

An aerial photograph showing a team of eight workers in orange safety gear and hard hats wading in a muddy river. They are using long-handled tools to collect sediment samples. Several blue and white buckets are scattered in the water, and a white equipment case is also visible. The riverbank is lined with green trees and shrubs.

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Of Sediments In  
Developing  
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A Socioeconomic  
Perspective**

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An aerial, black and white photograph showing a group of about ten workers in a riverbed. They are wearing hard hats and safety vests. Some are using long-handled tools to dig or measure in the mud. There are several buckets and a box on the ground. The riverbed is wide and shallow, with some vegetation on the left bank.

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# **THE MANAGEMENT OF SEDIMENTS IN DEVELOPING COUNTRIES: A SOCIOECONOMIC PERSPECTIVE**

## **Introduction**

1.1 Managers in developing countries see with astonishment that sedimentation rates are increasing to such an extent that very expensive national assets are deteriorating day by day and, in addition, that no effective action is being taken to remedy the situation (either by the private or public sectors). Sedimentation management involves a complex set of activities. Past approaches have been mainly “technical” in nature, in spite of the fact that the decision to produce one more unit of sediment (as a by-product of other economic activities) depends on economic and social factors.

1.2 An important management decision is the selection of investment programs either to reduce the rate of sedimentation or to mitigate the private or social costs which result from such levels of sedimentation<sup>1</sup>. The investment selection process is very complex since economic or technical considerations are not the only ones taken into account. Political and social factors

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<sup>1</sup> It is important to recognize, however, that there are positive effects of sedimentation, although this paper focuses on the negative ones.

are usually of prime importance. On purely economic grounds, however, those selecting and appraising projects are confronted with three main problems: (a) identification of benefits and costs, (b) assignment of monetary values to benefits and costs, and (c) introduction of intergenerational equity considerations. Because of the complex and vast nature of these problems, this paper touches very briefly on (a) and (b). For an expanded treatment, see Sfeir-Younis (1984).

## **II. Magnitude of the Problem and Typology**

2.1 A large number of dams in the world are literally becoming “sand boxes”. Actual rates of sedimentation are so high that the objectives for which these dams were designed for (e.g., generation of hydropower, control of floods, supply of water for downstream irrigation and drinking water) will, in the near future, be very difficult to accomplish.

2.2 Let us illustrate this problem using data from Mermel (1981), who presents information on the largest dams of the world (e.g., data on construction, capacity created). By grouping this information on a “decade” basis since 1940, three important tentative conclusions may be drawn, all of which have specific

implications with regard to sedimentation management.

2.3 First, the number of dams is declining over time, which suggests that readily available dam sites (an irreversible asset) are declining. If this trend is to continue, countries urgently need to put in place comprehensive sedimentation management policies to avoid severe limits to growth, or to deal with development options that are prohibitively expensive. Second, the capacity created by these dams is always increasing (at a faster rate) since 1940. This suggests that the fewer dams constructed in the last decades are larger than ever before. Furthermore, if there is a correlation between the capacity created and the size of the respective catchment areas, it also suggests that management schemes would be dealing with larger numbers of people (due to population growth), climatic and geographic factors, and diverse socioeconomic conditions; i.e., management may become more complex and probably intractable. And third, the world will lose vital productive capacity by the year 2000 if no action is taken now. If one assumes that sedimentation rate affects only two percent of the live capacity, the world would lose approximately one-third of the total dam capacity. If one assumes that sedimentation will affect one, two, three and four percent (in each decade since 1940) the world will lose approximately two-thirds of the

available dam capacity<sup>2</sup>.

### **III. Sedimentation Management**

3.1 Sedimentation management has been conceived of as a set of technical activities (e.g., predicting sediment loads, designing facilities). The economic and social dimensions have seldom been taken into account. Thus, interventions have been totally fragmented.

3.2 Such economic and factors as deforestation upstream and intensive cultivation of poorly managed lands, greatly influence the level of sedimentation downstream. In addition to those, management has to consider organizational, institutional and legal factors.

3.3 The fragmented approach is also due to the many ways scientists define the sedimentation problem (e.g., as a geologic erosion problem, hydrologic, dam design, or environmental problem).

3.4 To avoid fragmentation, all the abovementioned factors should be framed into a Sedimentation Management Matrix (SMM), considering the total catchment as a “unit of account”. This approach

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<sup>2</sup> These estimates are now subject to revision.

will allow planners to define and evaluate “standards” (e.g., sedimentation rates, erosion rates, water quality), to establish an integrated planning framework, and to set realistic and effective policy options.

#### **IV. Sediments as a Natural Resource**

4.1 In a simplified way, sediments may be considered a “natural resource” since their production is a by-product of mining the soil. If one focuses on the negative effects of sediment production, transport and deposition, several characteristics of this natural resource are worth noting: (i) sediments are very abundant; (ii) the stock has more value in situ; (iii) extraction costs are very low; (iv) sediment “production” is carried out by a set of agents while it is “consumed” or “stored” by other units in the economy, (v) sediments are seldom traded in the market and (vi) sediments are mobile.

4.2 If such characterizations reflect, at least in part, the nature of sediments, the implications for management are many. First, it will require adopting management policies that will affect both the producing and consuming units. Second, managers

will have to look at the catchment area as a whole rather than in a fragmented way. And third, it will require seeking appropriate water and land management policies.

## **V. Investments: Identification and Valuation of Benefits**

5.1 The failure to adequately identify the benefits of investments that will affect sedimentation is mainly due to the lack of understanding of the nature of the natural systems involved. Experience shows that in most instances these projects have a very low economic rate of return (ERR) because not all the benefits were accounted for. In this case a typology of sedimentation effects is essential. The proposal here is to classify these effects as “upstream”, “midstream”, and “downstream” effects. While the sedimentation of dams is an example of downstream effect, the destruction of farm terraces, roads and bridges are an example of the other two, respectively.

5.2 Even if all the benefits have been identified, economists still face the problem of valuation: how to assign monetary values to these benefits in order to estimate the ERR of those investments. Traditional Benefit Cost Analysis (BCA) is very limited and to

deal with this type of project, it will be necessary to “extend” BCA. The proposal here is to follow three basic steps: (a) conceptualizing sediments terms of their “characteristics” (e.g., volume, size, shape, chemical content) instead of as a “commodity”; (b) establish a clear relationship between changes in these characteristics and changes in productivity of tradeable commodities (e.g., via net income, profits, total cost, marginal cost, inputs cost); and (c) assess these changes in economic terms using the economic prices and values of the tradeable commodities affected (e.g., irrigation costs, replacement costs, income foregone). Let us illustrate this conceptual framework with two examples.

5.3 The first example assumes that an increase in sedimentation will only affect the volume of water that could be stored in a dam, and that, the cost of a sediment control project are well known. In this case, one has to establish a relationship between volume of sediments (a characteristic) and the economic activities performed by the facility. If it is hydropower, irrigation downstream or water supply, less will be produced. Thus, less water will probably mean a lower production level of such tradeable commodities as electricity, food crops or drinking

water. The benefits (or a proxy for benefits) will be the economic value of these tradeable commodities.

5.4 The second example assumes that the chemical content of sediments (another characteristic) affects the quality of water stored in the dam. A technical relationship between different levels of water quality and the production of tradeable commodities that use water as an input, is to be established. In particular, lower water quality may result in higher water treatment costs for drinking water. The cost avoided due to the sedimentation control project is a proxy for benefits.

## **VI Major Issues in Sedimentation Management**

6.1 From an economic point of view, there are many technical, economic, organizational, institutional and policy issues in sedimentation management. A brief outline of main issues follows.

6.2 Technical Issues. First, measuring sedimentation effects-how to define the appropriate metric in which to measure sedimentation. Second, relating sedimentation with changes in

productivity--how traditional notions could be reformulated to link changes in sedimentation rates and economic productivity. Third, sedimentation effects are non-uniform--how can analysts develop a framework to account for the heterogenous effects of sedimentation? Fourth, episodic nature of sedimentation--how one can account for random effects caused by changes, for example, in climatic or hydrologic factors. Fifth, assessment of sedimentation prevention practices--how to adequately predict the effectiveness of sediment prevention and relate these practices to productivity. Sixth, attribution of benefits and costs--how much of the total sedimentation is man-made and how much is geologic or hydrologic. And seventh, availability of data--how much data is enough (cross section as well as time series data).

6.3 Economic Issues. First, the interdisciplinary nature of the sedimentation phenomenon--how to integrate technical frameworks with economic methods and procedures. Second, appraisal of sedimentation management efforts--how to extend BCA to assess the most effective policies and investments to control sedimentation. Third, development of practical measures--how to define cause-effect relationships. And

fourth, the uniqueness of sediment control projects--how to deal with externalities, distributional impacts, monetary valuation, intergenerational equity and irreversibility.

6.4 Organizational Issues. First, the role of government--how to avoid fragmented public interventions and integration sedimentation management with development planning. Second, research and extension--how to improve research and, thus, generate the necessary data for technical and economic analysis, and how to change the production approach of extension to a conservation approach (or both). Third, monitoring and evaluation--how to improve the collection and processing of data in such a way that managers can make effective decisions and be able to adequately evaluate their programs. Fourth, farmers' participation--how to create awareness of those located upstream. And fifth, coordination among international donors--how to rationalize foreign aid among those who have programs upstream, midstream and downstream in the catchment.

6.5 Institutional Issues. First, tenancy--how to change existing tenancy systems to avoid high erosion rates upstream. Second, property rights--how to assign rights (to land) to create enough

incentives for farmers to adopt conservation policies. Third, availability of credit-how to avoid capital constraints in areas where rather expensive investments are needed. And fourth, legislation-how to enact laws, rules and regulations that not only sanction those who produce more sediment but also create incentives to conserve the soil.

6.6 Policy Issues. First, establishment of priorities and standards-how to develop a framework that provides the elements necessary to identify and assess standards that are acceptable to most agents locate in the catchment or that will benefit from or are affected by changes in sedimentation rates. Second, sedimentation versus macro-economic management-how to assess the major trade-offs between higher rates of sedimentation and existing food, export and many other short-term macro-economic objectives. Third, sedimentation management as an income policy-how to create awareness in policy makers that changes in land use practices (particularly of low income farmers) has to be accompanied with sound income policies. Fourth, sedimentation and the energy dilemma-how to avoid high rates of sedimentation when rural people are in great need of fuelwood. Fifth, demographic dimensions-

how to integrate demographic factors (population pressure on the land) with sedimentation management policies and projects. Sixth, distribution of wealth--how sedimentation management schemes should take account of distributional effects between generations, different economic agents, producers and consumers, among farmers, and farmers and operators. And seventh, investment priorities and technology policies--how to allocate scarce investment funds to an array of financially expensive activities, including the development of land saving techniques.

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