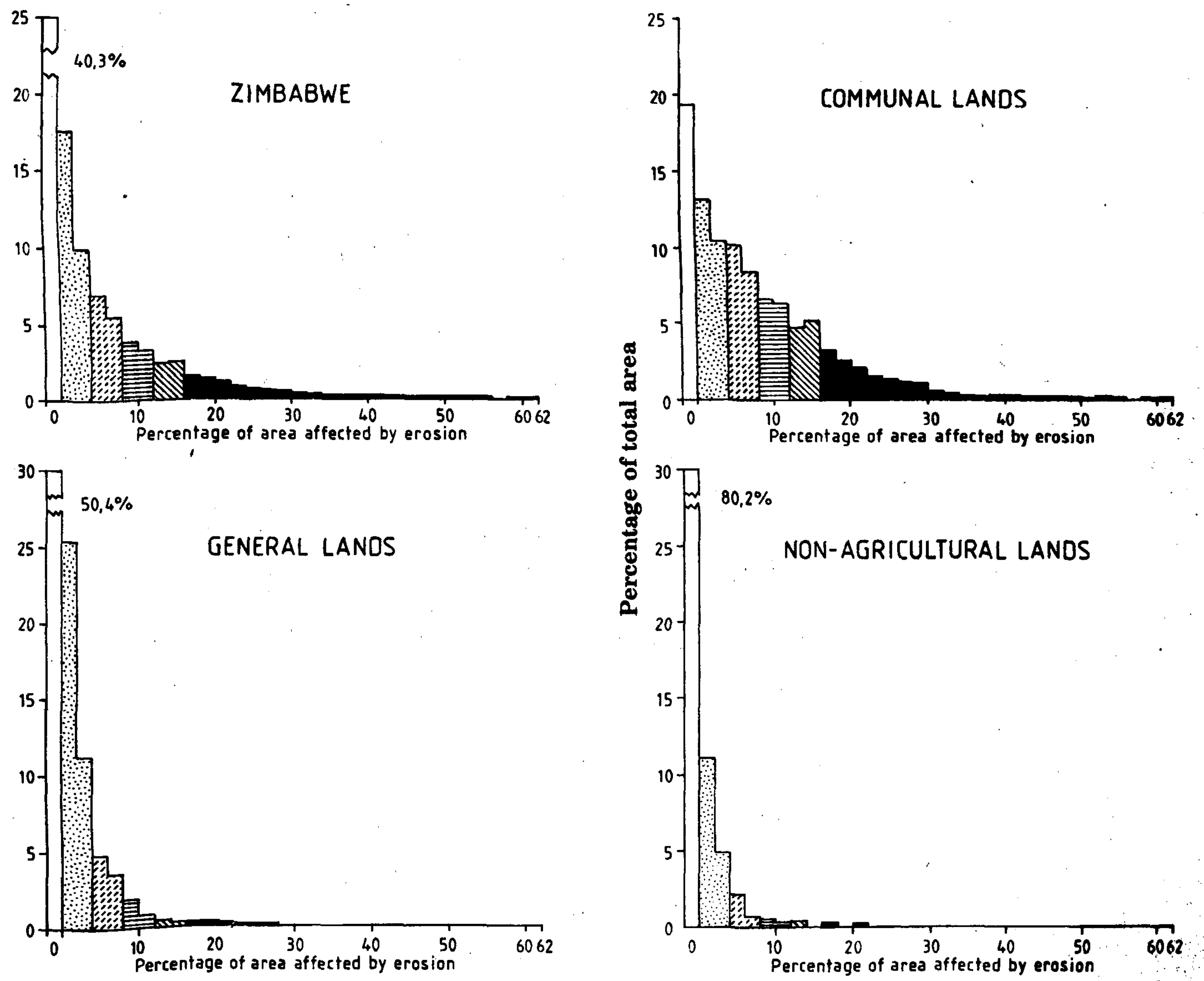


Figure 8 – Frequency distribution of erosion values.

pointed out that the aerial photo analysis *under-estimates* the extent of erosion, whilst in local areas the proportion of eroded terrain may be up to 40,0%. The maximum value recorded for a single grid cell was 61,8% for an area north of Mutoko. It is necessary, therefore, to examine the range of erosion values as well as the means.

Table 3 summarises the occurrence of eroded land within and between tenure types and the frequency distributions of eroded terrain are indicated in Figure 8. Erosion was recorded as negligible in just under two fifths of Zimbabwe and about one quarter (26,9%) of the country had very limited erosion (Table 3a). A further one fifth of Zimbabwe was recorded as having between 4,1 and 12.0% of the land eroded, that is limited to moderate erosion (classes 3 and 4). In the remainder of the country, 13,2% of the land, erosion was rated as severe to very severe; that is, over 12,0% of the land within a given locality was eroded and, as can be seen from the histogram for Zimbabwe in Figure 8, the proportion of eroded land is well in excess of this certain areas.

Erosion is obviously more extensive within the Communal Lands than in other parts of the country. For example, areas of severe to very severe erosion (classes 5 and 6) constitute well over one quarter of the Communal Lands compared with only 1,6% for the General Lands and 0,5% for the non-agricultural areas. At the other end of the scale, erosion was negligible to very limited in 85,6% of the commercial farmlands whilst in the non-agricultural areas the proportion of land within these classes increases to 95,2%. In contrast, within the Communal Lands barely two fifths of the terrain falls within these classes. The differences in the extent of erosion between the three tenure groups are brought out

TABLE 3: EROSION CLASSES ACCORDING TO TENURE

(a Within tenure types

Erosion Class	Communal Land	General Land	Non-Agricultural Land	Zimbabwe
1. negligible (0)	18,5	48,7	79,7	39,2
2. very limited (0,1-4,0%)	22,1	36,9	15,5	26,9
3. Limited (4,1-8,0%)	19,4	9,6	3,6	13,2
4. Moderate (8,1-12,0%)	13,1	3,2	0,6	7,5
5. Severe (12,1-16,0%)	9,9	1,0	0,2	5,0
6. Very severe (over 16,0%)	17,0	0,6	0,3	8,2

b) Between tenure types

Erosion Class	Commu- Land	General Land	Non-Agricultural Land	Zimbabwe
1. Negligible (0)	21,9	48,6	29,5	100,0
2. Very limited (0,1-4,0%)	38,0	53,6	8,4	100,0
3. Limited (4,1-8,0%)	67,8	28,3	3,9	100,0
4. Moderate (8,1-12,0%)	81,7	17,0	1,3	100,0
5. Severe (12,1-16,0%)	91,8	7,5	0,7	100,0
6. Very severe (over 16,0%)	96,4	3,0	0,6	100,0

clearly in Table 3b. The Communal Lands, for example, account for well over 90,0% of the severe to very severely eroded areas, whilst they also include four fifths of the moderately degraded land. The General Lands stand out as having a disproportionate share of areas with negligible to very limited erosion (48,6% and 53,6% respectively) and relatively low proportions in the higher erosion classes. The non-agricultural lands exhibit a similar pattern with a decreasing share of the more seriously eroded terrain. Moreover, nearly one third of the areas rated as having negligible erosion occur within this tenure type compared with only 21,9% for the Communal Lands.

These data clearly support the known general field situation that the most widespread and serious erosion is in the Communal Lands. Conditions in the General Lands are, on the whole, far better with only very localised areas of serious degradation, whilst the non-agricultural lands have the least serious erosion.

The contrasts between the three tenure groups can be expressed in ratios of the percentage mean erosion quoted earlier (Table 2). Thus the erosion in the Communal Lands is 13,6 times greater than that in the non-agricultural areas and 4,8 times greater than in the commercial farmlands; locally, however, the differences are many times greater than this. Degradation in the General Lands, by contrast, is only 2,8 times that of the non-agricultural areas.

It is just as important to know *where* the erosion occurs as it is to determine *how much* degradation exists. The distribution of erosion according to the six erosion classes defined earlier is shown in Figure 9. The erosion map is based on the ¼ grid cells because of the small format of this report which does not allow use of the finer resolution grid cell framework. Since the aggregation involved in producing the cruder map shown in Figure 6 changes the overall data set values, it also alters the frequency distribution between the six erosion classes. The differences between the ¼ and 1/16 grid cell frequency distributions are given in Table 4. This comparison shows that the ¼ grid cell data set, upon which Figure 9 is based, underestimates quite considerably the category of negligible erosion whilst overestimating, in compensation, the areas of very limited erosion. The next three classes (3 to 5) have slightly higher values for the coarser grid and areas with very severe erosion are under-estimated in extent. The general pattern of the frequency distributions for the two grid sizes is, however, generally the same with over 60,0% of the country allocated to the two lowest erosion classes on both scales and decreasing portions in the higher classes. These facts must be borne in mind when the distribution patterns of the erosion classes are described.

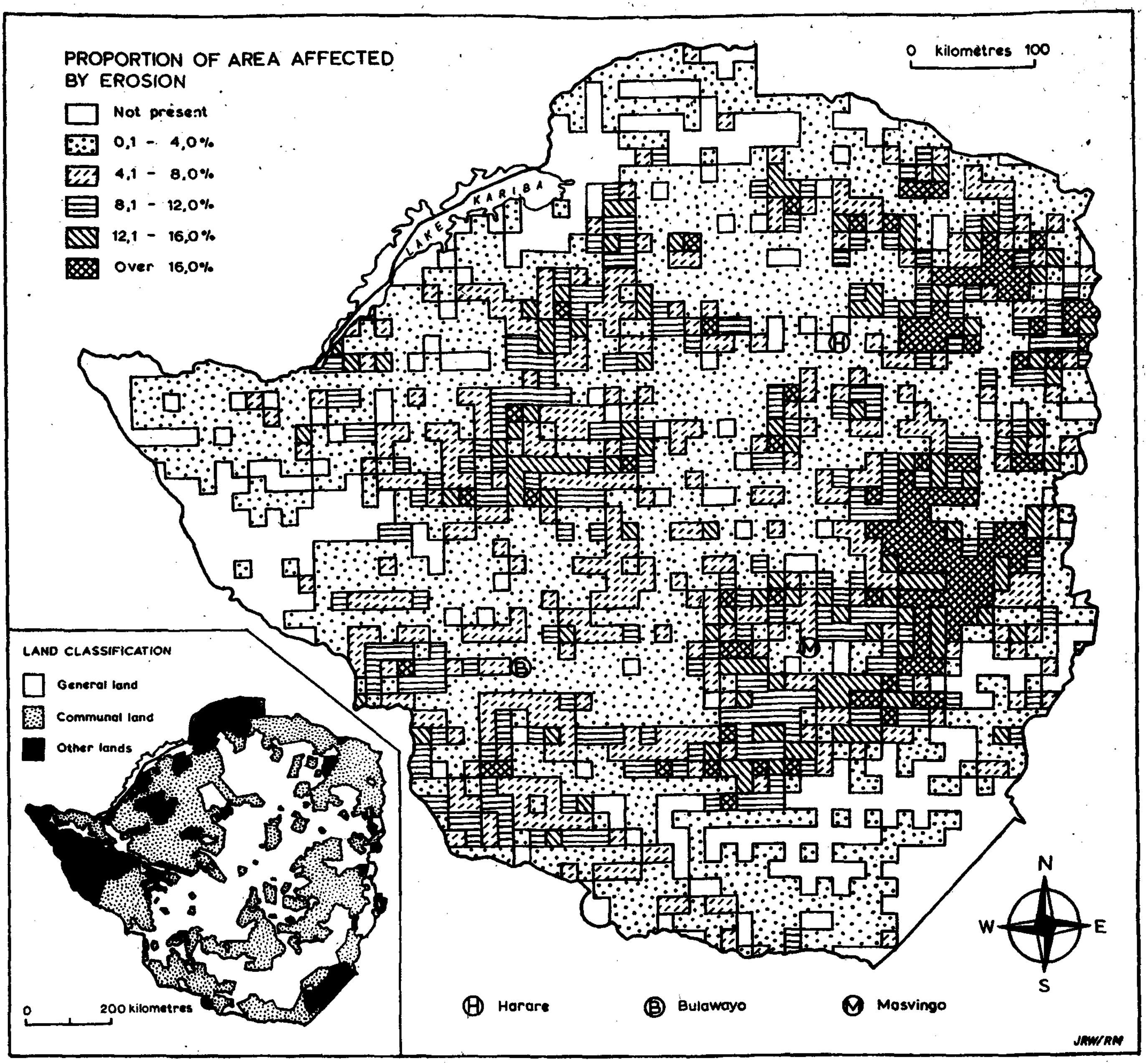


Figure 9 – National land degradation survey.

TABLE 4: DIFFERENCES IN FREQUENCY DISTRIBUTION FOR TOTAL EROSION DATA

Erosion Class	¼ grid cell (a)	1/16 grid cell (b)	Difference (a-b)
1. Negligible (0)	17,2	39,2	−22,0
2. Very limited (0,1-4,0%)	45,7	26,9	+18,0
3. Limited (4,1-8,0%)	16,0	13,2	+2,8
4. Moderate (8,1-12,0%)	10,2	7,5	+2,7
5. Severe (12,1-16,0%)	5,6	5,0	+0,6
6. Very severe (over 16,0%)	5,3	8,2	−2,9
TOTALS	100,0%	100,0%	

Areas with negligible soil erosion are located mainly in south east, west and extreme north of Zimbabwe (Fig 9). Much of this land is located within national parks and wild life areas, but includes also some of the more sparsely settled and remote Communal Lands. The south east region is dominated by extensive commercial ranches. The aerial photo analysis possibly under-estimated the extent of erosion in these areas since sheet-wash erosion is known to be locally severe beneath the patchy woody and herbacous plant cover in this part of the country. In addition, there are extensive areas of negligible erosion along the central watershed plateau between Bulawayo and Harare; for the reasons cited above much of this terrain falls within the class of very limited erosion and is mapped as such in Figure 9. Apart from the central watershed plateau, areas within the very limited erosion class include land bordering and to the south west of Kariba. The latter areas occur mainly within the Communal Lands and the former are characterised mainly by large commercial farms.

Just over one quarter of the country was mapped as having limited to moderate erosion, that is between 4,1 and 12,0% of the land being degraded. These erosion classes (3 and 4) display a patchy distribution throughout the country, mainly on the periphery of the central plateau. Such areas fall mainly, but not exclusively, within the Communal Lands. Severe to very severe erosion is more clearly associated with the Communal Lands, particularly in the broad arc of peasant farming areas centred on Masvingo. The extensive degradation in these areas within the Middle Save Valley in the east central part of Zimbabwe stands out clearly as a major problem area, supporting the account of this region given by Du Toit (1985) The Mutoko district in the north east of the country is also an area of widespread degradation, whilst there are numerous more localised areas of serious erosion in the north, central and western parts of Zimbabwe, restricted almost entirely to the Communal Lands.

What is abundantly obvious from the overall erosion data, in both statistical and map forms, is that *land tenure* has a profound influence on the severity and distribution of erosion. This is by no means a revelation since even the 1939 Commission came to essentially the same conclusion! The fundamental issue is that this survey has quantified the severity of erosion and determined the spatial patterns of degradation much more precisely. Moreover, this has enabled further analysis of erosion within particular tenure groups in relation to selected environmental and human factors.

b) Total Erosion and Natural Regions

Agricultural extension and planning in the commercial farming areas of Zimbabwe traditionally has been conducted within a scheme of natural regions, these regions being defined primarily on the basis of rainfall amount and variability. General details of these regions are as follows (Department of Conservation and Extension, 1976).

- **Natural Region I** — specialised and diversified farming rainfall above 1,000mm/year.
- **Natural Region II** — intensive farming (cropping); rainfall 750-1,000mm/year.
- **Natural Region III** — semi intensive farming (cropping/livestock); rainfall 650-800mm/yr.
- **Natural Region IV** — semi-extensive farming (livestock); rainfall 450-650mm/year.
- **Natural Region V** — extensive farming (livestock); rain fall low and erratic.

The scheme demonstrates that, in the absence of irrigation, water becomes an increasing limiting factor on farming from the high to low rainfall areas in the country and there is a corresponding shift from crop production to livestock rearing (and in more recent years, game ranching). The definition of farming within the five regions is obviously directed at the commercial sector and is *not* very satisfactory for the Communal Lands where, for example, cropping is widespread in the lower rainfall regions whereas adjacent commercial farms are used for livestock production. The reasons for discussing erosion in terms of such regions are firstly, it is a scheme familiar to many people involved in farming in the public and private sectors; and secondly, it enables an analysis of how erosion varies as conditions become, with respect to rainfall, increasingly marginal for agriculture.

Summary data on the extent of erosion within natural regions in Zimbabwe are given in Table 5. The distribution of these regions is shown in Fig 10; included on this map are the areas recorded as having severe to very severe erosion. The proportions of these seriously degraded areas within each of the natural regions is as follows:

Natural Region I — 3,3%
Natural Region II — 14,3%
Natural Region III — 17,7%
Natural Region IV — 13,6%
Natural Region V — 9,5%
Zimbabwe — 13,2%

On the basis of these figures Natural Region III is most affected by serious erosion with an overall mean erosion value of 5,89% (Table 5). The eroded land in this region was estimated at 417,200 hectares, approaching one quarter of the degraded terrain in the country; yet this region only comprises 18,1% of the national land. Insofar as this is regarded as a marginal region for arable farming, with infrequent heavy rains and prolonged dry spells (Department of Conservation and Extension, 1976), the extent of erosion in this region is obviously cause for concern.

TABLE 5: TOTAL EROSION ACCORDING TO NATURAL REGIONS

Natural Regions	% mean	Eroded lands Area (1,000ha)	% eroded	Area of Region (1,000ha)	% of Country
I	1,94	13,1	0,7	680,7	1,7
II	5,09	302,6	16,5	5946,5	15,2
III	5,89	417,2	22,7	7077,9	18,1
IV	4,87	727,7	39,7	14937,5	38,2
V	3,59	374,7	20,4	10430,5	26,7
TOTALS	4,70	1834,8	100,0	39073,1	100,0

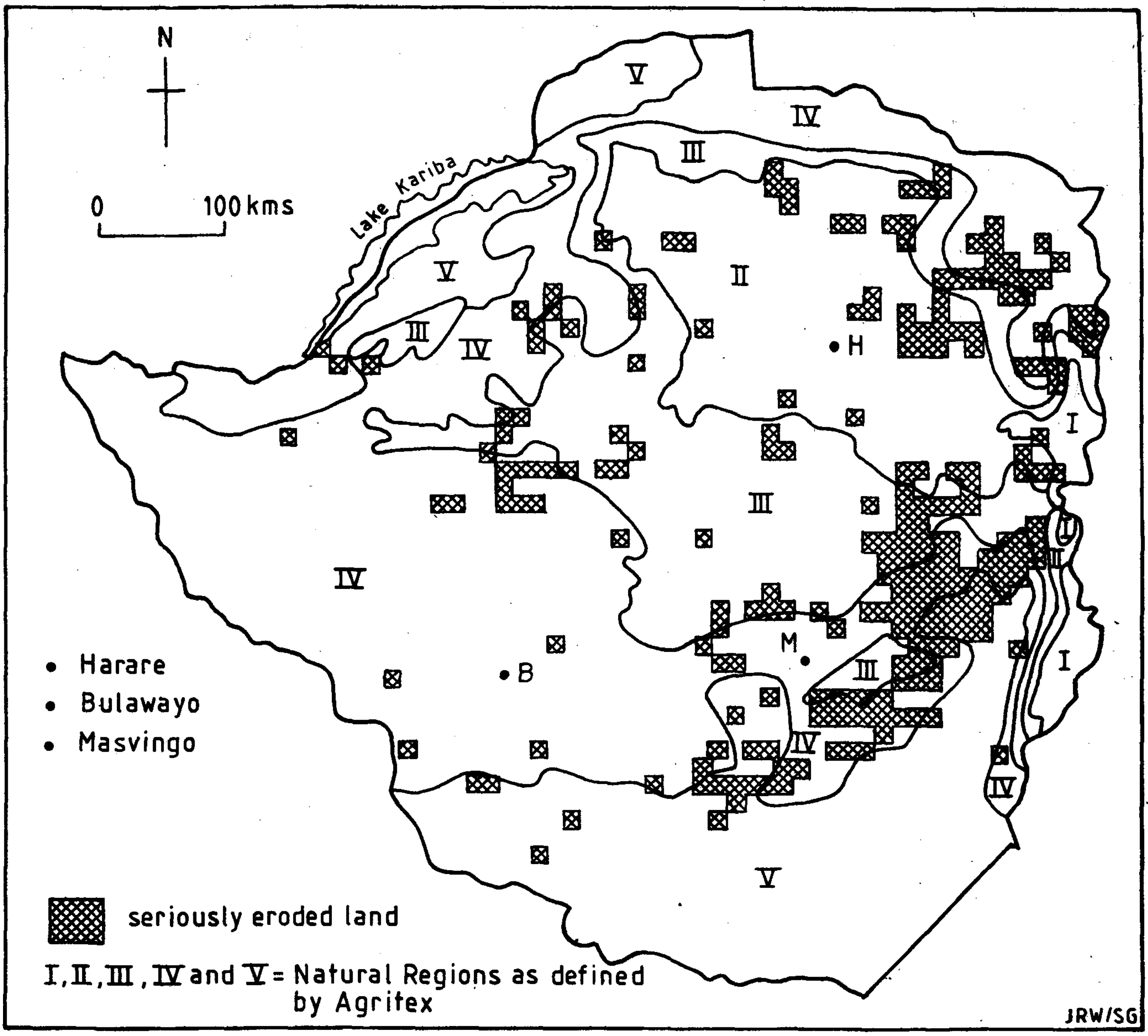


Figure 10 – Natural regions and seriously eroded land in Zimbabwe.

Natural Region II also stands out as having serious erosion with 14,3% of the region recorded as severely to very severely degraded and a mean erosion value of 5,09% (Table 5). It was estimated that there were 302,600 hectares of eroded land in this region. Although this only amounts to about 5,1% of the land in this region, it is a serious situation given that this part of the country is best suited to intensive dryland cropping.

Natural Region I, the smallest of the farming regions in area terms, has a very localised erosion problem with a mean of 1,94% eroded land and only 13,100 hectares of degraded terrain. Nevertheless, steep slopes and high rainfall in this part of the country make is especially vulnerable to erosion such that when erosion does occur it can be very serious locally.

Natural Regions IV and V cover nearly two thirds of Zimbabwe mainly in the south of the country but also including extensive areas in the west and north (Fig 10). Seriously degraded land constituted 13,6% of Natural Region IV and 9,5% of Natural Region V, the respective mean erosion values being 4,87% and 3,59%. Overall these two regions contain 1,102,400 hectares of degraded lands or 60,1% of the eroded terrain in Zimbabwe. Land degradation in these regions must be viewed as particularly serious since firstly, it reduces productivity in areas which are already marginal for agriculture and secondly, rehabilitation of eroded areas where rainfall is low and variable is likely to pose much greater problems than in other parts of the country.

TABLE 6: TOTAL EROSION ACCORDING TO LAND TENURE AND NATURAL REGIONS

	Natural Regions					Totals/
	I	II	III	IV	V	Average
Communal Lands:						
% mean	4,78	12,36	10,82	7,71	6,78	8,43%
area (1,000ha)	5,9	226,3	331,0	624,8	340,5	1528,5ha
% eroded	0,4	14,8	21,6	40,9	22,3	100,0%
Total area (1,000ha)	124,2	1830,4	3058,3	8098,8	5022,1	18133,8ha
% area	0,7	10,1	16,9	44,6	27,7	100,0%
General Lands						
% mean	1,43	1,78	2,31	2,48	0,61	1,77%
area (1,000ha)	7,2	70,5	79,0	91,9	22,5	271,1ha
% eroded	2,7	26,0	29,1	33,9	8,3	100,0%
Total area (1,000ha)	505,9	3950,5	3407,9	3711,4	3702,2	15277,9ha
% eroded	3,3	25,9	22,4	24,2	24,2	100,0%
Non-Agricultural Lands						
% mean	0,0	3,52	1,17	0,35	0,65	0,62%
area (1,000 ha)	0,0	5,8	7,2	11,0	11,2	35,2ha
% eroded	0,0	16,5	20,5	31,2	31,8	100,0%
total area (1,000ha)	50,6	165,6	611,7	3127,3	1706,2	5661,4ha
% area	0,9	2,9	10,8	55,2	30,2	100,0%

The situation within each of the natural regions does differ according to the land tenure systems. Data on this is summarised in Table 6. It has been pointed out already that the Communal Lands are affected by more extensive and intensive erosion than the General Lands and non-agricultural lands. Consequently, the emphasis here is on an analysis of differences within each of these tenure groupings according to the natural regions. The occurrence of severe to very severely eroded land within the tenure groupings is given in Table 7.

A large part, nearly three quarters, of the Communal Lands are located within Natural Regions IV and V. It was estimated that some 965,300 hectares of eroded land occur in these regions. The mean eroded proportions were 7,71% and 6,78% for the two regions and the respective shares of seriously degraded land were 24,5% and 19,5% (Table 7). Although regarded as fit only for livestock production (in the absence of irrigation) in the commercial farming sector, these regions in the Communal Lands are used extensively for cropping. Widespread cultivation, along with human and livestok population pressures, are undoubtedly factors promoting erosion in these marginal and ecologically sensitive areas.

The conditions in Natural Regions II and III, by definition more favourable for cropping, are more critical with mean erosion values of 12,36% and 10,82% respectively, whilst the proportions of seriously eroded lands amount to 42,3% and 37,3% for the two regions. It was estimated that there were some 557,300 hectares of degraded terrain in these regions, this constituting over one tenth of the land area. In production terms this is a serious loss given that the crop production potentials of these higher rainfall regions are somewhat greater than those in Natural Regions IV and V. In erosion terms Natural Regions I is a relatively unaffected area in the Communal Lands with a mean erosion value of 4,78% and an estimated 5,900 hectares of degraded land. This should not, however, detract from locally serious erosion and the fact that, unless careful conservation measures are taken, the erosion could become more severe in the future as pressures on the land increase.

In the General Lands the most extensive erosion was recorded in Natural Region IV with a mean erosion value of 2,48%, the estimated area of degraded land being 91,900 hectares. Thus eroded land in this region constitutes just over one third of the erosion in the General Lands although the region makes up 24,2% of these farming areas. Natural Region III is the next most important area in terms of erosion with 79,000 hectares recorded as being degraded and a mean erosion value of 2,31%. Locally within this region erosion is serious as shown by the figure of 3,1% for severe to very severe erosion (Table 7), but this is by no means as critical as the peasant farming areas where this proportion is 12 times greater.

Some 70,500 hectares of eroded land were recorded in Natural Region II, this constituting just over one quarter of the degraded terrain in the General Lands. This gives a mean erosion value of 1,78%, a low figure which has to be judged against the fact that this is the best agricultural land in the country. The extent of erosion in the remaining natural regions, I and V, is minimal amounting to only 29,700 hectares out of a total land area of 4,2 million hectares; that is, 11,0% of the eroded area on 27,5% of the General Land. Clearly, the erosion problem is less serious on the commercial farmlands but there are contrasts in the extent of erosion between the natural regions, variations which in turn are related to different causes given the differences in farming activities within the respective regions.

TABLE 7: PROPORTIONS OF SEVERE TO VERY SEVERELY ERODED LANDS WITHIN NATURAL REGIONS ACCORDING TO LAND TENURE

Natural Region	Communal Lands	General Lands	Non-Agricultural Lands
I	3,7%	3,6%	0,0%
II	42,3%	1,4%	16,7%*
III	37,3%	3,1%	0,8%
IV	24,5%	1,4%	0,0%
V	19,5%	0,2%	0,0%
Average	26,9%	1,6%	0,5%

* only 6 grid cells

The greater part of the Non-Agricultural Lands, some 85,4% (about 4,8 million hectares) is located within Natural Regions IV and V. The mean erosion values in these regions are very low, 0,35% and 0,65% respectively, and it was estimated that there were 22,200 hectares of degraded land in the two regions. Natural Region III had a higher mean erosion value of 1,17% with an estimated eroded area of 7,200 hectares. Some of the erosion in this region can be attributed to the activities of squatters in wildlife areas north west of Chegutu. A very small proportion, 3,8% or 216,200 hectares, of non-agricultural areas occur within Natural Regions I and II. No erosion was recorded within the former region; although very large gully systems occur in Nyanga National Park, for example, most of these are stabilised by dense woody vegetation and apparently are no longer active.

Some 5,800 hectares of eroded land were recorded in Natural Region II and locally it seems that the proportion of severe to very severe erosion (16,7% in Table 7) is high. This is attributed to the 'edge effects' of the adjacent degraded Communal Lands and the fact that only 36 grid cells overall were recorded in this region, thus accentuating the significance of the few grid cells where erosion seemed to be more prevalent. In comparison with other parts of the country the non-agricultural areas do not pose a serious erosion problem and there are no striking differences between the natural regions for land in this tenure grouping.

c) **Erosion on Cropland and Non-cropland**

One of the terms of reference of this survey was to be able to determine the varying extent of erosion on cropland and non-croplands, the latter being used in the farming areas mainly for grazing purposes. In presenting these results two aspects need to be borne in mind. These are the possible underestimation of sheetwash erosion, especially on cultivated areas, as mentioned in the methods discussion; and secondly, the lack of suitable data on the present extent of croplands and non-croplands. Existing data, outside the large scale commercial farming sector, are general estimates and often relate to large administrative units. This means that the erosion data cannot be expressed in terms of, for example, hectares of degraded cropland out of a known area under cultivation in a specified locality. Nevertheless, some interesting patterns did emerge from the analysis of the erosion data in terms of comparing relative levels of degradation in these two 'land use' categories.

Summary results on erosion in croplands and non-croplands are given in Table 8. The area of eroded cropland in Zimbabwe was estimated at 842,400 hectares or 45,9% of the total area of degraded terrain. Some 992,400 hectares of eroded land, 54,1% of the total, were recorded as non-cropland.

TABLE 8: EROSION IN CROPLANDS AND NON-CROPLANDS ACCORDING TO TENURE

	Communal Lands	General Lands	Non-Agricultural Lands	Zimbabwe
Croplands:				
% mean	4,24	0,43	0,15	2,15%
area (1,000 ha)	768,2	65,9	8,3	842,4ha
% eroded	91,2	7,8	1,0	100,0%
total area (1,000ha)	18133,8	15277,9	5661,4	39073,1ha
% area	46,4	39,1	14,5	100,0%
Non-Croplands				
% mean	4,19	1,34	0,47	2,54%
area (1,000ha)	760,3	205,2	26,9	992,4ha
% eroded	76,6	20,7	2,7	100,0%
total area (1,000ha)	18133,8	15277,9	5661,4	39073,1ha
% area	46,4	39,1	14,5	100,0%
Total eroded land: area (1,000ha)	1528,5	271,1	35,2	1834,8ha
% eroded	83,3	14,8	1,9	100,0%

There are, however, marked differences in the relative proportions of cropland and non-cropland erosion between the three land tenure groupings. In the Communal Lands, for example, the areas of eroded cropland and non-cropland were 768,200 hectares (50,2%) and 760,300 hectares (49,8%) respectively, that is slightly more erosion on the cultivated areas. In the General Lands the comparable values were 205,200 hectares (75,7%) for non-cropland and 65,900 hectares (24,3%) for croplands. This reflects the very much higher levels of conservation measures on arable lands in the commercial farming areas. However, the sizeable area of degraded terrain in non-croplands is no cause for complacency in these farming regions. Over three quarters of the degraded land in the non-agricultural areas, some 26,900 hectares, was recorded as non-cropland. The remaining area of eroded land (8,300 hectares) was within cultivated lands; as noted earlier the presence of cultivation in such areas is partly a function of edge effects and partly due to illegal occupation of parks and forest reserves. Overall the proportion of eroded cropland in such areas is very small, being equivalent in area to just over one tenth of a standard 1:50,000 map sheet.

Given the variations in the extent of erosion within the different natural regions as described above, it is useful to examine the breakdown of this erosion in terms of cropland and non-cropland in the three tenure groupings. Area estimates of eroded terrain are given in Table 9. The ratio values cited in this table were calculated simply by diving the non-cropland area by the cropland area. Where the ratio is under 1,00 the cropland degradation is more widespread than that on non-croplands and where the ratio is over 1,00 the situation is reversed. The cropland: non-cropland ration is abbreviated to C:NC is the discussion below.

TABLE 9: ESTIMATED EROSION (1,000's ha) IN CROPLANDS AND NON-CROPLANDS ACCORDING TO TENURE AND NATURAL REGIONS

	Natural Regions				
	I	II	III	IV	V
Communal Lands:					
cropland	2,0	102,9	175,0	321,8	166,5
non-cropland	3,9	123,4	156,0	303,0	174,0
ratio	1,95	1,20	0,89	0,94	1,04
General Lands					
cropland	1,1	24,3	20,3	16,1	4,1
non-cropland	6,1	46,2	58,7	18,4	18,4
ratio	5,54	1,90	2,89	4,71	4,49
Non-Agricultural Lands:					
cropland	0,0	3,7	3,3	1,1	0,2
non-cropland	0,0	2,1	3,9	9,9	11,0
ratio	0,00	0,57	1,18	9,00	55,00

In the Communal Lands in Natural Regions IV and V the C:NC ratios were 0,94 and 1,04 respectively; area estimates indicate that cropland erosion was slightly more extensive (488,300 hectares) than non-cropland erosion (477,000 hectares). Given that on the commercial farms in these same regions dryland cultivation is not seen as viable because of the low and variable rainfall and that such extensive degradation must reduce productivity of croplands, it is clear that this is a very serious and precarious situation. The widespread degradation on non-croplands, some 477,000 hectares, is also cause for concern since, as will be discussed later, this is a function of increased livestock pressures on a diminishing area of grazing land. In Natural Region III the C:NC ratio falls to 0,89 with more extensive erosion on croplands (175,000 hectares) than on non-croplands (156,000 hectares). Given the more favourable rainfall in this region, the widespread erosion on croplands may be a function, in part, of a tendency to overcultivate; that is, cropping is extending into marginal areas, where it should not be practiced, in efforts to increase overall crop output.

The area of non-cropland erosion in Natural Region II was estimated as 123,400 hectares, somewhat greater than that on the cultivated areas (102,900 hectares). Again this may be due to livestock pressures on a diminishing area of grazing land, a situation which prevails throughout many of the more densely settled Communal Lands (Whitlow, 1979b). Nevertheless, at least some of the erosion on present day non-croplands was initiated by cultivation in the past. Overgrazing is not necessarily the universal cause of erosion, but it certainly does not assist in rehabilitation of now abandoned and degraded cropland. The least extensive erosion was recorded in Natural Region I where non-cropland degradation (3,900 hectares) was nearly double that observed on the croplands.

The circumstances in the General Lands are very different since non-cropland erosion is over three times greater than that on croplands within this tenure type. However, in the ranching areas, that is Natural Regions IV and V, the C:NC ratio increases to 4,71 and 4,49 respectively. In these regions cropland accounts for only 20,200 hectares of eroded lands whereas non-cropland constitutes 94,200 hectares. This contrasts with the Communal Lands where cropland erosion was equal to that on non-croplands and the overall area of eroded terrain was nearly 8,5 times greater. The contribution of eroded cropland to total erosion increases in Natural Regions III and II (C:NC rations of 2,89 and 1,90 respectively) constituting 44,600 hectares compared with 104,900 hectares of degraded non-cropland. Since cultivation assumes greater significance in these regions than in the drier parts of the country, this shift in C:NC ratios is to be expected. In Natural Region I the area of eroded non-cropland (6,100 hectares), although low, is 5,5 times greater than that on croplands. Since cultivation in this region requires great care over the conservation meassures, the limited erosion on the croplands is a good sign that such efforts have been successful. Clearly more attention needs to be given to the non-croplands.

The Non-Agricultural Lands are located mainly in Natural Regions IV and V within which non-cropland erosion (20,900 hectares) is substantially greater than that on croplands, particularly in Natural Region V where the C:NC ratio is 55,00. The existence of degraded cropland in Natural Regions II and III has been commented on earlier in terms of edge effects and illegal occupation of land. In any event the area of eroded non-croplands in these two regions is relatively low (6,000 hectares), being 46,5 times lower that equivalent figures for the Communal Lands and 17,5 times lower than those in the General Lands.

5. INFLUENCE OF PHYSICAL FACTORS ON EROSION

Three aspects of the influence of physical factors on erosion are discussed in this section. Firstly the patterns of erosion are compared with the potential erosion hazards described by Stocking and Elwell (1973); secondly, the significance of areas of extensive rock outcrops is discussed; and thirdly, the importance of erosion on sodic soils is outlined. It is important to realise that certain physical factors only become important in erosion problems when they interact with human factors. For example, areas of extensive steeply sloping granitic domes are only vulnerable to degradation when the slopes around the domes are cleared for cultivation and the vegetation on the domes is exploited for firewood and building materials. Consequently, a clear separation of physical and human influences on erosion is neither practicable nor desirable.

a) Erosion and Potential Erosion Hazards

The present aerial photo survey provides data on the patterns of *actual erosion* whereas the hazards survey presented by Stocking and Elwell (1973) defines *potential erosion* in terms of a series of environmental factors known to influence erosion. It is of interest, therefore, to examine the relationship of actual to potential erosion. To isolate the importance of physical factors as erosion hazards, the analysis used the hazards assessment excluding the human influences factor as described by Stocking (1975). Before comparing actual and potential erosion, it is necessary to outline briefly the nature of physical erosion hazards in Zimbabwe.

The four physical factors considered in the hazards survey were plant cover, soil erodibility, rainfall erosivity and average slope. Plant cover is a vital protective force in the erosion system (Stocking, 1980). For example, a dense plant canopy inhibits the effects of raindrop impact on soil surfaces, whilst litter reduces rates of overland flow and roots (particularly of herbaceous plants) bind soil aggregates together. Not surprisingly one finds that where there is a decrease in plant cover invariably this results in an increase in soil erosion. This has been demonstrated clearly for both croplands and grazing areas in Zimbabwe (Stocking and Elwell, 1976a; Elwell and Stocking, 1976a).

However, given that the nature and extent of man's impact on vegetation in different parts of the country are highly varied, it is difficult to quantify the present status of plant cover in relation to erosion. In their study Stocking and Elwell (1973) assumed that plant cover decreased along a gradient from high to low rainfall so that the mean annual rainfall map was used as a surrogate measure for plant cover. Intuitively this may be acceptable, but on the ground man's activities in terms of clearance of vegetation for cultivation and firewood and the effects of grazing have masked completly this relationship. Indeed, in the absence of adequate information on plant cover it might have been better to have excluded it from the survey or, alternatively, to have incorporated it via the human influences factor. The importance of plant cover and biotic pressures will be discussed further in the next section.

Soil erodibility concerns the ability of soil to withstand the impact of raindrops, for example, which detach particles from soil aggregates and mark the early stage of surface wash erosion (Morgan, 1979). Erodibility is a function of both physical and chemical properties of soils. For example, soils which are very sandy and which have a low organic matter content typically are characterised by very poorly developed aggregates which disintegrate readily when pounded by raindrops or when ploughed. Large areas in Zimbabwe, approximately two-thirds of the country, are characterised by such soils derived from granitic rocks, Karoo sediments and aeolian deposits (Thompson and Purves, 1978). Furthermore, these sandy soils are generally very infertile being low in weatherable minerals and especially deficient in nitrogen, phosphorous and sulphur (Grant, 1981).

Where such soils are used for cultivation, particularly for maize, it is vital to supplement fertility with chemical fertilizers and organic residues like manure. If this is not done properly, plant growth is poor resulting in low yields and a sparse canopy which exposes a high proportion of the ground to rainsplash erosion. Stocking and Elwell (1973) single out sodic and non-calcic hydromorphic soils as being the most vulnerable soils in Zimbabwe as far as erosion is concerned. Erosion on the latter, commonly referred to as *vlei soils*, is discussed under human influences whilst further comments on sodic soils are given later in this section.

The plant cover and soil factors can be modified readily by man to reduce or exacerbate erosion. In contrast, the factors of rainfall erosivity and average slope are not amenable to manipulation, at least not in a direct way. The erosive powers of high intensity tropical rainstorms have been recognised for a long time (Hudson, 1970). Considerable attention has been paid to this facet of erosion in Zimbabwe as demonstrated by the research of Stocking and Elwell (1976b, 1976c). Their research has shown that mean annual rainfall erosivity, a parameter derived from converting measurements of rainfall intensity into energy terms (in this case, joules mm/m²/hour), is greatest in the north-central and eastern parts of Zimbabwe (Fig. 11A). High erosivity was recorded also for the area south-east of Masvingo. This suggests that erosion risks in terms of rainfall are greatest in these parts of the country which, broadly speaking, is true. Nevertheless, one must recognise that many rainfall stations, especially in the lower regions, record a high propertion of very intensive storms in the early part of the rain season (Stocking and Elwell, 1976b).

This is critical for erosion since this is a time when crops have not established a fully protective canopy or, in the case of many peasant farmlands, have barely passed the seedling stage. Plant cover at the end of the dry season is typically very sparse in the grazing areas and may have been destroyed by burning to expose a high percentage of bare ground. As a result the early season, high energy rainstorms can cause an immense amount of damage literally within a period of a few minutes.

Average slope was the fourth physical factor considered by Stocking and Elwell (1973). This was chosen from a number of terrain parameters as being the best expression of the influence of topography on erosion (Stocking, 1972b). In particular, average slope was found to correlate very well with lengths of gullys and earlier studies by Keech (1968) suggested that there was a close relationship between the extent of gullying and

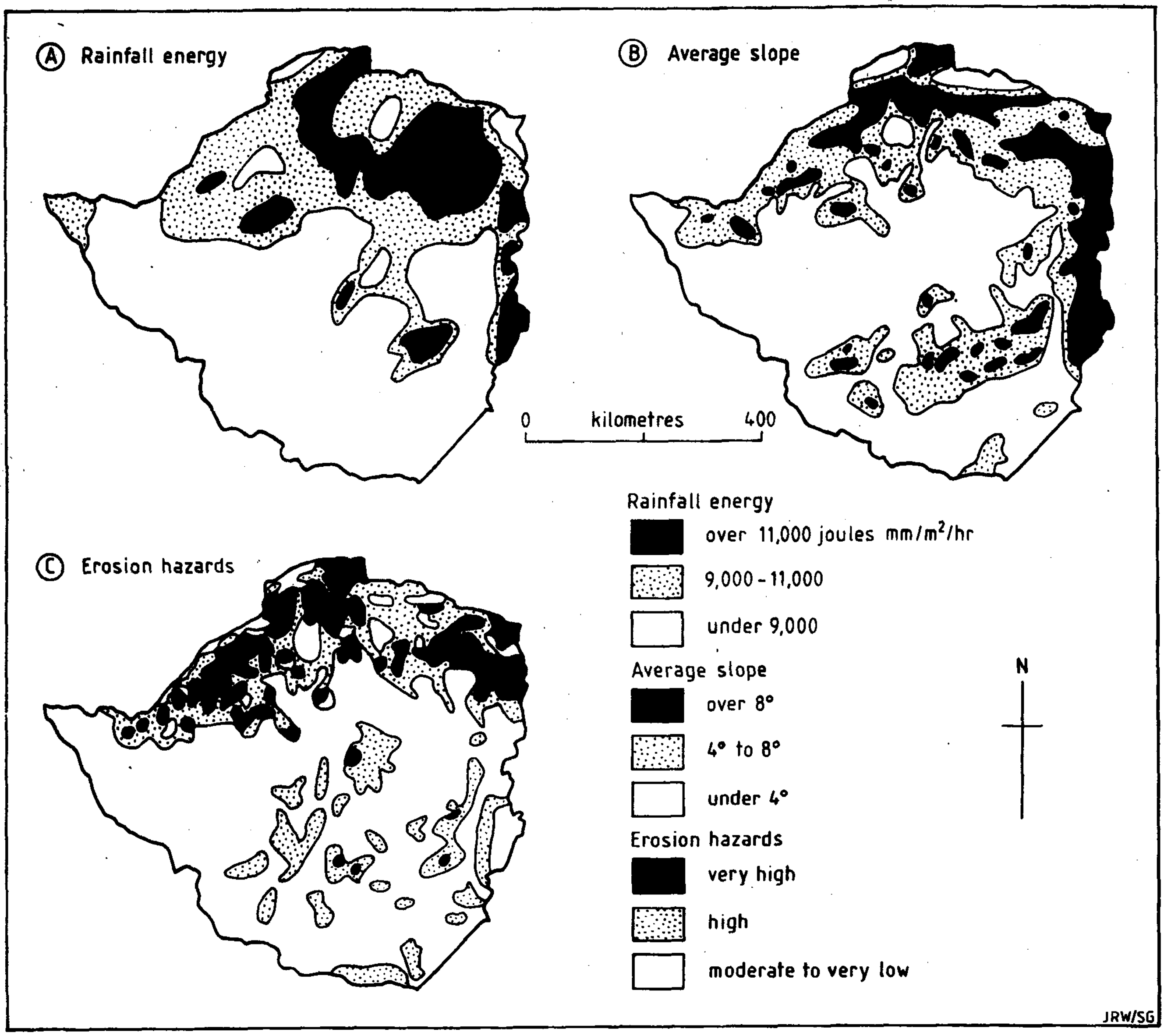


Figure 11 – Physical factors influencing erosion (after Stocking and Elwell, 1973).

severity of sheetwash and rill erosion. Measurements of average slope were obtained by means of sample transects within ¼ grid cells on 1:50,000 topographical maps in Zimbabwe. The results were expressed in degrees of slope and plotted in the form of an isoline map (Stocking 1972b), a simplified version of which is given in Figure 11B.

As might be expected the survey shows the most steeply sloping terrain within the Eastern Highlands and parts of the Zambezi Valley in the north and north west of the country. In addition, there are areas of relatively steep terrain to the east and south of Masvingo (Fig 11B). Some of the areas of steeply sloping terrain correspond with regions of large granitic domes which are discussed later. The significance of slope in erosion processes is twofold. Firstly, runoff is likely to increase at the expense of infiltration as slopes become steeper; and secondly, gravitational forces are more effective at promoting downslope movement of detached soil particles on steep slopes than in areas of gently undulating ground. The need to construct and maintain contour banks on sloping croplands has been recognised as an essential conservation measure in Zimbabwe for many years (Cormack, 1972). Where this is not done extensive erosion occurs as will be illustrated in the next section.

The general results of the potential erosion hazards study are simplified in Figure 11C. This reveals that the main areas of high to very high erosion hazards are in the north of the country extending from the Mutoko area in the north east to the lands bordering Lake Kariba in the west. In addition, there are sizeable patches of potentially 'hazardous' land in the central and south east of Zimbabwe. Such areas amount to one third of the nation's land, 25,2% for areas with high potential hazards and 8,4% for areas with very high potential hazards (Table 10a). The remainder of the country was regarded as having less potential for erosion, some two fifths of the land rated as having moderate risks (although Stocking (1975) uses the term 'below average' for areas with factor scores of 11 to 12).

The occurrence of potential erosion hazard classes within and between tenure groupings are summarised in Table 10a and b. Just over one quarter of the Communal Lands was mapped as having low to very low hazards, whilst 38,7% was rated as having high to very high risks. The equivalent values for the General Lands are 21,5% and 25,4% and those in the non-agricultural lands are 42,4% and 39,2%. On this basis it seems that conditions are slightly more conducive to degradation in the Communal Lands. This contention is supported by examining the occurrence of hazard classes between tenure types (Table 100b). Clearly, the Communal Lands have the greatest share of the high to very high risk areas, although they also contain a large portion of areas with lower risks as well. The non-agricultural lands include the majority of the low risk areas, these forming extensive parts of Hwange National Park and Gona Re Zhou in the south east of the country. The General Lands occupy an intermediate position, with the moderate risks class accounting for over half the land in this tenure type.

TABLE 10: POTENTIAL EROSION HAZARDS IN ZIMBABWE
(data derived from original compilation map of Stocking and Elwell, 1973)

a) ***Within tenure types***

Erosion Hazard*	Communal Lands	General Lands	Non-Agricultural Lands	Zimbabwe
Very low (8)	4,8	0,5	24,5	6,0
Low (9-10)	21,5	21,0	17,9	20,8
Moderate (11-12)	35,0	53,1	18,4	39,6
High (13-14)	29,1	22,9	18,8	25,2
Very high (over 14)	9,6	2,5	20,4	8,4
Totals	100,0%	100,0%	100,0%	100,0%

* original factor scores after Stocking (1975)

b) ***Between tenure types***

Erosion Hazard	Communal Lands	General Lands	Non-Agricultural Lands	Zimbabwe
Very low	37,5	3,1	59,4	100,0%
Low	48,0	39,5	12,5	100,0%
Moderate	40,9	52,4	6,7	100,0%
High	53,6	35,6	10,8	100,0%
Very High	53,3	11,5	35,2	100,0%
Totals	46,4%	39,1%	14,5%	100,0%

TABLE 11: MEAN TOTAL EROSION ACCORING TO EROSION HAZARDS AND TENURE

Erosion Hazards	Communal Lands	General Lands	Non-Agricultural Lands	Zimbabwe
Very Low	5,15	1,34	0,18	2,08
Low	8,21	1,86	0,46	4,73
Moderate	9,92	1,70	1,39	5,04
High	7,52	1,92	0,90	4,81
Very high	7,91	1,28	0,33	4,48
Averages	8,43%	1,77%	0,62%	4,70%

In comparing the actual erosion observed with the potential risks assessed, one might suppose that the greater the risks then the more extensive the erosion. An analysis of the frequency distribution of the actual erosion classes and the values for mean total erosion according to erosion hazards (Table 11) does not, however, support this contention. For Zimbabwe as a whole there is no clear increase in the percentage of eroded land from areas of very low risks through to areas of very high risks. This also applies to the three tenure categories, although in the case of the Communal Lands it seems that erosion is slightly more pronounced in areas of moderate risks; the same is true of the non-agricultural lands.

This evidence indicates that the basic premise on high risks correlated with extensive erosion has to be qualified and that physical factors alone are inadequate to determine erosion hazards. The human factor obviously has to be considered as well. The fact that there was very little erosion in areas of high to very high risks within the non-agricultural lands suggests that human population density might be an important influence on erosion. This was confirmed for the erosion patterns in the Communal Lands (Table 12) where there is a more clearly defined pattern of degradation within and between hazards classes.

Thus as population density increases so the proportion of mean erosion rises, for example, from 0,78% to 14,66% for low risk areas where densities range from 0 to over 40 persons/km². Similarly the erosion estimates in the high and very high risk areas are typically greater in the higher density classes than in areas with lower risks for example, the highest mean erosion value of 20,05% was estimated for very high risk areas where population densities were over 40 persons/km².

The same analysis in the General Lands revealed no obvious pattern so it seems that land use and management factors are also important determinants of the erosion which might occur in localities with varying physical risks of erosion.

TABLE 12: MEAN TOTAL EROSION IN THE COMMUNAL LANDS ACCORDING TO EROSION HAZARDS AND POPULATION DENSITY

Population Density (Nos/km²)	very low	Erosion low	Hazards moderate	high	very high
0*	1,13	0,78	1,63	0,86	2,10
Under 11	4,39	5,26	4,61	3,89	4,39
11-20	6,25	7,46	7,38	7,60	7,01
21-30	6,70	8,94	10,69	12,70	12,29
31-40	9,66	12,61	12,86	10,92	19,75
Over 40	—	14,66	15,44	14,76	20,05
Average	5,15%	8,21%	9,92%	7,52%	9,91%

* very sparsely settled areas.

While Stocking and Elwell (1973) do make use of a human influences factors in their evaluation of erosion risks in Zimbabwe, the results of this study indicate that this factor should have been given much greater emphasis in their survey. This does not diminish the fact, however, that the areas they define as having high to very high risks are regions which have to be utilised carefully if excessive erosion is to be avoided.

b) **Erosion and Rock Outcrops**

The occurrence of massive rock domes, referred to by geomorphologists as *bornhardts*(Plate 2), poses major constraints on human activity in some parts of Zimbabwe. The main problems are firstly, the steep slopes and shallow pockets of acid, granular soils on the domes preclude their use for farming although they may provide firewood and limited grazing; secondly, the domes typically occupy between 20 to 35% of the land area and locally much more, thus reducing the availability of land for cropping; and thirdly, the steep bare slopes of the bornhardts promote rapid surface runoff during intensive rainstorms and this, in turn, favours sheetwash and gully erosion on slopes adjacent to these features (Plate 3).

The distribution of areas of bornhardt terrain in Zimbabwe is shown in Figure 12A with summary data according to land tenure being given in Table 13. There are nearly 5,9 million hectares of this terrain in Zimbabwe, some 15,1% of the national area. Bornhardt features form a distinctive arc extending from the Matopos south of Bulawayo through to the Mutoko area north-east of Harare (Fig 12A). Islands of domes within this arc are

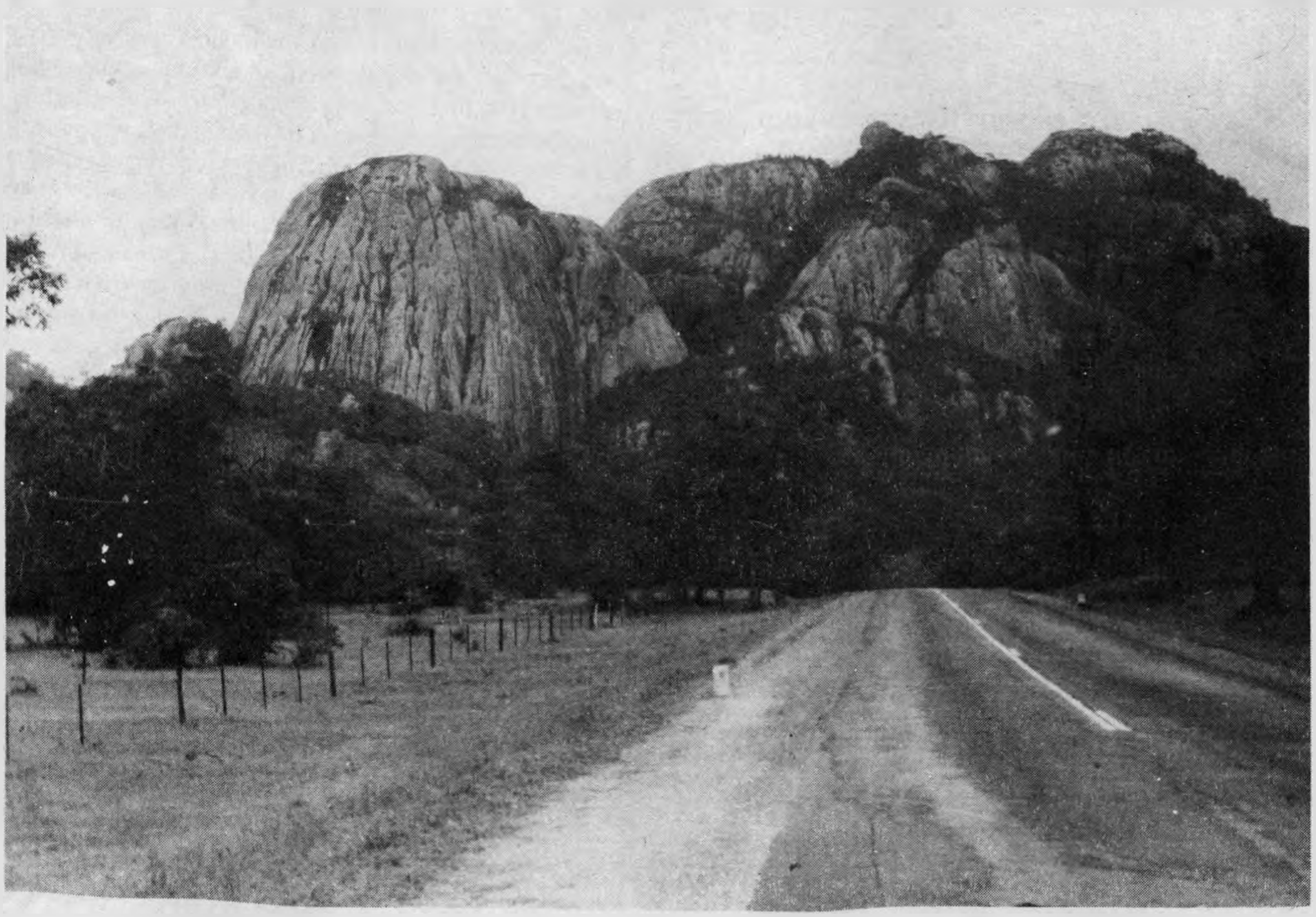


Plate 2 – Granitic domes near Masvingo.

Plate 3 – Aerial photo of an area near Mutoko (Source: Surveyor General).

associated with large batholith complexes such as the Chinamora Batholith just to the north of Harare. Using the map presented by Whitlow (1980b), it was estimated that 68,0% of this terrain occurs within Communal Lands, 29,6% is in General Lands and only 2,4% is in Non-Agricultural Lands, notably the Matopos park south of Bulawayo.

In the last of these tenure groupings the spectacular scenery of the domes is a major asset, while the diversity of habitats provides ideal conditions for a large number of plants and animals. The ecological and hydrological balance of such areas, particularly in the drier parts of the country, can be modified completely where they are used extensively for farming and settlement purposes (Fig 12B). The case of the Matopo Hills has been documented by Lighfoot (1981, 1982), illustrating the contrast between the relatively intact ecology of the national park and the devastated conditions in the surrounding Communal Lands. It is clear that the main erosion problems in areas of bornhardt terrain are associated with the densely settled Communal Lands so subsequent discussion is focused on such areas (Whitlow, 1980b).

The Communal Lands include over 4,0 million hectares of this terrain, this constituting just over one fifth of the peasant farming areas (Table 13). Critical degradation

TABLE 13: OCCURRENCE OF BORNHARDT TERRAIN IN ZIMBABWE

	Bornhardt Terrain (BT) area (1,000ha)	% of BT area	% of total area	Total Area (1,000ha)
Communal Lands	4010,3	68,0	22,1	18133,8
General Lands	1743,0	29,6	11,4	15277,9
Non-Agricultural Lands	142,6	2,4	2,5	5661,4
Zimbabwe	5895,9	100,0%	15,1%	39073,1

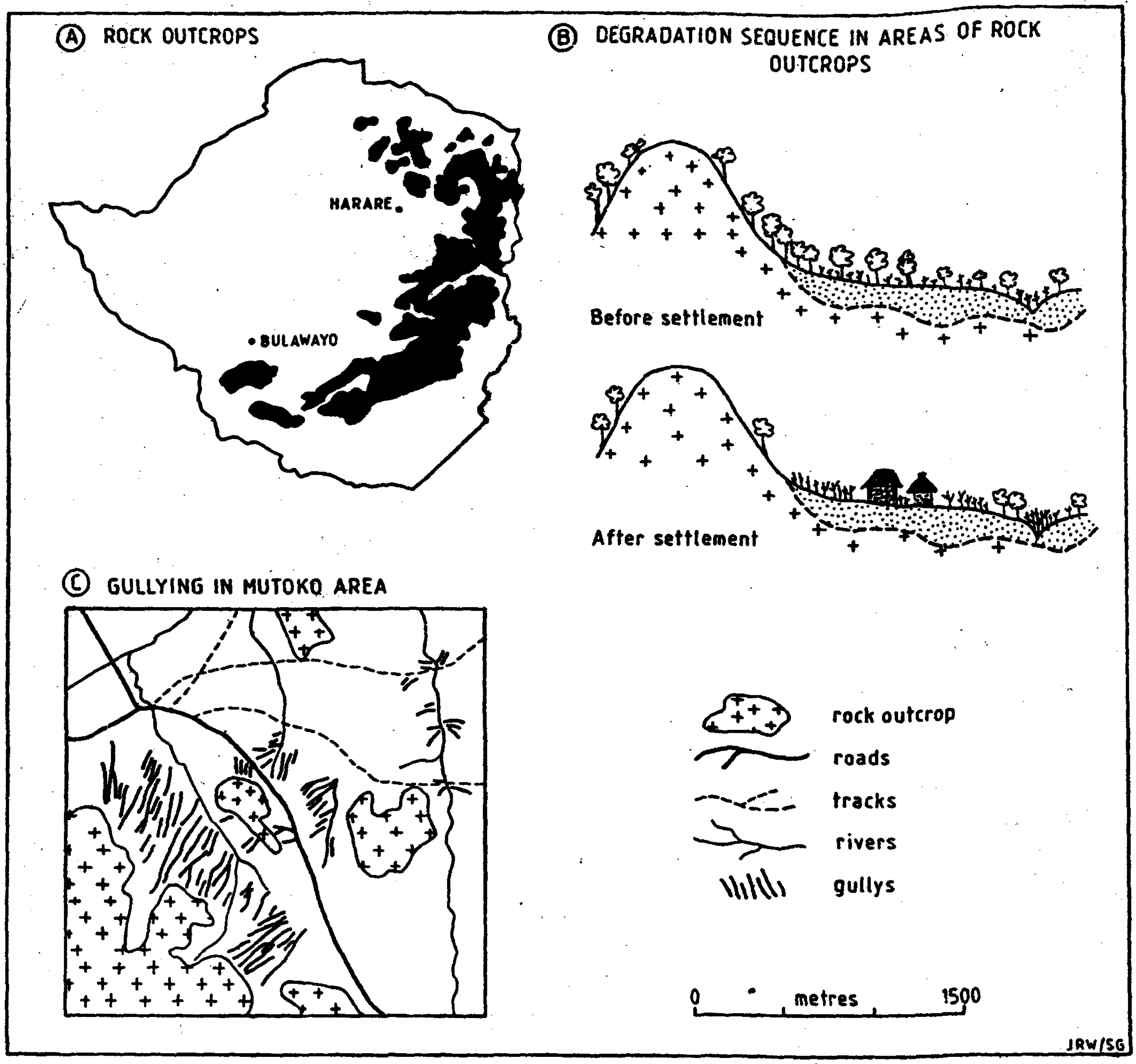


Figure 12 – Bornhardt terrain and erosion problems.

problems occur when such terrain coincides spatially with areas of excessive population pressures (Whitlow, 1980c). This situation occurs in the Communal Lands to the south and east of Masvingo as well as in the Mutoko district, the Chinamora area and parts of Chiweshe. It is not uncommon to find numerous and lengthy gullies on cultivated slopes adjacent to large domes in these areas (Fig 12C), especially where contour banks are poorly constructed and cropping occurs right to the bases of the outcrops. The mean total erosion for areas where bornhardts were present was 14,4%, more than twice that of areas without domes (6,73%). This difference could be attributed, in part, to the greater densities of population in areas on bornhardt terrain rather than any specific effect of the terrain itself.

To isolate more clearly this specific effect, data on mean cropland erosion were divided according to population density (Table 14). The results show that for areas where population densities are over 10 persons/km^2 that mean erosion values are between 1,5 to 2,0 times greater in areas of bornhardt terrain than in areas of comparable population density where such features are absent. The greater severity of erosion in areas of bornhardt terrain is brought out even more clearly in Table 15. This indicates that although this terrain only comprises 22,1% of the Communal Lands, such areas include nearly two fifths (38,6%) of the severely eroded lands and just under half (47,0%) of the very severely degraded lands.

TABLE 14: MEAN CROPLAND EROSION IN THE COMMUNAL LANDS ACCORDING TO THE PRESENCE OF BORNHARDT TERRAIN AND POPULATION DENSITY

Population density (Nos/km²)	Bornhardt Terrain absent	Bornhardt Terrain present
0*	0,38	0,00
Under 11	1,91	2,00
11-20	3,14	6,04
21-30	4,10	7,72
31-40	5,22	8,38
Over 40	6,78	10,40
Average	3,10%	8,25%

* sparsely settled areas.

TABLE 15: EROSION CLASSES WITHIN COMMUNAL LANDS ACCORDING TO THE PRESENCE OF BORNHARDT TERRAIN

Erosion Class	Bornhardt Terrain Absent	Bornhardt Terrain Present	Totals
1. Negligible	97,5	2,5	100,0%
2. Very Limited	89,7	10,3	100,0%
3. Limited	80,6	19,4	100,0%
4. Moderate	71,0	29,0	100,0%
5. Severe	61,4	38,6	100,0%
6. Very Severe	53,0	47,0	100,0%
Totals	77,9%	22,1%	100,0%

The seriousness of this situation must be stressed particularly since much of the bornhardt terrain in the Communal Lands occurs within Natural Regions IV and V. Consequently, the rock domes compound the problems of farming and risks of erosion in regions which are already marginal for agriculture because of low and erratic rainfall. The improvement of socio-economic conditions in the face of such widespread and continuing degradation is going to require, amongst other things, a major drive to conserve and rehabilitate the land.

c) Erosion on Sodic Soils

Sodic soils, variously known as *mopani soils* or *isikwakwa*, are those which contain abnormally high proportions of exchangeable sodium. About one tenth of Zimbabwe is characterised by such soils, the main distribution of these being indicated in Figure 13A. In the central and southern parts of the country sodic soils are associated mainly with gneissic granites, but in the north west and north they occur mainly on Karoo sandstones and related sediments (Wendelaar, 1976). In addition, localised patches of sodic soils occur in higher rainfall areas on the central plateau region, particularly where there is poor drainage.

The sodium in these soils is derived from the weathering of sodium rich minerals, especially plagioclase feldspars, in the parent materials. Whereas in the higher rainfall areas there is abundant throughflow of water in the soil and ions released by weathering are leached away, in the lower rainfall areas (under 600mm/year) throughflow is less pronounced. The result is a progressive accumulation of salts, particularly sodium, in the subsoil (Purves, 1975). The sodium has the effect of deflocculating or separating the clay fraction in the soil which promotes the development of a dense, impermeable subsoil horizon. For this reason these soils are prone to high rates of surface runoff and hence active sheetwash erosion, whilst concentrated throughflow in subsoils favours subsurface piping or tunnelling (Fig 13B; Stocking, 1976), a process which contributes towards the growth of extensive gully systems (Fig 13C).

Indeed, it is the existence of enormous gullies which first attracted the attention of soil conservationists (Plate 4). Some of these gullies are in the order of 8 to 10 metres in depth, over 100 metres wide and may extend for up to 2 kilometres (Fig 13C). There are good examples of such gully systems in the upper reaches of the Muzvezve catchment in Mhondoro and Ngezi Communal Lands, an area which has been studied in detail by Stocking (1976, 1977, 1978). Such spectacular gullying is by no means restricted to the peasant farming areas or this specific locality. However, since this is an area where the causes and processes of gully erosion have been investigated most fully it is useful to discuss this locality, especially the gullies near St Michael's Mission, in some detail.

The response of soil conservationists to these gully systems since the turn of the century has been documented by Stocking (1978). Until the early 1930's there was no official concern over these gullies since the area was very isolated and little assistance was given to the peasant farmers by the European administration. In 1934 there were reports of severe overgrazing in the northern parts of Mhondoro and it was suggested that people move out of this area southwards into the Muzvezve region to relieve pressure on the land. At this stage there was growing awareness of soil erosion in the country, especially in the then 'native reserves'. This situation led eventually to the institution of the 1939 Commission as discussed earlier. The primary cause of degradation in the reserves in general was regarded as wanton and inappropriate forms of land use by the peasant farmers.

As settlement and cultivation extended in the Muzvezve catchment so the large gullies started to attract attention and various attempts were made to stabilise some of them (Stocking, 1978). For example, one of the earliest measures to control the advance of the St Michael's Gully, at that time called Timba Gully, was

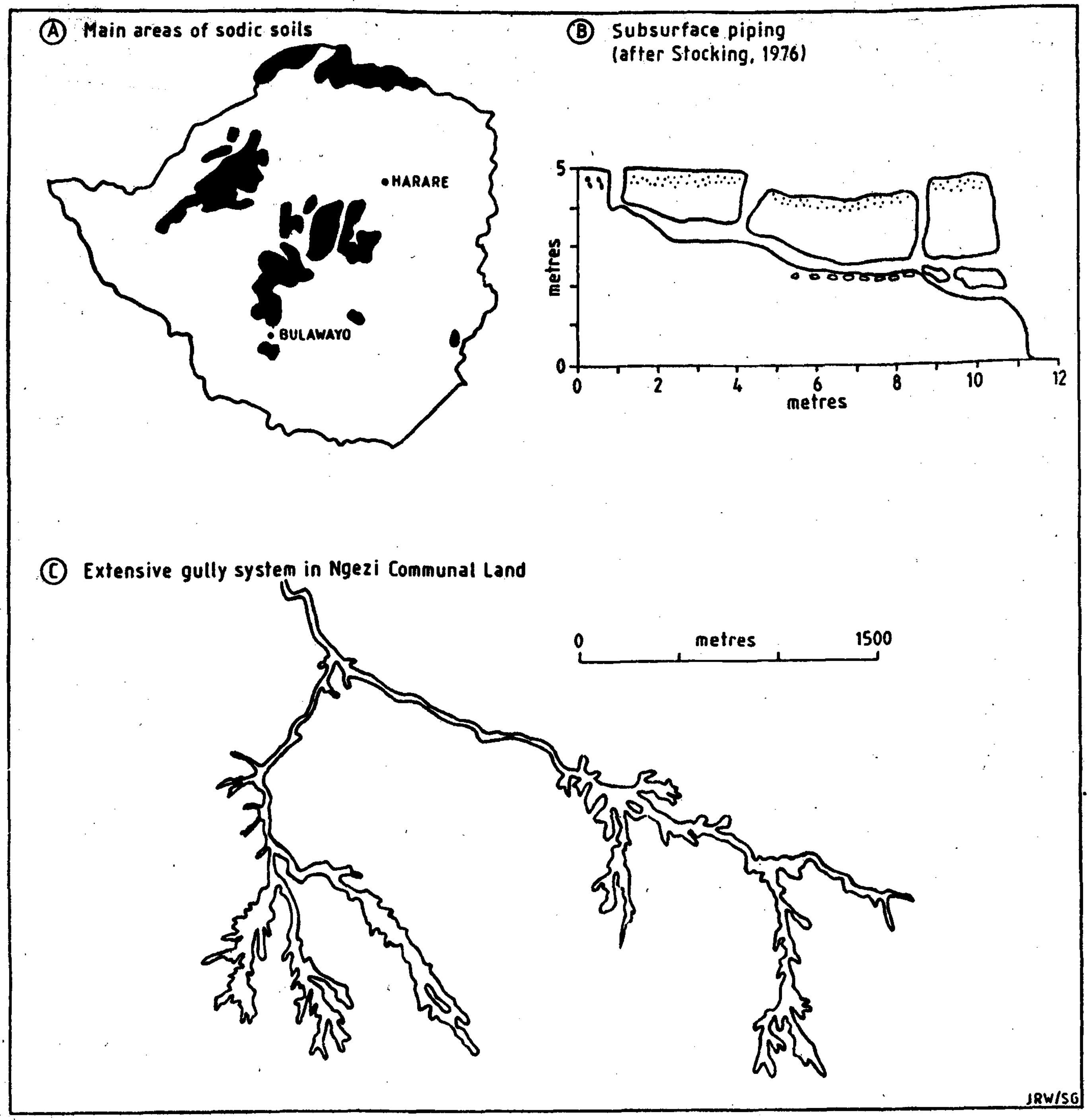


Figure 13 – Sodic soils and gullying.

the construction of large contour banks around the gully head in the late 1940's. Presumably the aim was to reduce surface runoff into the gully system and thereby slow down its advancement. In practice the contour banks concentrated surface water, localised infiltration and favoured the development of subsurface tunnels which in turn accentuated the erosion problem. Within a few years the gully cut through one of these banks and a tributary gully developed upslope of the bank.

Other attempts to counteract these gullies have included fencing of gully heads to keep out livestock and improve vegetation, and the construction of wired stone bolsters within the gullies. The fences were damaged or stolen, the bolsters were undermined and the gullies continued to grow. Planting of sisal and bulldozing of headcuts also failed to halt the advance of the gullies. It became obvious that these ravine-like features were no ordinary gullies and that their primary causes were independant of, but not unaffected by, local farming practices.

Subsequent reasearch has demonstrated that there are several interacting physical factors favouring the development of large gullies in the Muzvezve catch-

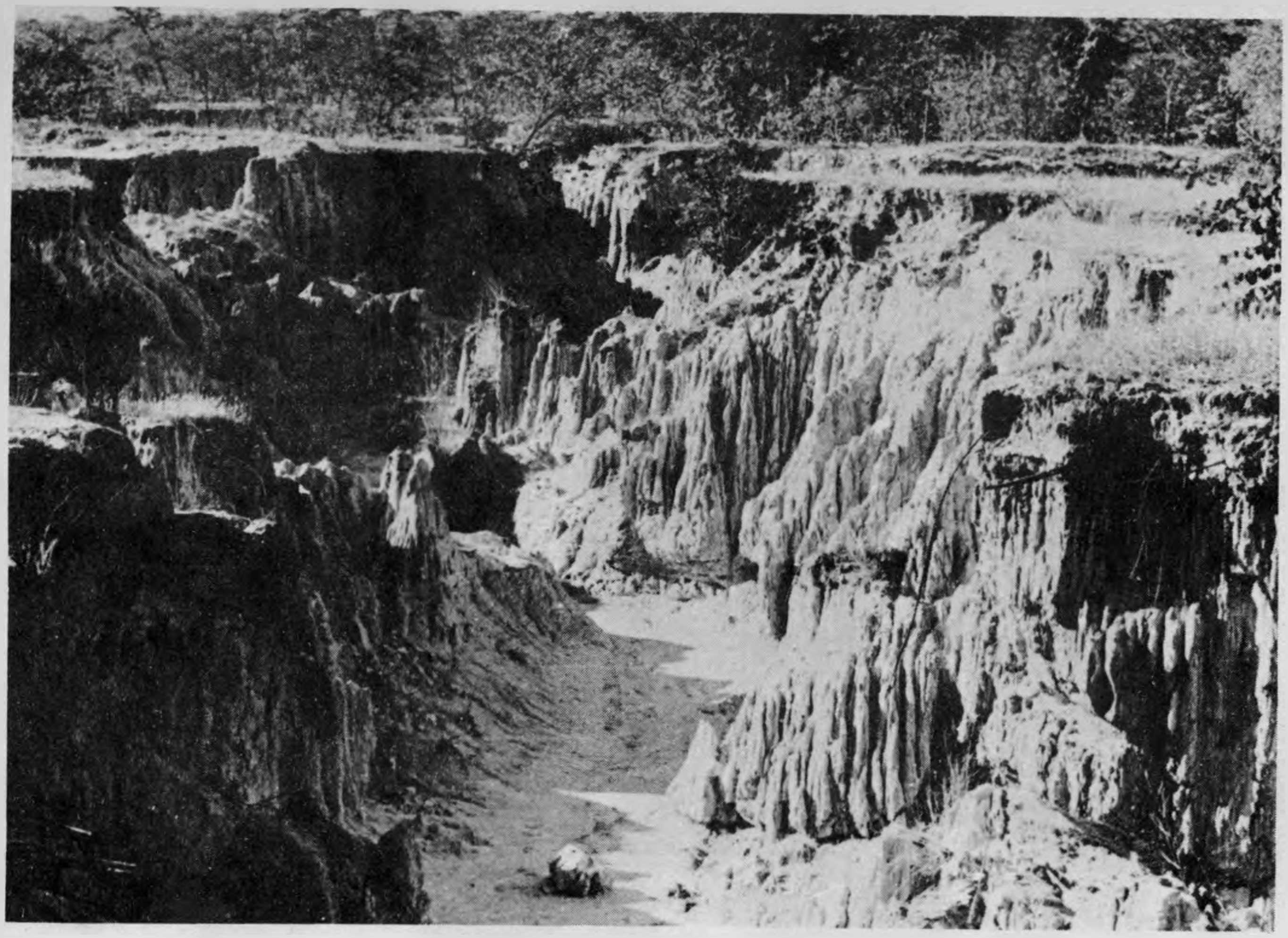


Plate 4 – Sodic gully system near St. Michael's Mission, Ngesi Communal Land. (Source: Dr M.A. Stocking).

ment (Stocking, 1977). For example, incision of the Muzvezve River system has lowered local base levels to which tributary channels, including gullies, are adjusted. This has encouraged deepening and widening of the gullies, this being facilitated by a considerable depth of cohesive soils and weathered bedrock. More crucial factors peculiar to these sodic soils, however, are the processes of liquefaction and piping. The sediments in the St. Michael's Mission area mainly comprise very fine wind-blown sands. When the near vertical walls of the gullies become wet, mass flow of materials occurs through a process termed liquefaction. This instability results in large scale mass movements of material widening the gullies, the sediment deposited within the gullies being removed gradually by storm runoff. The great depths of the gullies means that when undercutting of the gully walls occurs then enormous slabs of soil may break away and fall into the gully floors. The process of liquefaction, however, is restricted mainly to the fine Karoo sediments and may not occur on all sodic soils.

The process of tunnelling is more typically a feature of sodic soils. Stocking (1976, 1983) has described the complex manner in which subsurface piping develops. In very simple terms it involves the lateral movement of water beneath the impermeable and cohesive sodium-rich subsoil. This results in the development of underground tunnels which may extend several metres back from the gully margins (Fig 13B). Once initiated a tunnel attracts throughflow of water and material is stripped from its walls and base. In time this may lead to the subsidence of large blocks of soil as shown in cross-sectional form in Figure 13B. Where vertical cracking occurs then the presence of piping may be detected by the existence of sink holes (Wendelaar, 1976).

Gully headcuts influenced by piping may appear to be dormant for long periods. This may instill a false sense of security insofar as the unseen tunnels are probably actively enlarging. Eventually they will collapse and a phase of rapid headcut advancement will occur. It should be noted, however, that waterfall-controlled headcuts common to non-sodic gully systems also contribute towards the extension of sodic gullies, but the process is more continuous and obviously visible, unlike tunnelling.

Sodic soils are clearly inherently unstable and prone to gullying as well as extensive and severe sheetwash erosion. Such soils are relatively easy to identify in the field (Cooper, 1972, Wendelaar, 1976), if only by the presence of widespread degradation and stunted woody growth, especially of *Colophospermum mopane.* It seems

Plate 5 – Aerial photo of a sodic gully in Ngesi Communal Land (Source: Surveyor General).

that prevention, insofar as this is possible, is a more satisfactory solution than reclamation of eroded sodic soils. Although reclamation measures have been developed for Zimbabwe conditions (Dye, 1979), they do require the use of large quantities of gypsum and lime, for example. The costs involved in this have to be weighed against the benefits of reclamation and in any event, may be too high for application in peasant farming areas. Preventative measures in the form of maintaining a good basal plant cover, encouraging even infiltration of water, avoiding exessive trampling by livestock and carefully diverting runoff from roads are less costly and more practicable.

Furthermore, since sodic gullies are easy to identify on aerial photos (Plate 5), it may be desirable to map the occurrence of these features on 1:50,000 base maps for the main areas of sodic soils to determine the exact locations of these gullies prior to embarking on any conservation measures to counteract such erosion.

6. INFLUENCE OF HUMAN FACTORS ON EROSION

Some mention has been made in the previous section of the role of man in accelerating erosion dependent, in part, on the nature of the physical environment. The history of soil conservation described earlier in this report demonstrated the circumstances giving rise to very different erosion situations in the General Lands and Communal Lands. In this section four main aspects of man and erosion are discussed. These are the significance of population density, erosion on croplands, degradation in grazing areas and finally, deterioration of wetlands. Statistical analyses of the variations in the extent of erosion indicated that the most important influences on erosion are population density and land tenure, variables which govern the types of land use and degree of pressure on the land. The most widespread and intensive erosion occurs within the Communal Lands so the main focus of discussion will be on these areas.

a) Population Density and Erosion

According to the 1982 population census (CSO, 1984), the total population of Zimbabwe is around 7,546,000 giving an average density of 19,3 persons/km^2. The African population comprises over 97,5% of the total. Data on the distribution of the African population were derived from the 1982 census and are summarised in Table 16. These data indicate that some 4,2 million people live in the Communal Lands which support about three quarters of the rural population on just over two fifths of the land. There are some 1,2 million Africans in the General Lands, comprising mainly farm workers and their dependents. Such areas support about one fifth of the rural population on two fifths of the land in Zimbabwe. Consequently, the Communal Lands popu-

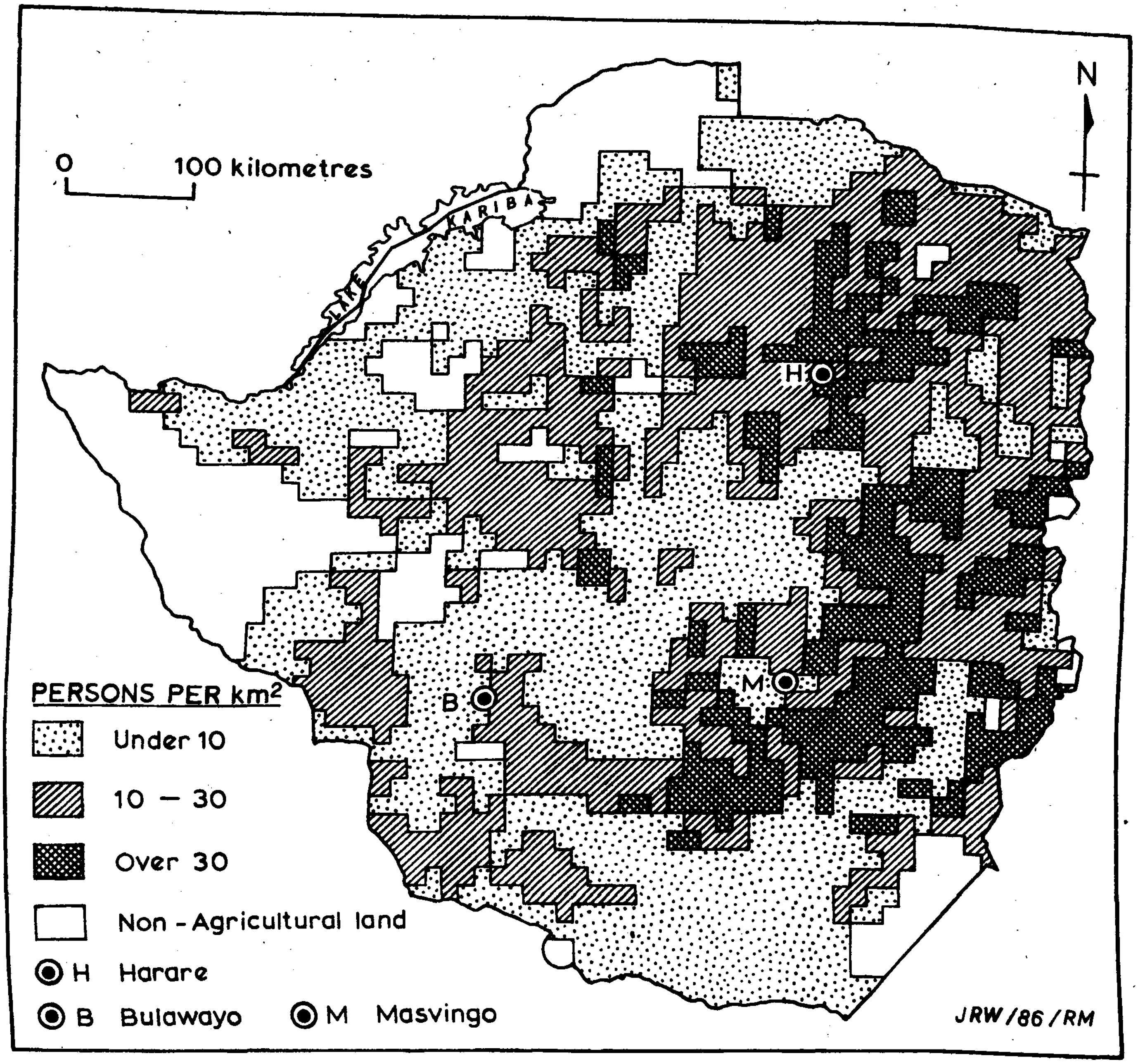


Figure 14 – Population density in Zimbabwe (1982 census).

lation density at 25,5 people/km² is neary 3,5 times that of the General Lands (7,6 people/km²). The SSCFAs in 1982 had an estimated population of 166,600 giving a relatively low density of 12,4 people/km². Differences in the extent of erosion between these areas are, in part, a function of these differences in population density.

An analysis of variations in population density was carried out using the 1982 dot distribution map (Davies and Wheeler, 1986). Summary data on this is presented in Table 17 and a simplified density map is given in Figure 14. Just over half of Zimbabwe was mapped as having population densities in the range 0 to 10 persons/km²; such areas occur in the north west and extreme south of the country, but include also part of the central watershed region between Bulawayo and Harare. Just

TABLE 16: AFRICAN POPULATION DISTRIBUTION IN ZIMBABWE IN 1982

	Communal Lands	General Lands	SSCFA+
Population ('000)	4195,1	1198,4	166,6
% of total population	56,9	16,3	2,3
% of rural population	75,5	21,5	3,0
Land area (km²)	164600	158200	13400
% of land area	42,1	40,5	3,4
Population density (Nos/km²)	25,5	7,6	12,4

* Urban population estimated at 1,780,100 giving a total African population of 7,365,000.

\+ SSCFA – small scale commercial farming areas.
Source: Zinyama and Whitlow (1986).

TABLE 17: VARIATIONS IN POPULATION DENSITY ACCORDING TO LAND TENURE

Population Density (Nos/km²)	Communal Lands	General Lands	Zimbabwe
0	7,5	20,2	22,6
Under 11	26,1	41,9	30,7
11-20	25,7	22,6	21,5
21-30	13,6	6,6	9,0
31-40	13,2	5,4	8,4
Over 40	13,9	3,3	7,8
Totals	100,0%	100,0%	100,0%

under one third of Zimbabwe was mapped with densities in the range 11 to 30 persons/km². These areas occur mainly in the eastern part of the country, but include large parts of the Gokwe region in the west and lands to the south and west of Bulawayo. The most densely settled areas, where densities exceed 30 persons/km², comprise 16,2% of the country. These include areas around Harare and a distinctive arc centred on Masvingo. The General Lands are relatively sparsely populated with 62,1% of the land having densities of 10 persons/km² or less, whilst only 8,7% of the commercial farmlands were within the two highest density classes (Table 17). In contrast, about one third of the Communal Lands were mapped as being sparsely populated and 27,1% were regarded as densely populated (over 30 persons/km²).

Summary data on mean total erosion according to population density are given in Table 18 for the Communal and General Lands. There is obviously a strong relationship between increasing population density and increasing extent of erosion within the Communal Lands. For example, in sparsely populated areas mean erosion was under 4,5% whilst in the most densely settled areas (densities of over 40 person/km²) mean erosion was about 15,3%, some 3,5 times greater.

There is, in fact, a marked spatial coincidence of areas of high population density and regions of granitic outcrops within the arc of Communal Lands centred on Masvingo and in the Mutoko area. It is not surprising, therefore, that these regions should experience extensive erosion (compare Figures 9, 12A and 14). There is less extensive erosion within the General Lands and increases in population density do not result in markedly more erosion, as occurs in the Communal Lands. High population densities in commercial farming areas typically are associated with intensive horticulture and irrigation as occur, for example, around Harare and Chiredzi in the lowveld. Erosion is kept in check by good farm management so population densities have little, if any, effect on resource status.

An examination of the extent of erosion according to variations in population density within the Communal Lands shows that there is a clear link between these two factors (Table 19). For example, in sparsely populated areas (10 persons/km² and under) the proportion of negligible to very limited erosion was between 62,8% and 89,2% of the land. The equivalent proportions for the two highest density classes (31-40 and over 40 person/km²) were 15,8% and 10,5%. At the other extreme only 1,3% and 10,7% of the sparsely settled areas were rated as severely to very severely eroded. In the densely populated regions these proportions increase to 43,1% and 56,3% (Table 19). There is, therefore, a demonstrably positive relationship between erosion and population density. High densities of settlement almost invariably are associated with widespread soil erosion; but locally serious degradation can occur in even sparsely settled areas, dependent of course on the nature of the terrain and measures taken to reduce erosion.

Whilst population density does give an indication of pressure on the land and hence the likelihood of erosion, the crude density values used so far do not measure the degree of pressure *per se*. Actual pressure on resources is a function also of the quality of land and the manner in which it is utilized. Where, for example, poor management occurs on low quality land then even low population densities might cause serious erosion and high densities could be calamitous. Kay (1975) has analysed the population pressures in the Communal Lands using the

TABLE 18: MEAN TOTAL EROSION ACCORDING TO POPULATION DENSITY

Population density (Nos/km²)	Communal Lands	General Lands
0	1,23	1,05
Under 11	4,47	1,78
11-20	7,32	2,04
21-30	10,86	2,21
31-40	12,76	2,50
Over 40	15,28	2,19
Averages	8,43%	1,77%

TABLE 19: VARIATIONS IN EXTENT OF EROSION ACCORDING TO POPULATION DENSITY IN COMMUNAL LANDS

Erosion Class	Population Density (Nos/km²) 0	10 and under	11-20	21-30	31-40	Over 40
1. Negligible	63,8	33,5	15,2	3,7	2,9	1,6
2. Very limited	25,4	29,3	27,0	19,5	12,9	8,9
3. Limited	7,5	17,6	22,8	23,8	21,5	16,2
4. Moderate	2,0	8,9	13,4	16,4	19,6	17,0
5. Severe	1,0	5,0	9,3	13,2	14,8	17,0
6. Very Severe	0,3	5,7	12,2	23,4	28,3	39,3
Totals	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

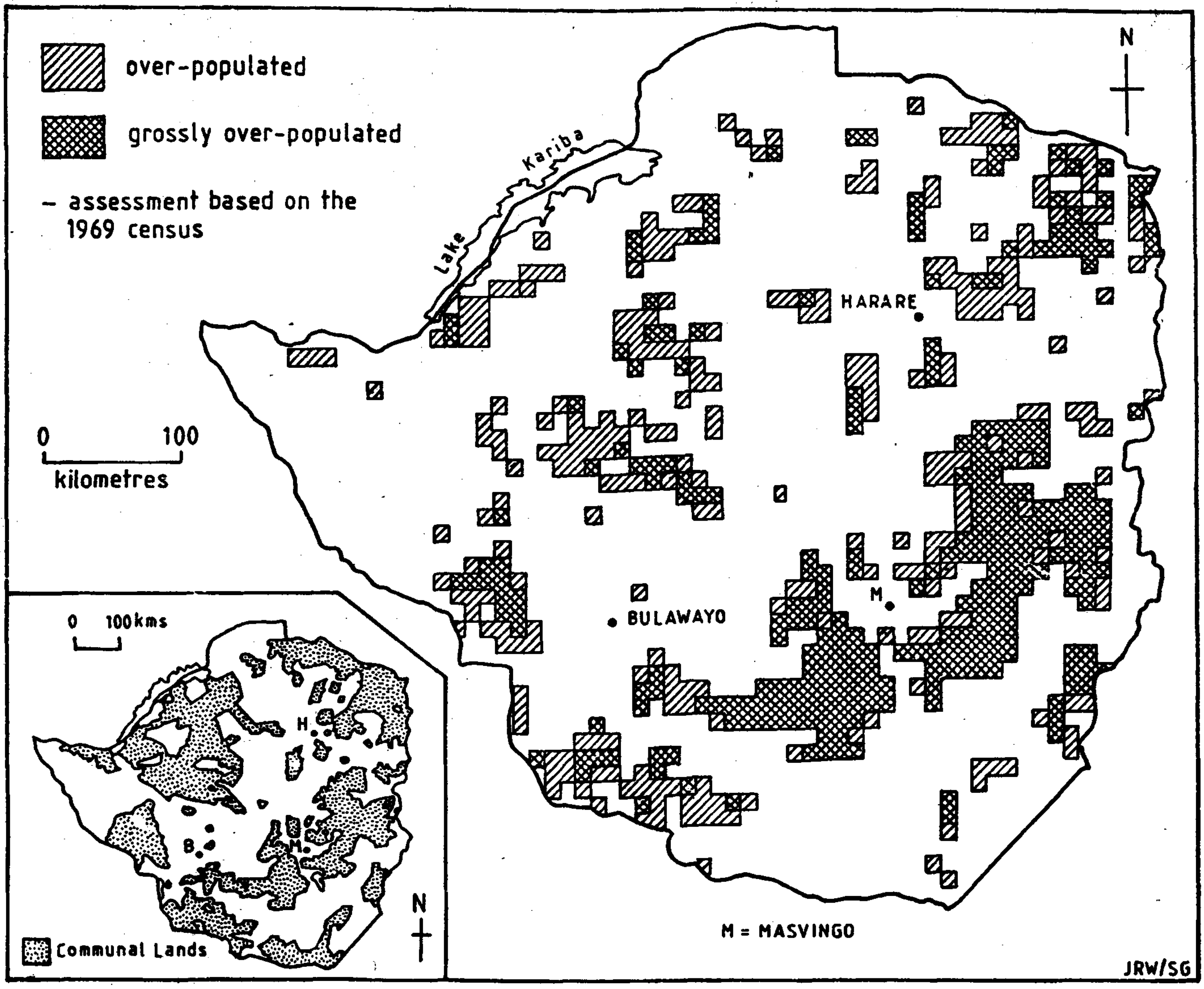


Figure 15 – Population pressures in Communal Lands based on 1969 census (after Kay, 1975).

1969 census data and the agro-ecological regions defined by Vincent and Thomas (1961). Differing density ranges were used within each agro-ecological region to define varying degrees of population pressure.

This study showed that 16% of the Communal Lands were under-populated and 27% had optimum population densities in relation to prevailing land use and environmental conditions. The remaining Communal Lands, some 57%, were rated as over-populated, some grossly so (Fig 15). The overpopulated areas are located mainly in the arc centred on Masvingo but also include Communal Lands near and to the north east of Harare, areas south and west of Bulawayo and parts of the Gokwe region in the west of Zimbabwe. A comparison of Figure 15 with the patterns of erosion shown in Figure 9 demonstrates that areas of excessive degradation invariably are associated with regions experiencing pressure on the land.

A crucial concept in assessing the presence and consequences of pressure on the land is the concept of carrying capacities. With respect to the concept as applied to subsistence agriculture Allan (1949) comments that ".... any area of land will support in perpetuity only a limited number of people ... if this limit is exceeded, without a compensating change in the system of land usage, then a cycle of degenerative changes is set in motion, which must result in deterioration or destruction, of the land." A decline in resource status, in turn, has adverse effects on living standards. As poverty becomes worse so the ability to effect changes in land use to reverse the 'cycle of degenerative changes' is reduced. In this way a vicious cycle of poverty and land degradation is established. This, in essence, is precisely what has happened throughout many Communal Lands. It is important therefore, to examine what has happened in these areas in response to population growth, and hence increased pressures on land resources.

A simple model of subsistence land use placed under increasing population pressures is presented in Figure 16. This model shows that a common response to increases in population is to extend the area under cultiva-

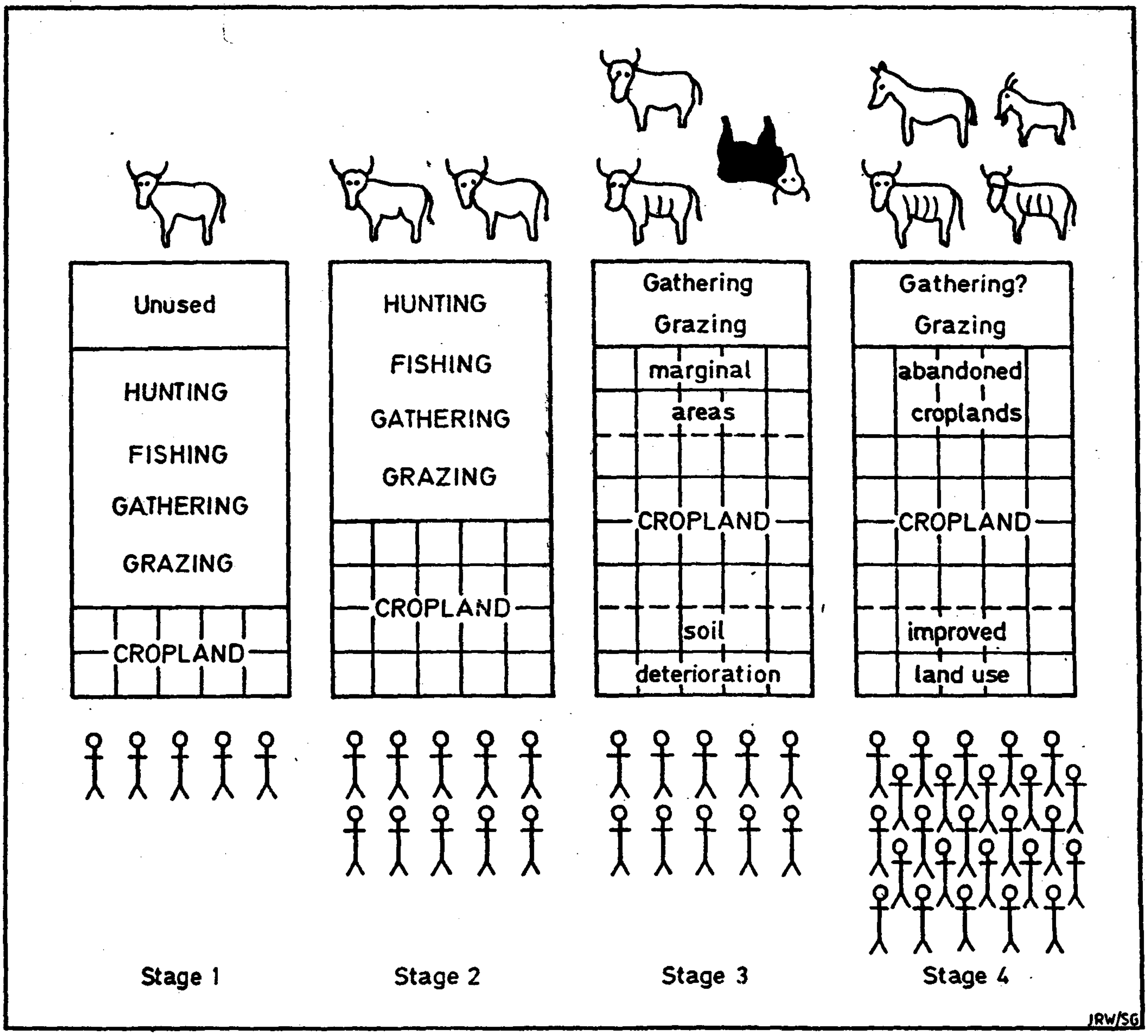


Figure 16 – Subsistence land use model (adapted from Kay, 1975).

tion, rather than to intensify production (Kay, 1975). As long as population densities are low this extension of cropland can be accommodated and still leave adequate land for livestock grazing and gathering of natural foodstuffs, as shown in the change from Stage 1 to Stage 2 in Figure 16. With further increases in human populations (and associated increases in livestock numbers), cultivation inevitably extends into more marginal terrain and encroachs upon areas previously used for grazing and gathering (as in Stage 3).

Overall yields may in fact decline due to depletion of fertility on areas where prolonged cultivation has occurred, whilst marginal croplands by definition give lower yields. Early signs of land degradation are likely to occur within grazing areas where more and more animals are restricted to less and less land, depending on how far extension of cropland has progressed. Moreover, shortages of natural products such as firewood, thatching grass and wild fruits are initiated during this stage.

The final stage, Stage 4, suggests that the lack of even marginal land precludes the extension of cultivation to feed an ever increasing human population. Indeed, it is possible that excessive degradation has forced the abandonment of certain croplands. At the same time, the limited success of agrarian reforms may have improved yields in favourable environmental and socio-economic circumstances. Overall production levels, however, are barely adequate to meet the needs of the large population. The critical degradation at this stage is located mainly in the remnants of grazing lands. Here depletion of plant cover and erosion make it difficult to sustain cattle populations and, increasingly, these are prone to greater malnutrition and mortality, especially during periodic droughts. Where advanced degradation occurs goats and donkeys, which are hardier animals, tend to increase where cattle cannot survive easily. Whilst such animals are blamed almost universally for the process of rangeland destruction, from this model it is clear that man is the chief culprit!

Many of the areas regarded by Kay (1975) as overpopulated or grossly overpopulated can be depicted as Stages 3 and 4 of this model. The fact that people manage to survive in such areas is due, in no small measure, to links with the cash economy in urban centres and on the commercial farmlands (Kay, 1970); but *survive* is the operative word. It is clear that, in the absence of resettlement and compensating changes in land use, continued increases in population in the Communal Lnads are going to be disastrous for the rural families and their land (Elwell, 1985; Whitlow, 1985a). Further aspects of this model are discussed in relation to erosion on croplands, grazing areas and wetlands. A more detailed account of how this model applies to the peasant farming areas is given by Whitlow (1979b).

b) Erosion on Croplands

The survey showed that there were 842,400 hectares of eroded cropland in Zimbabwe, some 91,2% of this degraded land being in peasant farming areas and only 65,900 hectares in the General Lands. As indicated earlier it is likely that erosion, especially the incidence of sheetwash erosion, was under-estimated in cultivated areas so these estimates are conservative ones. However, they do show that the main erosion problem in croplands is in the Communal Lands. Given the fundamental differences in land use history and magnitudes of erosion in the peasant and commercial farming areas, it is necessary to comment on these separately.

1. Erosion in croplands on Commercial Farms

The degradation of croplands on commercial farmlands, due mainly to inappropriate and exploitative cultivation methods in the early decades of this century, was one of the reasons which prompted the Commision of Enquiry in 1939. Since then a combination of subsidies for conservation works, improved extension and farm planning, and a high level of conservation awareness engendered through the ICA movement has managed to contain the erosion problem. In addition to mechanical protection, factors such as crop rotations and proper tillage were soon accepted as essential in reducing erosion, increasing water retention and improving yields. However, even where good standards of management prevail very intensive rainstorms can do an immense amount of damage (Plates 6 and 7). Where management is substandard, erosion is even more likely (Cormack, 1972).

Plate 6 – Severe sheetwash on sandy soils on a tobacco land in the Headlands area (Source: H.A. Elwell).

Plate 7 - Sedimentation of waterway downslope of tobacco land shown in Plate 6 (Source: H.A. Elwell).

A survey conducted by extension staff on commercial farms several years ago (Elwell, 1974) identified the following major causes of erosion on arable lands in order of priority:

- badly constructed and maintained layouts
- overcropping e.g. continuous monoculture
- steep grades on crop rows
- erodible soil not managed correctly
- steep slopes not protected adequately
- unprotected lands
- poor ploughing methods
- poor crop husbandry practices.

Virtually all of these causes are capable of being eliminated or their effects minimised by careful management. Since this survey was carried out, Elwell (1978) has developed a method for assessing soil losses due to sheetwash erosion on arable lands. This method, known as SLEMSA (Soil Loss Estimation Model for Southern Africa), enables determination of alternative crop rotations and ridging practices which could be employed under differing environmental conditions to reduce soil losses to acceptable levels of between 2-4 tonnes/hectare/year.

In this model, the maintenance of plant cover to intercept rainfall, and so minimise rainsplash impact on the soil, is regarded as a key element of conservation management. A considerable amount of research in Zimbabwe has been directed at the significance of crop cover in erosion. (e.g. Stocking and Elwell, 1976a). Results have shown that there are distinctive patterns of soils loss during the growing season dependent on the protection afforded by a crop canopy at different stages of growth. Experimental results of a ten year trial for maize given in Figure 17 illustrate some important features of this issue (Elwell and Stocking, 1976).

During the early rainy season (late October to November) there is little or no crop cover, but since the freshly tilled soils have a high infiltration capacity rainstorms generate limited runoff and soil loss. The crucial phase for erosion is during December. At this time, depending on fertilizer inputs and supplementary watering, the maize crop will be growing rapidly but the crop canopy is still very open. Higher soil moisture reserves and inwashing of fine particles into surface hollows will have reduced infiltration into the soil. Consequently, the high energy storms in December may cause a marked increase in runoff and soil loss. As the season progresses and a more complete crop cover is established so there is a pronounced reduction in runoff rates and soil erosion. Thus intensive storms from January to March have less impact in terms of erosion.

Different crops, not unexpectedly, have different cover curves. Cotton, for example, provides very poor cover during the first part of the rainy season, high cover values only being achieved from mid January onwards (Stocking, 1972c). This exposes a high proportion of bare soil to raindrop impact during this period and

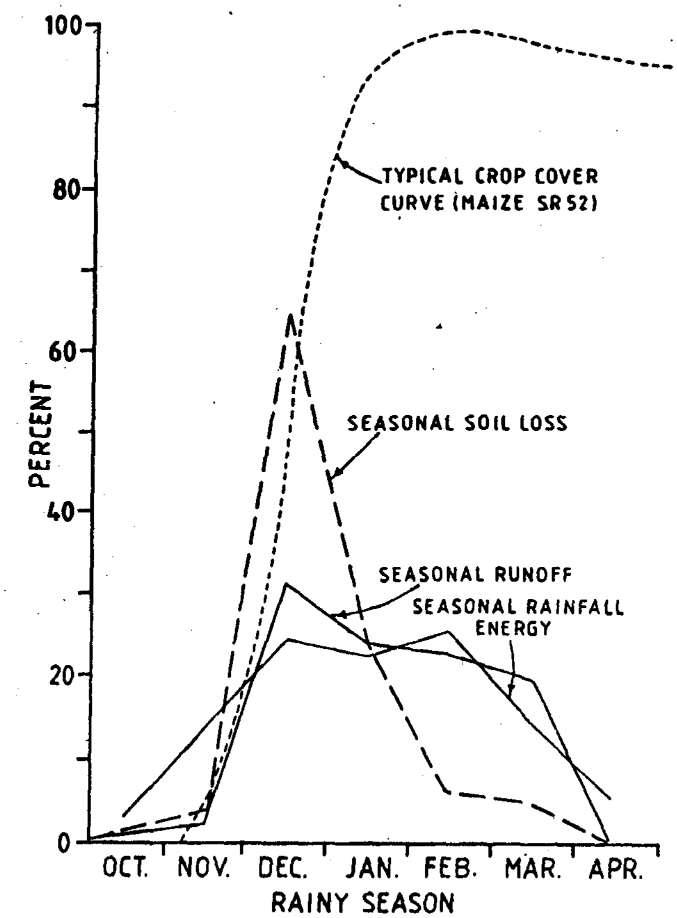


Figure 17 – Maize growth curve and erosion (after Elwell and Stocking, 1976).

excessive rates of soil loss occur. Once the cotton canopy is well developed, however, it provides excellent protection through to the end of the rainy season. In contrast, tobacco provides less cover than either maize or cotton on a seasonal basis. Large areas of ground may be exposed for several weeks during the early stages of growth (see Plate 6) and once fully grown the leaves are harvested, thereby reducing canopy cover fairly dramatically during the latter part of the rainy season. Since tobacco is grown most widely on sandveld soils which are susceptable to erosion, it obviosly requires a high level of management to minimise soil losses (Hudson, 1957).

Through varying spacing and densities of crops it is possible to reduce the period of exposure of the soil to intensive rainstorms (Stocking and Elwell, 1976a). Where this is combined with practices of mulching and tie-ridging to promote increased infiltration then runoff rates and soil losses can be reduced considerably (Elwell, 1985). Better moisture conservation promotes better growth which increases not only protection of the soil but also yields are higher. Thus conservation management makes good sense both economically and environmentally (Cormack, 1972; see also Water in Agriculture, Zimbabwe Agricultural Journal Technical Bulletin No. 15).

2. Erosion on croplands in peasant farmlands

Within the Communal Lands the common practices of late planting, shallow ploughing and limited manuring or fertilizer applications result in a poorly developed crop canopy for much of the rainy season. Consequently rainsplash erosion is more pronounced in these areas than on commercial farms. Erosion is especially serious in the early part of the rainy season (November-December) when fields have been ploughed but the crops have barely emerged. There are, however, enormous local differences in crop cover such that adjacent fields could be subject to very different degrees of erosion (Plate 8).

As argued previously an important aspect of erosion on croplands in peasant farming areas has been the continued encroachment of cultivation into more marginal lands. Consequently the focus in this section is on the effects of extending the area under cultivation. Although data on extension of croplands in communal areas are, at best, 'guesstimates' there is evidence to suggest a marked increase in recent years in the total area under cultivation and per capita area cultivated (Table 20). As population has increased and fertility of soils declined (Grant, 1981), so the trend has been to extend the area under crops. In some areas, such as Zimunya Communal Land south of Mutare, there has been a massive increase in cultivation from the early 1960's to the present day (Figure 18). In the case of Zimunya this is clearly related to increases in density of settlement (for

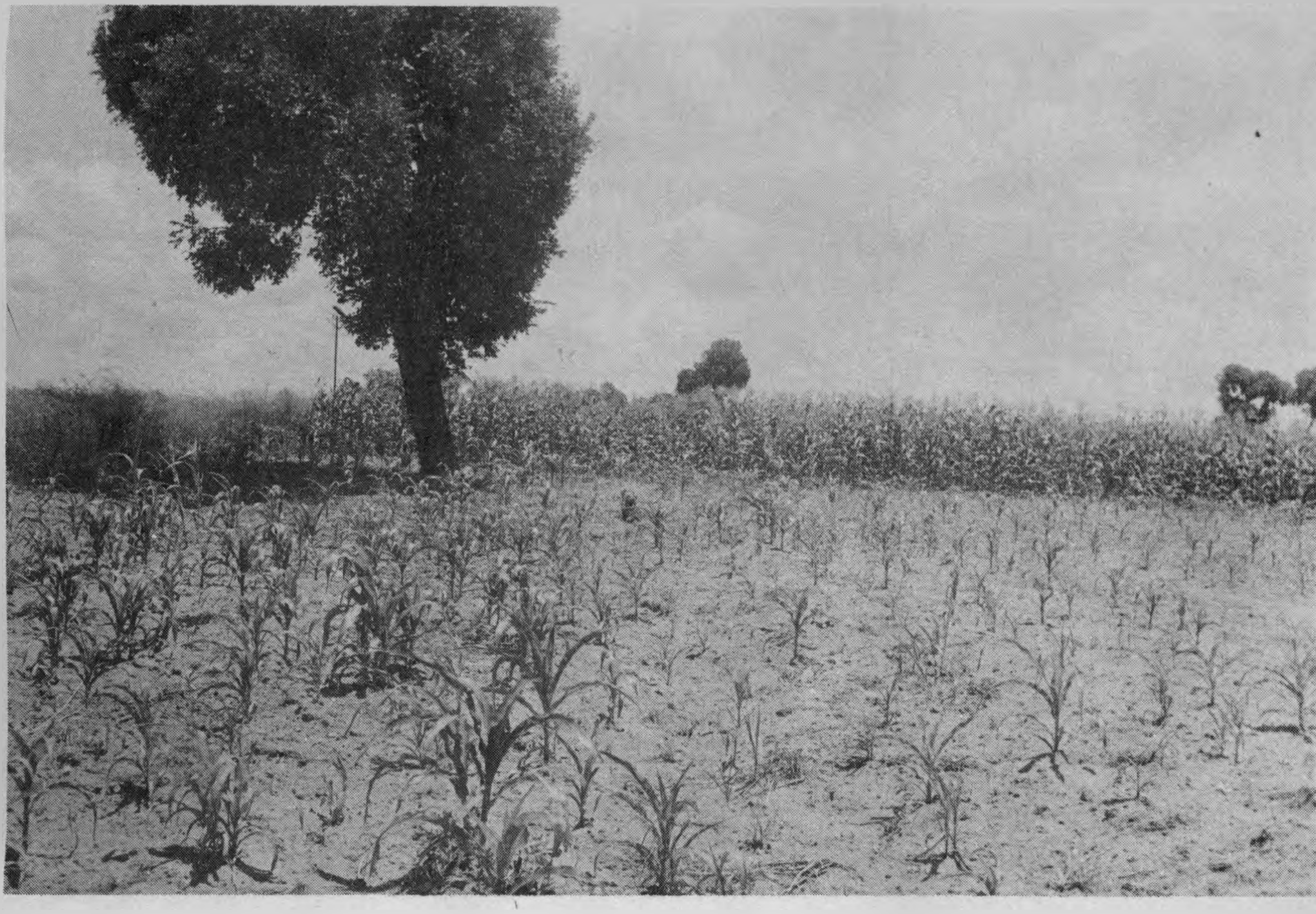


Plate 8 – Very sparse and dense stands of maize in Chikwakwa Communal Land in 1986/87 season (Source: author).

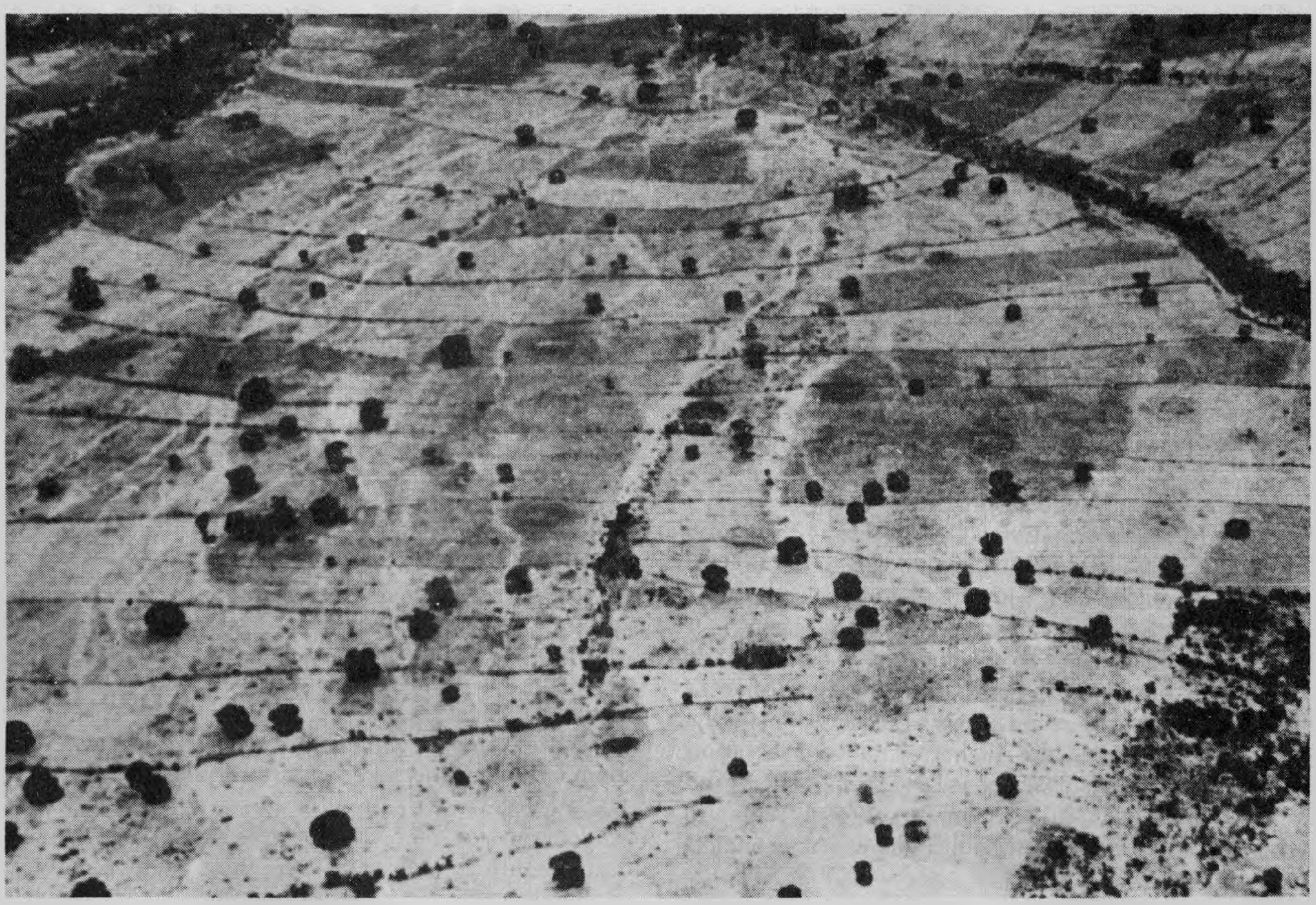


Plate 9 – Severe sheetwash and rilling on arable lands in a peasant farming area (Source: H.A. Elwell).

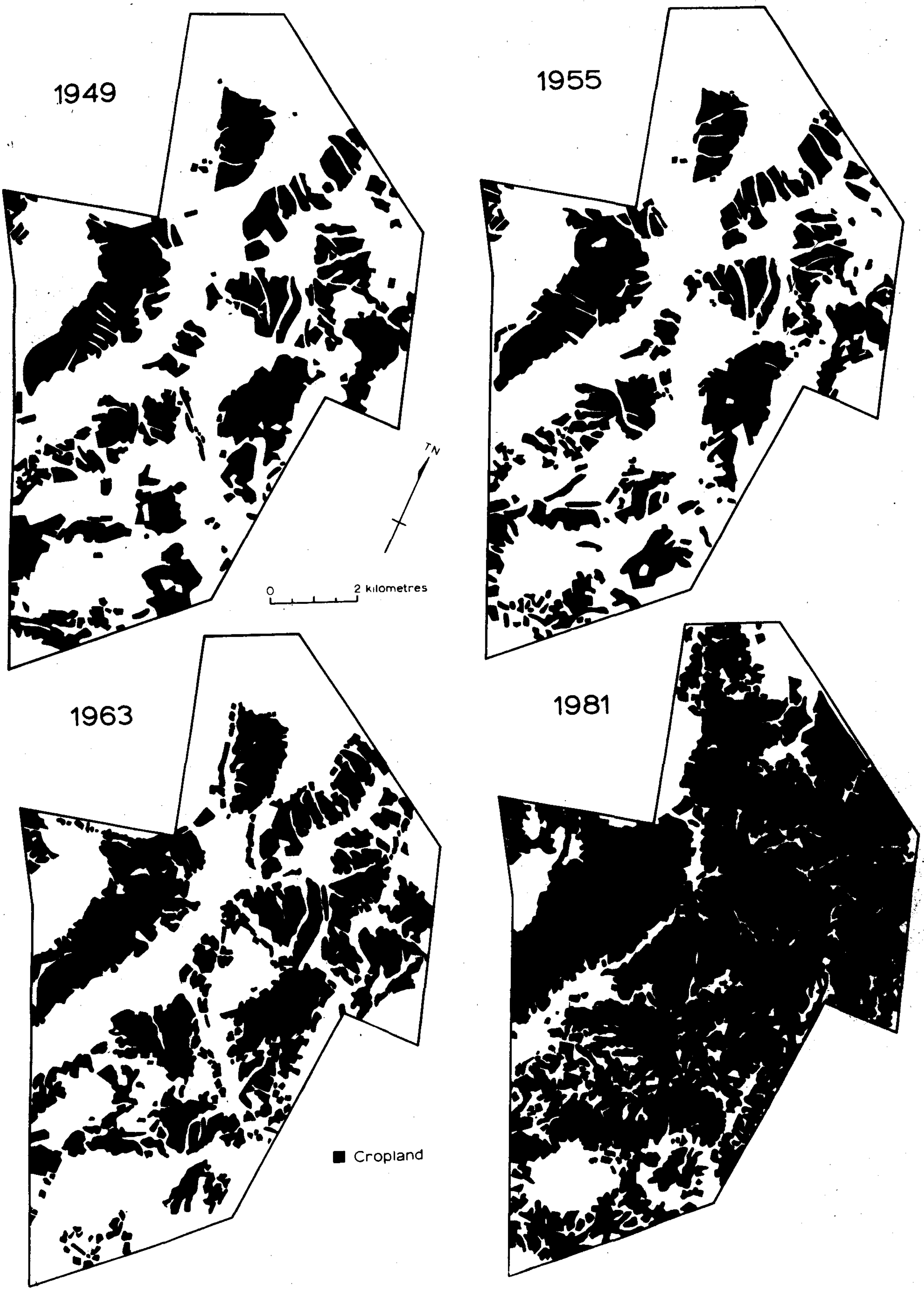


Figure 18 - Changes in extent of cropland in Zimunya Communal Land, 1949-1981 (after Whitlow and Zinyama, 1988).

TABLE 20: CHANGES IN CULTIVATED LANDS IN COMMUNAL AREAS

Year	Cropland area (ha)+	Cropland per person (ha)
1945	480,000	0,48
1962	1,134,000	0,52
c1975*	2,584,000	0,65

* based on aerial photos taken between 1972 and 1977 (Whitlow, 1979a).
+ the area actually planted in a given year may be lower than the figure cited.
Source: Whitlow (1979b)

a more detailed account of this area see Whitlow and Zinyama, 1988). As pressure on land has increased so cultivation has been extended into more marginal terrain.

In Zimunya, for example, cultivation has been extended to river banks and well into the steeply sloping hills, sometimes with very limited measures to prevent erosion. Protection by contour ridging does not always guarantee reduced erosion (Plate 9), especially where such ridges are not maintained properly or are not aligned correctly. Where no contour ridges are constructed very rapid erosion can occur in the matter of only two or three rainy seasons, as demonstrated by Whitlow and Bullock (1988) for a small gully system in Mangwende Communal Land (Plate 10).

Changes in croplands and erosion which are typical of some of the more densely settled Communal Lands are illustrated in Figure 19. This shows a portion of Mangwende Communal Land where gully erosion is particularly widespread; this area was selected after mapping all of Mangwende and Chikwakwa Communal Lands on 1:20,000 scale using 1981 aerial photos. Systematic large scale mapping of the gullied area was carried out using aerial photography for 1951, 1965, 1972 and 1981. Summary data on the area are given in Table 21.

Although gully features could not be identified consistently on the 1951 photos, because of poor quality imagery, what was apparent was the alignment of fields and plough furrows up and down the slope and the lack of contour ridges. By 1951 most of the land had been or was under cultivation and there was evidence of formerly cropped lands on hillslopes and in wetlands. Only 23 homesteads were observed giving an overall density of 2,6 households/km² or about 13 persons/km², assuming a household comprises 5 people. Consequently, pressures on the land were relatively low, but land use practices were clearly not conducive to soil conservation.

By 1965 the settlement density had increased to 4,0 households/km² and the cultivated area had been extended to cover some 85% of the land (Fig 19). What is

Plate 10 – Nyagui gully in Mangwende Communal Land (Source: author).

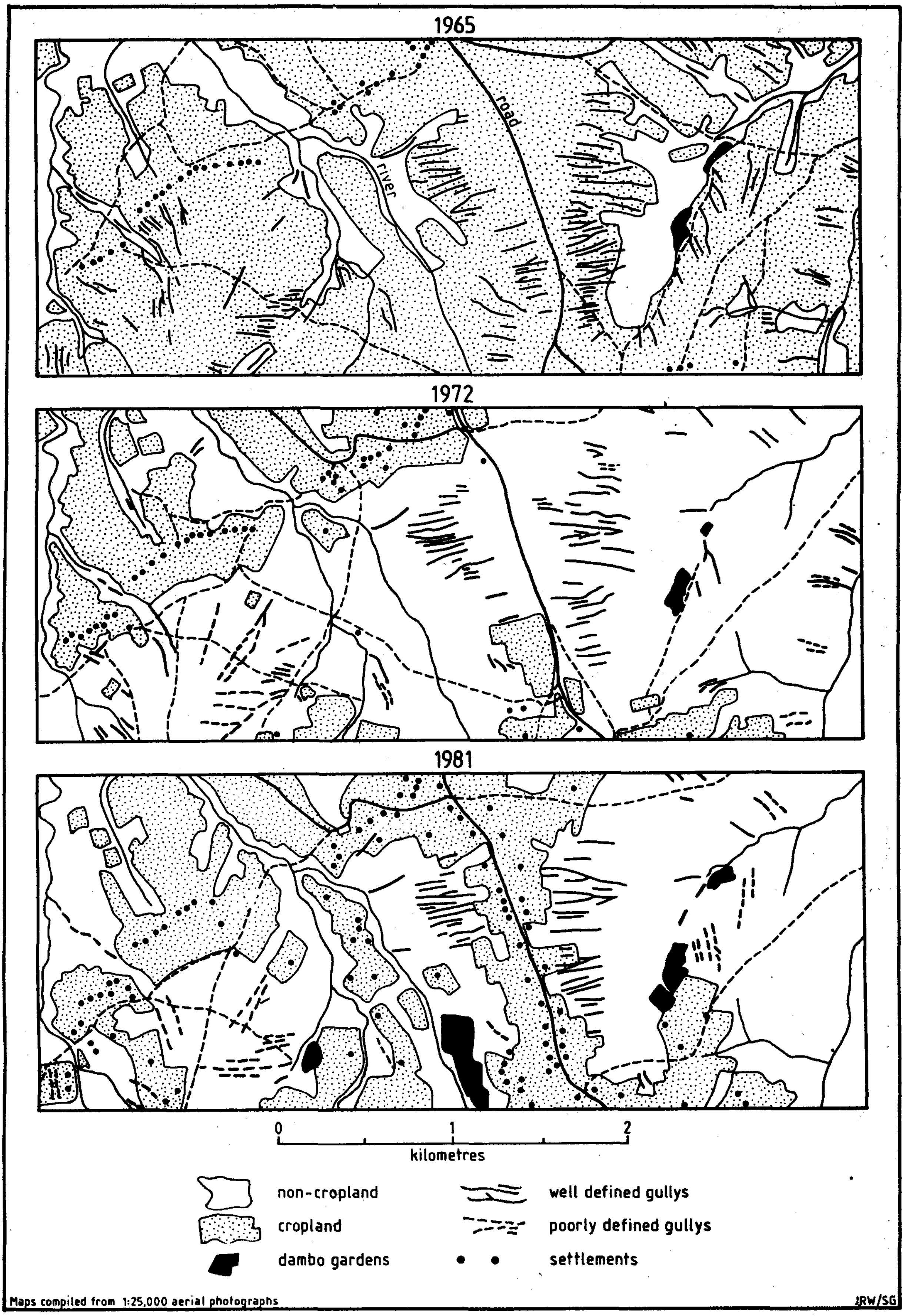


Figure 19 - Land use changes and gullying in part of Mangwende Communal Land, 1985-1981.

TABLE 21: CULTIVATED LANDS AND GULLY EROSION IN A PART OF MANGWENDE COMMUNAL LAND

	1951	1965	1972	1981
Households:				
Number	23	36	53	100
Density (No/km²)	2,6	4,0	5,9	11,2
Cropland area (%)	70	80	30	45
Gullies:				
Number*	n.d.	147	74	35
Total length (m)	n.d.	24210	12060	7650
Density (m/km²)	n.d.	2705	1350	855

n.d. = no data * only well defined gullies.

most striking is the large number of gullies, nearly 150, with an overall length of 24,2 kilometres giving a density of 2,705 metres of gully per square kilometre. Some of these gullies undoubtedly existed by 1951, but many of them appear to be of more recent origin, being bare and steep-sided. Excessive gullying, along with sheetwash, was undoubtedly one of the main reasons resulting in widespread abandonment of croplands by 1972 (Fig 19). Only the deeper and longer gullies seem to have persisted between 1965 and 1972 with the number of well defined gullies falling to 74 and gully density being around 1,350 metres/km². Some of the gullies in the south west of the area were poorly defined in 1972 and seemed to have been stabilised by vegetation and inwashed sediment. At the same time the number of households had increased to 53, so there was an increase in pressure on the land. By 1981 this pressure was even greater with about 100 households and a settlement density of 11,2 households/km², some four times that of 1951. Cultivation had been extended into formerly cropped lands, although badly degraded areas were still avoided. In addition, and perhaps of necessity, there was an extension of wetland 'gardens'.

Preliminary mapping (Whitlow, unpublished data) in Mangwende and Chikwakwa Communal Lands indicates that this basic trend of extension of cropland, widespread erosion, abandonment of cropland and subsequent extension into less degraded areas has been repeated, with local variations, throughout this region. Bearing in mind that the national erosion survey was carried out with the most recent, mainly 1980's, aerial photography, it is important to realise that extensive erosion may have occurred in the past. Consequently, the seriousness of land degradation may have been under-estimated. Moreover, gullying which is located today in areas used for grazing purposes may well have been initiated when the land was under cultivation. Whilst undoubtedly livestock do cause excessive erosion, it is possible that they are blamed wrongly sometimes for erosion which was actually initiated by the plough!

c) Erosion and Grazing

Some 992,400 hectares of degraded lands were recorded in non-cropland areas, over three-quarters of this eroded terrain being within the Communal Lands. The most conspicuous erosion observed by means of aerial photographs was in the form of degraded, rutted tracks and denuded areas around livestock enclosures and dip tanks. Weekly dipping of cattle takes place in the Communal Lands throughout the wet season and less frequently in the dry months. Several thousand cattle may converge on a single dip site with excessive erosion being caused by trampling and overgrazing.

A good example of the result of this practice is the degradation around Sengu Dip in Mangwende Communal Land (Fig 20). Gully erosion to the south of this dip is associated clearly with tracks. The tracks themselves are in the form of 'bush highways', that is several parallel paths up to 10 metres wide, the product of herding large numbers of cattle(Plate 11). Compaction makes these multiple tracks virtually impermeable and local ruts can develop very easily into sometimes extensive gullies as shown near Sengu Dip. The problem is more acute where slopes around dips are steep and there are massive granitic domes surrounding the dip sites which restrict access routes and generate rapid surface runoff (Stocking, 1972a). Pressure on existing dip sites could be relieved by constructing more dip tanks; but unless these are planned carefully, this strategy could result in the creation of more degraded sites.

The Communal Lands appear to be in the perplexing situation of being both *overstocked* and *understocked* (Hornby, 1968). They are overstocked insofar as under prevailing habitat conditions and poor grazing 'management', the numbers of livestock are in excess of the carrying capacity of the land, sometimes considerably so (Whitlow, 1979b, 1980c). According to a survey on rangeland conditions in the early 1960's (Cleghorn, 1966), nearly half of the Communal Lands were rated as bare to very overgrazed (Table 22); that is the grazing areas were either almost entirely devoid of grass cover for much of the year or had very sparse herbaceous vegetation with dry season forage being in short supply. Overgrazing was especially widespread in the lower rainfall regions (Natural Regions IV and V in Table 22).

The effects of overgrazing are both ecological and hydrological. Excessive and selective grazing leads to an increase in annual species at the expense of perennial species, thereby increasing year to year fluctuations in plant biomass dependent on rainfall (Kelly and Walker, 1976). More crucial, however, is the decrease in infiltration on bare areas and the associated increase in surface runoff. For example, observations in Matibi No. 2 Communal Lands in the south east lowveld indicated that infil-

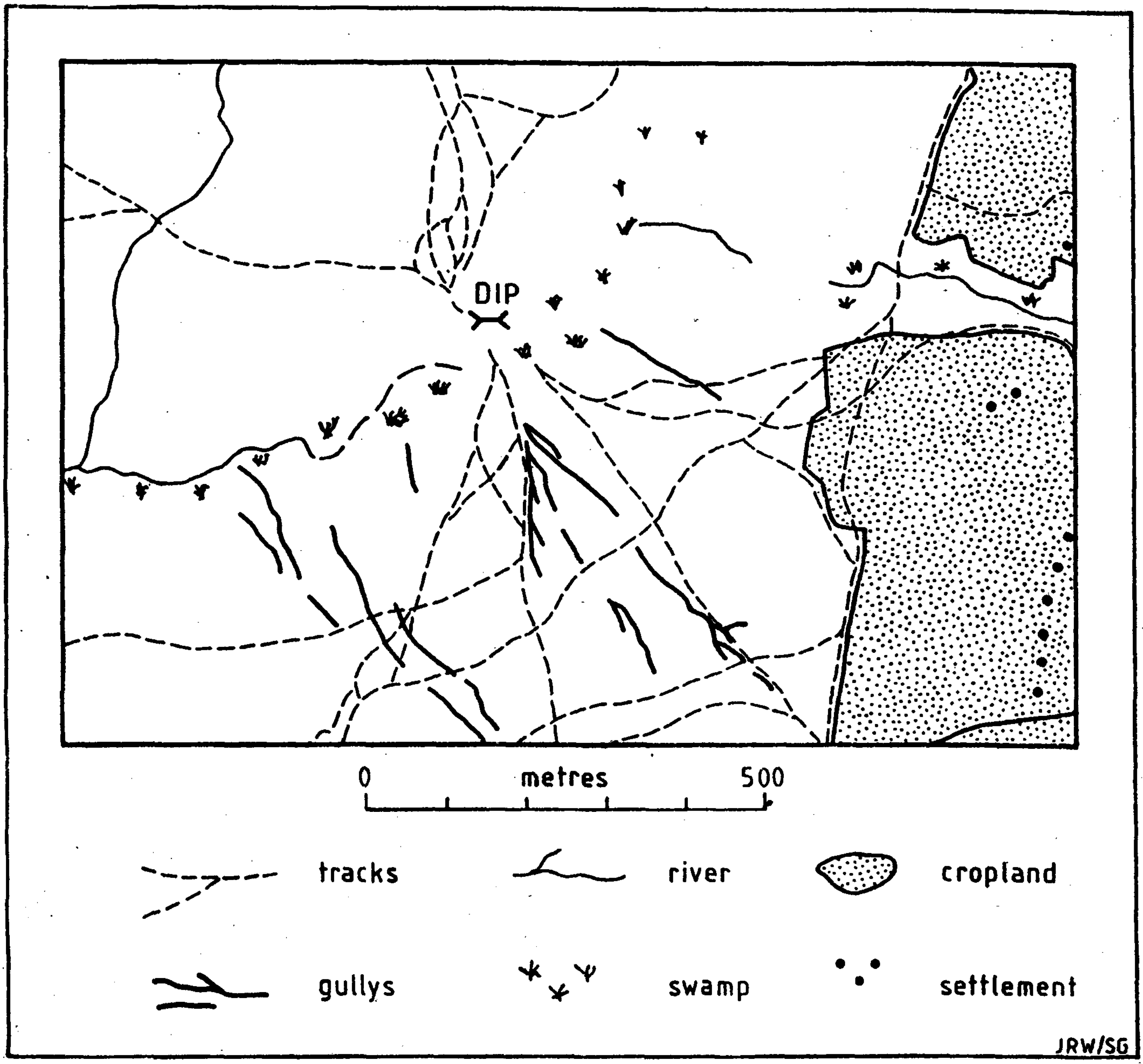


Figure 20 - Gully erosion around Sengu cattle dip, Mangwende Communal Land.

tration rates on litter covered surfaces were nine times those on bare areas, the latter constituting about three-quarters of the land surface (Kelly and Walker, 1976). The increased surface runoff on such areas favours high rates of soil erosion and a gradual desiccation of the landscape, with the concomitant negative effects on plant growth and livestock (Whitlow, 1983b).

The Communal Lands reported by Cleghorn (1966) as predominantly bare to very overgrazed are shown in Figure 21A. These include the Communal Lands arc centred on Masvingo, large parts of southern and western Zimbabwe (i.e. Matabeleland), and some of the densely settled areas around Harare. Livestock densities (cattle, sheep and goats) were over 40 animals/km^2 in just over half of the Communal Lands in 1977 (Whitlow, 1979b; Fig 21B). Such areas are typically the

TABLE 22: CONDITIONS OR RANGELANDS IN COMMUNAL LANDS IN THE EARLY 1960'S

Condition of Rangeland	Natural Region* I	II	III	IV	V	Average
Bare	—	—	—	4,8	39,1	13,0
Very overgrazed	21,4	65,5	68,2	29,7	26,3	36,4
Moderate	76,7	18,0	12,9	16,6	9,8	14,8
Good	1,9	16,5	18,9	48,9+	24,8+	35,8
Totals	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

* Natural Regions based on Vincent and Thomas (1961)
\+ Mainly tsetse fly infested regions with virtually no livestock present.
Source: Clehorn (1966)

Plate 11 – Multiple tracks or 'bush highways' caused by cattle (source: author).

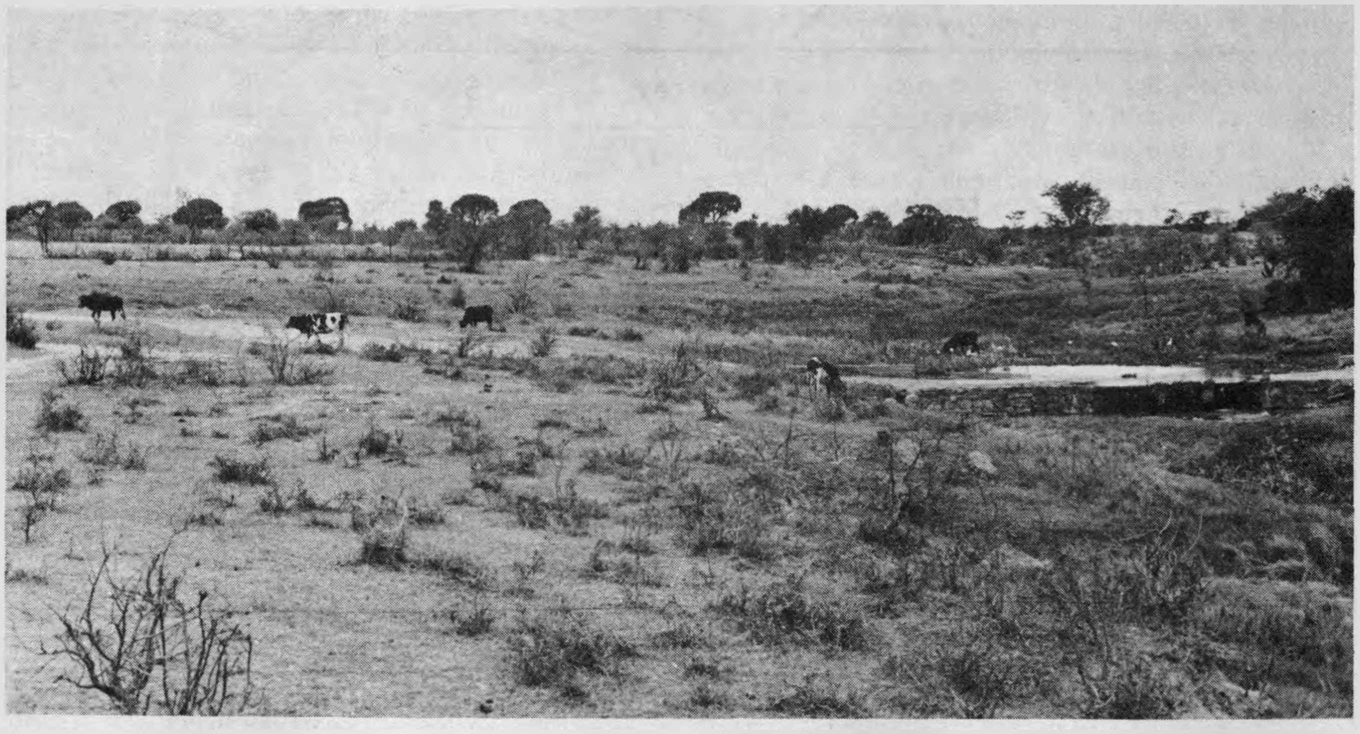


Plate 12 – Degraded rangelands in Chiwundura Communal Land (Source: author).

most degraded in terms of plant cover and soil erosion, but lower stocking rates in the low rainfall areas can cause serious degradation since carrying capacities are very much lower in these drier regions.

Moreover, where rainfall is low the negative hydrological effects of overgrazing are more crucial and the rehabilitation of degraded rangelands, even if biotic pressures are reduced (as occurs with livestock deaths during droughts), is a very protracted process. Although goat populations are typically higher in the drier and denuded rangelands (Fig 21C), they did not necessarily cause the onset of desert-like conditions (Hornby, 1968). Rather, as suggested by Stage 4 of the land use scenario described earlier, it is because they can survive on degraded rangelands.

During the last twenty years or so massive increases in livestock numbers have exacerbated the depletion of plant cover and stripping of soils in the Communal Lands (Table 23). Since compulsory destocking ceased in the early 1960's, allowing for fluctuations in livestock due to the effects of drought and disease, there has been a marked increase in the cattle population. Between 1964 and 1984, the cattle increased from 1,9 million to over 3,2 million animals, especially in the more densely

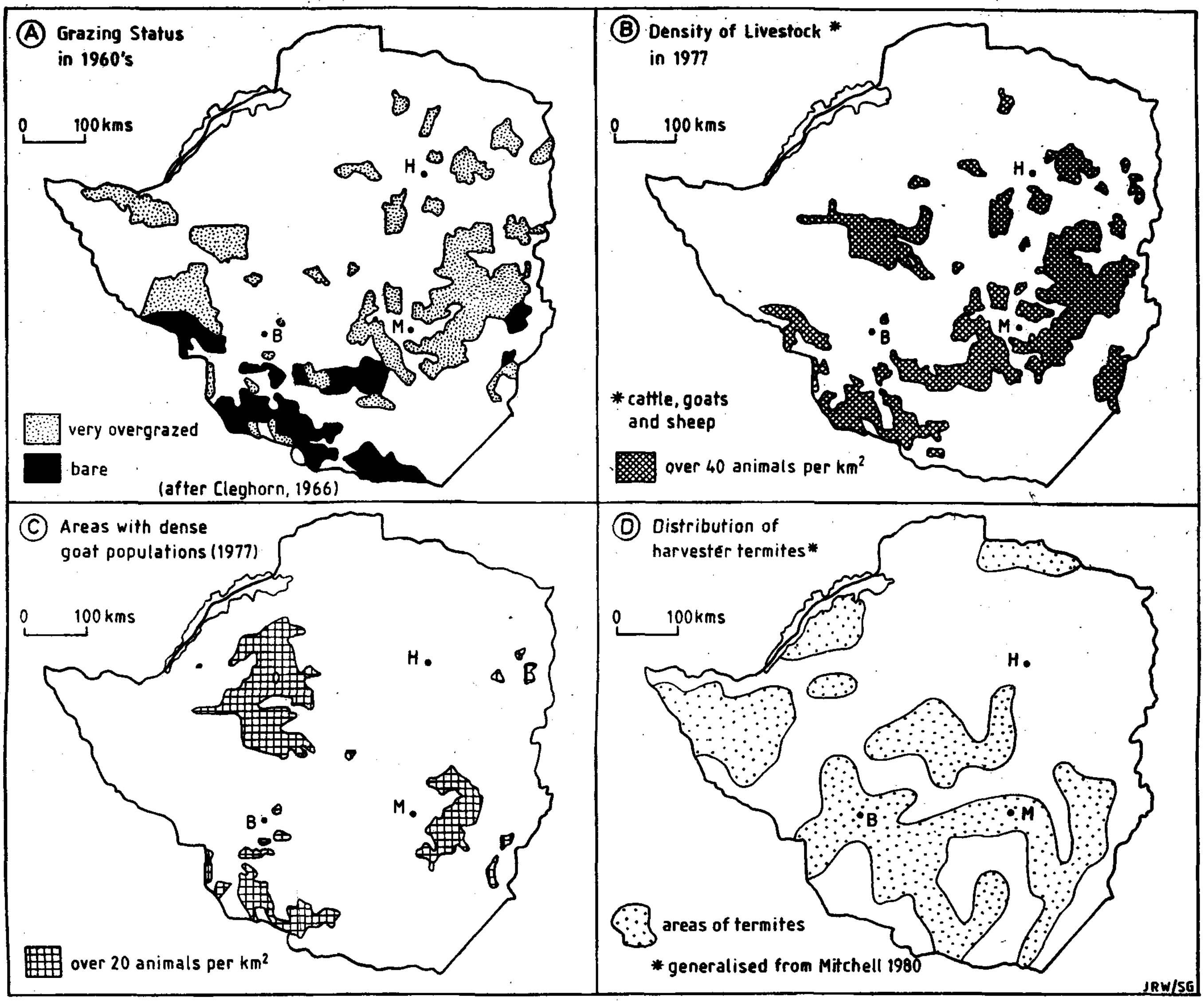


Figure 21 - Aspects of overgrazing and livestock pressures in the Communal Lands.

settled regions where carrying capacities had been exceeded already by the early 1960's. Equally important, and sometimes ignored, is the extraordinary increase in numbers of smaller livestock. Over the 1964-84 period the goat population increased dramatically from 579,000 to over 1,5 million animals. During the same period the sheep population more than doubled to some 410,850 animals and by 1984 there were an estimated 229,100 donkeys in the Communal Lands. The net result of this enormous increase in livestock numbers has been continued and, locally, accelerated and degradation (Plate 12).

The extension of cultivation into grazing areas, particularly in the more densely settled Communal Lands, has intensified the problem of rangeland degradation. The cattle stocking rate, for example declined from 6,2 ha/head to 4,1 ha/head from the early 1960's to the late 1970's (Stubbs, 1977). Availability of grazing land would be very much lower in areas such as Zimunya Communal Land mentioned earlier (See Fig 18). If one adds the estimated 2,2 million (1984) goats, sheep and donkeys that also have to survive on the declining areas of rangeland, it is not surprising that serious erosion has occurred.

TABLE 23: GROSS CHANGES IN LIVESTOCK NUMBERS IN THE COMMUNAL LANDS 1964 to 1984*

	Cattle	Goats	Sheep	Total
1964 Number	1916000	579000	186000	2681000
%	71,5	21,6	6,9	100,0%
1984 Number	3230950	1513450	410850	5155250
%	62,7	29,4	7,9	100,0%
Increase 1964-84				
Number	1314950	934450	224850	2474250
%	68,6	161,4	120,9	92,3

* Numbers rounded off.
Source: CSO (1978) for 1964 figures
Ministry of Agriculture for 1984 figures.

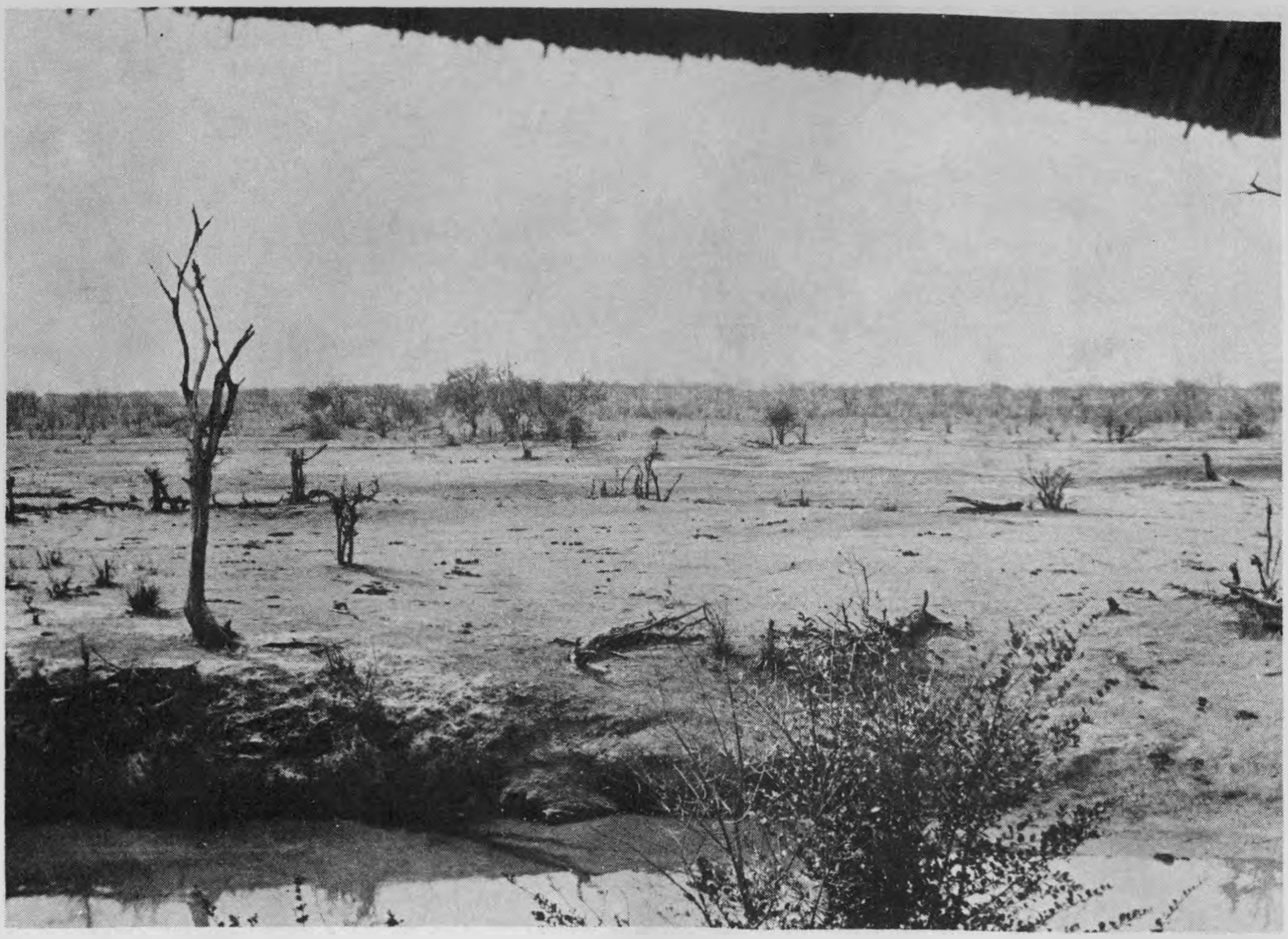


Plate 13 - Denuded terrain around a pan in Hwange National Park (Source: H.A. Elwell).

Moisture stress during prolonged droughts which characterise Natural Regions IV and V add to the problems of degradation. For example, a vegetation survey following the 1965-66 drought in Southern Matabeleland (NRB, 1968) showed that about 80% of the Communal Lands were virtually bare of plant cover compared with about one third of the land in the more lightly stocked commercial ranches. The denudation of the vegetation may be increased by the activity of harvester termites in the lower rainfall areas (Fig 21D); these insects can strip and lay bare locally extensive patches of ground and obviously compete with livestock for available forage (Hood, 1972).

Under present circumstances there is clear evidence of overstocking in the Communal Lands. At the same time, these areas are short of draft power for ploughing and manure to improve soil structure and fertility; that is, they are understocked. A crucial factor in preventing degradation and increasing livestock production is the problem of uncontrolled and uneven grazing. Grazing programmes have met with limited success in the past (Froude, 1974) although the basic technical solutions to improve livestock output and rangeland conditions are well known (Barnes, 1978).

The difficulty lies in the implementation of pastoral management schemes, that is in obtaining the co-operation of people in rational management of a communal resource. There are, fortunately, already positive signs of progress in this field but the rehabilitation of degraded rangeland is likely to be a very slow and costly process. This will require full financial and technical support from the government if the problems of the past are to be resolved successfully.

Degradation by livestock and/or game animals is much more localised in the commercial farming areas and in non-agricultural lands such as national parks. On commercial ranches livestock numbers are controlled so that they do not exceed the carrying capacities of the rangelands, there is a high level of management (e.g. rotational grazing) and often there is supplementary feeding of animals. Increasingly, commercial ranching is incorporating game animals into the production system. One of the guiding principles in this is that game utilise a wider variety of plants and do less damage to the habitat than domestic stock. However, a study by Thompson and Walker (1978) on Buffalo Range Ranch in the south east lowveld shows that game can cause as much erosion as cattle, partly because there is little control over their movements and they tend to concentrate in favoured sites.

In the case of national parks like Hwange extensive denudation of plant cover and soils occur around pans (Plate 13) and along trails converging on these sites. Degradation is especially prevalent around pans which are serviced by boreholes to keep the pans full of water throughout the year, partly to attract game for the benefit of tourists. Provision of more boreholes to service more pans is an obvious way to spread the pressure on existing pans and thereby reduce erosion.

d) Degradation of Wetlands

There are about 1,3 million hectares of wetlands (known variously as vleis, bani, matoro etc) in Zimbabwe. They are associated with the headwater valleys of river systems draining the central watershed region (Fig 22A), especially on granitic rocks where up to one third of the landscape may comprise wetland (Whitlow, 1984). The wetlands are subject to seasonal waterlogging, the vegetation is typically herbaceous with coarse sedges and grasses dominating, and soils vary from being very sandy to sandy clays with a humic topsoil of varying depth. Geomorphologically these features resemble the *dambos* of Zambia and Malawi (Whitlow, 1984) so this term will be used in the discussion below.

Dambos behave rather like sponges soaking up water during the rainy season and slowly release stored water to maintain (or at least prolong) the dry season flow of rivers. When disturbed by uncontrolled grazing and cultivation dambos are prone to erosion and drying out (Whitlow, 1985c). For example, the depletion of plant cover and breakdown of soil structure in dambos (as on hill slopes) favour overland flow at the expense of infiltration; in turn, this creates conditions favourable for gullying and destroys the sponge effect of dambos. Locally serious erosion has occurred in dambos and given the hydrological significance of these features they have been singled out for separate attention in this report.

Over one million hectares of dambo occur within the commercial farming areas. There is very limited degradation of dambos in these areas for a number of reasons. These include the strict enforcement of regulations controlling their use, especially for cultivation; limited use for late dry season grazing; and the presence of numerous small dams which maintain high water tables and prevent headward incision of natural river systems.

Nevertheless, in the earlier part of this century widespread cultivation took place in dambos on some of these farms. To enable growth of maize and wheat the dambos had to be drained partially. Invariably the open ditches excavated for this purpose turned into gullies (Haviland, 1927). During the 1940's extensive erosion took place in some of the dambos in the Mvuma area, and evidence of this is still visible today (Plate 14). Rattray, Cormack and Staples (1953) cite the decomposition of organic matter and deterioration of soil structure resulting from several successive years of winter wheat production as main causes of this erosion. Mechanical ploughing downslope and across seepage zones also contributed to rilling and gully initiation.

The erosion of these dambos was partly responsible for the subsequent restrictions on cultivation of wetlands (vleis, marshes, swamps, streambanks) in terms of the Natural Resources Act. This reinforced the earlier limitations within the Water Act of 1927 designed to prevent indiscriminate ploughing and drainage of wetlands (Whitlow, 1983a). A protective 'hands-off' policy was adopted towards dambos, at least for cultivation purposes. Certainly high rates of surface runoff from saturated dambo soils can cause erosion of large amounts of soil (Plate 15; Elwell and Davey, 1972). However, with adequate grassed waterways and avoidance of seepage zones, wetland cropping of maize has proved viable (Grant, 1974) and need not cause erosion.

More crucial is the degradation of dambos in the Communal Lands where the area of such wetlands is estimated to be about 262,000 hectares. There is field and documentary evidence that dambo cultivation was widespread in Zimbabwe prior to European occupation in the late nineteenth century (Whitlow, 1983a). Even today rice, 'tsenza' and various vegetables are grown in dambo gardens where they can be irrigated easily from shallow wells since the watertable, generally (except after prolonged droughts), is near the ground surface. Availability of water throughout the year enables high yields and, more importantly, continuous crop production.

There is a direct relationship between the well-being of rural families and access to dambo gardens (Thiessen, 1974; Hotchkiss, 1986). Prior to the land reforms of the 1950's dambo cultivation seems to have continued unchecked in the Communal Lands. Thereafter restrictions on cultivation were enforced in terms of the legislation mentioned earlier. Many peasant farmers lost their dambo gardens in whole or part; from aerial photographs it is relatively easy to detect former cultivation in dambos as show in Fig 22B for a portion of Mangwende Communal Land.

Ostensibly, the policy of restricting cultivation of dambos was designed to prevent degradation. In practice, it may well have created conditons favourable for erosion (Whitlow, 1985c). There are two reasons for stating this. Firstly, restrictions on dambo gardens were

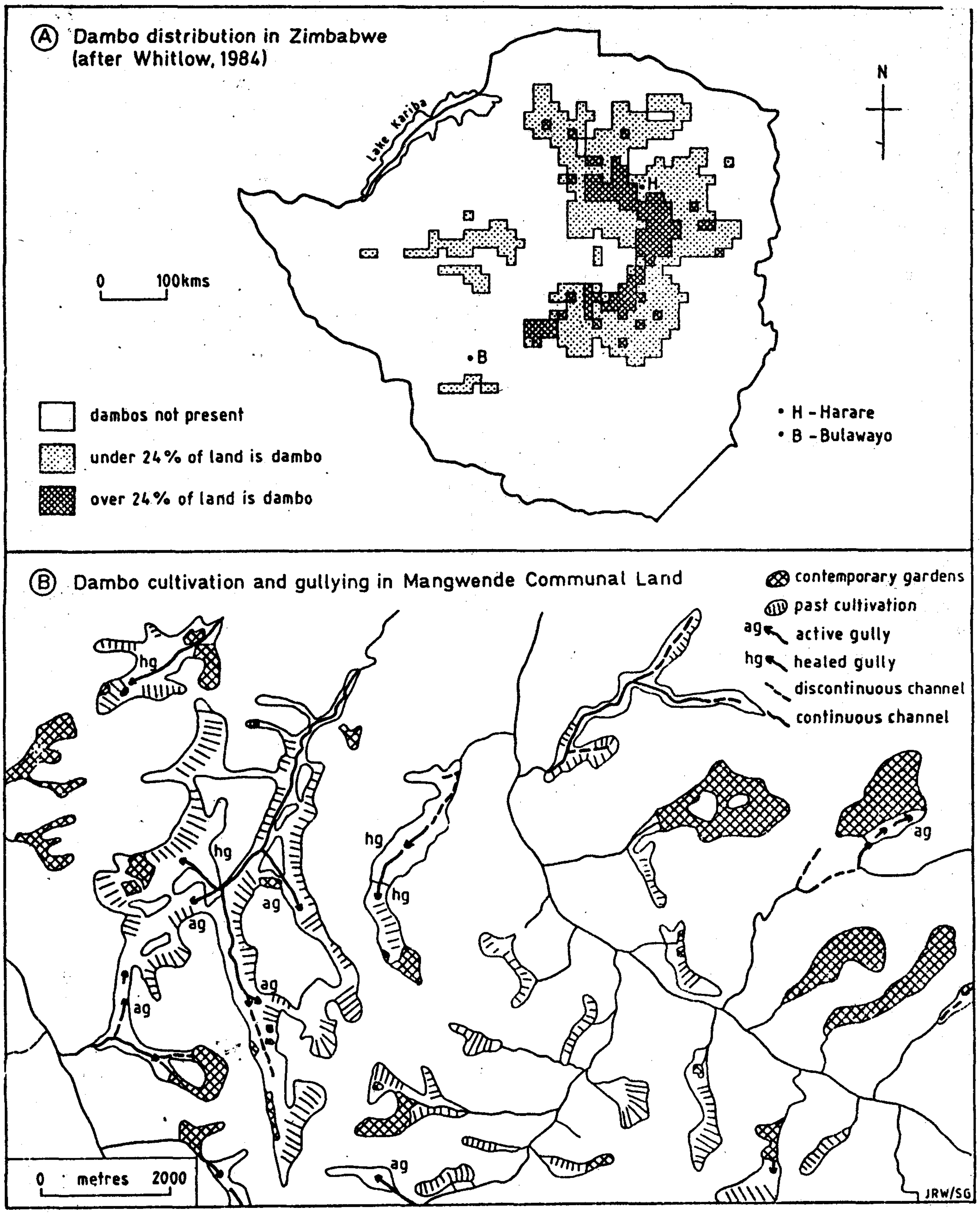


Figure 22 – Dambos in Zimbabwe.

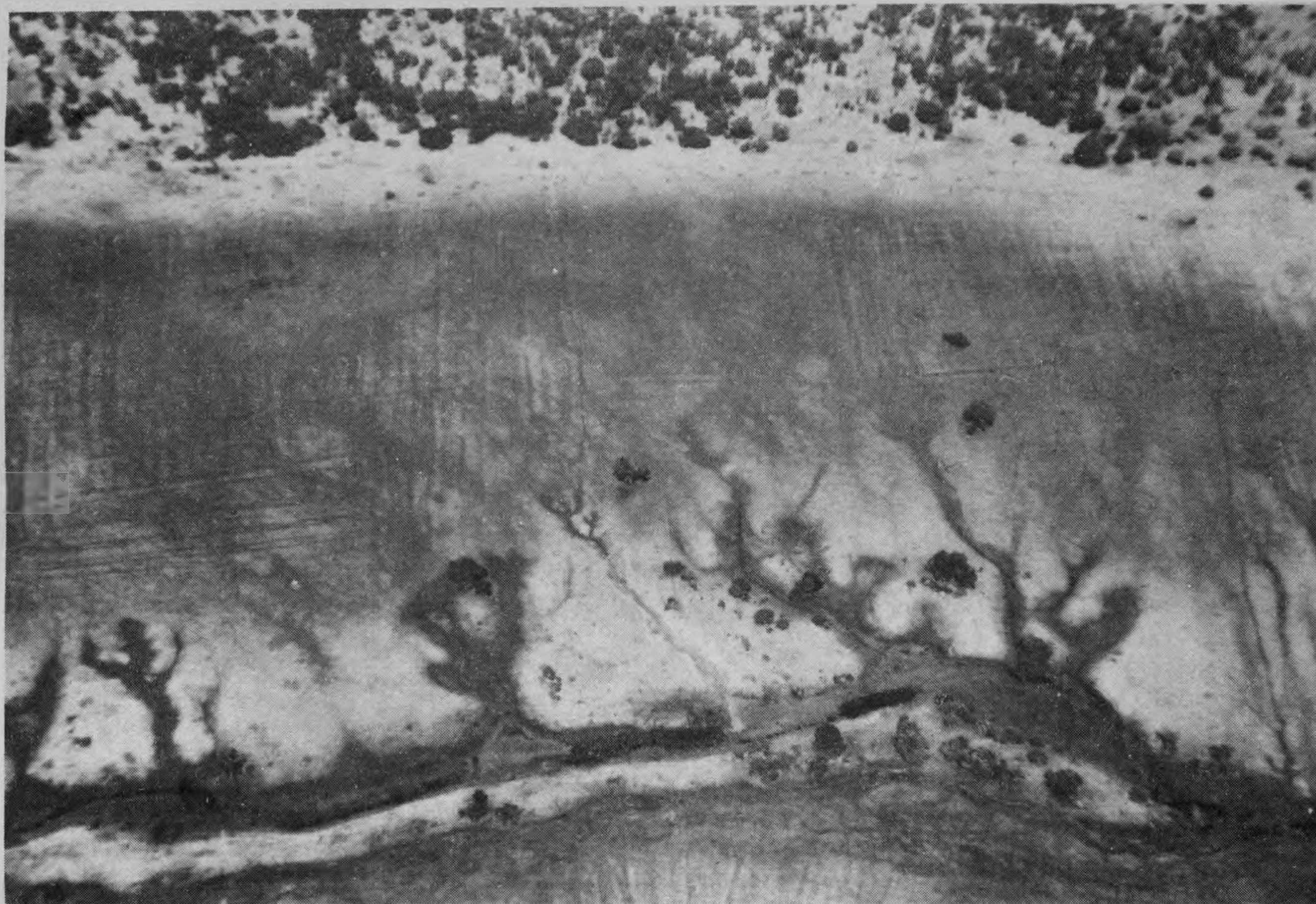


Plate 14 – Former gully channels, now stabilised, in a wetland area near Mvuma (Source: author).

Plate 15 – Severe sheetwash and rill erosion on the margins of a stand of wetland maize (Source: H.A. Elwell).

very unpopular since they compromised the capacity for a rural family to grow food during the dry season. Where, as in Chiwundura Communal Land, extension staff had to enforce legislation on wetland cultivation, they lost the trust of the peasant farmers (Thiessen, 1974). This made it more difficult to introduce basically sound agricultural practices and so contributed towards a general decline in man-land relationships. Secondly, most dambos were taken over for livestock grazing. Whilst dambos in the commercial farming areas are lightly stocked and grazed for a relatively short period in the year, this is not the case in the Communal Lands. Here livestock use dambos throughout the year and trampling and grazing by communal herds can cause serious 'poaching' of the ground surface (Plate 16).

This is certainly a contributory factor in the development of gullies in dambos. However, the map extract in Figure 22B shows that not all dambos have gullies, whilst in those which do have incised channels there are continuous, discontinuous and healed gully systems. This suggests that livestock are not entirely responsible for this form of erosion. It has been discovered, for example, that furrows on abandoned dambo gardens can concentrate runoff to initiate gullying, whereas this is very rare on regularly used gardens.

What is alarming about dambo gullying is that in some areas very rapid rates of headcut advancement can occur. An example of this is shown in Figure 23 for a dambo in Chikwakwa Communal Land, an area singled out it the early 1960's rangeland survey as having numerous gullies in the dambos (Cleghorn, 1966). The actual initiation of this particular gully may have been influenced by a track routing runoff into the natural channel in the lower part of the dambo in 1951. By 1965 the channel had extended some 75 metres up the dambo axis, an annual rate of headward advancement of just over 5 metres.

The gully channel by 1972 was well defined with steep near-vertical banks and sparse vegetation cover. Between 1965 and 1972 it had extended about 120 metres at an average rate of about 17 metres/year. However, there was a clearly defined seepage network by 1972 possibly due, in part, to cattle trekking down to the gully head to get water. By 1981 these seepage lines had become entrenched to extend the gully by some 210 metres, with an annual rate of headward incision of about 23 metres between 1972 and 1981.

In addition, by 1981 numerous lateral gully channels had developed. The period 1981 to 1984 was characterised by very poor rains and there was no appreciable change in the gully system. The dry conditions encouraged deep cracking of the black clay soils during this drought phase. With the onset of heavy rains in the

Plate 16 – Trampled or 'Poached' humic soils in a dambo in Chiwundura Communal Land (Source: author).

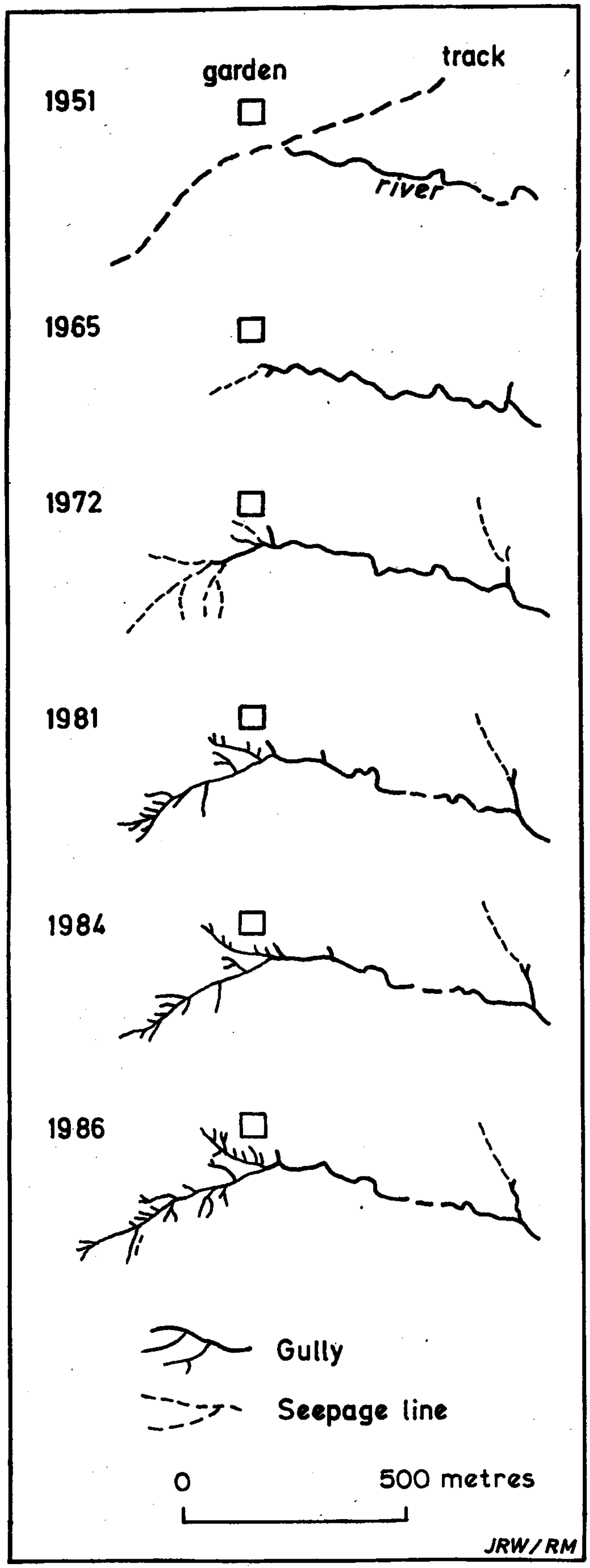


Figure 23 – Gully growth in a dambo in Chikwakwa Communal Land, 1951–1986.

1984/85 and 1985/86 rainy seasons conditions were ideal for gully extension. The main gully in two years extended some 75 metres, an annual growth rate of 37,5 metres! The smaller lateral gullies also showed signs of extension.

Gully erosion of this nature is serious for two reasons. Firstly, because it is indicative of an imbalance in the hydrological status of the catchment where man's activities have been instrumental in changing patterns of run-off. Secondly, because the gullying is both a cause and product of the dambos drying out, so reducing their role in supplying the dry season flow of rivers. However, our knowledge of the processes of dambo gullying is very limited and investigations are currently in progress on this problem in Chikwakwa and Mangwende Communal Lands. Only when the basic causes and processes of such gullying are understood can preventive and reclamation measures be devised. Such measures, however, would need to be integrated carefully into the peasant farming system.

7. CONCLUSION

The main objective of this study was to define the magnitude of the erosion problem in Zimbabwe. It is beyond the scope of this report and the author's limited practical experience to suggest solutions to this problem. However, it appears that there is already sufficient knowledge on suitable measures to reduce erosion and, at the same time, increase agricultural production (e.g Plowes, 1976; Barnes, 1978; Grant, 1981). The difficulties are not technical but socio-economic. Whilst some progress has already been achieved in improving farming in the most degraded parts of the country, the Communal Lands (Bates 1980), it is apparent that much more effort is needed in integrating technical solutions into the socio-economic fabric of these areas. This may well involve changes in traditional land tenure, a factor which has compromised conservation efforts in the past (Blaikie, 1985; Hudson, 1983).

This will be no easy task. It will require skilled and determined political leadership. This has been provided already by the President in, for example, his support for National Tree Planting Day and, more recently, the National Conservation Strategy. This political support, however, must filter throughout the hierachy of decision making if it is to yield tangible results.

Despite the scale and complexity of the erosion problem, it is clear that the present social outlook in Zimbabwe is favourable for instilling what Elwell (1980b) terms the Spirit of Conservancy. Thus conservation programmes may be received more readily now than in the past. Such programmes will require massive financial and manpower backing. Given the growing demands on a limited government budget, it seems that the future of such programmes rests in the hands (or pockets) of international aid agencies and, through a self-help strategy, the people of Zimbabwe. It is hoped that this report will assist in improving general understanding of the soil erosion problem in this country and, through so doing, galvanize positive actions to conserve one of our primary resources, the soil.

REFERENCES

Allan W. (1949) *Studies in African Land Usage in Northern Rhodesia*, Rhodes-Livingstone Paper, No. 15.

Anonymous (1935) Soil Conservation Advisory Councils, *Rhodesia Agricultural Journal*, 32, 132-33.

Aylen D. (1939) Soil and water conservation, *Rhodesia Agricultural Journal*, 36, 12-30.

Aylen D. (1942) Conserving soil in the native reserves, *Rhodesia Agricultural Journal*, 39, 152-60.

Aylen D. and Roberts R.H. (1937) Soil conservation, *Rhodesia* Agricultural Journal. 34, 90-120.

Bannerman J.H. (1982) The Land Apportionment Act: a paper tiger? *Zimbabwe Agricultural Journal*, 79(3), 101-06.

Barnes D.L. (1978) Problems and prospects of increased pastoral production in the Tribal Trust Lands, *Zambezia*, 6(1), 49-59.

Bates D.B. (1980) Important innovations introduced by agricultural extension to the tribal farmers over the last twenty years, *Zimbabwe Science News*, 14(7), 187-90.

Beach D.N. (1984) Towards a population history of precolonial Zimbabwe, unpublished paper, Department of History, University of Zimbabwe.

Blaikie P. (1985) *The Political Economy of Soil Erosion in Developing Countries*, Longman, Harlow.

Bond W.E. (1948) Soil conservation and land use planning in native reserves in Southern Rhodesia, *Tropical Agriculture*, 25, 4-13.

Central Statistical Office (1984) *1982 Population Census: a preliminary assessment*, CSO, Harare

Christopher A.C. (1971) Land tenure in Rhodesia, *South African Geographical Journal*, 53,39-52.

Cleghorn W.B. (1966) Report on the condition of grazing in Tribal Trust Land, *Rhodesia Agricultural Journal*, 63, 57-67.

Commission of Enquiry (1939) *Report of the Commission to enquire into the preservation etc. of the natural resources of the Colony.* Government Printer, Salisbury.

Cooper G.R. (1972) A field method for the estimation of sodium status of Rhodesian soils, *Rhodesia Agricultural Journal*, 69, (6), 127-28.

Cormack J.M. (19720 Efficient utilization of water through land management, *Rhodesia Agricultural Journal*, 69 (1), 11-16.

Cripps L. (1909) The erosion of soil, *Rhodesia Agricultural Journal*, 6, 669-70.

Davies D.H. and Wheeler R.G. (1986) 1982 Population Distribution in Zimbabwe, 1:1 million map, CSO and Surveyor General's Department, Harare.

Department of Conservation and Extension (1976) Rhodesia Natural Regions, Land Tenure and Intensive Conservation Areas, 1:1 million map compiled and drawn by the Planning Branch, Salisbury.

Du Toit R.F. (1985) Soil loss, hydrological changes and conservation attitude in the Sabi catchment of Zimbabwe, *Environmental Conservation*, 12(2), 157-66.

Du Toit R.F., Campbell B.M., Haney R.A. and Dore D. (1984) *Wood Usage and Tree Planting in Zimbabwe's Communal Lands*, Report prepared for the Forestry Commission of Zimbabwe and the World Bank, Harare.

Dunne T. (1977) Evaluation of erosion conditions and trends, pp53-83 in *FAO Conservation Guide No. 1*, Guidelines for Watershed Management, Rome.

Dye P.J. (1979) Feasibility of reclaiming and improving sodic soils *Rhodesia Agricultural Journal, 76(2), 65-68.*

Elwell H.A. (1974) *The condition of the arable land in the farming areas of Rhodesia*, Department of Conservation and Extension, Salisbury.

Elwell H.A. (1975) Conservation implications of recently determined soil formation rates in Rhodesia, *Rhodesia Science News*, 9(10), 312-13.

Elwell H.A. (1978) *Design of Safe Rotational Systems*, Department of Conservation and Extension, Salisbury.

Elwell H.A. (1980a) A soil loss estimation technique for Southern Africa, pp 281-92 in *Soil Erosion* edited by M.J. Kirkby and R.P.C. Morgan, Wiley, London.

Elwell H.A. (1980b) Soil, the basis of life, *Zimbabwe Science News*, 14 (12), 299-300.

Elwell H.A. (1985) An assessment of soil erosion in Zimbabwe, *Zimbabwe Science New*, 19(3/4), 27-31.

Elwell H.A. and Davey C.J.N. (1972) Vlei cropping and soil and water conservation, *Rhodesia Agricultural Journal Technical Bulletin*, 15, 155-68.

Elwell H. A. and Stocking M.A. (1976) Vegetal cover to estimate soil erosion hazard in Rhodesia, *Geoderma* 15, 61-70.

Elwell H.A. and Stocking M.A. (1984) Estimating soil life-span for conservation planning, *Tropical Agriculture*, 61(2), 148-50.

Floyd B.N. (1961) Changing patterns of African agriculture in Southern Rhodesia, *Journal for Geography*, 1(9), 7-18.

Floyd B.N. (1962) Land apportionment in Southern Rhodesia, *Geographical Review*, 52, 566-82.

Froude M. (1974) Veld management in the Victoria Province tribal areas, *Rhodesia Agricultural Journal*, 71(1), 23-38.

Grant P.M. (1974) What is necessary for wetland maize, *Rhodesia Farmer*, 45(15), 43-45.

Grant P.M. (1981) The fertilization of sandy soils in peasant agriculture, *Zimbabwe Agricultural Journal*, 78(5), 169-75.

Hamilton P. (1964) Population pressure and land use in Chiweshe Reserve, *Rhodes-Livingstone Journal*, 36, 40-58.

Haviland P.H. (1925) Further notes on soil erosion, *Rhodesia Agricultural Journal*, 22, 831-38.

Haviland P.H. (1927) Preventive measures against soil erosion in Southern Rhodesia, *South African Journal of Science*, 24, 110-16.

Haviland P.H. (1928) Soil erosion, *Rhodesia Agricultural Journal*, 25, 1217-24.

Haviland P.H. (1934) Soil erosion, *Rhodesia Agricultural Journal*, 31, 420-50.

Hood R. (1972) The Harvester — scourge of Rhodesia's ranching lands, *Rhodesia Farmer*, 42(40), 21-3.

Hotchkiss P.F. (1986) Socioeconomic aspects of dambo cultivation in Zimbabwe, paper presented at a workshop on The Use of Dambos in Zimbabwe's Communal Areas, University of Zimbabwe, Harare.

Hornby H.E. (1968) Overstocking — a modern approach to the problem, *Rhodesia Agricultural Journal*, 65, 67-74.

Hudson N.W. (1957) Soil erosion and tobacco growing, *Rhodesia* Agricultural Journal, 54, 547-55.

Hudson N.W. (1963) A historical background of erosion and its control, *Rhodesia Agricultural Journal*, 60, 175-77.

Hudson N.W. (1971) *Soil Conservation*, Batsford, London.

Hudson N.W. (1983) Soil conservation strategies in the Third World, *Journal of Soil and Water Conservation*, 38 (6), 446-49

Hughes A.J.B. (1971) Tribal Land Tenure — an obstacle to progress? *South African Journal of African Affairs*, 1, 56-73.

Interconsult (1985) National Master Plan for Rural Water Supply and Sanitation, Vol 32 — Soil and Water Conservation, Interconsult, Harare.

Ivy P. (1979) *Proposed erosion classification system*, Department of Conservation and Extension, Salisbury.

Jennings A.C. (1921) Soil washing, *Rhodesia Agricultural Journal*, 18,461-68.

Jennings A.C. (1923) Erosion, especially surface-washing, in Southern Rhodesia, *South African Journal of Science*, 20, 204-07.

Johnson R.W.M. (1964) *African Agricultural Development in Southern Rhodesia: 1945-1960*, Stanford University, Stanford.

Kay G. (1970) *Rhodesia: A Human Geography*, University of London Press, London.

Kay G. (1975) Population pressures and development prospects in Rhodesia, *Rhodesia Science News*, 9(1), 7-13.

Keech M.A. (1968) Soil erosion survey techniques, *Proceedings and Transactions of the Rhodesian Scientific Association*, 53, 13-16.

Kelly R.D. and Walker B.H. (1976) The effects of different forms of land use on the ecology of a semi-arid region in south-eastern Rhodesia, *Journal of Ecology*, 64, 553-76.

Kennan P.B. (1971) The development of the extension service among the European farmers in Rhodesia, *Rhodesia Agricultural Journal*, 68, 116-20.

Kennan P.B. (1980) Agricultural extension in Zimbabwe, 1950-1980, *Zimbabwe Science News, 14(7), 183-86.*

Lightfoot C.J. (1981) The history and the natural resources of the Matopo Hills, *Zimbabwe Science News*, 15(11), 213-17.

Lightfoot C.J. (1982) Land use in the Matopo Hills — a perspective, *Zimbabwe Science News*, 16(5), 110-12.

Magadza C.H.D. (1984) An analysis of siltation rates in Zimbabwe, *Zimbabwe Science News*, 18, 63-6.

Mangwende Commission (1961) Report of the Commission of Enquiry into Disorder in the Mangwende Reserve, Government Printer, Salisbury.

Millington A.C. and Townshend J.R.G. (1984) Remote sensing application in African erosion and sedimentation studies, pp 373-84 in *Challenges in African Hydrology and Water Resources* edited by D.E. Walling S.S.D. Foster and P. Wurzel, IAHS Press, Wallingford.

Ministry of Finance (1978) *Integrated Plan for Rural Development*, Ministry of Finance, Salisbury.

Mitchell B.L. (1980) Report on a survey of the termites of Zimbabwe, *Occasional Papers of the National Museums and Monuments*, Series B, Natural Science, Vol 6, Part 5.

Morgan R.P.C. (1979) *Soil Erosion*, Longman, London.

Murton T.A. (1971) Land-use planning in the Tribal Areas of Rhodesia, *Rhodesia Agricultural Journal*, 68, 3-8.

Natural Resources Board — annual reports from 1942 to 1982, NRB, Harare.

Natural Resources Board (1966) *25 Years of Conservation in Rhodesia*, NRB, Salisbury.

Natural Resources Board (1968) *The Use of Marginal Lands of Rhodesia*, unpublished report.

Owens L.B. and Watson J.P. (1979) Rates of weathering and soil formation on granite in Rhodesia, *Soil Science Society of America Journal*, 43, 160-66.

Palmer R. (1977) *Land and Racial Domination in Rhodesia*, Heinemann, London.

Phillips Committee (1962) Report of the advisory committee on the development of the economic resources of Southern Rhodesia with particular reference to the role of African agriculture, Government Printer, Salisbury.

Plowes D.C.H. (1976) Technical problems of tribal crop production, *Rhodesia Science News*, 10, 244-7.

Prescott J.R.V. (1961) Overpopulation and overstocking in the native areas of Matabeleland, *Geographical Journal*, 127, 212-25.

Purves W.D. (1975) Genesis and management of some granite derived soils, *Rhodesia Science News*, 9(3), 80-81.

Ranger T. (1985) *Peasant Consciousness and Guerilla War in Zimbabwe*, Publishing House, Harare.

Rattray J.M., Cormack .R.M. and Staples R.R. (1953) The vlei areas S. Rhodesia and their uses, *Rhodesia Agricultural Journal*, 50, 465-83,

Republic of Zimbabwe (1982) *Transitional National Development Plan, 1982-85*, Ministry of Finance, Harare.

Republic of Zimbabwe (1986) *First Five Year National Development Plan, 1986-1990*, Ministry of Finance, Economic Planning and Development, Harare.

Rodel M.G.W. and Hopley J.D.H. (1973) Investigations into systems of farming suitable for the Tribal Lands, *Rhodesia Agricultural Journal*, 70(1), 1-18.

Roder W. (1964) The division of land resources in Southern Rhodesia, *Annals of the Association of American Geographers*, 54, 41-58.

Stocking M.A. (1972a) Aspects of the role of man in erosion in Rhodesia, *Zambezia*, 2(2), 1-10.

Stocking M.A. (1972b) Relief analysis and soil erosion in Zimbabwe using multivariate techniques, *Zeitschrift fur Geomorphologie*, 16, 432-43.

Stocking M.A. (1972c) Planting pattern and erosion on a cotton crop, *Rhodesia Science News*, 6(8), 231-32.

Stocking M.A. (1975) Soil erosion potential: the overview, pp 1-7 in *Engineering Handbook*, Department of Conservation and Extension, Salisbury.

Stocking M.A. (1976) Tunnel erosion, *Rhodesia Agricultural Journal*, 73(2), 35-39.

Stocking M.A. (1977) Erosion of soils on Karoo Sands in Central Rhodesia with particular reference to gully form and process, unpublished PhD thesis, University of London.

Stocking M.A. (1978) Relationship of agricultural history and settlement to severe erosion in Rhodesia, *Zambezia*, 6(2), 129-45.

Stocking M.A. (1980) Environmental education through the use of erosional features, *Geographical Proceedings of Zimbabwe*, 13, 47-71.

Stocking M.A. (1981) A working model for the estimation of soil loss suitable for underdeveloped areas, *Development Studies Occasional Paper No. 15*, University of East Anglia, Norwich.

Stocking M.A. (1983) A model of piping in soils, *School of Development studies Reprint No. 125*, University of East Anglia, Norwich.

Stocking M.A. (1986) *Effect of soil erosion on soil nutrients in Zimbabwe*, Vol 1, Final Report, FAO Consultants Working Paper No. 3, Rome.

Stocking M.A. and Elwell H.A. (1973) Soil erosion hazard in Rhodesia, *Rhodesia Agricultural Journal*, 70(4), 93-101.

Stocking M.A. and Elwell H.A. (1976a) Vegetation and erosion: a review, *Scottish Geographical Magazine*, 92(1), 4-16.

Stocking M.A. and Elwell H.A. (1976b) Rainfall erosivity over Rhodesia, *Transactions of the Institute of British Geographers New Series*, 1(2), 231-45.

Stocking M.A. and Elwell H.A. (1976c) Erosivity determinations for seven rainfall stations in Rhodesia, *Research Bulletin No. 21*, Department of Conservation and Extension, Salisbury.

Stubbs A.T. (1977) The Tribal Trust Lands in transition: land use, *Rhodesia Science News*, 11(8), 181-84.

Tatterfield J.R. (1982) The role of research in increasing food crop potential in Zimbabwe, *Zimbabwe Science News*, 16(1), 6-10.

Taylor R.D. and Walker B.H. (1978) Comparisons of vegetation use and herbivore biomass on a Rhodesian game and cattle ranch, *Journal of Applied Ecology*, 15, 565-81.

Thiessen R.J. (1974) The cultivation of vleis in QueQue Tribal Trust Land, unpublished report, Ministry of Internal Affairs, Salisbury.

Thomas D.S.G. (1985) Evidence of aeolian processes in the Zimbabwe landscape, *Transactions of the Zimbabwe Scientific Association*, 62(8), 45-55.

Thompson J.G. and Purves W.D. (1978) A guide to the soils of Rhodesia, *Rhodesia Agricultural Journal Technical Handbook No. 3.*

Vincent V. and Thomas R.G. (1961) *An Agricultural Survey of Southern Rhodesia. Part I — Agro-ecological Survey*, Government Printer, Salisbury.

Walling D.E. (1984) The sediment yields of Africa rivers, pp 265-83 in *Challenges in African Hydrology and Water Resources* edited by D.E. Walling, S.S.D. Foster and P. Wurzel, IAHS Press, Wallingford.

Wendelaar F.E. (1976) Field identification of sodic soils, *Rhodesia Agricultural Journal*, 73(3), 77-82.

Whitlow J.R. (1979a) An assessment of cultivated lands in Zimbabwe Rhodesia, 1972 to 1977, *Zimbabwe Rhodesia Science News*, 13(10), 233-38.

Whitlow J.R. (1979b) A scenario of changes in subsistence land use and its relevance to the tribal areas of Zimbabwe, *Zambezia*, 7(2), 171-90.

Whitlow J.R. (1980a) *Deforestation in Zimbabwe: Problems and Prospects*, Supplement to Zambezia, University of Zimbabwe, Harare.

Whitlow J.R. (1980b) Landuse, population pressures and rock outcrops in the tribal areas of Zimbabwe, *Zimbabwe Agricultural Journal*, 77(1), 3-11.

Whitlow J.R. (1980c) Environmental constraints and population pressures in the tribal areas of Zimbabwe, *Zimbabwe Agricultural Journal*, 77(4), 173-81.

Whitlow J.R. (1983a) Vlei cultivation in Zimbabwe: reflections on the past, *Zimbabwe Agricultural Journal*, 80(3), 123-35.

Whitlow J.R. (1983b) Hydrological implications of land use in Africa, with particular reference to Zimbabwe, *Zimbabwe Agricultural Journal*, 80(5), 193-212.

Whitlow R. (1984) A survey of dambos in Zimbabwe, *Zimbabwe Agricultural Journal*, 81(4), 129-38.

Whitlow R. (1985a) Conflicts in land use in Zimbabwe: political, economic and environmental perspective, *Land Use Policy*, 2, 309-22.

Whitlow R. (1985b) An erosion survey of the Mutoko region in north-east Zimbabwe, *Zimbabwe Agricultural Journal*, 82(4), 119-30.

Whitlow R. (1985c) Dambos in Zimbabwe: a review, *Zeitschrift fur Geomorphologie*, Supplementband 52, 115-46.

Whitlow R. (1986) Mapping erosion in Zimbabwe: a methodology for rapid survey using aerial photographs, *Applied Geography*, 6,149-62.

Whitlow R. (1987a) Soil conservation history in Zimbabwe, Part I — Large-scale commercial farming areas, *Zimbabwe Agricultural Journal* (in press).

Whitlow R. (1987b) Soil conservation history in Zimbabwe. Part II — Communal Lands, *Zimbabwe Agricultural Journal* (in press).

Whitlow R. and Bullock A (1987) Rapid gully development in Mangwende Communal Land, *Zimbabwe Agricultural Journal*, (in press).

Whitlow R. and Campbell B. (1988) Factors influencing erosion in Zimbabwe: a statistical analysis, *Journal of Environmental Management* (in press).

Whitlow R. and Zinyama L. (1988) Up hill and down vale: farming and settlement in Zimunya Communal Land. *Zimbabwe Agricultural Journal* (in press).

Whitsun Foundation (1981) *Rural Afforestation Study*, Whitsun Foundation, Salisbury.

Yudelman M. (1964) *Africans on the Land*, Harvard University Press, Boston.

Zimbabwe Science News (1980) The opening of the first National Conservation Congress of the Natural Resources of Zimbabwe, 14(12).

Zinyama L. and Whitlow R. (1986) Changing patterns of population distribution in Zimbabwe, *Geojournal*, 13(4), 365-384.

Appendix – Aerial Photographs examined in national survey

Mana Pools/Kanyemba — 1981	Nyamandhlovu — 1983
Bumi Hills/Kariba — 1981	Gweru — 1979
Mhangura — 1981	Shurugwi — 1979
Mount Darwin — 1981	Chimanimani — 1981
Binga — 1981	Plumtree — 1982
Copper Queen — 1984	Bulawayo — 1980
Harare — 1984	Masvingo — 1980
Mutoko — 1981	Chipinge — 1981
Hwange/Kazungula — 1983	Mphoengs — 1982
Kamativi — 1983	West Nicholson — 1982
Kwekwe — 1984	Mwenezi — 1982
Chegutu — 1984	Chiredzi — 1982
Mutare — 1981	Beitbridge — 1982
Dzivanini Pan — 1983	Malipati/Sango — 1982

Notes:
1. blocks listed north to south and west to east
2. current names used for each block