IDENTIFYING AND ASSESSING PROBLEM AREAS IN SOIL EROSION SURVEYS USING AERIAL PHOTOGRAPHS

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Abstract

Gully erosion has for many years been a problem in Rhodesia's Tribal Trust Lands.

This paper describes how Soil Conservation Service staff, with no previous ground knowledge of these areas, used good quality 1/25,000 *scale aerial photographs to measure the extent of the gully erosion and to pinpoint erosion "black spots." This enabled quick and reliable estimates of the cost of reclamation work to be made without the need for time-consuming field survey.*

The survey method discussed is capable of wide application wherever gully erosion occurs and needs to be brought under control.

1. INTRODUCTION

GULLYING is an advanced and destructive form of soil erosion of particular significance as a source of sediment in river catchments.

Although the intensive application of soil and water conservation measures in Rhodesia has done much to keep this type of erosion in check, they have been least effective in the African Tribal Trust Lands owing to mounting population pressures. Consequently, in 1964, the Ministry of Agriculture decided to give the problem more specific attention in terms of the Government's policy to step up agricultural production in the African farming areas of the country.

As part of the Government plan the Land-Use Planning Section of the Department of Conservation and Extension was instructed to carry out a survey of the major catchments in the Tribal Trust Lands to determine:

(i) The extent of the gully erosion in each catchment.

(ii) What mechanical measures would be necessary to remedy or stabilise the gullies.

(iii) The approximate cost of such measures.

The task fell to the authors who, in analysing these requirements, saw that it would be necessary to devise a fast, sound and practical method of survey which would:

(a) Reduce fieldwork to a minimum without sacrificing accuracy.

(b) Enable severely gullied areas to be identified quickly and easily so that reclamation work could be carried out in these areas first.

(c) Allow rapid measurement of the gullies and direct plotting of their positions to be made.

(d) Be usable by field staff and specialists alike.

(e) Be capable of widespread general application in the European as well as the African farming areas irrespective of climatic zone.

2. Method

Any field grid or transect system of survey combined with physical measurement of the gullies on the ground was ruled out by the necessity for speed.

The answer lay in an exacting stereoscopic analysis, under 3-power magnification, of up-to-date 1/25,000 scale aerial photographs. During this analysis the full drainage pattern, all obvious non-arable mountain land, and crests which might form potential roads were demarcated. As these data are basic land factors which are not liable to change on being field-checked their delineation is reliable—whilst the demarcated crests are a most useful navigational aid and guide to the design of water disposal layouts in subsequent field reconnaissance.

In addition every erosion gully, cattle track, cattle dipping tank and potential dam site was identified and defined on the stereo-cover (Fig. 1). Provided the

FIG. 1. Vertical stereogram showing: (1) Active gullies; (2) Cattle dipping tank; (3) Gullying cattle track. Photo-scale: 1/25,000.

photography is up-to-date the demarcation of these data, also, is reliable as it entails direct identification and places no reliance on logical reasoning and deduction.

The use of binoculars of suitable power for identifying and accurately delineating this information is essential. This slows down the rate of work so that not more than 15,000 acres a day can usually be stereoscopically analysed and defined in this way on 1/25,000 scale stereo-cover.

The authors satisfied themselves that there was a sufficiently close correlation between the degree of sheet and rill erosion and the degree of gully erosion; sheet and rill erosion were therefore not recorded as separate factors on the stereo-cover, though they occur wherever there is gully erosion.

Eroded channels extending for more than one horizontal contour terrace interval were classified as gullies while those less than this length were regarded as rills.

FIG. 2. An upstream ground view of a stream-bed filled with sand from a badly eroded portion of the Tokwe river catchment in Chibi Tribal Trust Land.

FIG. 3. Vertical stereogram of the same sand-filled streambed. The point of the arrow indicates the crossing-point on the stream where the ground photograph (Fig. 2) was taken. Photo-scale: 1/25,000.

It was quite easy to see on the aerial photographs whether a gully was active or stabilized and, as the stereoscopic analysis progressed, it became possible to classify the gullies into two main types dependent on the method required to repair them:

(i) Those which could be repaired cheaply by simple hand methods and

(ii) Those which could be repaired only with heavy mechanical equipment.

Where gullying was intensive the rivers, as one would suspect, were full of sand. This, too, was identifiable in the stereoscopic image (Figs. 2, 3 and 4).

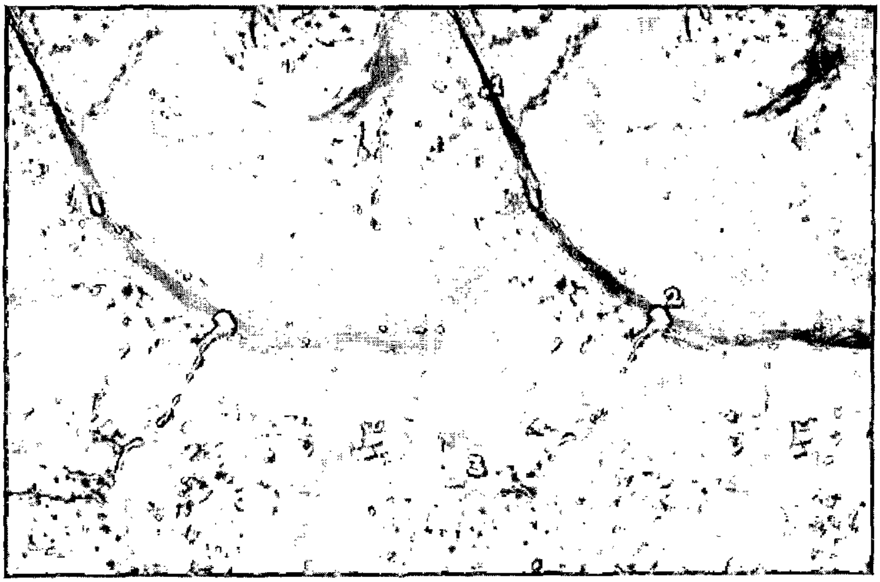

FIG. 4. Vertical stereogram showing: (1) and (2) Young arcuate deltas in the Sabi river bordering Sabi North Tribal Trust Land; (3) Active gullying adjacent to the stream which yielded the larger of the two deltas.

The aerial photographs were taken in 1964 shortly after the 1963 summer rains had ended.

Jones, in an aerial flight over the area in the 1965 dry season, discovered that the deltas had almost vanished. It is therefore possible that they resulted from one heavy storm towards the end of the 1963 rains and were then washed away during the 1964 rains.

The tributary which precipitated the larger delta (2) has a catchment area of 11,000 acres. Photo-scale: 1/25,000.

3. SOLONETZ SOILS

Heavy siltation of rivers and streams was also very apparent in the highly erodible solonetz soil areas of the catchments studied.

Although solonetz soil conditions under *Colophospermum mopane* vegetation have a very characteristic appearance on aerial photographs, showing up as a rash of black-and-white spots with low antheaps and bare areas of sheet erosion (Fig. 5), gully identification and classification were seldom possible in these areas.

This is because, with the soils having little or no agricultural value, the vegetation is usually left undisturbed and the gullies could not be seen. In any case surface gullying does not give a true picture of the erosion in these areas as the physical properties of solonetz soil, which influence its erodibility, are that it has a very low infiltration rate and wets reluctantly—but once saturated it loses cohesion so that its structure collapses. This results—not only in gullies—but in small sinkholes, subsurface slumping and tunnelling which cannot be seen on aerial photographs. Control and reclamation measures are thereby handicapped whilst the soil's low fertility and productivity status in any case make most reclamation measures uneconomic.

However, despite "on site" erosion damage being of little consequence—even in areas where mopani patches are extensive—it is important that the erosion be controlled if possible as it poses a siltration threat to large-scale irrigation dams built downstream. The irrigation potential of the catchment is also liable to be further reduced by the possibility of the run-off water gathering salts in solution.

FIG. 5. Vertical stereogram showing typical appearance (white patches) of Solonetz soil conditions under *Colophospermum mopane* in the middle veld area of Rhodesia. Photo-scale: 1/25,000.

4. MEASUREMENT

In addition to the demarcation of the data mentioned, conservation dams designed to hold 15 to 20 feet of water were stereoscopically sited 2–2½ miles apart using the method based on stream gradient changes evolved and advocated by Jones and his associates (1962)[1],[2] and (1964).[3]

The spacing of the dam sites was based on practical experience—which has shown that cattle utilise the grazing most efficiently when they do not have to walk more than 2000 yards in any direction to obtain water.

Besides improving the grazing "spread" the dam-siting exercise was designed to arrest the movement of sediment and give better distribution of water supplies leading to increased irrigation potential and an improvement in human- and animal-carrying capacities. It was also intended to help control erosion by reducing the risk of the gullied cattle tracks, excessive overgrazing and trampling characteristic of too heavily used watering points—whilst encouraging the people to take a hand in the gully repair work themselves.

On completion of the stereoscopic assessment the drainage pattern, non-arable land, crests and dam sites were transferred from the stereo-cover to base mosaics of the same scale, whilst the gullies were plotted on stable polyester overlays to the mosaics.

Each overlay was gridded in 1600-acre squares (2½ square miles)—a size selected as being not so big as to be meaningless and yet not so small as to be tedious, whilst also acting as a check on the correct spacing of the dam sites and on where additional dip tanks might be needed.

The gullies plotted on the overlays were then measured with a magnifying distance measurer and the total yardage of each of the two main types of gully recorded grid square by grid square—selected field checks being made to confirm the reliability of this method of measurement.

When all the gullies had been plotted, the allocation of priorities for reclamation work was quite easy as the erosion "black spots" on each overlay showed up clearly. The same applied to regional patterns and concentrations of erosion which were identified by transferring the grid to a 1/100,000 scale controlled base-map on which the grid squares were filled in in different colours to indicate the degree of severity of erosion based on the total yardage of gullies in each.

The criteria used for this purpose were as follows:

No recorded gullies: 1600-acre square was classed as "nil" erosion
From 1– 2999 yards: 1600-acre square was classed as "slight" erosion
From 3000– 6999 yards: 1600-acre square was classed as "moderate" erosion
From 7000–10,999 yards: 1600-acre square was classed as "severe" erosion
1600-acre squares with 11,000+yards of gullies were classed as "very severe".

These were quite arbitrary divisions used merely to establish a base from which to develop the survey though the figures do fall on an even curve when plotted. Subsequently, for the "badland" erosion in Mtoko Tribal Trust Land, it was found necessary to extend the scale for "very severe" erosion by adding another four levels, namely:

From 11,000–18,999-yard gullies per 1600-acre square
From 19,000–25,999-yard gullies per 1600-acre square
From 26,000–32,999-yard gullies per 1600-acre square
From 33,000 -yard gullies per 1600-acre square

Degrees of erosion expressed as a percentage of the total areas of five Tribal Trust Lands in the Tokwe River catchment are indicated in Table I.

TABLE I

Degree of erosion	*Tribal Trust Lands*				
	Selukwe	*Chilimanzi*	*Mashaba*	*Chibi*	*Victoria*
Nil	0	8	0	23	4
Slight	25	29	38	41	55
Moderate	49	41	45	29	19
Severe	25	19	15	2	11
Very severe	1	3	2	5	6

It is clear from this table that Selukwe Tribal Trust Land is most severely affected with almost three-quarters of its total area having moderate to severe erosion. Chilimanzi and Mashaba have about two-thirds of their total areas similarly affected, whilst Chibi and Victoria have less than half their areas damaged to the same extent.

Considering the 700,000 acres surveyed in the Tokwe River catchment as a whole—and on the basis of the Sabi Catchment Investigation Team's report (1964) that, in any one climatic zone, the Tribal Trust Land form of tenure will have the worst erosion—the overall picture is shown in Table II.

The survey carried out in part of the Mtoko Tribal Trust Land showed results in excess of this (Table III).

A special exercise carried out in Chilimanzi Tribal Trust Land involved the stereoscopic location of African huts in addition to the gullies, and there appears to be a direct relationship between gully intensity and population. The quality of the 1/25,000 scale stereo-cover was so good that, with 3-power magnification, it was even possible to identify small store huts less than 6 feet in diameter—used as granaries.

TABLE II

Degree	*Per cent of total area considered*	*Running total*
Nil	11	11
Slight	37	48
Moderate	35	83
Severe	13	96
Very severe	4	100

TABLE III (All figures are percentages)

Yards/1600 acres	*Mtoko*	*Selukwe*	*Mashaba*
0	0	0	0
- 2,999	1	25	38
- 6,999	10	49	45
-10,999	16	25	15
-18,999	34	1	2
-25,999	20	—	—
-32,999	13	—	—
33,000+	6	—	—
	100	100	100

The investigations showed that one-third of the population and one-third of the gullies occurred in the north of the area, and that the remaining two-thirds of the population and of the gullies were in the southern half. More research is being done to clarify this point.

From the work carried out so far it is probable that a relationship exists between population density, percentage arable and agro-ecological region which will enable a figure to be derived for the intensity of erosion likely to be found in any area. This factor, combined with analysed costs of catchment repair work at present being done in parts of Rhodesia, will make it possible to prepare more reliable overall figures than has been possible to date. Research into this aspect continues.

5. Critical Zone

In the arid areas of the U.S.A. maximum potential erosion occurs at 12 inches of rainfall. This is because, with little or no vegatation cover in these areas, there is nothing to hold the run-off in check when a storm does occur.

On a similar basis in Rhodesia—where the country has been divided into five Natural Regions based on climate and soil type[4]—field research by Keech (1964–5) has revealed that the worst erosion occurs in Natural Region III, the balance between rainfall intensity and vegetation cover being most critical in this Region.

A careful study of the gully overlays confirmed these research findings in respect of those areas of the catchments surveyed which fall within Natural Region

III. There are therefore sound reasons for supposing that the air-photo erosion assessment technique can justifiably be used as a confirmatory aid in the determination of critical erosion areas by more conventional methods.

6. Implementation

The Chiredzi Catchment in Rhodesia provides an example of gully reclamation work being implemented as a result of preliminary assessment on the air-photo cover. Here the stereoscopic examination revealed no spectacular gully erosion but only a general trend towards deterioration. Consequently, reclamation work is aimed at avoiding what would otherwise be a serious situation in 10–15 years' time.

The deteriorating erosion trend in Chiredzi is being checked by:

(a) Construction of contour ridges and storm drains on all arable land.

(b) Improving the standard of cropping with special emphasis on increasing the organic matter content of the soil.

(c) Constructing selectively spaced conservation dams for better water and livestock distribution and improved utilisation of grazing.

(d) Dip tank reclamation.

(e) Repairing what erosion exists—which in this catchment requires hand labour only—with 5 gangs of 20 labourers each, a tractor and trailer being assigned to each gang for carrying equipment.

7. Summary and Conclusion

Gully erosion in river catchments can be quickly and reliably assessed, and repair costs estimated, with the aid of good quality 1/25,000 scale aerial photographs—only the minimum amount of field reconnaissance being necessary.

By using the survey method described it is possible from a study of the aerial photographs and gully overlays, to:

(i) Identify erosion gullies as active or stabilised, measure their lengths, and classify them according to whether machine or hand methods are required to repair them.

(ii) Pinpoint erosion "black spots" that are yielding large volumes of sand to the rivers. This applies at both local and regional levels and includes the identification of solonetz soil areas.

(iii) Site and assess conservation dams for the threefold purpose of:

(a) Better utilization of grazing.

(b) Sediment detention.

(c) Increased distribution of water supplies and thus greater irrigation potential and improved human-and animal-carrying capacities.

(iv) Establish by convergence of evidence the critical Natural Region from the standpoint of erosion.

Selected field checks in the 2 million acres of Tribal Trust Land in Rhodesia so far surveyed in this way have fully confirmed the reliability of the information demarcated stereoscopically. In this connexion, by far the most important feature of the survey method is that—as only the stereoscopic delineation of physical terrain data is involved—the air photo-analysis can be done by conservationists having no previous ground knowledge of the area requiring examination *provided* they have been taught how to use a stereoscope properly. The method can therefore be successfully applied, not only in Rhodesia but in other parts of Africa,[5] in the Middle and Far East, and in the southern states of the U.S.A.[6]—where gully erosion is also a problem.

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Résumé

L'érosion du sol est un problème serieux dans les territoires tribales de la Rhodésie. Cette communication nous montre comment, sans aucun travail sur le terrain et munie des photographies de bonne qualité à 1 : 25,000, *la service de la conservation du sol pouvait s'informer sur l'étendue de l'érosion et de mettre en évidence les centres de danger.*