Journal of Management Science and Career Development
April, 2025 Editions
www.ssaapublications.com
JMSCD
Vol.8, No.7, E-ISSN 3027-0405
P-ISSN 3027-1010
Sahara African Academic

THE ECONOMICS OF GULLY EROSION CONTROL: A REVIEW OF COST-BENEFIT ANALYSIS APPLICATION IN GULLY CONTROL PROJECT PLANNING IN GOMBE METROPOLIS

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DOI: https://doi.org/10.70382/sjmscd.v8i7.032

ABSTRACT
This paper reviews the economic dimensions of gully erosion control, focusing on how economic models particularly cost-benefit analysis and cost-effectiveness analysis can inform project planning and resource allocation. A desk-based literature analysis was conducted to examine the costs of gully erosion, various control methods, and the frameworks used to assess their impacts. Key economic concepts such as the economically optimal level of erosion, on-site versus off-site effects, and direct versus indirect impacts are discussed. The review highlights the importance of comparing mitigation measures not only on physical effectiveness but also on financial return, ensuring that control costs remain below avoided erosion costs. Finally, guidelines are proposed for integrating both tangible and intangible effects into comprehensive economic assessments to support policymakers in selecting the most efficient gully control strategies.

Keywords: Economics, Gully, Erosion, Cost-Benefit, On-site, Off-site.

INTRODUCTION
Economic Models and Analysis refers to the use of mathematical and conceptual frameworks to study and understand economic phenomena. Economic models are simplified representations of real-world economic systems that help economists analyse and predict economic behaviour, relationships, and outcomes. These models typically involve a set of assumptions, variables, and

equations that capture the key economic factors and their interactions. The primary purpose of economic models is to provide insights into complex economic phenomena and facilitate decision-making. They allow economists to explore cause-and-effect relationships, predict the impact of changes in various factors, and evaluate the consequences of different economic policies and interventions (Hussain, 2023)

Economic analysis, on the other hand, involves applying these economic models and tools to examine and interpret real-world economic data and events. It involves the use of statistical techniques, mathematical tools, and empirical methods to test economic theories, estimate relationships, and derive meaningful conclusions from economic data. Economic models and analysis are essential in microeconomics, as they provide a framework for understanding individual economic behaviour, market interactions, production and cost structures, market failures, and policy implications. They help economists and policymakers make informed decisions by providing a systematic and rigorous approach to economic analysis (Hussain, 2023).

In economic terms, erosion control measures can only be considered for implementation only when the cost of the control is not higher than the value of the erosion impact avoided, this means that the erosion meaning from the economic point of view may be somewhat dynamic than in the physical sense, but minor soil removal are still erosion in a physical geography point of view (Haydones, Peter, Barbara, and Phillips, 2008). Assessing the costs of erosion's negative impact using different economic analysis models may allow policymakers to implement various soil conservation measures. Furthermore, subjecting gully erosion control project planning to economic analysis such as cost-benefit analysis, cost-effectiveness analysis, and other forms of economic model can allow for the implementation of the most effective gully control measure among the various mitigation measures that exist (Haydones et al, 2008).

The study, therefore, attempted to review the economics of gully erosion control, emphasizing how the economic analytical model, such as cost-benefit analysis, can be applied in gully erosion control planning for careful allocation of resources and effectiveness of the control method used.

Study Methodology

The methodology for this review is a desk-based analysis of relevant literature and documents related to the subject matter. several literatures were reviewed and analysed on the cost of gully erosion control, methods of gully control, gully erosion control project planning, as well as cost-benefit analysis.

The Economics of Erosion and Soil Conservation

Evaluating the costs of gully erosion may allow for the implementation of gully control measures to be prioritised. Furthermore, economic analysis can allow for the comparison between different control methods to assess the most efficient method for better allocation of resources as well as balancing costs with effectiveness and financial benefits.

Economic Frameworks for Assessment of Effects

Erosion is a natural process that is exacerbated, but not wholly attributable to, the use and management of land by people. It can be identified from its various physical manifestations and effects on the landscape but in economic terms, the significance of gully erosion is dependent on the consequences for resource use and human well-being. The economic effects of gully erosion in a particular locality will usually comprise destruction or damage to affected properties.

In economic terms, erosion control or mitigation measures are worthwhile as long as the costs of control are less than the gully erosion costs avoided. This means that the economic definition of erosion is somewhat more fluid than the physical definition: minor soil movements are still erosion in a physical sense, but if they have no appreciable impact on human activities, then there is no economic value in their mitigation. The economic literature talks of an economically optimal' level of erosion, where the cost of an extra unit of mitigation is equal to the value of additional erosion costs avoided (Crosson, 1997). To the extent that changing demands and available technologies lead to changes in the price of land outputs and inputs to mitigation measures, such an optimal level will move over time. Finding the optimum level also depends on having appropriate information about the long-term consequences of soil degradation and the degree of precaution exercised in dealing with uncertainties in that information.

Economic Categorisation of Effects

In the literature dealing with the economics of erosion such as that provided by Haydones, *et al* (2008) the effects of erosion are generally subdivided into two broad categories, on-site effects (i.e., effects occurring on the properties where erosion takes place) and off-site effects (i.e., downstream effects, usually resulting from sediment deposition on other properties or in watercourses). Another distinction that is sometimes made is between direct effects (i.e., those arising on properties directly affected by erosion and deposition) and indirect effects (i.e., those arising on properties not directly affected, such as costs arising from erosion-induced disruption to transport arteries or in the flow of produce available to be processed).

However, the distinction between temporary and longer-term effects is often not made because both types of effects are captured in a discounted cash flow or cost-benefit analysis over time. On-site effects are those directly felt by the properties experiencing erosion, while the off-site effects are those directly impinging on activities off-site, largely due to sedimentation and deposition, and Indirect effects involve those affecting entities as a consequence of a direct effect felt elsewhere, such as a processing plant that suffers reduced value added from changes in supply from primary producers, or similarly other primary producers who rely on the affected properties for part of their business. Some variation in the characterisation of effects exists in the literature, depending on the nature of specific studies and the data available to them.

Much literature focuses on the on-farm or on-property direct impacts of erosion, but a more comprehensive assessment of costs would also need to look at off-site or sedimentary effects of erosion, and at the consequences of lowering the rate of erosion across an area. There is also variation in the coverage of off-site or sedimentary effects in erosion studies. Some are restricted to relatively tangible effects, such as damage to infrastructure and increasing sediment load in waterways, but consequences could also be extended to include less tangible effects, such as impacts on landscape and amenity or biodiversity.

The assignment of specific effects to the above framework is still somewhat open to interpretation. For example, repair of damage to network infrastructure such as roads (from flooding) or power lines (from dust) could be regarded as an off-site effect or as an indirect effect further removed from the direct effect of erosion whereas some damage repairs might be caused by more direct impacts (e.g. washouts on roads). The categorisation is not critical provided all effects associated with particular types of erosion are recorded against it, but not double-counted (Table 1).

Table 1: On-site and Off-site effects of Gully Erosion

S/N	GULLY EFFECTS	IMPACTS
1	On-Site	Destruction of properties, such as buildings, plots of land, business premises, economic trees, and sometimes human and animal lives.
2	Off-Site	Deposition of sandy material on properties such as farmlands or irrigation fields downstream, deposition of material into other water courses, causing more siltation. Intangible effects that occurred as a result of communities relying on properties affected on-site.

Source: Aliyu (2024).

Application of Cost-Benefit Analysis in Gully Control Project

Cost-Benefit Analysis (CBA) is an assessment method that quantifies the value of all benefits of erosion mitigation projects. More generally, Cost-benefit analysis applies to policies, programs, projects, regulations, demonstrations, and other government interventions. The aggregate value of a policy is measured by its net social benefits, sometimes simply referred to as the net benefits (Boardman and Vining, 2014).

The broad purpose of Cost-benefit Analysis is to help policy makers in rational decision making, and more specifically, the objective is to have a more efficient allocation of public resources. In the conduct of CBA, one must be able to demonstrate the effectiveness of a particular mitigation measure relative to the other alternative measures, including the status quo (Boardman and Vining, 2014).

Analysing the cost-benefit of a project will allow decision makers to evaluate projects reliably. Cost-benefit analysis requires certain assumptions and decisions to be made to find out some of the input data, and there are definite questions that will be raised. It is necessary to make sure that the assumptions and methodological approach are reliable for the various projects being compared. Likely questions that may be asked include: what baseline will the benefits of the project(s) be estimated against, what is the order and spatial level of project impact(s), and which particular elements of the project/activities are most relevant to the cost-benefit analysis?

Cost-benefit analysis tools include Benefit Cost Ratio (BCR), Incremental Cost, Benefit Ratio, Net Present Value (NPV), The Payback Period, Accounting Rate of Return, and Internal Rate of Return. Cost-benefit analysis can be conducted only with a deep understanding of the impacts of gully erosion and the effectiveness of various gully erosion mitigation methods, as well as the benefits of such control to the affected people and communities. These impacts and benefits are then translated into monetary terms (Haydones *et al.,* 2008 as cited in Enters 1998; Tenge *et al.,* 2005).

There is a broad choice in the scope of coverage of a cost-benefit analysis. At its simplest, a cost-benefit analysis may be confined to the effects of gully on individual properties, in which case it is largely focused on the on-site private costs and benefits of alternative courses of action. The Cost-Benefit analysis can also incorporate both on-site and off-site effects of gully erosion as well as the off-site benefits of such measures (Haydones *et al.,* 2008). More challenging are those analyses that are extended to include intangible external effects, which require use of economic non-market or in-direct valuation methods, it's important to note that these valuation methods are sometimes costly to implement, contentious in their results, and often over-ridden by political or judicial decisions, such studies are less common than those that concentrate on more tangible effects.

According to Haydones et al. (2008), there are three choices of decision criteria for use in cost-benefit analysis. Net Present Value evaluates the difference between the present value of the benefits and costs over a defined period at a specified discount rate. The Benefit Cost Ratio assesses the ratio between the present value of the benefits and the costs, again using a specified discount rate over a defined period. For a Gully erosion control project to be economically viable, the NPV must be positive, and the BC ratio must be greater than 1. NPV and BC ratio are therefore driven by the same set of calculations: the NPV shows the scale of the net benefit, the BC ratio shows its return per unit input. The IRR is an alternative method that derives the discount rate at which the NPV is zero, i.e. the discount rate is not specified but emerges from the calculation. For a project to be economically viable, the IRR must be at least as high as the return from the next best alternative investment.

These three decision criteria allow for the ranking of different scenarios; however, their reliance on valuing attributes that are often not directly quantified means that the individual results should be interpreted with care. Choosing the right discount rate (used to compute the present-day value of net returns), time horizon (for costs and benefits to be realised), and valuing labour (family inputs versus wage rates for different genders, ages, skill levels) is important (Haydones *et al.,* 2008).

Implications for Public Policy Development

Weimet (2008), in his book, revealed that the economic approach to policy analysis gives a central role to efficiency. The conceptual starting point is Pareto efficiency. An allocation of resources to production and goods to consumption is Pareto efficient if it is impossible to find an alternative allocation that makes at least one person better off without making anyone else worse off. Reallocations are Pareto improving if they make someone better off without making anyone else worse off. Seeking Pareto improvements has obvious appeal; in specific circumstances, one would have to be malevolent to oppose gains to some that require no others to bear losses. Out of practical necessity, however, economic analysis generally measures gains in efficiency in terms of potential, rather than actual, Pareto improvements. A reallocation is potentially Pareto improving if it generates an excess of gains over losses so that it would be possible, through costless transfers, to make the reallocation Pareto improving.

Cost-benefit analysis (CBA) comprises the concepts and methods for measuring benefits and costs in a money metric to determine if proposed policy alternatives are potentially Pareto improving. The CBA decision rule, adopt the combination of policies that maximizes the excess of benefits over costs, suffers from at least two limitations as a guide for public policy. First, efficiency is rarely the only relevant value in choosing among policy alternatives.

Distributional concerns, individual freedom, and national security, among other values, often have widely recognized substantive relevance to prudential choice in various policy areas, and political feasibility often has instrumental importance in actual arenas of choice. Conflicts between distributional values and the CBA decision rule are particularly fundamental in that Pareto efficiency takes the existing distribution of wealth as given, and potential Pareto improvements do not require that everyone get at least their initial shares. Second, even when efficiency is the only relevant value, it may not be practically possible to measure it in terms of the money metric. Often, only some policy effects can be monetized. The reliability of the CBA decision rule depends on the comprehensiveness of the monetization. Either excluding important effects or monetizing they incorrectly can lead to the choice of policies that do not promote efficiency. Much criticism of CBA as a decision rule involves these limitations. Nevertheless, situations do arise, most often in the context of infrastructure investments such as bridges, dams, and highways, in which efficiency can be reasonably taken as the relevant value and all major impacts can be confidently monetized.

CBA has much broader application, however, as a protocol for identifying and monetizing the efficiency effects of policies. Efficiency is almost always one of the relevant goals in policy analysis. CBA concepts and methods enable analysts to rank alternatives in terms of their efficiency. When the ranking is in terms of the money value, not only is the comparison of alternatives in terms of efficiency facilitated, but trade-offs between efficiency and other goals can be made more easily. Thus, even analysts working in policy areas in which CBA is inappropriate as a decision rule are likely to find it useful as a protocol for measuring efficiency.

The most critical aspect of categorisation is the distinction between on-site and off-site effects, given the economic premise that public policy is best directed to addressing externality effects rather than interfering with private commercial decisions and risk taking. Some authors argue that landowners have sufficiently well-defined property rights to have the right incentives to make sound, long term decisions on the use of their land and protection of value in their properties (e.g., Crosson, 1997). The implication of this is that policy is probably better directed towards managing off-site effects than assisting landowners to adopt practices that will mostly benefit them.

Reinforcing that implication is the inference from a number of empirical studies of the costs of erosion that off-site impacts of erosion may have far larger economic costs than the on-site impacts (Colaciccio et al., 1989; Crosson, 1997). Nevertheless, if erosion is imposing undue external costs because landowners are not taking them into account, some policy may be justified in targeting landowners. For instance, if there are failures in the market for information about what soil conservation measures are most likely to enhance social value in different circumstances, promotion of soil conservation aimed at landowners could be justified if it delivered a greater off-site benefit. Intervention logic would suggest it is only worthwhile to assist private gains in this way if they also create external benefits sufficient to justify the intervention costs. The externalities implicit in soil conservation are:

i. Landowners will fail to take account of effects falling outside their properties (i.e., off-site).
ii. Landowners may fail to take account of long-term effects of their actions in deterioration of their property value – an argument that depends on the expectation that the market will fail to adequately reflect that deterioration in property value, and
iii. Landowners may be unable to access the information they require to make fully informed decisions about the long-term impacts on their property (bounded rationality).

Economic Analytical methods and approaches

Financial and economic analysis allow for comparison between different practices (e.g., implementation of soil conservation measures) against a base case scenario. The results can be used to assess the most efficient allocation of resources. Financial analysis refers to the market-price costs and benefits resulting from a particular project on an individual or group basis, while economic analysis also considers social costs and benefits (Enters, 1998; FAO, 2001; Haydones *et al*, 2008).

To evaluate the desirability of some proposed action, one would probably begin by attempting to identify both the gains and the losses from that action. If the gains exceed the losses, then it seems natural to support the action (Haydones *et al,* 2008). In benefit–cost analysis, benefits are measured simply as the relevant area under the demand curve since the demand curve reflects consumers' willingness to pay. Total costs are measured by the relevant area under the marginal cost curve. It is important to stress that environmental services have costs, even though they are produced without any human input. All costs should be measured as opportunity costs.

The opportunity cost for using resources in a new or an alternative way is the net benefit lost when specific environmental services are foregone in the conversion to the new use. The notion that it is costless to convert a forest to a new use is wrong if valuable ecological or human services are lost in the process. The ideal situation will be if the operational environmental-economic assessment tool can rank both costs and benefits for multiple remediation projects, which is the case for cost-benefit analyses. An overview of both costs and benefits makes it possible to calculate the net present value of the individual remediation projects to see if they are profitable. It will also help to decide which projects are most optimal from an economic perspective of the society. As it is often too complicated to evaluate the benefits and consequently to be able to prepare a complete cost-benefit analysis, a cost-effective analysis can be prepared. A cost-effective analysis can either investigate the costs of different alternatives to reach a certain environmental goal or investigate different environmental initiatives that can be achieved with a certain amount of money.

Evaluating the Cost of Erosion Control

To help make costs and benefits more comparable, economists have developed methods by which to quantify the economic benefits of environmental programs. The three most common methods for assessing economic benefits are cost-benefit analysis, cost-effectiveness analysis, and natural resource damage assessments.

A key environmental policy goal is to encourage producers to factor in the costs they impose on others through their pollution-generating activities. Ideally, the producers would choose those activities that are the most economically efficient in terms of the cost impacts on society. However, "Designing policies to achieve efficiency, however, is often impossible because the relationship between economic damages and nonpoint source pollution is seldom known" (Ribauldo, 1999; Haydones et al., 2008). Thus, policies are often designed to target environmental goals at the least cost.

There are serious limitations to choosing the most "cost-effective" strategies, however, due to the complex nature of erosion and sedimentation. First, erosion is difficult to measure at a reasonable cost because it is diffuse (soil erodes off of a farm field in many different places) and is impacted by random weather events (i.e., storms or droughts). Also, the process by which sediment is transported to and through rivers and lakes (where it causes economic damage) is influenced by several different factors, some of which are unpredictable. The random and unpredictable nature of the erosion and sedimentation process imposes serious limitations on crafting programs and policies that are cost-effective.

Another issue to consider is the scale of application. Erosion and sedimentation depend on many site-specific factors. The more site-specific that policies and programs can be, the more efficient they will be. However, designing and implementing site-specific programs can be very costly, as it requires the collection of site-specific data and information, which can be expensive to acquire.

Estimating the Cost of Gully Erosion Control

In Nigeria, the cost of gully erosion and its control measures engulfs billions of Naira. For example, to tackle erosion especially the gully erosion, the Federal Government of Nigeria and World Bank through the Nigerian Erosion Watershed and Management Project proposed Additional Financing (AF) for US$400 million, equivalent to SDR amount of 208.7 million (US$300 million from IDA 18 and $100 million from IDA 18 Scale-up Facility) for the Nigeria Erosion and Watershed Management Projects (NEWMAP report, 2017), which seeks to scale up successful gully restoration and watershed management activities and add new activities that have emerged from implementation experience, global commitments, and country initiatives.

The project development objective (PDO) as reported by the NEWMAP report of 2017 was "to reduce vulnerability to soil erosion in targeted sub-watersheds." NEWMAP was making significant progress in tackling land degradation and major gully erosion in Nigeria and has, succeeded where earlier initiatives failed, by adopting innovative, integrated approaches based on community participation. For the first time in Nigeria, the report also indicated that NEWMAP introduced a holistic watershed management approach linking poverty alleviation with maintaining sustainable ecosystems and better disaster risk management.

NEWMAP is currently working in seven states (referred to as tier 1 states), which have been participating in the project from the start (Anambra, Abia, Cross River, Ebonyi, Edo, Enugu, and Imo). An additional 12 states (referred to as tier 2 states) joined the project at a later stage during implementation these include Akwa Ibom, Borno, Delta, Gombe, Kano, Katsina, Kogi, Nasarawa, Niger, Oyo, Plateau and Sokoto (NEWMAP Report, 2017).

In May 2018, for example, the governor of Anambra State signed a contract for the control of gully erosion in the state for 9 billion naira. The erosion sites are: Enugwu-ukwu and Abidi-umuaji, which will cost 2 billion, Nnewi-ichi and Ojoto to cost 5 billion, and Ire-obosi site that will also cost 2 billion naira (VON, 2020). VON (2020) also reported that the Kogi State Government, in collaboration with NEWMAP, earmarked the sum of 378 million Naira to address the problem of gully erosion in part of the state.

Oyati, Lawal and Ojo (2021). Revealed in their study that the economic damage brought by gullies, mainly in Nigeria's southeast, could be up to $100million every year, with an agricultural yield loss of 30 – 90% in some areas (Climate Home News, 2020). Gully erosion contributes to environmental problems and causes damage estimated at over $100 million annually in most parts of Nigeria (NEWMAP, 2017).

Gully Erosion Control Project Valuation Methods

The process of soil erosion has two types of impact: on-site and off-site. The main challenge is to quantify these impacts and provide the economic agents with answers as to the real losses caused by erosion. Variables and methods are being tested in various countries depending on the available information, in an attempt to include the soil as a proxy in economic and social relations (Tiago, Sonia, Antonio de Sanza, & Maria-de Fatima*,* 2012).

On-site costs can be calculated using the cost of nutrient replacement, associating the physical quantity of erosion associated with nutrient losses, normally macronutrients: calcium, phosphorus, magnesium, nitrogen, and potassium, as reported by Tiago *et al.* (2012). This can be calculated on the basis of market prices for commercial fertilizers and the quantity necessary to replace lost nutrients, plus the application cost. The calculations can be based on lost yield, i.e., the decrease in productivity resulting from soil limitations, computed in terms of the reduction in profits. In more serious cases, the drop in land values can also be taken into account. Soil erosion valuation based on the concept of nutrient losses and replacement is treated as a variable of the good or service (Haydones et al., 2008).

This kind of approach does not measure the damage to other environmental goods and services, such as the loss of biodiversity, nor other impacts resulting from the erosion process that affect other parts of the ecosystem, such as the quality of water resources. Pimentel et al. (1995) and Uri (2000) estimated the costs of erosion, taking account of variables over and above nutrient losses, such as the type of management and loss of yield and quality, as well as the off-site costs, extrapolating their estimates to the entire American territory. The off-site effects are numerous and they are related to the processes of sedimentation and silting of water resources, causing serious repercussions on society, such as increased costs in generating electricity, increased cost of capturing and treating water for urban supply, a drop in the availability of water resources for regions requiring irrigation, road maintenance and finally, aid for victims of natural disasters (Clark, 1985).

The soil erosion process forces society to pay the expense of prevention, repair, and repression. In this case, the costs are borne by the State and absorbed by taxpayers. The majority of economic assessments of off-site impacts analyse the effects of reservoir sedimentation, which, in turn, are generally estimated in terms of the drop in the generation capacity of hydroelectric power plants and in irrigation water supply. For a more exhaustive and accurate analysis of erosion costs, off-site impacts must be taken into account. If they cannot be quantified, they should at least be listed. The economic impacts of soil erosion and conservation can therefore be assessed using financial and cost-benefit analyses. Studies can be carried out using one or both types of analysis on a variety of levels: local (productive unit or water basin), municipal, state, regional, or national. They can be used to verify on-site and/or off-site effects.

World Bank in its report edited by Alfredo Sfeir Younis in (2009) on Economic Aspects of Soil Conservation Programs in Less-Developed Countries (LDCs) discussed extensively several benefit-cost valuation methods that may be used depending on the characteristics of future 'with' and 'without' the project situations. Before outlining the nature of each method and in order to define and understand the nature of project benefits, one must understand the relationship between the natural system under study and the economic decision framework. Because the economic analysis often begins with an estimate of land productivity, economists tend to forget that several steps have been followed to compute yields. For example, one may need to know how losses in topsoil affect farm productivity (e.g., measured in crop yields). This would require first recognition that there is a relationship between losses of topsoil and losses of nutrients, and between losses of nutrients and changes in yields. The Universal Soil Loss Equation is often used to quantify potential losses in topsoil.

Economic Valuation of Cost and Benefit

Economic valuation is a tool used to quantify the costs and benefits of a gully erosion control project in monetary terms. Various methods have been developed to translate the value of the gully control project benefit to monetary value. However, it is important to know that not all gully control costs and benefits can be valued in monetary units (Xiang, 2018).

In general, economic valuation methods can be divided into three, namely, market-based, non-market-based valuation methods, and value transfer (Xiang, 2018). It's important to note that the suitability of any of the methods mentioned above depends on the different costs and benefits of gully erosion projects under study. The market-based valuation method is based on existing market behaviour, including direct market valuation (e.g. direct market price) and indirect market valuation (e.g. avoided damage cost, replacement cost, travel cost). Non-market-based valuation methods are more applicable in valuing intangible benefits, such as soil loss, nutrient loss that are associated with off-site effects, compared with market-based valuation methods. The principle of the value transfer method is to estimate the benefits value based on the results of other valuation studies in similar conditions. In this study, both market-based based non-market-based valuation methods as well as value transfer were used to value different benefits and costs associated with the control projects.

a) **Valuation of the cost of the project:** The total cost of the gully control projects executed in Gombe Metropolis was collated from different government agencies, and the documents included the financial documents that captured the cost of selected gully erosion control projects.

b) **Valuation of Benefits of the Control Project:** In the valuation of benefits of action against gully erosion, the costs of inaction represent the maximum level of benefit from action against land degradation (Mesfin, Singh, Apindi, Jane, Zinta and Gyde, 2015).

In this study, the theoretical maximum benefits of action referred to the cost of inaction against the gully erosion problem in the area. The actual benefit of action, however, depends on the level of efficiency of the type of intervention or action in averting the gully erosion menace, and hence the level of reduction in the associated lives and property losses. For example, different gully erosion control measures have different levels of efficiency in controlling gully erosion. It is also not possible to realize all of the costs of inaction as benefits at a time, for the fact that action or intervention requires both time and resources. Therefore, it is important to note that realistic assumptions will be used in estimating the benefits of action based on the market, non-market, and value transfer valuation in calculating the cost-benefit analysis for this research work. Thus, for the purpose of this study, the benefits of action were estimated as fraction of the costs of inaction using the following equations according to Mesfin *et al* (2015), where the fraction (λ) represents the rates by which cost of inaction was converted into benefits as follows:

BA1= nλCIA1………………………………………. (1)

BA2= nλCIA2………………………………………. (2)

Where:

BA1 = value of avoided physical properties lost.

BA2 = value of avoided economic trees lost.

λ = rate by which the factor causing the property loss is reduced at the time (t).

n = t-1, indicating that at the initial year of intervention, n=0 and hence zero benefit.

The cost-benefit analysis model was used in some studies to achieve some study objectives, such as that by Aliyu (2024), who carried out cost cost-benefit analysis of gully erosion control projects for FCE(T) and GSU Gully control projects respectively, which was effectively achieved through the use of two variables of the Cost-Benefit Analysis as follows:

a) **Net Present Value (NPV):** This represents the difference between the total discounted benefits ***minus*** the total discounted costs; thus, the net present value (NPV) is the most widely used criterion in cost–benefit analysis. It determines the present value of net benefits (or costs) by discounting the streams of benefits (B) and costs (C) at the rate (r) set at 3.5%, arising between the present (t=0) and (t) periods into the future. The NPV is thus calculated using the following equation:

$$NPV = \sum_{t=0}^{t} \frac{B_t - C_t}{(1+r)^t} = (B_0 - C_0) + \frac{B_1 - C_1}{(1+r)} + \frac{B_2 - C_2}{(1+r)^2} + \cdots + \frac{B_t - C_t}{(1+r)^t}$$

………………….. (3)

b) **Cost Benefit Ratio (BCR):** Benefit–Cost Ratios (BCR) are calculated by dividing the total value of benefits by the total value of costs. The BCR is thus calculated using the following equation:

$$BCR = \frac{\sum Bi/(1+d)i}{\sum Ci/(1+d)i}$$ Summed over 1=0 to n years… (4)

Where: Bi = the project's benefit in year i, where i = 0 to n years
Ci = the project's costs in year i, where i = 0 to n years
n = the total number of years for the project duration/ life span
d = the discount rate.

In economic terms, when BCR is less than 1.0, it means the costs exceeded the benefits. Solely on this criterion, the project should not proceed. While, when BCR equals to 1.0, Costs now equal the benefits, which means the project should be allowed to proceed, but with little viability, but when the benefits exceed the costs i.e, when the CBR is greater than 1.0 then the project should be allowed to proceed.

Conclusion

Through a systematic literature review, this study demonstrates that economic analysis is indispensable for planning gully erosion control projects. By applying cost-benefit and cost-effectiveness methodologies, planners can: Identify the economically optimal level of erosion mitigation, where marginal control costs equal marginal avoided damages. Compare alternative mitigation techniques to prioritize those offering the highest net benefits. Incorporate both on-site and off-site, direct and indirect impacts to capture the full spectrum of erosion costs. Account for intangible effects, such as landscape amenity and biodiversity, to avoid underestimating total benefits.

Adopting such an analytical framework ensures that limited resources are directed toward interventions with the greatest returns, reducing soil loss while maximizing economic welfare. Future research should develop standardized metrics for valuing fewer tangible impacts and refine dynamic models that reflect changing land-use patterns, technology costs, and environmental uncertainties. By embedding rigorous economic evaluation into gully control planning, policymakers can achieve sustainable soil conservation that balances ecological health with human well-being.

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