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THE PREDICTION AND ESTIMATION OF EROSION IN SUBTROPICAL AFRICA : PROBLEMS AND PROSPECTS

by

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RESUME

L'érosion des sols est un problème grave dans les régions subtropicales. Les facteurs d'érosion, seuls ou combinés, conduisent à des vitesses élevées de l'érosion qui dépassent de loin les niveaux tolérables. Certains de ces facteurs ont été analysés. Comme première étape dans la détermination des mesures de conservation appropriées, il est nécessaire de prévoir les vitesses d'érosion. Les méthodes actuelles de prévision, en particulier l'Equation universelle de perte des sols, ne conviennent pas ici à cause de la grande masse de données requises, le temps et l'argent nécessaires ainsi que les conditions différentes de l'environnement rencontrées en Afrique.

A la place de cette équation, une approche par étape est présentée qui tient compte d'une part, de la complexité du problème et d'autre part, de la nécessité de solutions immédiates. Là où cela est possible, comme dans le cas des récoltes, des classifications simplifient les variables en cause ou bien, comme dans le cas du pouvoir érosif des précipitations, une combinaison de facteurs peut être considérée comme une seule variable. On peut penser que c'est seulement par l'intermédiaire de ces types de mesures que le but ultime de la préservation des sols pourra être atteint.

Erosion prediction is an inexact science. There are a multiplicity of variables involved, some known but unmeasurable, some unknown, and a few that can be estimated within a reasonable degree of accuracy. Attempts have been made mainly in the United States to put erosion prediction on a sound quantitative footing, but the problems are formidable. In subtropical Africa the problems are compounded by the fact that not only are the countries developing and lacking in finance but also erosion is especially severe. It is worthwhile briefly to review some factors in erosion and their significance in subtropical Africa before turning to a suitable approach to prediction. Most examples will be drawn from Rhodesia but the principles are readily applicable to much of the tropics and subtropics of Africa.

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SOME RELEVANT FACTORS IN EROSION

a) Rainfall erosivity

Subtropical rainfall is notorious for its erosive power, termed "erosivity" (STOCKING, 1971). Not only are intensities generally higher but also the rainfall is concentrated into a short season with consequent increases of runoff and erosion. The distribution and nature of the erosive rain show that certain areas of intermediate rainfall have a very much higher erosivity per millimetre of rainfall than others (STOCKING and ELWELL, 1975a).

However, of greater significance is the interactive effect of vegetation cover and erosivity. In the zone of approximately 600-800 mm mean annual rainfall erosion is at a maximum because while total erosivity is certainly less than the higher rainfall areas, a far higher percentage of erosive rainfall is falling on bare ground due to the sparse vegetation cover. The existence of this critical zone of rainfall has been recognized not only for Rhodesia (STOCKING and ELWELL, 1975b) but also Tanzania (RAPP et al., 1972) and elsewhere (LANGBEIN and SCHUMM, 1958).

Of the total landsurface of Rhodesia, 56 percent is in the critical 600-800 mm rainfall zone and 83 percent in the subcritical 500-900 mm zone (Figure 1). More alarmingly, 95 percent of African farming areas are in this subcritical zone.

b) Soil erodibility

There are two important aspects with regard to the erodibility of subtropical soils ; first, the precise susceptibilities of the various soil types and second, the degree of damage to the soil of a unit quantity of erosion.

In the first instance, subtropical soils vary considerably in their erodibility. By themselves the large areas of granite sands that give medium to coarse sandy loams should be fairly stable. But in fact the high rainfall intensity and kinetic energy soon destroy the surface soil structure and sort the size components of the soil mass. This gives rise to capping in which the finer particles fill the pore spaces between the larger particles with the result that infiltration is seriously reduced. Sandy loams are particularly badly affected in this respect since a) they have a suitable range of size particles for effective capping (Table I) and b) they normally allow good penetration of water under natural conditions of rainfall and vegetation cover, and the relative effect of capping is, therefore, appreciable. As granite covers 60 percent of Rhodesia and the granite-derived sandveld soils are largely coincident with the areas of poor tribal farming, the importance of capping to the erosion processes must be emphasised.

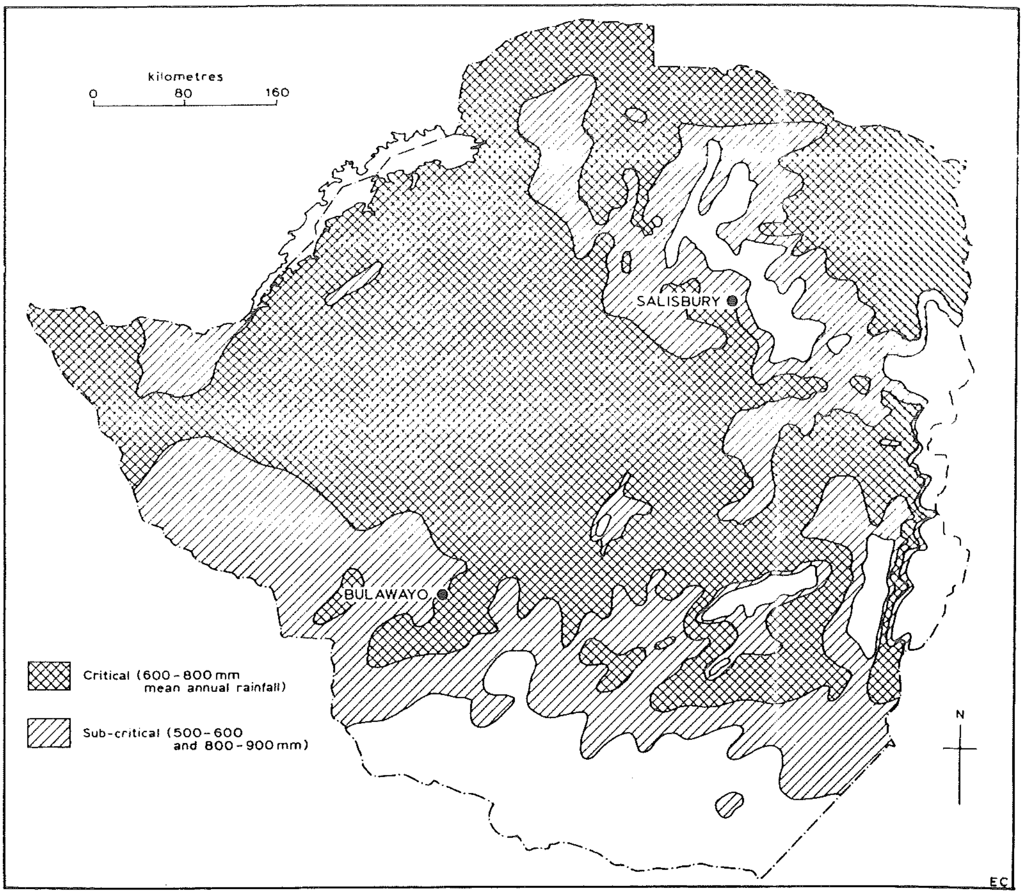

Fig. 1 : Critical rainfall zones for erosion.

Table I. Representative surface size fractions of soils derived from granite.

Area	Rutenga	Salisbury	Karoi	Maran-dellas	Bikita	Inyanga
Mean annual rainfall mm	405	840	865	915	1 525	2 540
C.S. °/o	21	35	5	41	20	18
M.S. °/o	22	30	14	20	18	22
F.S. °/o	43	24	57	13	24	35
Silt °/o	8	4	9	8	15	14
Clay °/o	6	7	15	18	21	11

Note : Coarse sand (C.S) 2,0 - 0,5 mm diam.
Medium sand (M.S) 0,5 - 0,2 mm
Fine sand (F.S) 0,2 - 0,02 mm
Silt 0,02 - 0,002 mm
Clay less than 0,002 mm

There are also several soil types derived from local conditions of parent material (e.g. basalt vertisols) and/or drainage (e.g. alkaline, sodium-rich soils) which present their own peculiar problems and high degrees of erosion susceptibility. The sodium-rich soils are very unstable to slight changes in land use and can cause extremely serious piping and gully erosion (STOCKING, 1975).

Erosion tolerance of subtropical soils is minimal. The finer fractions, silt, clay and organic matter, are the first to be removed, and it is these size ranges that are at a premium in most of the common soils. Therefore, the relative loss in fertility and the degree of damage to granite soils especially is very high even with comparatively small erosion losses. It is noticeable that silt, clay and organic matter contents in the lower rainfall regions are appreciable smaller than in the high rainfall areas (Table I).

As with tropical soils, it can be stated that subtropical soils are generally unstable to changes induced by cultivation and they require very careful handling. Decline in fertility and a consequent reduction of vegetation cover causing more erosion is a real and ever-present vicious circle in Africa.

c) Geomorphological factors

It has been shown that gully erosion is related to the average slope of the land (STOCKING, 1972). There are, however, some interesting local geomorphological factors that, when combined with human and natural factors, can cause significantly increased erosion hazard.

To illustrate this a comparison may be made of two common granite landscapes ; "castle kopje" or well-jointed granite forms, and "dwala" or massive granite forms (termed 'monolithic domes' by TRICART, 1972). A generalised catenal sequence of soils and vegetation on each is illustrated in Figure 2. Because of the nature of the bedrock and its influence on drainage, the 'dwala' catena has a higher water table than that on "castle kopje" granite. The soils, too, are adjusted to wetter conditions and the vegetation is considerably sparser. These factors combine to give higher erosion rates on the massive granites.

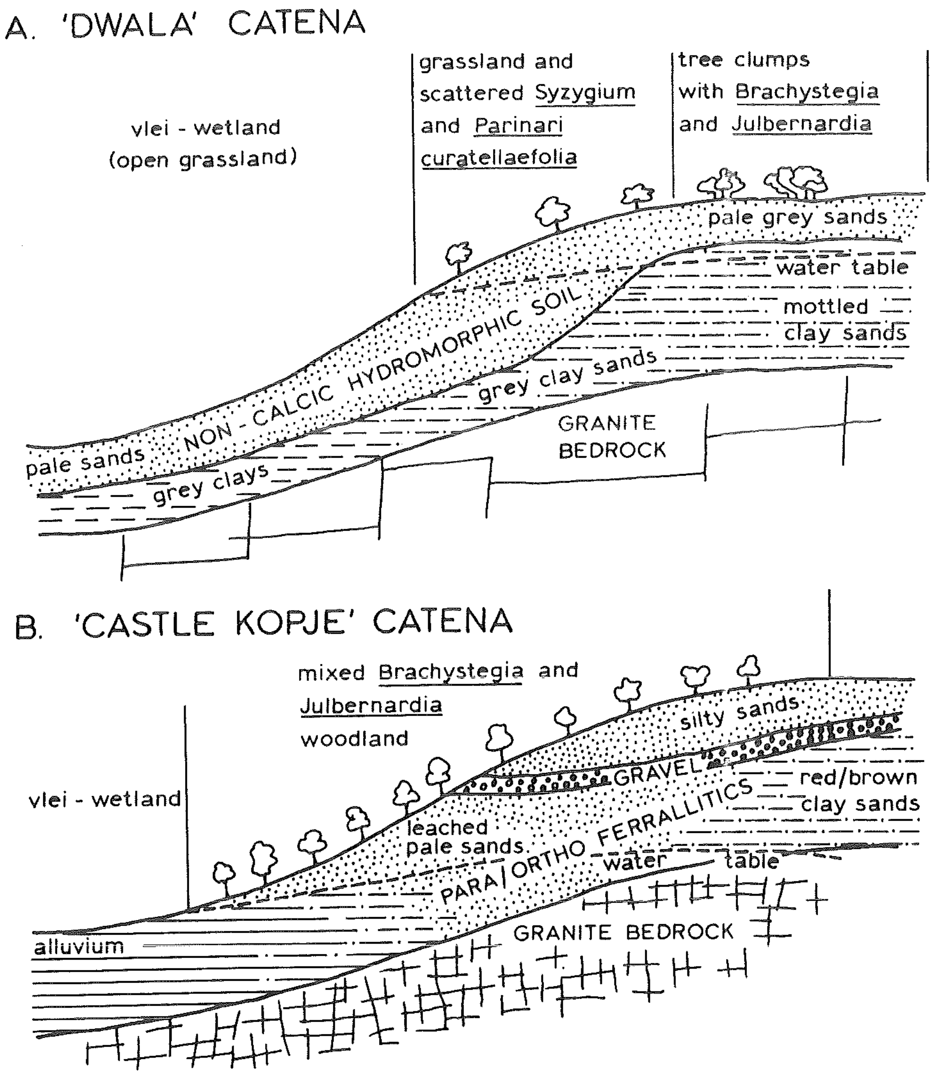

Fig. 2 : Contrasting granite catenas in the high rainfall (1000 mm) area : A. on massive granite and B. on well-jointed granite (after ELWELL, 1975 d).

It is interesting to note that the vegetation sequences are good indicators of the erosion susceptibility. For example, gullies will tend to form where there are no trees. This is not because there are no trees but because a common factor, the bad drainage, both promotes erosion and inhibits the growth of woody vegetation.

A further factor common to the subtropics is the extensive areas of bare rock, often associated with the massive granites again. Cultivation is necessarily confined to the soil covered areas on the pediments and adjacent to the stream lines, while the interfluves being bare are useless from man's point-of-view. Runoff from the interfluves is virtually instantaneous and, because of the build-up and timing of runoff, sheet and gully erosion can be very serious (Figure 3). Add to this the fact that in these very areas man is far more concentrated than official population figures might suggest because of the bare rock, then much damage may be caused. Parts of Mtoko Tribal Trust Land in Rhodesia are 60 percent bare rock. At a population density of 60 persons per square kilometre, this represents a density of 150 persons per usable square kilometre or approximately 0.7 hectares per person. Given the subsistence methods of cultivation and the dominance of traditional practices this is overpopulation that far exceeds the carrying capacity of the land.

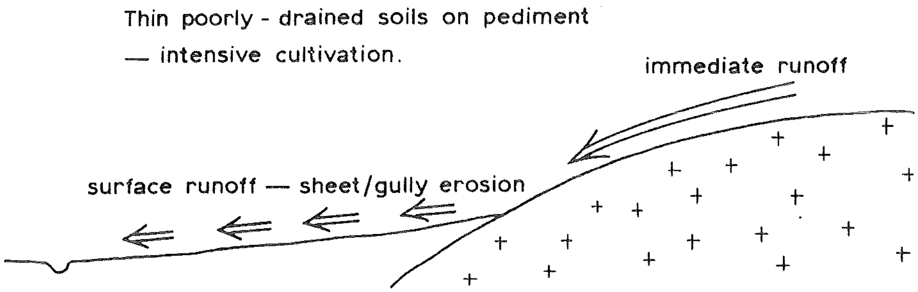

Fig. 3 : Concentration of runoff on pediment causes severe erosion on massive granites.

It can be seen then that erosion in the subtropics is a very real problem through the natural factors alone. When these are combined with human occupation of the land, problems are compounded and some of the highest rates of erosion in the world may be expected.

EROSION PREDICTION

Soil conservation has the aim of reducing erosion to so-called safe or tolerable limits. The concept of soil loss tolerance has been the subject of some debate but the safest and perhaps most rigorous definition of soil loss tolerance is that value which allows "the permanent preservation or improvement of the soil as a resource" (STAMEY and SMITH, 1964). Implicit in such a definition is a knowledge of the safe rate of erosion. Indeed research may well find that there is an optimum rate of erosion above which the soil resources are not being renewed fast enough, and below which there is an insufficient replacement of minerals. Soil conservation must, therefore, not only be able to calculate a tolerable rate of erosion but also predict erosion from the many and varied types of land use, thereby enabling the design of safe rotations and conservation schemes.

a) The 'Universal' Soil Loss Equation

The most comprehensive scheme for prediction is that of 'the United States' "soil loss equation" (WISCHMEIER and SMITH, 1965). The equation is the result of much knowledge and research accumulated over the years from the erosion experiment stations in the United States. In the equation soil loss is related to six factors that can be quantified for arable lands. In effect the equation isolates each factor and assigns a quantitative value to it which, when multiplied by the values for the other five factors, gives a direct value of soil loss.

The equation is in the form :

$$A = R \times K \times L \times S \times C \times P$$

where A is soil in tons per acre

- R is the rainfall erosivity ; measured by an energy-intensity parameter, EI_{30} (WISCHMEIER, 1962).
- K is soil erodibility ; a parameter that varies as soil loss occurring per unit of erosivity, R under specified standard conditions.
- L is slope length ; a ratio that compares soil loss from various slope lengths to soil from a standard slope length of 22.6 metres.
- S is slope steepness ; as for L with a standard steepness of 9 %
- C is crop management ; a ratio comparing soil loss from varied treatments to that from a standard cultivated bare fallow.
- P is conservation practice ; as for C with a standard absence of conservation.

In order to apply the equation, the values for each factor are found with reference to standard U.S. Department of Agriculture tables. When multiplied together the predicted rate of erosion, A, is derived. The object of the exercise is to limit the calculated value of A to the maximum acceptable soil loss. Since the equation contains four factors over which man has little control, the value of A must be brought down to a tolerable level by manipulating factors C and P. The application of the equation is in the making of recommendations to farmers on the type of crop, management and conservation practices to be used. HUDSON (1971) points out that there is no single absolute solution to the equation since the kind of recommendation might be a high value of P (no conservation) with low C (close growing, dense forage crops), or low P (terracing) with high C (cash cropping). Hence, farmer choice is still preserved within safe limits.

The equation and its application is undoubtedly elegant and has served the Conservation Service in the United States well, being based on over 10000 plot-years of data and accumulated field experience. There are, however, difficulties in applying the equation to other countries and to non-arable situations.

First, the equation depends upon a large quantity of data and research, the end product of an elaborate and long-term research programme. The requisite facilities, money and technical knowledge are just not available in developing countries.

Second, the Universal Soil Loss Equation has, for example, 60 values for C (crop management) for one crop, maize. These values reflect different types of tillage, rotations, fertility and general management. If one considers that farming techniques are more standardized and regular in the United States than in Africa, the number of values that must be measured for subtropical conditions become alarming. Data from the United States cannot be called upon since environmental conditions are out of the range of those measured in the U.S. and crop types, rotations and practices are also very different. Therefore the number of experimental plots with adequate replications that would need to be set up is astronomical. In Rhodesia one 10 x 30 metre plot with collecting tanks for soil and runoff costs approx. U.S. $ 1200 in materials and construction alone.

Thirdly, the usefulness of the equation largely depends on the value for tolerable soil loss, inserted as A in the equation in order to manipulate C and P, being a true and meaningful value. The levels adopted in the United States vary from 1 to 14 tonnes/ha/year (SMITH and WISCHMEIER, 1962). While these have the advantage that they can be achieved in practice, they may be at least an order greater than soil formation rates and natural erosion (ELWELL, 1975a).

Fourthly, and possibly of greatest importance, the Universal Soil Loss Equation as it stands lays little emphasis on man and man's influence through grazing systems. To illustrate the point, it is well known that a badly constructed contour bank is more hazardous than no bank at all. In Rhodesia the digging of contour banks is legislated for and under compulsion, perhaps with little understanding of the need for a bank, a tribesman is unlikely to construct a good one. How can this sort of human unreliability be quantified ? Difficulties of this nature are far more prevalent in primitive societies and it is these societies that most require the protection afforded by soil conservation and prediction facilities. Clearly the problem has to be tackled at its roots through education. But time is not on man's side.

b) Approach for the subtropics

It is imperative that some method be found for realising an easy and rapid method of soil loss prediction from limited data. The framework of the Universal Soil Loss Equation has been suggested by some (e.g. HUDSON, 1971). There is, however, a very real danger that the almost arbitrary assigning of numbers to an equation with a meagre data base will lead to serious cumulative errors. Indeed the attitude that 'any number is better than none at all' should be avoided. Rather, qualitative expressions will have to be employed which may be refined as and when data become available.

Through its Research Engineer, H.A. Elwell, the Department of Conservation and Extension in Rhodesia is working towards a programme for estimating soil loss and runoff in southern Africa (ELWELL, 1975b). The phased approach that is being adopted deserves consideration by other countries in and out of the subtropics.

The approach is based on four important considerations :

1. A developing country has limited resources. Programme must therefore depend less on expensive field measurements and more on simulation and model techniques.
2. The large number of variables in soil loss estimation are dynamic in both time and space. Experience in Rhodesia has shown that complex interactions between variables, especially vegetation, are important.
3. Immediate solutions are required in view of the continued rapid deterioration of soil resources.
4. Greater degrees of predictive accuracy will eventually be required because soil formation rates are known to be slow in the subtropics (OWENS, 1964).

These points can be accomodated in a programme of research which progresses from approximate solutions to more accurate ones, and which realises the limited finance available. A brief outline of the programme is given below.

In Table II six steps are recognised, progressing from the general to the specific. The *factor identification* stage is to define the boundaries of the study and decide on the farming conditions and practices which must be taken into account.

Because of the dynamic nature of the problem of soil loss estimation, it is obviously impossible to measure every variable and every permutation of variables. The important variables must be measured, but many can be grouped together in a pre-quantitative classification. The soils classification of Rhodesia (THOMPSON, 1965) is one such example that links common morphological, mineralogical and chemical characteristics of soils. By classifying as many factors as possible the number of variables and hence the complexity of the problem is reduced.

The development of indices is the next step in which one may begin to express the variables in quantitative terms. An early stage in this development is a soil erosion model (STOCKING, 1973) and the use of comparative indices to delimit areas of erosion hazard (STOCKING and ELWELL, 1973a). A soil erodibility index is another vital aspect requiring investigation in the subtropics. At present conservation is operating on a very general textural index which ignores the important rainfall stability and profile characteristics of soils.

Table II. Steps and applications in a research programme for erosion prediction (from ELWELL, 1975b)

Step		Application
1	Factor Identification	Education Research decisions
2	Pre-quantitative Classification	Reduction of number of variables
3	Development of Indices	Empirical design
4	Demarcation of Homogeneous Areas	Uniformity Priorities Finance
5	Field Measurements for Specific Farming Systems	Estimation equations
6	Resource Monitoring and Inventory	Resource planning and control

A move must now be made towards applying the detailed knowledge and information gained. In the demarcation of homogeneous areas, regions and sub-regions may be delimited where crops and agricultural enterprises are similar. Certain crops are suited only to certain soil types. Several practical advantages arise. It would be wasteful to assess erosion rates on crop and environmental conditions which do not occur in practice. Also, it is necessary to know how far data from one locality may be extrapolated to other localities. Areas within which geology, soils, climate, relief and farming practices are uniform within predetermined tolerances may safely be used as homogeneous areas for which data from a representative locality may be used. A further advantage is that it will be made clear which areas are more prone to erosion. This information will provide the basin for the determining of priorities and the concentration of limited physical conservation resources. Tobacco areas for instance present a great degree of uniformity and it is known that the crop is very dangerous as regards erosion.

Already this has been recognised as a priority (ELWELL, 1975c). Similarly, the mixed farming of tribal areas, cotton rotations and coffee may be delimited and their high erosion hazard rating emphasised and suitable conservation methods and prediction capabilities designed.

The final two steps in Table II of *field measurements and resource monitoring are* largely futuristic. They must be based upon the carefully planned information in the previous four stages. For example, there is little point in carrying out a full field programme in one locality only or under atypic conditions. Rather, soil loss and runoff measurements must be based on representative sites in each of the homogeneous areas. Estimation equations can be developed for the prediction of soil losses under the common conditions in each area and suitable protection systems designed to reduce soil losses to allowable levels. Advances have been made along these lines in predicting erosion from grazing lands(ELWELL and STOCKING, 1974).

Finally, it must be emphasised that soil loss estimation is a continuing exercise ; an exercise that requires constant refinement and adjustement as system variables change.

c) Some advances in prediction in Rhodesia

To date in the six step programme or research we have progressed at least to step 3, the development of indices, and on some fronts (for example, tobacco lands) preliminary estimation equations (step 5) have been calculated and put into practice. Two examples of the progress made will be discussed briefly.

A crop cover classification has been adopted on the evidence that percent vegetal cover is a major factor influencing erosion hazard (STOCKING and ELWELL, 1975 ; ELWELL and STOCKING, 1975b). Percent vegetal cover has been adopted as a suitable and useful quantitative expression for soil loss estimation equations. It has the very real advantage over the "cropping-management factor" of the Universal Soil Loss Equation in that the influence of the crop can be assessed independently of the other factors. Also different crops but ones with similar growth and rooting characteristics can be grouped together. For example, tall upright crops such as maize, sunflowers or sugar cane can be linked initially into one category. Refinements can be added later.

Another advance has been in the field of rainfall erosivity parameter identification (STOCKING an ELWELL, 1973b ; ELWELL and STOCKING, 1975a). Previous erosion experiments were extensively used to discover the parameters that best describe the erosivity of rainfall under a variety of environmental conditions. It was found that the best parameter varied according to soil type, vegetation cover, management conditions and, to a minor extent, slope. Many of these variations can be rationally explained in terms of the effect of say, crop or soil type on the erosive power of rain. Indications are that various measures of rainfall erosivity might be employed to combine many of the interactive effects at the air/soil interface. This will considerably ease erosion prediction by limiting the number of variables and it holds considerable promise as a short-cut method towards a composite erosion prediction model.

CONCLUSION

The prediction of soil erosion is the basis of the design and implementation of soil conservation practices. Prediction must advance from the present ad hoc methods in most countries of Africa to the more rigorous and soundly-researched ways. This is because the factors in erosion both natural and human are often critical in the subtropics.

For reasons of time, cost and practicability, the American Universal Soil Loss Equation is not suitable. Instead a phased approach where emphasis is placed on factorization and progressive development as finance becomes available is considered a better alternative. An important advantage is that by expressing the variables as comparative indices immediate use can be made of the meagre data. Advance can then steadily be made from approximate to more accurate and detailed solutions.

The problems of dealing with a subject in which the variables are not always understood and the interrelationships are often obscure are many. The prospect is one of slow and steady progress towards the ultimate goal of fully computerised complex estimation techniques linked to the much wider concept of resource management. Whether this goal is attainable time only will tell but meanwhile it is imperative that farming and especially tribal agriculture systems should be able to benefit immediately from the fruits of erosion prediction. The critical situation is such that only if this short-term objective is realised will the soil resources for the long-term be preserved.

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REFERENCES

ELWELL, H.A. (1975 a).- Conservation implications of recently determined soil formation rates in Rhodesia. *Rhodesia Science News*, v. 9 pp. 312-313.

ELWELL, H.A. (1975 b).- Programme for estimating soil loss and runoff in Southern Africa. *Department of Conservation and Extension, Salibury, Rhodesia, Research Bulletin*, n° 17,

ELWELL, H.A. (1975 c).- Estimate of annual soil loss and runoff from tobacco lands. *Department of Conservation and Extension, Salisbury, Rhodesia, Research Bulletin*, n° 18.

ELWELL, H.A. (1975 d).- Geomorphological factors and on-site indicators as aids to soil surveys. *Rhodesian Engineer paper*, n° 169.

ELWELL, H.A. and STOCKING, M.A. (1974).- Rainfall parameters and a cover model to predict runoff and soil loss from grazing trials on the Rhodesian sandveld. *Proceedings of the Grassland Society of South Africa*, v. 9, pp. 157-163.

ELWELL, H.A. and STOCKING, M.A. (1975 a).- Parameters for estimating annual runoff and soil loss from agricultural lands in Rhodesia. *Water Resources Research*, in press.

ELWELL, H.A. and STOCKING,M.A.(1975 b).-Vegetal cover to estimate soil erosion hazard in Rhodesia. *Geoderma*, v. 15, in press.

HUDSON, N.W. (1971).- Soil Conservation, Batsford, London.

LANGBEIN, W.B. and SCHUMM, S.A. (1958).- Yield of sediment in relation to mean annual precipitation. *Transactions of the American Geophysical Union*, v. 39, pp. 1076-1084.

OWENS, L.B. (1974).- Rates of weathering and soil formation on granite in Rhodesia. *Unpublished report, University of Rhodesia, Salisbury.*

RAPP, A., MURRAY-RUST, D.H., CHRISTIANSSON, C. and BERRY, L. (1972).- Soil erosion and sedimentation in four catchments near Dodoma, Tanzania. *Geografiska Annaler*, v. 54 A, pp. 255-318.

SMITH, D.D. and WISCHMEIER, W.H. (1962).- Rainfall erosion. *Advances in Agronomy*, v. 14. pp. 109-148.

STAMEY, W.L. and SMITH R.M. (1964).- A conservation definition of erosion tolerance. *Soil Science*, v. 97, pp. 183-186.

STOCKING, M.A. (1971).- Soil erosion problems in Rhodesia. *Journal of Soil and Water Conservation*, v. 26, pp. 239-240.

STOCKING, M.A. (1972).- Relief analysis and soil erosion in Rhodesia using multivariate techniques. *Zeitschrift für Geomorphologie*, v. 16, pp. 432-443.

STOCKING, M.A. (1973).- Towards a model of soil erosion - an example from Rhodesia. *South African Geographer*, v. 4, pp. 253-257.

STOCKING, M.A. (1975).- Tunnel erosion. *Rhodesian Agricultural Journal*, in press.

STOCKING, M.A. and ELWELL, H.A. (1973 a).- Soil erosion hazard in Rhodesia. *Rhodesia Agricultural Journal*, v. 70, pp. 93-101.

STOCKING M.A. and ELWELL, H.A. (1973 b).- Prediction of subtropical storm soil losses from field plot studies. *Agricultural Meteorology*, v. 12, pp. 193-201.

STOCKING M.A. and ELWELL, H.A. (1975 a).- Rainfall erosivity over Rhodesia. *Transactions of the Institute of British Geographers*, in press.

STOCKING, M.A. and ELWELL, H.A. (1975 b).- Vegetation and erosion ; a review. *Scottish Geographical Magazine*, in press.

THOMPSON, J.G. (1965).- The soils of Rhodesia and their classification. *Governement Printer, Salisbury.*

TRICART, J. (1972).- Landforms of the humid tropics, forests and savannas. Longman, London.

WISCHMEIER, W.H. (1962).- Storms and soil conservation. *Journal of Soil and Water Conservation,* v. 17, pp. 55-59.

WISCHMEIER, W.H. and SMITH, D.D. (1965).- Rainfall erosion losses from cropland east of the Rocky Mountains. *U.S. Dept. of Agriculture. Agricultural Handbook,* n^{o} 282, 47 p.

DISCUSSION

G.E.K. Ofomata :

1) How long have the rotational systems for tobacco lands been tried ?
2) Why are rainfall parameters considered the most significant ?
3) On the question the soil being unstable, our experience in Southeastern Nigeria shows that it is the stability rather than the instability of the soil that is important in explaining certain aspects of soil erosion. Our analysis showed an I_s (stability index) everywhere less than 1 (unity) which is the critical level for structural stability of the soil. It was found that it was rather structural stability of the soils in parts of South-eastern Nigeria that the responsible of maintaining the gullies once initiated as sheet wash is then incapable of keeping pace with downward incision of the surface by concentrated run-off.

M.A. Stocking :

1) For about 8 years.
2) Rainfall parameters were not considered the most significant. I did, however, make the point that the use of different rainfall parameters for varying environmental conditions of cover, soil and slope may be a possibility in order to reduce the number of variables. We have found that the best rainfall parameter on individual fields varies according to the cover.
3) I cannot comment on indices of stability or instability since we have been dealing primarily milk agricultural lands. Indices of erodibility that hold most promise are the percentage of water stable aggregates of certain sizes, but more work needs to be done on this.

J. Savat : Can you prove that the percentage of vegetal cover is more important than the rooting system in making the crop classification ?

M.A. Stocking : There is no absolute proof that percentage cover is more important, but all our experiments have shown a very significant relationship between cover and erosion. Rooting characteristics may be important for some crops that have extensive surface systems, but this is taken into account in the crop classification.

I. Douglas : When you applied the concepts derived by Langbein and Schumm in the United States, what corrections, if any, to their effective precipitation values did you make to ascertain the range of precipitation associated with maximum erosion hazard in Rhodesia ?

M.A. Stocking : We use our own figures in determining the precipitation associated with maximum erosion hazard. These were derived from experiments at different localities and also the results for single years at the same locality, so that a range in annual rainfall could be obtained. As far as we can ascertain our results are similar to those of Langbein and Schumm given effective precipitation values and correction for temperature.