Approaches to controlling erosion in rural areas

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Abstract. The intensive utilization of rural areas for the settlement of expanding populations and for the increased production of food and timber can lead to acute sediment erosion problems when careful planning is not implemented.

The conservation of soil resources, while at the same time permitting their maximum development for man, calls for research which integrates all the factors relating to the sediment problem in entire basins, followed by the application of research knowledge at the local and regional level. Considerable experience already exists on practical measures which may be used to control erosion, including vegetation management, land use and physical control structures. To be effective, conservation measures must be based on an understanding of all factors involved, human as well as physical.

Les mesures pratiques à appliquer pour contrôler l'érosion des zones rurales

Résumé. L'utilisation intensive des zones rurales pour l'installation de populations en expansion et pour la production accrue des produits alimentaires et forestiers peut provoquer des problèmes aigus d'érosion et de sédimentation si la planification n'est pas établie avec soin.

La conservation des ressources en sols, tout en permettant leur mise en valeur maximale pour l'homme, nécessite des recherches intégrant tous les facteurs qui affectent les problèmes de l'ensemble du bassin versant, auxquels fait suite la mise en œuvre des résultats de la recherche tant au niveau local qu'au niveau régional. De vastes connaissances existent déjà sur les mesures pratiques qui peuvent être appliquées pour contrôler l'érosion, y compris l'aménagement de la végétation, l'utilisation des terres et les structures de contrôle mécanique. Pour être efficaces, les mesures de conservation doivent être fondées sur une compréhension de tous les facteurs en jeu, tant humains que physiques.

THE RURAL SEDIMENT EROSION PROBLEM

The sediment problem may be defined as the detrimental depletion by erosion and transport of soil sources from land surfaces and the subsequent accretion by deposition on other land surfaces, in river channels, irrigation systems, lakes, reservoirs and coastal areas. Sediment erosion, transport and deposition are natural processes which are altered, usually for the worse, by land use changes aimed at increasing food, water or other economic yields from land resources. Wind and water are the dynamic agents in sediment erosion and transport, and of these, water is in most cases the dominant influence. Wind erosion will not be considered further in this paper.

When making quantitative studies of the sediment problem in a river basin, the total catchment area must be considered, both in terms of the physical characteristics (topography, vegetation, soil type and land use) and in terms of the hydrology of the region, including time-variable rainfall and energy inputs, and evaporation, infiltration, overland flow, channel and reservoir flow routing, and diversions into and out of the system.

A BRIEF THEORY OF SEDIMENT MOVEMENT

Practical and theoretical studies of the components of the hydrological and sediment response of catchments have served to illustrate the complexity and interaction of the processes rather than providing an integrated approach for quantifying the problem.
Sediment moves from land surfaces into rills, gullies and river channels as sheet wash suspended in overland flow, and as mass movements usually triggered by intense rainfall. Rain falling on the land surface loosens sediment grains. The detachability of these sediments is related to the energy of the raindrop impact, the grain size and the cohesion of the soil surface. Grain size may be defined by measurement and related to soil type classifications. The energy of raindrop impact will be dependent on the amount and intensity of the rainfall which in turn is affected by the canopy density and type of vegetation cover. Cohesion of the soil surface is dependent on the vegetation and on land use such as ploughing, grazing, engineering works and other surface disturbances.

The transport of detached sediment by overland flow will be dependent on the magnitude and frequency of occurrence of this flow. Overland flow forms when rainfall reaching the ground is in excess of the infiltration capacity, and hence factors affecting infiltration capacity have an effect on this form of soil transport. It should be emphasized that although sheet wash is considered to be an important form of erosion, it can in some regions be less than the erosion by landslides, mud flows and other mass movements. This is illustrated by an example from the Mgeta area of the Western Uluguru mountains in Tanzania (Temple and Rapp, 1972). Here a single storm on an area of 20 km$^2$ caused an estimated 270,000 m$^3$ of the soil to erode by landslide activity in a 3-h period compared to an estimated 10,000 m$^3$ of soil due to sheet wash over a period of 4 years.

Existing theories on land surface erosion have concentrated on developing empirical sediment yield relations which account for the dominant factors affecting movement. The best example is the universal soil loss equation (Wischmeier and Smith, 1960) where soil loss is related to rainfall energy, soil erodibility, farming practice, cropping management and topography. This equation was intended for use on individual field plots, but was later modified for use on catchments in the Blacklands of Texas (Williams and Berndt, 1972). Other soil erosion and soil splash equations have been developed. Each of these methods however ignores the fact that soil erosion is a dynamic process variable in time and from one zone to another within a region (Fleming and Fahmy, 1973). In addition, they are not easily applied to other regions with different climatic, hydrological and land surface characteristics.

In much the same way as the components of soil erosion have been studied, theories on the components of sediment transport in rivers and deposition in reservoirs have been developed. The majority of this development, however, has taken place in isolation divorced from the theories governing the sources of sediment supply. The tractive force and regime theories of bed sediment transport have been reviewed (ASCE, 1971). The conclusions of the review stated:

'It is clear that bed sediment discharge formulae cannot be expected to give precise results.'

'It is recommended that calculations with formulae be based on observed stream characteristics such as slope, depth, velocity, bed material size . . . and temperature whenever possible. Also, if reliable sediment discharge quantities are essential, they should be based on suspended load samples and estimates of unmeasured sediment discharge . . .'

The 'unmeasured discharge' may be quite high in some cases — for instance the bedload movement in mountain torrents. However where direct measurement is not possible indirect means may sometimes be used to arrive at estimates of sediment discharge — for instance reservoir sedimentation or historical evidence of landslides.

Much of the difficulty with sediment transport formulae lies in the inability to assess sediment supply from contributing land surfaces. For example in the River Clyde in Scotland (Fleming, 1969), estimates of sediment bedload transport from
formulae gave a range of 100–10,000 tons/h of sediment at a flow of 283 m$^3$/s, compared with a measured load of 0.2 tons/h. This specific case arises from lack of sediment supply due to a variety of reasons, but highlights the fact that formulae assess the hydraulic transporting capacity of a river without considering the quantity of detached sediment actually available for transport. It should also be emphasized that once severe erosion has been initiated, much of this material deposits on valley floors. Although the extreme floods capable of moving this surplus storage may have a recurrence interval of once in 100 or 1000 years, when they do occur this material is a major source of supply. Hence even the best conservation techniques may not solve the river transport and sedimentation problem of the future. Erosion that has already taken place on large areas of the land surface guarantees the long-term nature of the sediment problem. River basin planning, therefore, should take this into account.

The approach of developing mathematical models for hydrology is also relevant to the subject of sediment erosion, transport and deposition. Several models are being developed (Foster and Meyer, 1972; Fleming, 1972) and offer a method for total catchment analysis of both the hydrology and sediment processes and for estimation of water and sediment yields.

MAN’S INFLUENCE ON EROSION AND POSSIBLE CONTROLS

In rural areas the activities that affect the erosion process include: deforestation to clear land for agriculture; overgrazing and stock movements on grasslands; unsuitable cropping practices; ill-planned drainage; and uncontrolled forest and grassland fires. A wide range of conservation measures is available for controlling soil loss under these different conditions. However it is essential that the conservation techniques to be employed be related to the entire region both in terms of their social, economic and political impact and in their overall effect on the natural sediment processes. They must also take account of the feasibility of implementation since many soil conservation plans have failed due to resistance by farmers and peasant communities.

An example of the effect of the human factor was the failure of the Uluguru land usage scheme introduced by the colonial administration in that area of Tanzania between 1945 and 1955 (Temple, 1972). Although the unsuitability of some of the measures which were introduced contributed to the scheme failure, the main reason was resistance by the local people for political reasons and because of the threat the scheme appeared to pose to the traditional social and cultural system of land ownership. Human obstacles to land and water development can take many forms (Finkel, 1973) and though often more important than the physical problems they have in the past been frequently ignored. The approach of understanding the human cause of an erosion problem and attempting to meet the legitimate interests of the people at the same time as introducing conservation methods is illustrated in a Forest Development Plan in Korea which notes that ‘the destructive methods for collecting fuel, fodder and composting materials are the primary reasons for the unproductive and eroding forest lands’. Under the plan, the needs of the villagers for fuel are recognized and highly productive village fuelwood forests are proposed which combine timber trees and fuelwood species. This combination gives a ‘simple and inexpensive way to produce an annual crop of fuel, an annual income from the sale of seed, and a substantial periodic income every 8 to 10 years from the sale of timber’ together with good soil conservation (FAO/Korean Government, 1973).

CONCLUSION

Basically all analytical methods for sediment yield assessment are dependent on the data available. The trend still continues to develop simple empirical theories to suit
limited data or no data and then to justify the use of these theories. Rather the theories relating to sediment movement should be integrated, using the most advanced technical knowledge available and researching into the subject where gaps in our knowledge exist. An example of this approach is found in an FAO land and water conservation project in a Mediterranean climate zone, where a study has been proposed that would have two parts: (a) a study at research level by mathematical model analysis of hydrological and sediment erosion processes in research areas which typify major climatic, geographical and land use conditions and (b) the application of the model to regional problems, using the response parameters derived from the research areas. At the same time a programme would be initiated for the collection of the additional data required for the model input and calibration in the research areas, and for its wider application at the regional level.

Research data needs should be assessed on the basis of accuracy of prediction required to solve the complex total catchment sediment problem with as complete an understanding of the hydrological, social, environmental and economic implications of the problem as is possible within the constraints of manpower and finances available. For regional application, surveys should be made to classify the population distribution, land use, vegetation, topography, soil and geological conditions, hydro-meteorological data networks established to collect information on rainfall, stream-flow and sediment transport, and experimental areas chosen which represent the range of soil erosion, transport and deposition characteristics of the region. Such data collection programmes should be established on a long-term basis. Parallel to the physical assessment of the sediment problem lies the need to evaluate the social, cultural, environmental and economic impact of proposed conservation measures. An essential requirement for a conservation programme to be successful is its willing adoption by the rural population concerned.

In addition to the research and field application described above, an interesting activity which FAO is undertaking, in cooperation with the UN Environment Programme and other international organizations, is a world-wide inventory of soil degradation in all its forms of which the main one is soil erosion. This inventory will be essentially based on the FAO/UNESCO soil map of the world and the wealth of soil information gathered during its compilation. Estimates will be made, and shown on maps, of the present status of soil degradation and of the hazards of further resulting from changes in land use. Specific recommendations for soil conservation adapted to the conditions prevailing in representative ecological zones will also be made.

REFERENCES


