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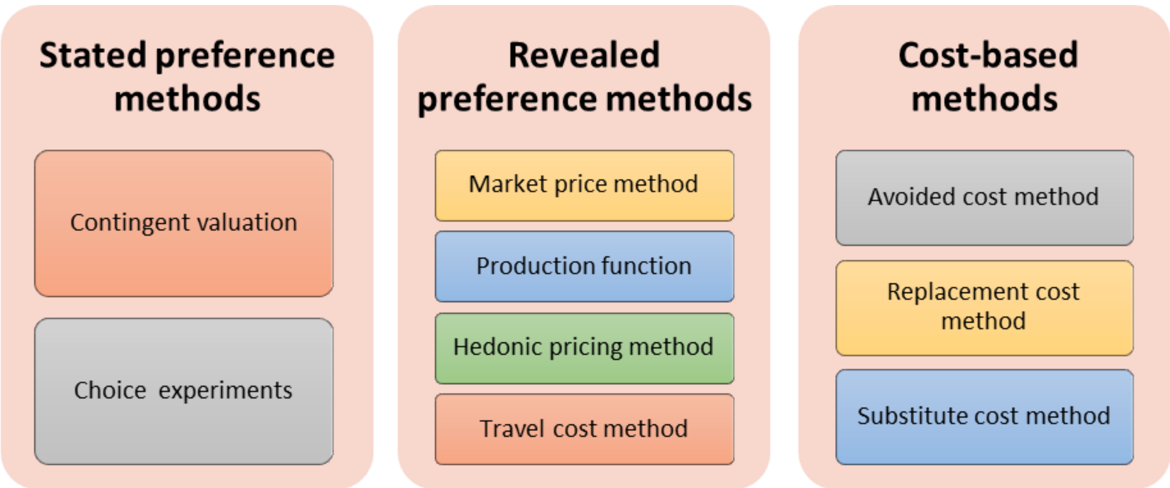
Technical Guideline Note

Economics Evaluation Methods of Soil and Water Conservation Techniques



Towards the Effective Scaling of Soil and Water Conservation Technologies Under Different Agroecosystems in North and Central West Tunisia

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Table of content

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AHP	Analytic Hierarchy Process
CBA	Cost- Benefit Analysis
MCA	Multi Criteria Analysis
SWC	Soil and Water Conservation

Background

Soil and water are basic for any agricultural production system. They are available under a huge pressure due to the increasing population and climate changes (Kumawat et al., 2020). Among the various degradation processes, soil erosion contributes seriously to the deterioration of soil and water resources. Soil erosion has also hampered agricultural productivity and economic growth in many regions and countries (Hengsdijk et al., 2005; Balana et al., 2010). Food production reduction in a specific country or region due to natural resources degradation, may not have a significant effect on food supply because of the potential substitution from other producing areas. However, the effect could be dramatic to food security of large number of people and to local economic activity (Scherr & Yadav, 1996). Practices related to soil and water conservation (SWC) enhance crop production, food security and household income (Adgo et al., 2013). Therefore, investments are promoting SWC technologies for improving agricultural productivity, household food security and rural livelihoods. Different SWC technologies have been encouraged among farmers to control erosion for example. However, investments by farmers in SWC are influenced by the ecological, economic, and social impacts of the SWC technologies (Huang et al.,2018). In Tunisia, since antiquity, inhabitants of arid and semi-arid regions have constructed water harvesting systems to cope with limited water supply. Impoundments were built to capture surface run-off. These structures are known to reduce soil erosion (Oweis et al., 2004). The Tunisian government has invested into soil and water conservation practices through institutional and legislative measures. A national strategy for soil and water conservation and agricultural development was launched since 1990. More than 600 000 hectares received conservation measures (Abouabdillah et al., 2014). The rapid expansion of soil and water conservation practices has raised questions concerning their economic and environmental impacts. The economic impact of SWC practices is mostly evaluated in monetary terms (cost-benefit analysis) (Bizoza and Graaff, 2012; Teshome et al., 2013). However, social, and ecological impacts as well as the interactions between different impacts are not easily quantified in monetary values (Tenge, 2005). Many evaluation methods of SWC measures are used to quantify the monetary and non-monetary value of SWC practices to enhance the decision-making process.

Farmers' goals and motivations for investing in different SWC alternatives are different from those of researchers and extension staff, as they have other objectives besides reducing soil loss and maximizing benefits. These objectives may be conflicting, so no SWC measure can provide the best outcome for all farmers (Tenge, 2005).

The objective of this work is to provide a technical guide on the different methods of economic evaluation of soil and water conservation practices for an efficient scaling up of SWC technologies, under different agroecosystems in Tunisia.

This technical guideline is fulfilled in the framework of the SWC @Scale project that has concentrated its efforts and investments in two different sites in Tunisia (Northwest, Siliana, and Central west, Kairouan).

Introduction

Over the last decades, nature has been under pressure due to the living system of the global population imposed by the industrial revolution that led consequently to a hug intensification of the agricultural production. The continuous overexploitation of the natural resources accelerated the global ecological disruption.

Intensification of agriculture, to ensure the increasing world's food supply, is considered one of the main causes of soil and water degradation. Since soil erosion is one of the major limits for the sustainable development of agriculture, and according to the principal of the sustainability, structure and quality of the natural and anthropogenic capitals should remain unchanged (Ashoori et al., 2016; Kociszewski, 2018; Widomski, 2011).

Soil erosion is considered as one of the main origins of the decrease of the agricultural productivity. For instance, soil erosion caused a damage of $26 billion annually to productive soils in Africa (Lal, 2001). In addition, Soil erosion present an on-site and off-site effects that causes significant losses that threating farmer and society's welfare. The various on-site and off-site losses caused by soil erosion are illustrated in the table below:

Table 1. On-site and off-site effect of soil erosion

On-site losses	***Off-site losses***
Soil loss	Sedimentation
Nutrient loss	Sedimentation of lakes and rivers
Yield drop	Drop in the capacity of lakes and rivers
Damage to plantations and improvements	Landslides
Production loss	Flooding

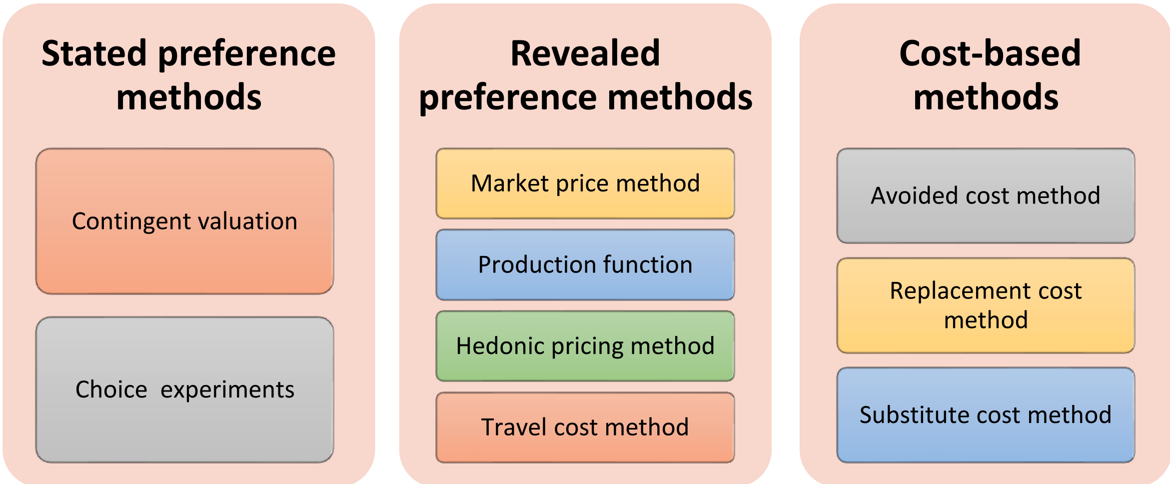
Source: (Tells et al., 2011).

Accordingly, environmental issues received a significant attention through several standards and procedures. Protection of the environment; preservation of the fresh water and prevent soil degradation and other natural resources became an urgent priority over the last decades (Franjic, 2018). Therefore, to achieve a sustainable development of agriculture through providing a safe and secure food supply in balance with ecological, economic and social standards, soil and water conservation is considered the best alternative (Kociszewski, 2018). Obviously, conservation of soil and water is a crucial practice that permit a better soil productivity through increasing the level of organic matter, maintaining a better soil fertility, improving crop yield, and consequently raising farmers' income (Semgalawe and Folmer 2000; Hudson 2004). In order to ensure an efficient and sustainable use of the natural resources (land and water), adoption of soil and water conservation practices is required.

To provide a better understanding of environmental issues through preventing the environmental damage and improving the environmental services, the economic aspect is announced. The economic analysis plays a crucial role in the decision-making process. Therefore, to improve the environmental quality, it's necessary to refer to the valuation of the natural and environmental resources (Longo, 2005).

In the agricultural economics, acceleration of the land degradation and climatic variability attracted the attention of the policy makers. Thus, soil and water conservation (SWC) efforts have been deployed to ensure the agricultural and consequently environmental sustainability. SWC practices include economic, environmental, and social impacts. However, the environmental and social benefits of the SWC practices are not quantified in monetary values signifying that these practices are not economically profitable (Adimassu et al., 2012). Therefore, the holistic evaluation methods are useful to evaluate nonmonetary and less quantifiable effects of the SWC practices (Teshome et al., 2014). Numerous methodological approaches were developed to evaluate the economic significance of the soil and water conservation. Valuation methods of the soil and water conservation are essentially used to evaluate the on on-site and off-site impacts of soil erosion and soil conservation (Enters, 1998). As shown in figure 1, methods of environmental valuation include mainly three catogories of method; i)the stated preference methods, ii) the revealed preference methods and iii) the cost-based mrthods.

Figure 1. Methods of environmental valuation



Source: Longo (2005) and Guijarro & Tsinaslanidis (2020).

On-site impacts of soil and water conservation

According to Bekele (2003), the main objectives of the economic analysis of the SWC are as follow:

- To estimate the benefits of SWC measures,
- To assess the key factors affecting the SWC decision behavior of farmers,
- To define the adjustment of the *for and against* of the SWC decisions using the economic modeling tools

1.1. Impacts of soil erosion and soil conservation on agricultural productivity

In order to provide a better understanding regarding the relationship between erosion and crop productivity and consequently farmer income, numerous empirical researches have been conducted. The on-site impacts of soil erosion through estimation of the erosion effect on crop yield which led to an estimation of the benefits of the adoption of the SWC measures (Stocking, 1987; Lal, 1988). To figure the cost and benefits of soil conservation, three valuation methods are mainly applied: i) hedonic pricing method, ii) replacement cost and iii) change of productivity (Enters, 1998).

Hedonic pricing method

In the Economic theory, Rosen (1974) classified the hedonic price as “the *implicit price of attributes and are revealed to economic agent from observed prices of differentiated products specific amounts of characteristics associated with them”.*

The hedonic pricing method has been applied to understand the relation between the environmental resources and the prices of marketable goods through the estimation of the market value of the environmental services such as irrigation water (Mallios et al., 2006). The hedonic pricing is defined as the model of valuing and economic pricing of the environmental amenity (Khorshiddoust, 2013).

This method was widely used to estimate the agricultural water value, through determining the effect of irrigation water supply on agricultural land prices (highland economics, 2019). With reference to soil and water conservation, this method was applied to value soil degradation resulting from erosion taking into account the sale price of land. That’s to say, the hedonic pricing model is helpful to interpret the impact of attributes on the value of a property (e.g., land) (Martínez-Jiménez et al., 2017). Among the studies on the in-site cost of soil degradation, Herzler et al. (1985) focused on valuing the effect of soil degradation on agricultural land price. Authors suggested that the loss of future productivity due to soil erosion is estimated to 400$ per hectare. However, other studies reveal that soil degradation have not a direct reflect on land price (Bishop, 1995). Therefore, relying on several studies Bishop (1995) concluded that the Hedonic pricing method is applicable only if land market is developed.

The replacement cost approach

The replacement cost is the cost incurring when replacing the current asset with an equivalent asset at the present price. replacement cost method defined as an environmental valuation method that derive an economic value of the ecosystem service. Jackson et al. (2014) considers the replacement cost method as an approach allowing the attribution of a monetary value to a part of the larger total economic value of an ecosystem good or service.

Therefore, the replacement cost method is useful to appraise the protective functions of ecosystem such as valuing the flood protection capacity of wetlands (Sundberg, 2004). This method is also applied to estimate the cost of substituting an ecosystem service with a man-made protection. (Farber et al., 2002) illustrated the case of replacing the recycling of nutrients (as an organic soil fertilization) by chemical fertilizers. Therefore, the replacement cost of this ecosystem service is considered as the indirect use value of this ecosystem service. Grohs (1994) suggested the replacement cost to estimate the cost of fertilizers applications to compensate nutrients loss due to erosion. Stocking (1986) conducted also study on estimation of the cost of additional input to compensate the loss of plant nutrient. Authors concluded that total cost of replacement plant nutrient losses due to soil erosion is estimated to 50$/ha/year.

Productivity change approach

Productivity change is illustrated as output quantity change relative to input quantity change (Vancauteren et al., 2009). This approach considers then at what rate of output change can be interpreted by the rate of change of combined inputs (OECD, 2001).

In the soil and water conservation circumstances, this approach, referring to empirical estimates, is appropriate for assessment of the erosion impact on crop productivity. Considering the productivity change approach, Grohs (1994) indicate that the erosion damage is not ither than the value of the lost crop production valued in market prices. Enters (1998) argued that the productivity change approach is one of the commonly applied methods for valuing the on-site cost. Nevertheless, Bishop (1995) declared that the main limit of this approach is that the relation between soil erosion and crop and livestock yield has not been pointed out by several studies. In the framework of valuation of the erosion impact on crop yield, Grahs (1992) used two empirical models to estimate the erosion-yield relation. Authors reported that yield losses for maize due to erosion is estimated at 0.3-1.4%.

Still within the framework of the evaluation of the effect of erosion on productivity, other methods have been used to highlight the on-site economic benefits of SWC. The frequently used methods are the CBA (Cost Benefit Analysis), MCA (Multi Criteria Analysis) and the choice experiment and the contingent valuation.

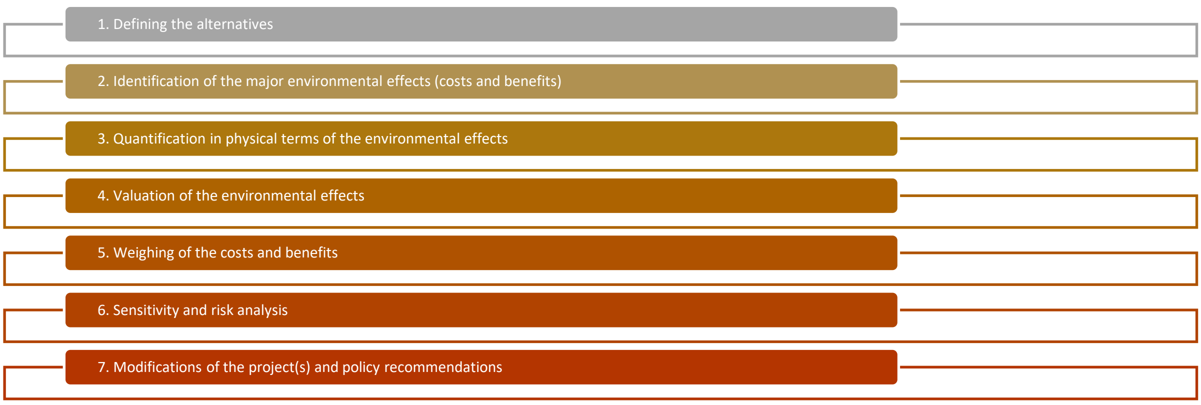
Cost Benefit Analysis (CBA)

The Cost Benefit Analysis is mainly used for evaluating the SWC investments which consist on comparing the before and after case and focus on the efficiency criterion. There are mainly four evaluation criteria used to compare the cost and benefit of alternative actions; internal rate of return (IRR), benefit- cost ratio (BCR), net present value (NPV) and net benefit- investment ratio (Enters, 1998). Bojö et al (1990) defined the CBA method as:

"A coherent method to organize information about social advantages (benefits) and disadvantages (costs) in terms of a common monetary unit. Benefits and costs are primarily valued based on individuals' willingness to pay for goods and services, marketed or not, as viewed through a social welfare ordering representing the preferences of the relevant decision-maker".

As presented in figure 2, Angelsen and Sumaila (1995) described the main steps of the CBA.

Figure 2. Steps of the Cost-Benefit Analysis



Source: Angelsen and Sumaila (1995)

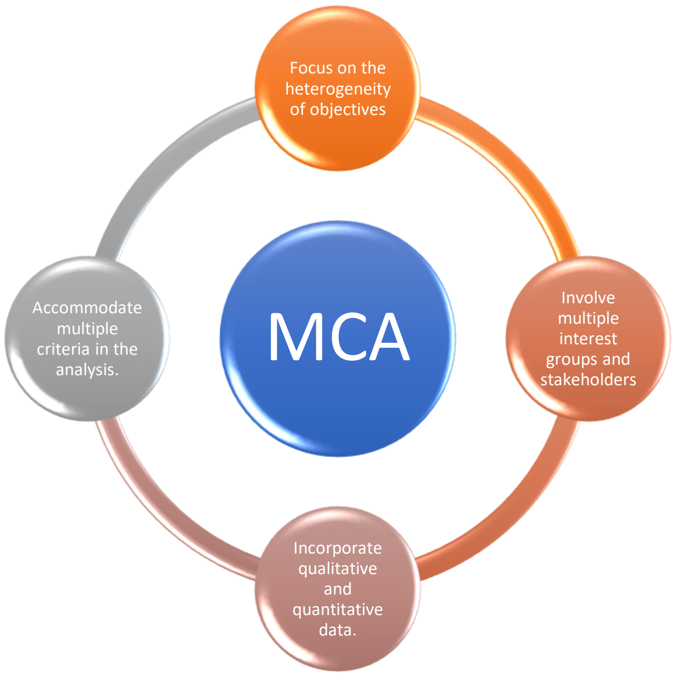
Nevertheless, many studies suggested that the application of CBA method present limitations such as; the CBA rely considerably on the quantifiable and monetary measures are unethical (Chichilnsky, 1997). However, Bojö (1992) and other authors (Clark, 1996; Enters, 1998) claim that the appropriate adaptation of this method could improve decision-making in SWC.

Multi Criteria Analysis (MCA)

To evaluate a number of alternatives for various planning purposes, multicriteria evaluation approach is frequently used.

According to CIFOR (1999), multi-Criteria Analysis is defined as *"a decision-making tool developed for complex multi-criteria problems that include qualitative and/or quantitative aspects of the problem in the decision-making process".* In the context of SWC practices evaluation, decision making process include environmental, economic, and social criteria, thus, MCA is considered as the adequate tool to evaluate the relative importance of different criteria. The main advantages of the MCA are summarized in figure bellow:

Figure3. Advantage of the Multi-Criteria Analysis



Source: (CIFOR, 1999)

Principal techniques used in the MCA are Ranking and Rating, Pairwise Comparison:

Ranking and Rating

Ranking and rating are considered as the simplest methodologies in the criteria and indicators assessment. Raking technique consist of attributing a rank to decisions depending on their importance. Similarly, rating involve attributing scores to the decision elements. Thus, the assigned scores must vary from 0 to 100 and the total scores for all elements must be equal to 100.

The pairwise comparison

The pairwise comparison methodology is essentially based on the Analytic Hierarchy Process (AHP) firstly introduced by Saaty (1995). this method is a useful decision-making tool to examine the relative weights at the indicator level (Mendoza & Prabhu, 2000).

According to the (CIFOR, 1999), AHP consist in organizing the important components of a problem into a hierarchical structure similar to a family tree. In addition, this method provides a decomposition of a complex decision into series of pairwise comparisons.

The choice experiments

Choice-based approaches come from the discipline of economic and belong to the category- stated preference methods – of the multi-attribute valuation family. Choice experiments method is considered as the simplest of the choice-based approaches (Vega & Alpízar,2011). This method reflects the real market situation and consequently permits to attribute a monetary value to environmental impact assessment.

Experiment design methods are used to construct choice tasks through which respondents reveal the marginal values they place on each attribute. Offered choices are defined in terms of these attributes, utility maximizing individuals will choose the alternative that gives the highest level of utility (Colombo et al., 2006). The Choice Experiment method can produce useful estimates of environmental benefits. Not only can the relative importance of the different attributes be identified but the aggregate benefits for different policy/action designs can also be calculated (Colombo et al., 2003).

Contingent valuation

Contingent Valuation is a survey-based technique for valuation of nonmarket resources, typically environmental attributes (Alberini and Kahn, 2009). It uses a hypothetical market to appraise consumer preferences by directly asking their willingness to pay for changes in the level of environmental goods or services (Carson and Hanemann 2005). It is “contingent”, because people are asked to state their willingness to pay, contingent on a specific hypothetical scenario and description of the environmental service. This method is criticized in countries with low-income households. Using monetary measures in those countries valuation studies leads to a high number of zero bids resulting from severe financial constraints ((O’Garra et al., 2009; Godwin et al., 2011). Therefore, in some developing countries other measuring units such as the labor contribution is used for the valuation of public goods (Hung et al., 2007). According to Ahmed et al. (2015), by applying a contingent valuation technique, it is possible to assess the willingness of the communities to participate in the soil conservation activities. the mean willingness to contribute for soil conservation practices in the central rift valley of Ethiopia was 25 man-days per year.

1.2. Assessment of the key factors affecting the SWC decision behavior

Taking into consideration the socio- economic dimension of the soil and water conservation, empirical research focused on the behavioral factors affecting the soil and water conservation decision making. For this purpose, the most used econometric methods are logit and probit models.

Logit and probit models

This type of model is principally used to evaluate the behavior factors affecting the SWC decision making. In order to make the appropriate decision concerning the adoption or not of a SWC practices, farmers consider the marginal advantages and disadvantages of adoption. Parameters of the decision are generally unobservable, and a latent variable “Y” is usually defined. This variable is considered as the index of the willingness of each farmer to adopt the SWC practices which is related to a set of variables X (Burton et al.,1999). Consequently, the logistic models (probit and logit) are generally applied to reflect the observed status of SWC practices on farms in catchment. Within this frame, Pindyck & Rubinfeld (1998) reported that: *"The use of probit and logit models, that give not directly indicate the effect of change in the maximum likelihood estimates overcome most of the problems associated with linear probability models and provide parameter estimates which are asymptotically consistent, efficient and Guassian so that the analogue of the regression t-test can be applied".*

These statistical techniques are appropriate to estimate the probability of a dichotomous outcome (adoption or non-adoption of SWC) using a set of explanatory variables (Alufah et al., 2012). The study results of Alufah et al. (2012) reveal that the household size, perception of soil erosion problem, training in soil erosion control, ownership and access to institutional credit are the main factors that have a significant effect on adoption of SWC measures.

1.3. The long-term perspective of the economic implication of soil and water conservation investments

Soil erosion generates usually, soil loss which mean a decrease in soil productivity and consequently losses in farm profitability in a long term. Obviously, effect of soil erosion in considered dynamic since soil loss of a current year will have a repercussion on the yield level of the current year and the succeeding years. Therefore, the long-term perspective is required to appraise the economic implication of SWC investments. For this purpose, the dynamic economic modeling techniques are suggested. Burt (1981) applied the dynamic programming to obtain the exact solution to optimization problems using two state variables (topsoil depth and percentage of organic matter in in the topsoil) and a decision variable (percentage of land under wheat). Analysis results reveal that the soil erosion problems have not a dramatic effect on the future soil productivity since loss in topsoil depth and percentage of organic matter could be recovered using the technological progress. In 1983, McConnell also applied a dynamic optimization model in decision on SWC. In this model, soil depth was used as the state variable and soil loss as decision variable. Other authors, such as LaFrance (1992) and Hu et al. (1997), considered the McConnell model to estimate effect of fluctuation in output/input price on SWC decisions.

Off-site effect of soil and water conservation

According to Enter (1998), when soil and excessive runoff crosses the boundary of the farm household, they generate an off-site effects and costs which are external to farmer's decision making. The off-site impacts of soil and excessive runoff are known as externalities which can be positives or negatives. However, most of studies focus principally on the impact of negative externalities. In order to estimate the off-site economic impact of soil erosion, off-site costs are calculated in term of the net present value of net economic benefits from any loss of downstream economic activity (Barbier, 1996). Generally, methodologies used for measuring the off-site costs are approaches of estimating environmental externalities. According to Grohs (1994), estimating the cost of the negative externalities, excessive sedimentation of reservoirs, is possible using three approaches:

- Change of productivity,
- Replacement cost,
- Preventive expenditures.

Nevertheless, the choice of methodologies applied in estimating the off-site costs depend essentially on the type of downstream impacts and the potential losses to be encountered (Barbier, 1996). Since downstream impacts of soil erosion are numerous, most research studies focused on sedimentation and the reduction of a dam's service life since sedimentation of dam reservoirs is considered as the major result of land degradation and erosion. In his study, Barbier (1996) classified the main calculated impacts and considered as the cost of sedimentation as follow:

- Reduction in service life,
- Increase sedimentation of active storage,
- Increase sedimentation of dead storage.

Among the study cases illustrating the off-site impact of soil erosion, Magrath and Arens (1989) focused on the off-site costs of reservoir sedimentation in nine major dams on Java in terms of foregone hydroelectric and irrigation benefits. The study result reveal that an annual average sedimentation across all reservoirs on java caused a decrease of total reservoir capacity and dead storage capacity by 0.5% and 2.3% respectively.

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