Zambezia (1978), VI (ii).

RELATIONSHIP OF AGRICULTURAL HISTORY AND SETTLEMENT TO SEVERE SOIL EROSION IN RHODESIA

M. A. STOCKING

School of Development Studies, University of East Anglia

SOME 100 KILOMETRES south-west of Salisbury, well away from the main road, lies a tribal area distinctive because of its severe erosion and its fine, white Karoo sand. Amidst gently rolling relief are found gully scars up to six metres deep and three kilometres long. The contrast in relief is remarkable; moving through the area, one meets slopes of no more than four degrees at one moment and a ravine with vertical sides dissecting the landscape at the next. More alarming than this static display of erosion, however, is the way in which these gullies maintain themselves. Gully-head cuts have within living memory advanced hundreds of metres, cutting roads, destroying vegetation, draining an already parched landscape and generally disrupting rural life. In short, it is a soil conservationist's nightmare; a badlands landscape reminiscent of a cross between the Grand Canyon and American dust-bowl conditions. One is tempted, as others have been, to point to the local population to lay the blame for this severe erosion. Is this fair? Can the erosion and contemporary rates of advance of the gullies be linked to the population and the way it utilizes the land?

Man has long been recognized as an important control variable in the erosion process. The evidence is irrefutable. While soil erosion is essentially a natural process governed by rainfall, soil conditions, slope and vegetation, man controls the system through the upsetting of the steady state. Usually this is through a destruction of the vegetation that promotes increased runoff and inadequate protection of the soil. The many means by which this can be done have been reviewed elsewhere.[1] In a Rhodesian context, aspects of man's influence on erosion have been discussed in an earlier article in this journal by the present writer.[2]

[1] L. D. Meyer and J. V. Mannering, 'The influence of vegetation and vegetative mulches on soil erosion', in *Biological Effects on the Hydrological Cycle* (W. Lafayette Indiana, Purdue University, Dep. of Agricultural Engineering, Proceedings of the 3rd International Seminar for Hydrology Professors, 1971), 355-66; M.A. Stocking and H. A. Elwell, 'Vegetation and erosion: A review', *Scottish Geographical Magazine* (1976), XCII, 4-16.

[2] M. A. Stocking, 'Aspects of the role of man in erosion', *Zambezia* (1971-2), II, ii, 1-10.

Against this view of man's over-riding influence on his soil resources must be set the fact that quantitative evidence is lacking. The degree to which man causes increased soil erosion is not known and, indeed, the exact mechanism by which the erosion takes place is little understood. Erosion modelling is in its infancy. Heinemann and Piest[3] report that the emphasis in the United States is increasingly turning toward developing comprehensive models that consider soil detachment and transport mechanisms in detail. The modelling and simulation of sheet erosion has received particular attention through a modified version of the Universal Soil Loss Equation incorporating hydrological variables,[4] and through mathematical simulation techniques.[5] If developed and co-ordinated, such models with appropriate and tested refinements hold promise of precise and logical explanation of both sheet and gully erosion, and we will have progressed toward 'the ultimate goal of watershed modelling',[6] deterministic models in which all cause-effect linkages and feedbacks are known and understood. Since neither the quantitative evidence nor practicable models (testing procedure) are to hand, there remains the real need to test emotive assumptions such as man's ubiquitous influence on erosion. Already evidence appears to favour a mixture of man and climatic change as being responsible in parts of the United States for severe gullying,[7] but local natural circumstances may still be of significant importance. The tenuous basis of much research to date is well summarized by Cooke and Reeves: 'almost all investigators have made an assumed relationship between vegetation and runoff, the cornerstone underlying their respective hypotheses'.[8]

This paper will seek by two very different avenues to determine man's role in promoting erosion in the headwaters of the Umsweswe River in central Rhodesia. Conclusions may be applicable to other badly gullied situations especially where most erosion is through deep, long gullies, variously termed as 'lavaka' by the French, as 'bocorocas' by South Americans, and

[3] H. G. Heinemann, and R. F. Piest, 'Soil erosion-sediment yield research in progress', *Eos Transactions* (1975), LVI, 149-59.

[4] C. A. Onstad and G. R. Foster, 'Erosion modeling on a watershed', *Transactions of the American Society of Agricultural Engineers* (1975), XVIII, 288-92.

[5] W. P. David and C. E. Beer, 'Simulation of soil erosion — Part I. Development of a mathematical erosion model', *Transactions of the American Society of Agricultural Engineers* (1975), XVIII, 126-9, 133; 'Simulation of soil erosion — Part II. Steamflow and suspended sediment simulation results', ibid., 130-3.

[6] K. J. Gregory and D. E. Walling, *Drainage Basin Form and Process* (London, Arnold, 1973), 226

[7] See R. U. Cooke and R. W. Reeves, *Arroyos and Environmental Change in the American South-West* (London, Oxford Univ. Press, 1976), which gives a wide-ranging review of the problem.

[8] Ibid., 7.

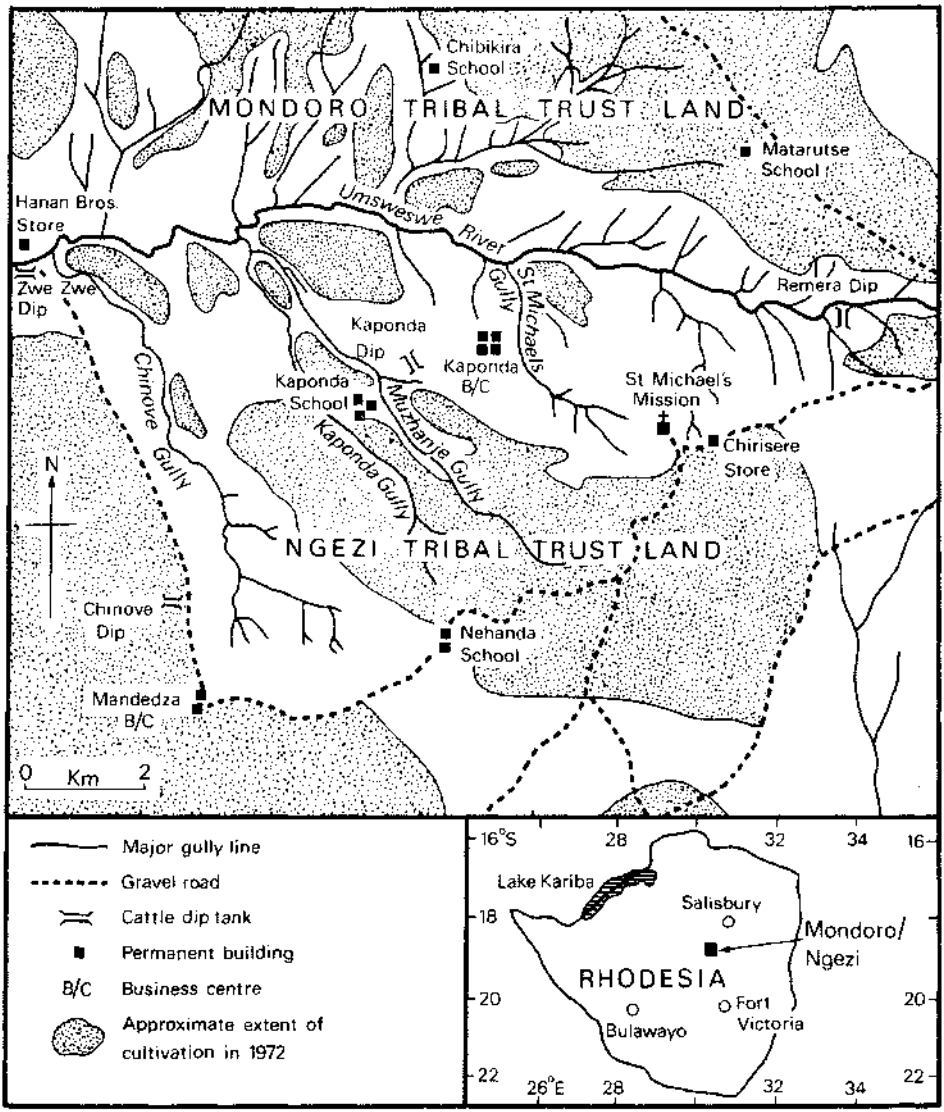

Figure 1: SITE AND LOCATION OF THE UMSWESWE CATCHMENT

as 'arroyos' by North Americans,[9] which are a peculiarly tropical and subtropical phenomenon occurring in fine-grained sands of a cohesive nature.

First, an examination is made of the history of early settlement and agriculture in Mondoro which includes the headwaters of the Umsweswe River to determine if there is any qualitative evidence to suggest man's involvement in erosion. Secondly, through a variable describing human pressure on the land, a statistical test is made of the relationship between gully growth and man. The study area is shown in Figure 1. It is a basin of deep Karoo sands underlain by granite. Archival records, interviews and experimental observation provide the main sources of information. The experiment on linking gully erosion to man is part of a broader study on the factors, both human and natural, that control rates of erosion; this wider study is unpublished[10] but the results are used in this account.

EARLY SETTLEMENT

Early Agriculture, 1890-1950. Native Reserves were set up in Southern Rhodesia at an early date following European settlement. Although it could fairly be said that in 1890 the whole country was available to the African population, the beginnings of land apportionment were very soon manifest. The Lippert Concession of 1891 provided for the selling and leasing of large tracts of land to incoming settlers. It could do so with relative impunity because the African population was small and the majority were in inhospitable country.[11] After the Matebele and Mashona rebellions of 1896-7, a Southern Rhodesia Order in Council (1898) placed the responsibility of providing sufficient land for Africans in the hands of the British South Africa Company. In practice this responsibility was devolved on to the district Native Commissioners and there was no standard practice in allocating land. As Palmer notes,[12] these African Reserves usually carry the connotation of land left over after European exploitation. Nevetheless it was widely believed at the time that the Reserves 'were not only sufficient but liberal, and will prove to be ample for the requirements of the native inhabitants for many

[9] M. Petit and F. Bourgeat, 'Les lavaka malgaches; Un agent naturel d'évolution des versants', *Bulletin de l'Association de Geographes Français, Paris* (1965), CCCXXXII-III, 29-33; J. Tricart, *Landforms of the Humid Tropics, Forests and Savannas* (London, Longmans, 1972); F. L. Prandini, 'Occurrence of "bocorocas" in southern Brazil — geological conditioning of environmental degradation', *Proceedings of the 2nd International Congress of the International Association of Engineering Geology* (Sao Paulo, Instituto de Pesquisas Tecnológicas, 1974), I, iii, 36.1-36.10; S. A. Schumm, and R. F. Hadley, 'Arroyos and the semiarid cycle of erosion', *American Journal of Science* (1957), CCXXV, 161-74.

[10] M. A. Stocking, 'Erosion of Soils on Karoo Stands in Central Rhodesia with Particular Reference to Gully Form and Process' (Univ. of London, unpubl. Ph.D. thesis, 1977).

[11] G. Kay, *Rhodesia : A Human Geography* (London, Univ. of London Press, 1970), 47.

[12] R. Palmer, *Land and Racial Domination in Rhodesia* (London, Heinemann, 1977), 57.

years to come, even taking into consideration the rapid rate at which they and their stock increase, as well as their extensive methods of cultivation'.[13] By 1913 there were no less than 104 Reserves ranging in size from 2 000 to 600 000 hectares.[14] The situation is little changed today (although the area set aside for exclusive African occupation is rather greater at about 47 per cent of total land) and is enshrined constitutionally.

Against this background of land alienation must be set the rapid increase in African population accompanied by an even more dramatic crease in livestock over the whole country. In 1900 there were about 600 000 Africans with, it is estimated, 55 000 cattle. Through control of both human and cattle diseases by 1945 there were some 1,75 million Africans with 1,9 million cattle.[15] Today an African population of 4,5 million (40,4 per cent in urban areas and, therefore, holding no cattle) has well over 2 million cattle, about 650,000 goats and numerous other small stock. Both Kay and Palmer[16] document the serious deterioration in the man-land ratio without any compensating improvement in man-land relationships. Indeed, changes in land usage such as the change from traditional foodstuffs and hunting to maize monoculture and cattle keeping have added to pressures on the land. For instance in 1900 it is estimated that the cultivated area was 0,43 ha per person. By 1945 it was 0,48 and by 1962 it had risen to 0,71 ha per person.[17]

Though little documentary evidence remains, the Umsweswe catchment was never settled by Europeans as the soils are relatively infertile and the area is away from the main gold-producing districts which attracted most early attention. From what must have been a very sparse population at the turn of the century the area for African settlement was compressed into the Mondoro Reserve with large tracts of land either side of European settlement along the Salisbury-Hartley-Que Que-Bulawayo and Salisbury-Enkeldoorn-Fort Victoria axes. In the first two decades of this century there were considerable influxes of people; not only those dispossessed of their land but probably more importantly those moving from districts infested by tsetse fly. For example it was noted in 1913 that 'on account of the Fly people were moved from the Sanyati-Umfuli area to near the Zwezwe River in Mondoro'.[18] Several such population movements are mentioned, other factors being tribal disputes and the natural search for better lands,

[13] Quoted in ibid., 60.
[14] Kay, *Rhodesia*, 49.
[15] Ibid., 48, 79. Figures for African-owned cattle are problematic. Palmer, *Land and Racial Domination*, 94, cites approximate figures of 44 000 in 1901 and 1,8 million in 1951 with specific counts of 195 837 in 1908 and 406 180 six years later. The impression of exactness is spurious but the increase is nonetheless dramatic.
[16] Kay, *Rhodesia*, 79-93; Palmer, *Land and Racial Domination*, 96-8.
[17] Kay, *Rhodesia*, 80.
[18] National Archives of Rhodesia, Salisbury, NSE/4/2/1 (N[ative] C[ommissioner] and Magistrate, Hartley : Reports : Monthly : Sept. 1912-Dec. 1919), Month ending 31 Aug. 1913. All documents cited hereafter are in the National Archives unless otherwise indicated.

all of which add to a sizeable influx of people. In 1915 it was estimated that some 19 acres (7,5 ha) were available for each African and it was remarked that this was 'exceedingly good';[19] it does not, however, compare favourably with the countrywide average in 1962 of 8 ha per person in the Tribal Trust Lands. Some areas close by remained unsettled by Black or White farmers; the Native Commissioner, Hartley, noted in 1921 that an area to the south of the Umsweswe River and a little to the west of the study area was 'clear of natives and may be alienated'.[20] Such alienation probably only served to further restrict available land and increase the effective population pressure.

Comments in reports on early conditions and standards of agriculture are highly subjective but there are many references to the difficult physical conditions in Mondoro, though no mention whatsoever is made of the gullies. In 1918 it was reported that 'the natives living in the sandy parts of Mondoro were not reaping much from their lands because it became so wet and crops failed to mature'.[21] The destruction of crops by game animals seemed an ever present problem and swarms of locusts were sometimes noted in 1925. The area surrounding the Umsweswe River was described in 1925 as a 'moving mass of hoppers'.[22] Apparently 2 453 separate swarms were destroyed that year with the help of adjacent European farmers whose interests might have been prejudiced.[23] All these 'natural' hazards appear to have reduced the state of agriculture in the first three decades of the century to a poor and parlous condition, exacerbating man-land relationships.

By the 1930s the situation appears to have become more stabilized. At least one agricultural demonstrator was active in the area and Native Commissioner's reports note fairly good crops and good responses to attempts at improving standards of agriculture.[24] There was, however, mounting concern over grazing land pressures. A letter from the Agriculturist, Native Department, to the Chief Native Commissioner, of 18 April 1934, reported

[19] NSE/2/3/1 (N.C. and Magistrate, Hartley : Out Letters : Superintendent of Natives, Salisbury : 18 Nov. 1913-14 Mar. 1917), Ngizi Reserve, 19 Mar. 1915 : A remark by the authorities not by the populace.

[20] NSE/2/3/2 (Out Letters : 15 Jan. 1920-23 Dec. 1922), Circular from N.C., Hartley, 'Reverted Reserves', 9 Mar. 1921.

[21] NSE/4/2/1, Report, 13 June 1918.

[22] S1032 (Ministry of Agriculture, Salisbury : Correspondence : N.C., Hartley, 1906-25), letter from N.C., Hartley to C[hief] N.C., Salisbury, 14 Jan. 1925.

[23] The whole campaign against locusts in the Charter District is documented in S1827/1425/1/8 (Ministry of Agriculture, Botany and Plant Pathology, Correspondence and Other Papers, Numerical Series, 1904-58 : Locust Campaign, Charter, 30 Sept. 1932-24 Feb. 1943).

[24] For example, S138/72 (C.N.C., Correspondence, Numerical Series, 1923-33 : Agricultural Activities within the Department of Native Development, 1927-33), D26/30, Alvord to Director of Native Development, 27 May 1930. Considerable local interest was being shown in 'Before Harvest Meetings'.

that the overgrazing, especially in the northern sector of the Mondoro Reserve, was particularly bad, and so recommended control of grazing and the migration of people to south of the Umfuli River and into the Umsweswe catchment.[25] At the same time there was also a general increase in awareness of soil erosion especially in the Native Reserves which culminated in the Report of the Soil Erosion Committee of the Rhodesian Agricultural Union in 1932[26] which drew heavily on early American experience in erosion. Yet no specific mention is made of the gully erosion in the Umsweswe catchment. Several indirect references are to be found and one report illustrates well the paternalism of the era:

> The natives are simply running wild and ploughing up large areas of land every second year. Not only are they ruining good soil through bad farming but destroying all the valuable timber. This is country that can support a lot more natives if properly settled. The main offenders here are non-indigenous natives who have cleared acres and acres of the best soil, farming it very poorly and working it as though it was a private farm . . . There is no rotation of crops and no manure applied which means he will soon be looking for another 100 acres of good soil to ruin.[27]

There were also other problems to contend with. At times the Native Department agricultural demonstrators, though Africans themselves, were unpopular, it is alleged because of their involvement with Mission schools.[28] However, Demonstrator Dawa in Mondoro seems to have overcome this problem by 1933 and had 346 'co-operators' who were following approved agricultural methods including manuring, using improved maize seed and practising rudimentary conservation measures. Increased yields and the production of surplus maize gave rise to a further problem which exists even today: marketing and transport.[29] The Reserves are usually some distance from main communication routes and the poor state of the roads and lack of marketing facilities obviously retarded any attempts at production of surplus produce. This general problem is seen today in declining productivity in the Tribal Trust Lands and a money economy unable to absorb the increasing rural population.

Boundary Change and Administrative Responsibility. The limited awareness of soil erosion and in particular of the gullies, coupled with a general lack of any documentary information south of the Umsweswe River has already

[25] S1542/A4 (C.N.C., Correspondence, General, 1914-43 : Agriculture, 1933-9, Reports and Surveys on Reserves), I.

[26] Ibid., unpubl. report, mimeo, 14pp.

[27] Ibid., III, Inspection Report of Assistant Agriculturist, G. R. Polner to C.N.C. Salisbury, 26 Mar. 1938.

[28] S138/72, Agricultural Status of Reserve Natives, H. Jowitt, Director of Native Development to Superintendant of Natives, Fort Victoria, 14 Feb. 1930.

[29] Ibid., Report on Before-Planting Inspection of Demonstrator's Plots on Reserves Season 1932-3, Alvord to C.N.C., undated. Alvord notes that, 'demonstration work has taken a set-back because plot owners have not been able to sell the improved maize grown on plots and are wondering if it is worth while to give up the old easy methods and do the hard work required on plots'.

been noted. No obvious reason is to hand as the area was certainly settled by Africans prior to 1918 and even as early as 1899 administrative responsibility was apportioned to the various district offices. The answer to the lack of information probably lies in two related reasons; first, the distance and poor communications from the nearest district offices (Hartley to the north-west and Fort Charter or Charter at the Range to the south-east); secondly the history of boundary changes in the area and later changes in responsibility for different aspects of native agriculture.

In 1899 the boundary between Hartley and Charter Districts was taken to be the 'Umgezi' [Ngezi] River[30] which runs parallel to the Umsweswe and to the south of the study area. The Umsweswe headwaters were therefore in the Hartley District. This boundary was reaffirmed in 1909[31] although some documents in the interim appear to show some administrative functions carried out by the Native Commissioner at the Range (Charter). Hartley is some 95 km from the study area but 175 km by road, most of it on poor dirt. That is the situation today; in 1900 all administrative communication was by horse and the Umsweswe catchment was on the very periphery of the Hartley District unconnected except by bush path and seldom visited.

In 1920 the boundary between Hartley and Charter Districts was moved north to the Umsweswe River[32] and about this time all native land to the Ngezi River was named Mondoro Reserve and land south of the Ngezi named 'Umgesi' Reserve. By 1935 the Southern Rhodesia 1:1 million map shows the area south of the Umsweswe, now called 'Umgezi and Mondoro South', in 'Charter at the Range' District and the area north of the Umsweswe, called 'Mondoro North', as being in Hartley District.

After 1935 the situation is confused and staff shortages especially in agricultural personnel necessitated the grouping of areas which took little account of then existing boundaries. Because of its outlying position the Umsweswe catchment appears to have been sadly neglected, being rarely mentioned.

The final documented changes in administrative responsibility arose from the 1961 Southern Rhodesia Constitution where all African lands were grouped together to form larger blocks of land to be known as Tribal Trust Lands.[33] The area south of the Umsweswe River (Ngezi T.T.L.) now found its administrative headquarters under the District Commissioner at Gatooma, some 40 km south-west of Hartley. Mondoro T.T.L. north of the Umsweswe remained with Hartley although it does appear that one Agricultural Officer served the two District Commissioners at Gatooma and Hartley for the whole

[30] Southern Rhodesia, Govt Notice 13/1899.
[31] Southern Rhodesia, Govt Notice 131/1909.
[32] Southern Rhodesia, Govt Notice 146/1920.
[33] Southern Rhodesia, Govt Notice 518/1963.

of Mondoro and Ngezi. At around this time also responsibility for African agriculture, which had for many years been with the Ministry of Agriculture (dealing both with African and European agriculture), was transferred to the Ministry of Internal Affairs which now had sole responsibility for all aspects of the tribal areas. Many agriculturalists considered this a retrograde step, especially as many of the experienced Agricultural Officers remained with the Ministry of Agriculture dealing with European farming alone. The extra responsibility placed on Internal Affairs field staff was great and inevitably expertise in agricultural matters suffered.

The Land Tenure Act of 1970 finally fixed the sizes of Ngezi T.T.L. as 56 900 ha and Mondoro as 130 500 ha, the situation pertaining today.

The sorry history of administration of the Umsweswe headwaters contrasts with the tighter control exercised in areas closer to the main district offices. A large part of the mismanagement and general neglect of the area can perhaps be related to these administrative changes. How far this neglect through administrative change affected erosion is uncertain. It was not until the 1950s with the implementation of the Land Husbandry Act that there was any concerted effort at finding out the problems of the area.

LAND HUSBANDRY ACT

The Native Land Husbandry Act of 1951 was the product of mounting concern over the deterioration of the tribal areas and unworkable earlier legislation such as the Natural Resources Act (No. 9 of 1941). The new Act provided regulations for enforcing conservation and good farming with serious penalties for offenders. It also provided for the assessment of the carrying capacity of each tribal area and the redistribution of arable holdings. Since the data base for much of the implementation of the Act did not exist, each area had to convene an Assessment Committee which met to consider the overall picture. The information collected for each committee would consist of a census of people and animals, areas of arable land, historical background of tribes and general impressions of the state of the agriculture. Information varied in quality but it seems that that for Mondoro South was good.

The Assessment Committee for Ngezi-Mondoro Reserve met on 12 September 1956.[34] They divided the Reserve into three, the northern zone closely corresponding to the study area south of the Umsweswe River. This northern zone was approximately 175 km² with a population estimated at 5 500 giving a density of about 31 persons per square kilometre. However, the point was made that some half of the male population was out of the Reserve and working in towns leaving a resident male population of only 532; the effective population density is then less than 29 persons per square kilometre. Other pertinent 1956 data are shown in Table I. It should be noted that many of the figures are probably grossly underestimated to reduce tax assessment and cattle dipping fees. It is impossible to estimate the numbers of 'hidden'

people and livestock but experience elsewhere indicates that the underestimation for cattle could be of the order of 50 per cent.

Through the Land Husbandry Act the only comprehensive count of populations was carried out. As such it was an extremely useful exercise although many of the recommendations based on the collected data failed to materialize into firm changes in land use and practice. Perhaps the only real changes were firstly a maintenance of approximately 4 000 head of cattle in the area until today (a ratio of one beast to 4,37 ha) and secondly a fairly drastic reduction in cultivated area. These moves seemed also to stem increase in human population at the expense of areas further to the south.

Table I

STATISTICAL INFORMATION ON THE NORTHERN SECTOR OF NGEZI RESERVE

Human population	5 500
Total number of:	
cattle	4 029
calves	500
donkeys	162
sheep	213
goats	287
large stock equivalent	4 294
taxpayers	1 250
resident males	532
kraal heads	61
stockowners	686
landholders	1 038
Cultivated area (ha)	5 216
Proportion cultivated land to grazing land	30
Number of stockowners owning:	
1 - 3 cattle	121
4 - 6	300
7 - 9	168
10-12	69
13-15	18
16-18	9
19-21	1

[34] Relevant data for consideration by the Assessment Committee was submitted in an unpublished report from R. E. Jenkinson, Land Developemnt Officer, Aug. 1956 (now held by District Commissioner, Hartley). The findings of the Committee occur in : Minutes of Meeting of Assessment Committee for Ngesi Mondoro Reserve in the Charter District, unpubl., Sept. 1956 (held by Minister of Internal Affairs, Salisbury). The latter is largely a copy of Jenkinson's report.

RECENT EROSION AWARENESS

As the population of the Umsweswe catchment grew and the area was opened up, the gullies did start to attract attention because of their sheer size. Other aspects of erosion were neglected.

The earliest attempts at dealing with the gullies were as a result of a meeting of Native Department and conservation staff at Hartley in 1946 or 1947.[35] From this meeting a series of large contour banks designed to a gradient of 1:600 were built around the heads of St Michael's Gully (then called Timba Gully) and a few of its tributaries. These banks were so massive that they are clearly evident today on the ground. St Michael's Gully has progressed through the first bank and one of its tributaries is now following the contour on the upstream side of the bank. Without doubt it was the worst course of action that could have been taken since the contour banks served only to concentrate surface waters and led to preferential infiltration and the development of tunnels

Also at this time three dams were built (none surviving now) for stock watering to reduce concentrations of cattle along the river banks. The heads of the gullies were fenced but it appears that the fencing material was stolen within one or two years and the members of the Assessment Committee for the Land Husbandry Act were unaware of its existence in 1956.

It was not until 1969 that the authorities showed any firm resolve to tackle the problem of advancing gullies. A series of Ministry of Internal Affairs departmental reports and memos in 1970 and 1971 leave a record of unfortunate recommendations and conclusions.[36] For example, despite an adverse report from the Rhodesia Forestry Commission on the planting of trees in the immediate vicinity of gullies[37] several belts of exotic trees were planted. Their growth has been minimal and has probably only retarded grass growth within the belts. Much was also written on the mismanagement and overgrazing of the catchment with little evidence to support such a contention. The result was an expensive programme of fencing the gully heads to allow regrowth of grasses with minimum grazing; the D.C., Hartley, reported in 1969 that 39 miles of fencing were recommended at £100 per mile.[38] The fencing programme has continued through to 1975 with further considerable cost. Since the fencing depends on both regular maintenance and the closing of the few main gates into the enclosures, the onus for success

[35] F. Micklesfield, retired Agricultural officer, personal communication, 17 May 1976.

[36] Ministry of Internal Affairs, Salisbury, AGR/5/50 (Correspondence and Reports, 1967-71), Soil Conservation Special Project Ngezi Tribal Trust Land and Mondoro Tribal Trust Land.

[37] Rhodesia Forestry Commission, Ref. 399, 'Tree Planting for Gully Reclamation, Memo from T. J. Hodgson, Forest Officer, 29 Jan. 1971.

[38] Ministry of Internal Affairs, Salisbury AGR/7/12/69, Gullies : Hartley and Gatooma, Woollacott to Provincial Commissioner, Mashonaland South, 21 Nov. 1969.

of the scheme was placed on local tribesmen, a responsibility not appreciated by many. Certainly by 1974 the fencing was relatively ineffective and no measured differences in grass cover were found inside and outside fenced areas, indicating that cattle were effectively free to graze at will.

Recently the Natural Resources Board has taken an interest in gully reclamation. A series of stone bolsters have been placed in the base of St Michael's Gully and in several of the heads of the Chinove-Bhiza section with finance raised by the Natural Resources Board. The bolsters consist of ironstone wrapped in chicken wire. Some considerable sedimentation has occurred upstream of the bolsters and the floor of St Michael's Gully near its head cut is now 75 cm higher. However, the cost of construction of the bolsters and subsidiary efforts such as planting and watering of grass has been exorbitant. While it has been demonstrated that some sedimentation has occurred, the effective gain in land has been negligible and the advance of the head cuts has hardly been retarded. Without the sizeable grants from Government sources, any reclamation would be impossible and it is felt that any workable scheme is financially impractical. To date the programme of stone bolsters is continuing. Other less successful (or even disastrous) attempts have been discontinued, examples of which were the bulldozing of head cuts to smooth the profile (the head cut in one instance reinstated itself after one storm) and the planting of sisal.

From all of these more recent experiences it may be concluded that little real practical benefit in land reclamation has been achieved. The focus of attention has always been the head cut and the immediate gully base. The catchments have been largely neglected because perhaps by comparison with other tribal areas they are fairly well covered by vegetation. Finally, there has been very little recognition that the gullies might conceivably be primarily a product of natural processes. The erodible nature of the soils is occasionally mentioned but the blame has all too readily been placed on local tribesmen for mismanagement of the land — a factor which is not necessarily supported by observational evidence and enquiry.

QUANTITATIVE ASSESSMENT

The evidence from a study of the history of occupation of the area suggests that while mismanagement and administrative neglect have occurred, the population has never been excessive and no extraordinary man-induced influences may be invoked to account for severe erosion. It remains, however, to determine if contemporary erosion may be aided by pressure of population on the land. The most obvious means of doing this is to compare rates of advance of gully head cuts between catchments with differing population pressures. Since catchment variables such as area and vegetation cover are also likely to be different between catchments, it is necessary to take these into account in a multiple regression model along with the human factor. It is reiterated that the purpose of this paper is to test man's influence on

erosion; the other variables are introduced only for statistical rigour and their significance is reported on fully in my unpublished thesis.[39]

A Variable for Population Pressure. The choice of a parameter to measure population pressure in problematic. On the one side, it is not known how man affects erosion; on the other, it is not known how much pressure land can sustain without irrevocable damage. Carrying capacity formulae have been designed[40] but all are based on untestable assumptions and data that are not always available. A proxy variable for population pressure is necessary which integrates the many unknown linkages. In a study of differences between types of land tenure, population densities and severity of erosion, it was found that in most instances population density was related to erosion.[41] In the present study all catchments to gullies are wholly within one type of land tenure, the communal grazing and small arable plots of the Tribal Trust Lands. Therefore, the major difference that may have a bearing on erosion between catchments is the numbers of people making use of the land. The main assumption is that every person through his practices and through the grazing animals he keeps affects erosion equally. That this is not so on an individual basis can be demonstrated by comparisons of sheet erosion and declining fertility on adjacent smallholdings; farming has multiple objectives and multiple paths to reach those objectives. Nevertheless over large groups of peoples the averaged effect should approximate to the assumption, and population density be a suitable proxy variable for man's influence on erosion through farming practice.

Population density was measured on a square kilometre grid basis by 100 per cent count. From Figure 2 it can be seen that the density is quite variable (between 0 and 130 persons per square kilometre) depending on the location of the larger village groupings on the edge of the arable lands and along the main watershed boundary roads. Mean population density in 1974 was 31,4 persons/km^2 indicating a slight increase over 1956. The total population was 5 645 with a rather greater density (34,1) south of the Umsweswe River than north of it (25,8).

Other Variables of Gully Growth. In the multiple regression model, population density, D, represents one of the independent variables. The others are:

[39] See footnote 10.

[40] W. Allan, 'How much land does a man require?', in *Studies in African Land Usage in Northern Rhodesia* (Lusaka, Rhodes-Livingstone Institute, Paper No. 15, 1949), 1-23; R. Feachem 'A clarification of carrying capacity formulae', *Australian Geographical Studies* (1973), XI, 234-6.

[41] Stocking, 'Aspects of the role of man in erosion'.

[42] I. Seginer, 'Gully development and sediment yield', *Journal of Hydrology* (1966), IV, 236-53; J. R. Thompson, 'Quantitave effect of watershed variables on rate of gully-head advancement', *Transactions of the American Society of Agricultural Engineers* (1964), VII, 54-5.

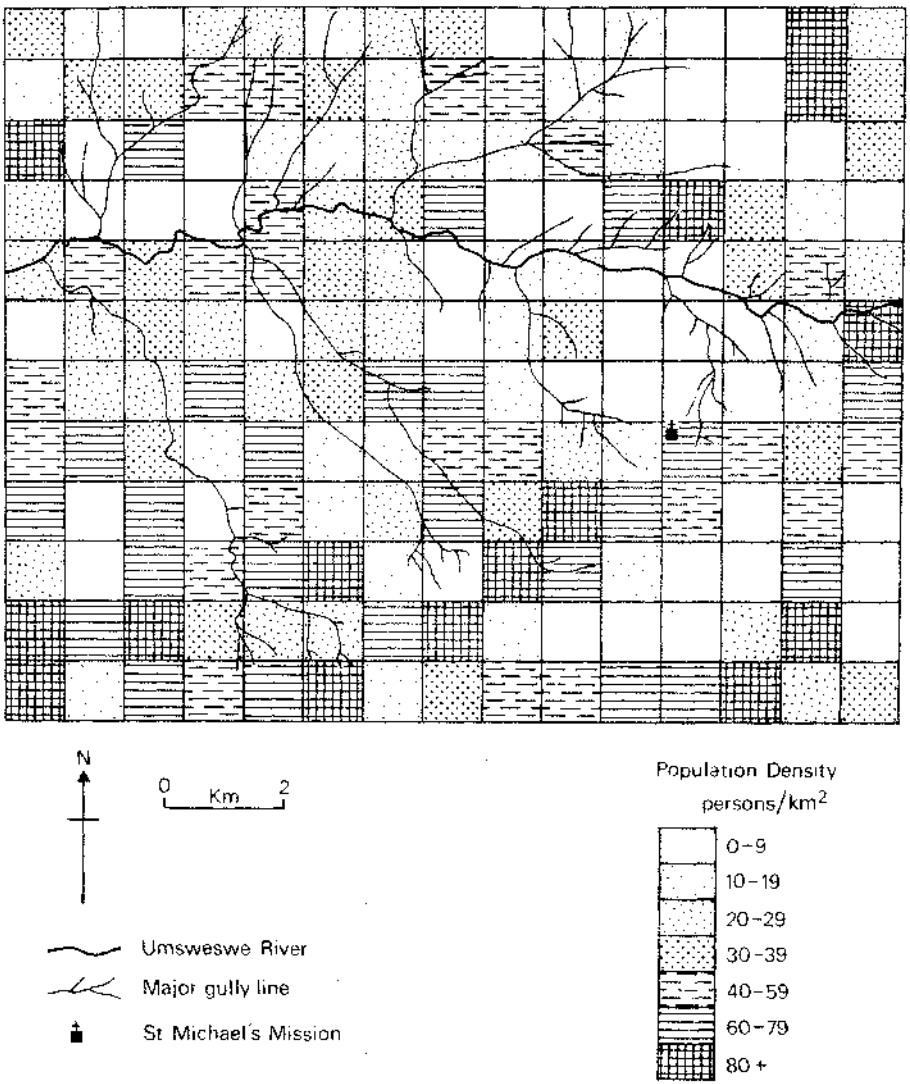

Figure 2: POPULATION DENSITY OVER THE UMSWESWE CATCHMENT.

Precipitation, P mm
Antecedent precipitation index, A_p mm
Catchment area to gully head, A_c km^2
Mean vegetation cover, C %
Height of head cut, H m
Slope of approach channel, S degrees

While many other variables could have been used, of those chosen some are ones that have been found important elsewhere[42] and others would have a high degree of interdependency with extra variables. Gully growth is measured by the volume of soil removed from the head cut after each storm event, Y m^3.

Results. Using a step-wise multiple regression procedure whereby the least significant contributory variables (based on t-value) are progressively dropped, the most significant variable remains. At the same time the contribution of the other variables towards explanation of gully growth may be monitored (Table II). A sample of gully heads retreating principally through waterfall erosion was used; the wider study, of which this is a part, also considered other head cuts at different time scales. Results are broadly similar to the ones reported here in Table II.

The most significant individual variable is A_c (product-moment correlation coefficient, $r = 0{,}686$), followed by H (0,606), A_p (0,535) and P (0,361). Variables C, D (population density) and S are nearly randomly correlated with gully growth and are eliminated at an early stage in the step-wise regression. Interaction between the other variables, P, A_p, A_c and H gives an equation that explains 80,1 per cent of the variation ($R = 0{,}895$). With a 10 per cent loss in explanation ($R = 0{,}844$) A_p may be eliminated to give what is probably the optimum prediction equation for these gully heads:

$$Y = 6.87 \times 10^{-3}\ P^{1.34}\ A_c^{\ 1.00}\ H^{0.52}$$

Discussion. Population density fails to improve the prediction of head cut growth and, by itself, has a very low correlation with gully growth ($r = 0.018$). The reason for this is either that population density is an ineffective measure of population pressure on the land or that population pressure is not an important contributory factor to erosion under the conditions investigated. It has already been argued that population density is likely to be a crude but significant parameter for population pressure, and, therefore, the latter explanation is preferred. Indeed, the results suggest an essentially natural basis for gully formation in the area and no discrimination is found in rates of erosion between catchment areas with high population density and those with low density.

[43] M. A. Stocking, 'Tunnel erosion', *Rhodesia Agricultural Journal* (1976), LXXIII, 35-9.

Table II

GULLY GROWTH PREDICTION EQUATIONS FOR WATERFALL HEAD CUTS

Regression	*Degrees of Freedom*	*Multiple Correlation Co-efficient R*	*t—values of Variables*						
			P	A_p	A_c	C	D	H	S
$Y = 2{,}55 \times 10^{-2} P^{1{,}02} A_p^{0{,}56} A_c^{0{,}90} C^{-0{,}28} D^{-0{,}09} H^{0{,}46} S^{-0{,}29}$	40	0,902	4,06	4,41	4,95	—1,05	—0,41	4,67	—1,30
$Y = 2{,}03 \times 10^{-2} P^{1{,}01} A_p^{0{,}56} A_c^{0{,}90} C^{-0{,}31} H^{0{,}47} S^{-0{,}29}$	41	0,901	4,08	4,52	4,99	—1,19	—	4,76	—1,31
$Y = 4{,}97 \times 10^{-3} P^{1{,}06} A_p^{0{,}52} A_c^{0{,}85} H^{0{,}49} S^{-0{,}23}$	42	0,898	4,30	4,34	4,82	—	—	5,12	—1,05
$Y = 4{,}14 \times 10^{-3} P^{1{,}07} A_p^{0{,}53} A_c^{0{,}86} H^{0{,}50}$	43	0,895	4,40	4,39	4,86	—	—	5,22	—
$Y = 6{,}87 \times 10^{-3} P^{1{,}34} A_c^{1{,}00} H^{0{,}52}$	44	0,844	4,73	—	4,86	—	—	4,52	—
$Y = 4{,}42 \times 10^{-2} P^{1{,}13} A_c^{1{,}47}$	45	0,760	3,37	—	6,91	—	—		—
$Y = 3{,}5 A_c^{1{,}50}$	46	0,686	—	—	6,40	—	—	—	—

Note: Series of regressions follows the step-wise procedure giving equations with the higher multiple correlation coefficient with a given number of variables.

CONCLUSIONS

There is neither firm historical evidence nor contemporary experimental and statistical evidence to support the contention that man has largely brought about the severe erosion in the Umsweswe catchment. Historically, it has been shown that the population has remained fairly static over recent years, having risen gradually from the mid-nineteenth century. Cattle and livestock populations likewise have little changed. There are some documented agricultural difficulties, such as locust swarms, administrative neglect and unwise conservation treatment of the gullies, but these cannot solely account for the formidable erosion manifest today.

This qualitative view is supported by experimental evidence of rates of erosion compared to population pressures within the catchments to the gullies. From a large sample of gully heads and individual storm events there is no basis for present high population densities to be the cause for measured rates of gully advance. It may be that if population were to continue to increase above some threshold, gully advance would also increase but this threshold, if it exists, has not been reached by existing population densities.

Care must be taken in applying the results to other situations. Certainly the variety of valley bottom gully characterized by steep or vertical walls in cohesive fine sediments and flat wide floors, and variously called 'lavaka', 'arroyos' or 'bocorocas', should not immediately be taken as evidence for mismanagement of the land. As in the case studied, these gullies are probably a natural response to changing environmental conditions. This is not to say that man may not aggravate the conditions; he often does, but he is not the principal cause. Similarly, other forms of erosion may be natural responses to particularly erosive conditions. In the tropics, soil types are often responsible for serious tunnel erosion.[43] Other cases may come to light. At the same time, man's role should not be diminished. He is undoubtedly responsible for many if not most cases of land degradation. But he may not be responsible for all. There exists a wide field for research in erosional processes and forms in the tropics.

ACKNOWLEDGEMENT

Funds for this research were provided by the Research Board, University of Rhodesia.