Scientia Agricola

Point of view

Valuation and assessment of soil erosion costs

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Edited by: José Miguel Reichert

Received May 04, 2012
Accepted December 07, 2012

ABSTRACT: Soil is an essential natural resource for humans and an important part of the environment. However, soil is often used and managed inappropriately, causing its erosion and degradation, with concomitantly negative social, political and economic impacts. This study aimed to discuss sustainable development; and losses and problems caused by soil erosion, and to suggest a model for assessing erosion costs. The relevance of economic models for costing soil erosion is stressed. Based on an economic theory, it presents a procedure for assessing economic costs of soil erosion, centered on the on-site and off-site costs that are generated. The physical processes of soil erosion are described and their economic effects reviewed, drawing on theoretical and empirical sources. Limited data and information is available on the economic losses resulting from erosion, which hampers assessment and valuation.
Keywords: soil degradation, soil loss, soil conservation, sustainable development

Introduction

One of the most important natural resources for humans is soil. It is a limited, strategic resource of huge social, economic and environmental significance. However, the use of inappropriate farming methods can lead to erosion and limit the productive capacity of the soil (Bennett, 1935; Lal, 2006; Sparovek and De Maria, 2003). Soil erosion disrupts the natural balance and it can lead to a decrease in the productive potential of agricultural land (Pimentel et al., 1995). This is due to the loss of topsoil layers and soil fertility, a decrease in yield per unit of applied inputs, loss of income and profit to the farmer, a reduction in crop and livestock farming activities, a drop in the value of the agricultural land, pollution and destruction of water resources and public assets, flooding and silting up of waterways and migration of rural populations to urban areas (Telles et al., 2011).

Soil erosion costs can be divided into on-site costs (direct or internal for the farmer), consisting of losses incurred on the farmland, and off-site costs (indirect or external effects for society) occurring away from the farmland and affecting everyone. Each additional loss resulting from soil erosion imposes cumulative penalties, generating marginal costs for society, which has to bear the on-site and off-site economic costs of soil degradation. Marginal costs incurred by farmers are passed on to consumers as price increases for agricultural products. Social marginal costs are borne by all citizens, together with the adverse effect on social well-being.

From this perspective, it is clearly necessary to conceptualize the economic value of the natural resources in the environment and develop techniques to estimate losses incurred by inappropriate use of the soil. In the specific case of soil erosion, it is fundamental to compare the costs incurred by the degradation of these resources as a result of different management and production systems. Using conservationist practices that control erosion, these costs can be minimized, ensuring the sustainability of the agriculture sector (Lal, 2006; Montgomery, 2007). Therefore, this study aimed to discuss sustainable development and the losses and problems caused by soil erosion, and to present a model to estimate and assess soil erosion costs.

Sustainable rural development

The world is experiencing a phase of reflection on environmental problems and their economic repercussions. Current discussions would lead us to believe that the only reason that environmental degradation, especially on farmland is not worse is because a large part of the earth population is excluded from the consumer society. At the top of the agenda are those issues relating to the limitations of a crop and livestock farming sector formerly grounded on a historical and economic ideology centered on production and consumption as phenomena for generating and exploiting market value, based on the idea that natural resources are an inexhaustible source of matter and energy, a point of view that is now being replaced by a model based on the pursuit of sustainable development.

There are times during which developmental ideologies reache a field of historical singularity, embodied in a powerful concept that attracts generalized interest, that is intensely discussed and used as a guideline for government programs, and in particular, driving social groups interested in the benefits of the changes associated with this concept (Janvry et al., 2002).

The first phase of this kind was born out of the significant economic growth achieved during the period 1950 to 1975 (Meier and Rauch, 2000), with a new and complete understanding of agriculture. This gradually became the dominant force throughout the world, not solely in scientific areas, but also in the different agricultural systems in the countries that subscribed this idea. Founded on what was referred to as the "green revolution", this phase manifested itself in a sophisticated technological standard of production. As this standard was disseminated throughout agriculture, where it earned the tag "modern", the world began to use natural resources more intensively.

Against this backdrop, agriculture was seen merely as the absorption of new propagating technologies, leading to increased yield, and therefore assumed to be a virtuous phenomenon associated with increased family income, "rural development", but not necessary sustainable.

The second phase during which there was a resurgence of this theme is characterized by a perception of the apparent impossibility of development or, at least, the enormous difficulties involved in its realization: a complex set of new social and economic processes, associated with globalization. Thus, the theme development, general and rural, gradually reappeared in social debates and disputes on a global scale. For instance, currently there is a heated debate concerning climate change and discussions on the degradation of agricultural areas due to inappropriate soil management, due in part to the predatory way in which the land has been used. Therefore, sustainable development is closely linked to environmental issues, indicating the need for strategies. From this perspective, the age-old problem of soil erosion has fallen under the spotlight as a process that limits food production (Pimentel et al., 1995; Crosson, 2007). This is why erosion is one of the main threats to sustainable development and the productive capacity of agriculture (Pimentel et al., 1995).

Bearing in mind that the relationship between erosion and production is reflected in data of public interest, linked directly to income and costs, researchers throughout the twentieth century and in this first decade of the twenty-first century studied the effects of erosion and made various estimates of soil erosion costs (Table 1).

Losses and costs incurred by soil erosion

Any human activity changes the environmental equilibrium. Agricultural activities cause various impacts on the environment, including soil erosion and degradation. In this context, concepts from the field of economics have been used to develop models for calculating environmental costs (Figure 1), as well as the benefits of conserving natural resources such as the soil, in pursuit of an alternative path towards development that could be considered sustainable.

Changes in prices and production caused by soil erosion costs are presented in Figure 1, in which the rising curve C represents the costs of agricultural production, expressed in terms of the amount of work and inputs required for cropping; D represents the demand for agricultural products and is equivalent to the marginal social benefits; C' represents the costs of soil erosion, expressed by Equation 1, i.e. the sum of on-site and off-site costs; P represents the price and Q the production of agricultural commodities. For the farmer, the losses incurred by soil erosion can be computed as a marginal social cost that is higher than his marginal production cost. Initially, the farmer maximizes his profits on curve C, producing quantity Q_1 at price P_1 (intersection A), equal to the marginal cost. However, as the erosion process continues, there is a drop in soil fertility and productive capacity, forcing the farmer towards C'. This shift creates a new intersection (B) at which the quantity produced drops to Q_2 and the price rises to P_2 (Figure 1).

The impacts of soil erosion begin with a change in the physical, chemical and biological characteristics of the soil, causing a gradual drop in its potential productivity. In an attempt to solve this problem, farmers use technologies for compensating the loss in the soil fertility, applying more nutrients and using management practices that increase production costs. However, impacts on the soil biota, which also cause great harm to agriculture, cannot be offset by the using more inputs (Crosson, 1995, 1997).

For society, the process of agricultural soil erosion depresses demand, since each unit produced results in off-site costs. This happens because the price of the product is increased by the amounts spent on repairing the damage that soil erosion causes on the farming

Table 1 – Valuation of the on-site and off-site damage of soil erosion.

On-site damage	Off-site damage
Nutrient loss	Sedimentation
Lost yield	Flooding
Drop in land values	Water treatment
Biological losses	Electrical power generation
	Repairing public property
	Global warming
	Disasters
	Food price increases

Source: Prepared based on Bennett (1933), Baver (1951), Marques et al. (1961), Larson et al. (1983), Clark (1985), Ervin and Mill (1985), Gardner and Barrows (1985), Fletcher (1985), Hertzler et al. (1985), Crosson (1985, 2007), Crowder (1987), Moore and McCarl (1987), Foster et al. (1987), Holmes (1988), Ribaudo et al. (1989), Palmquist and Danielson (1989), Colacicco et al. (1989), Robertson and Colletti (1994), Pimentel et al. (1995), Alfsen et al. (1996), Tenberg et al. (1998), Pimentel and Kounang (1998), Marques (1998), Uri (1999, 2000, 2001), Gunatilake and Vieth (2000), Pretty et al. (2000), Bandara et al. (2001), Herath (2001), Riksen and Graaff (2001), Knowler (2004), Rodrigues (2005), Cohen et al. (2006), Pimentel (2006), Martínez-Casasnovas and Ramos (2006), Lal (2006, 2007), Montanarella (2007), Hein (2007), Bertol et al.(2007), Salvati and Zitti (2009), Pugliese et al. (2011).

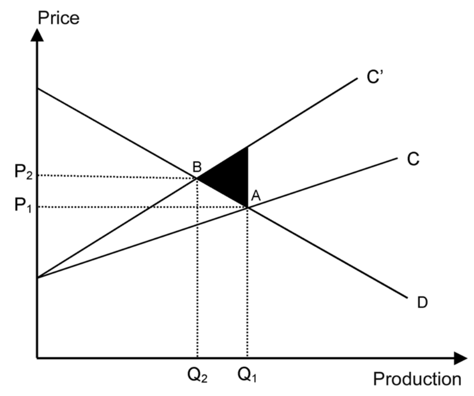

Figure 1 – Changes in prices and production caused by soil erosion costs. C = agricultural production costs; C' = soil erosion costs; D = demand for agricultural produce; P = price of agricultural commodities; Q = production of agricultural commodities.

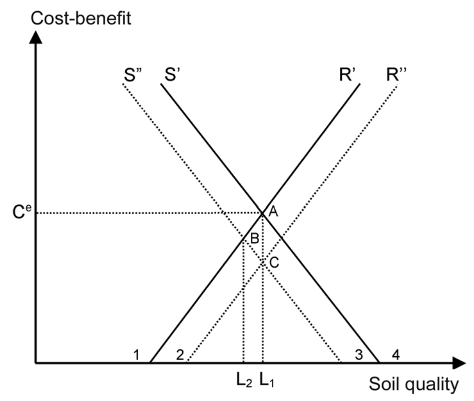

Figure 2 – Changes in soil quality as a function of degradation and conservation. C^e = stable cost; L = soil quality; S' = soil degradation; R' = soil conservation; S" = increase in degradation; R" = increase in investments in soil conservation.

land (represented by the shaded area in Figure 1). This off-site impact shifts C to C', generating a shift along curve D from point A to point B, so that the quantity produced drops from Q_1 to Q_2, and the price increases from P_1 to P_2 (Figure 1). Therefore, the displacement from curve C to C' will happen as a result of both the drop in productivity and the rise in production costs, as well as the off-site costs generated by soil erosion (Figure 1, Table 1).

The erosion process also brings about a loss of soil quality (Blaschke et al., 2000), and one of the ways of minimizing and even correcting the consequences of erosion is the adoption of conservationist practices (Montgomery, 2007; Ni and Li, 2003). But, despite this, some farmers resist to this approach, because in their view they understand that working the soil with a given stock of natural fertility is an adequate solution, as long as net earnings are higher than production costs or the costs of adopting conservationist management techniques. However, this approach could lead to the exhaustion of some soils, making agricultural activities economically unsustainable, and in some cases, leading to the abandonment of the concerned areas.

Figure 2 illustrates the relationship between soil degradation (S′) and the benefit of conservation (R′) for maintaining soil quality, taking account of the stable cost- benefit (C^e) (Jayasuriya, 2003). The optimum soil quality is given by the intersection of curves S′ and R′ at cost-benefit C^e (point A), the stage at which total costs and benefits are minimized, since they will be split between soil degradation costs and conservation cost-benefit, represented by the area 1A4. Conservation cost-benefit is concentrated in area $4AL_1$ and degradation costs in $1AL_1$. However, if the adopted management practices aggravate the erosion process, the soil degradation curve will be shifted from S′ to S″, moving the equilibrium from point A to B – which corresponds to the intersection of R′ and S″, resulting in a drop in soil quality from L_1 to L_2. This phenomenon causes a loss of soil quality which, if not controlled, could compromise yields in the medium and long terms. To avoid this, new investments in soil conservation are required, shifting R′ to R″, which means that S″ and R″ will intersect at point C, bringing the soil quality back to its equilibrium level, i.e. from L_2 to L_1.

As time progresses, soil conservation always brings economic advantages to the farmer. This is certain. However, farmers often resist adopting conservationist practices because the lack of economic information on erosion costs means that farmers have a limited idea about how soil degradation impacts their earnings. But the cost of not adopting these practices does not affect farmers alone. It also impacts society in general. Therefore, even in a situation in which soil conservation did not bring economic advantages to the farmer, it does to society, since if it is not implemented, net social returns will be lower than the private returns. This is because society will bear the cost of repairing the off-site damage caused by soil erosion.

Soil erosion cost valuation methods

The process of soil erosion has basically two types of impact: on-site and off-site (Table 1). 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 (Adhikari and Nadella, 2011; Boardman, 2006; Stroosnijder, 2005; Telles et al., 2011).

Bennett (1929, 1933, 1935, 1939, 1940, 1955), Pimentel et al. (1995) and Uri (2000, 2001) are among the leading researchers who have devoted time and effort to study the costs of on-site soil erosion (based on nutrient losses and drops in yield) and off-site soil erosion (based on off-site impacts). 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 (Amaral Sobrinho and Mazur, 2005; Adhikari and Nardella, 2011; Bertol et al., 2005, 2007; Gunatilake and Vieth, 2000; Marques et al., 1961; Pimentel et al., 1995; Pugliesi et al., 2011; Tengberg et al., 1997) 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 (Adhikari and Nadella, 2011; Hartwick, 1977). 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 (Stevens et al., 1994).

The value of lost yield, representing the economic cost of the soil use opportunity, does not normally incorporate the costs associated with inter-temporal questions, which take account of the availability of natural resources for future generations. To do this, it would be necessary to estimate future economic impacts for non-renewable resources, requiring information on a range of factors which is not readily available. Thus, whenever such directly-estimated costs represent a small part of total costs, impeding decision-making, other methods and procedures must be used (van Kooten et al., 1990; Walker, 1982). In addition, the loss of productivity is not due solely to the erosion process. Calculating the costs based on the drop in land values would entail using an ample and consistent historical land price data set, rendering this method impracticable (Ervin and Mill, 1985; Fletcher, 1985; Hertzler et al., 1985; Palmquist and Danielson, 1989).

Hertzler et al. (1985) conducted a study on the cost of soil use, based on a generalized Leontief function, split into two parts: nutrient losses and soil physical degradation. Estimates were made using information on annual crop yield, initial soil depth, nutrient stocks, erosion rate, and annual remaining nutrient stocks in the topsoil layer subject to erosion, and fertilizer prices. Pimentel et al. (1995) and Uri (2000, 2001) 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 basically 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).

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 tax-payers. The majority of economic assessments of off-site impacts analyze 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 (Table 1). 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 (Kuhlman et al., 2010). 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.

A theoretical model

The main methods in the literature used for estimating erosion losses, with all their limitations of scale (field, watershed or river basin), are the Universal Soil Loss Equation (USLE), Modified Universal Soil Loss Equation (MUSLE), Revised Universal Soil Loss Equation (RUSLE) and Water Erosion Prediction Project (WEPP). Taking these as a basis, a model can be built for estimating the costs generated by soil erosion. To define the total cost of soil erosion, we propose calculating the on-site costs (based on the sum of nutrients in the soil and water, lost by erosion) and off-site costs (based on sediment yield), as described in the theoretical model below:

$$C' = C_{on\text{-}site} + C_{off\text{-}site} \quad (1)$$

where: C' = total costs of agricultural soil erosion; $C_{on\text{-}site}$ = costs resulting from losses occurring on agricultural property; and $C_{off\text{-}site}$ = costs resulting from losses occurring away from agricultural property and affecting society as a whole.

Although on-site costs represent losses mainly in the form of nutrient replacement and lost yield, it is not possible to more accurately determine these costs solely relating to average content values for nutrients carried off with the sediment, since the drop in productivity can be associated with other factors. To estimate on-site erosion costs, we propose the following equation:

$$C_{on\text{-}site} = \sum_{i=1}^{m} (C_i Q_i) \quad (2)$$

where: $C_{on\text{-}site}$ = costs of soil erosion on agricultural property; C_i = prices of different types of nutrients (per unit); Q_i = quantities of nutrients carried off by soil erosion estimated by USLE; i = nutrient (1- m).

The quantities of nutrients carried off by soil erosion (Q_i) can be estimated by assessing the nutrients in sediment and floodwater samples, for example, on each rainfall event causing runoff in eroded plots, for different soils, managements systems and crops. The drop in the value of agricultural land as a function of erosion is the result of two factors: loss of the soil's productive capacity, entailing a drop in earnings since the farmer will bear increased costs in the form a fertilizer applications, and the high cost of recovering areas already degraded, expressed not only in monetary terms but also as a function of time (Trimble and Crosson, 2000).

Determining soil loss is helpful in visualizing off-site problems generated by erosion. This is because the sediments carried off directly impact water resources. The sediment yield can be estimated by MUSLE or USLE + Sediment Delivery Ratio (SDR), among other methods. In this case, the estimates can take the form of increased running costs for water treatment (especially to remove phosphorus and nitrogen) and electrical power generation, repairing damage to public property, such as bridges and roads, and dredging rivers and lakes.

The off-site impacts vary and therefore represent the costs associated with erosion require a large volume of information, which is not always available. As can be seen in Table 1, there is no fixed ceiling on the number of variables and it should be borne in mind that they cannot be determined exactly, a fact that could limit the possibility of creating an empirical model.

It is worth noting that the model described lists n variables for off-site effects. We propose the following equation for estimating the off-site costs of erosion:

$$C_{off\text{-}site} = \left(\sum_{i=1}^{n} E_i V_i \right) \quad (3)$$

where: $C_{off\text{-}site}$ = costs of soil erosion away from agricultural property; E_i = values (prices) generated by the off-site effects of soil erosion; V_i = volume (quantity) of off-site effects (sediment volume, estimated using MUSLE or USLE + SDR, etc.); i = different off-site effects, from 1 to n (for instance, on reservoirs, rivers, waterways, harbors, irrigation channels, etc.).

If we focus our attention on costs, we need to understand the cost-generating process derived from the economic theory. According to Binswanger (1974), Christensen et al. (1973), Chambers (1988), Kim (1992), and Silberberg and Suen (2001), the cost function expresses the cost of production as a function of the prices of inputs used in the production process and of the amount produced. Thus, for each amount produced, the corresponding point of the cost function will be the minimum.

$$C = f\,(Y, P_1, P_2, P_3, \ldots, P_N), \quad (4)$$

where: C = minimum cost for production level Y; P_1, P_2, P_3,..., P_N, = prices of inputs used in the productive process.

However, this function is very generic. Thus the approach in equation (4) leads to the restrictions inherent in function of the Cobb-Douglas type, taking all elasticities of factor substitution equal to 1. Attempts have been made to find alternative approaches so that substitution is unrestricted and not simply a constant (Greene, 2008).

The transcendental logarithmic, or translog function, is the most frequently used flexible function in empirical economic studies. This function was developed by Kmenta (1967) as a means of approximating the CES production function and was introduced formally in a series of studies. It remained as the most popular and most reliable of several available alternatives (Greene, 2008).

Generically, we arrive at a translog cost function represented by:

$$\ln C = \beta_0 + \sum_{i}^{n} \beta_i \ln P_i + \frac{1}{2} \sum_{i}^{n} \sum_{j}^{n} \beta_{ij} \ln P_i \ln P_j, \quad (5)$$

where: β = structural parameters and indices; i and j = production factors used in estimating the cost function.

In order to equation (5) satisfy the theoretical properties of the cost function, the equation has to be continuous and price-differentiable, and satisfy symmetry and linear homogeneity conditions (first-order homogeneity in factor prices), and still establish positive, almost concave monotonicity restrictions on factor prices.

The symmetry condition is imposed by the restriction $b_{ij} = b_{ji}$, for ij, and linear homogeneity is guaranteed by the following:

$$\sum_{i}^{n} \beta_i = 1 \ \text{e} \ \sum_{i}^{n} \beta_{ij} = \sum_{j}^{n} \beta_{ji} = 0 \quad (6)$$

The translog function, monotonicity and concavity conditions are conferred locally. The monotonicity is conditioned by the behavior of the cost installments and will be satisfied if they present a non-negative signal, since the increase in the use of the factors causes costs to rise. To satisfy concavity, the bordered Hessian matrix must be negative semi-definite. Below are some empirical models for on-site and off-site costs that can be generalized. The translog function, monotonicity and concavity conditions are conferred locally. The monotonicity is conditioned by the behavior of the cost installments and will be satisfied if they present a non-negative signal, since the increase in the use of the factors causes costs to rise. To satisfy concavity, the bordered Hessian matrix must be negative semi-definite. Below are some empirical models for on-site and off-site costs that can be generalized.

An empirical model for on-site soil erosion costs

On-site costs can be represented using the following equation:

$$\ln C_{\text{nutrients}} = \beta_0 + \beta_1 \ln P_1 + \beta_2 \ln P_2 + \ldots + \beta_k \ln P_k + \frac{1}{2}\beta_{11}(\ln P_1)^2 + \frac{1}{2}\beta_{22}(\ln P_2)^2 + \ldots + \frac{1}{2}\beta_{kk}(\ln P_k)^2 + \frac{1}{2}\beta_{12}(\ln P_1 \ln P_2) + \frac{1}{2}\beta_{13}(\ln P_1 \ln P_3) + \ldots + \frac{1}{2}\beta_{1k}(\ln P_1 \ln P_k) + \frac{1}{2}\beta_{23}(\ln P_2 \ln P_3) + \ldots + \frac{1}{2}\beta_{2k}(\ln P_2 \ln P_k) + \vdots \; \frac{1}{2}\beta_{k-1k}(\ln P_{k-1} \ln P_k) \quad (7)$$

where: $C_{\text{nutrients}}$ = on-site costs of soil erosion; P_i = nutrient prices; and i = various nutrients, from 1 to k.

These variables represent a set of on-site effects caused by soil erosion, and can include the operational costs of reapplying the fertilizers necessary to supply the nutrients carried off by surface runoff and the drop in the value of the eroded land.

An empirical model for off-site soil erosion costs

An example of how off-site soil erosion costs can be represented, taking account of the costs incurred in removing sediment from bodies of water and the volume removed, in this case can be represented by the following equation:

$$\ln E_{\text{sediment}} = \gamma_0 + \gamma_1 \ln P_1 + \gamma_2 \ln P_2 + \ldots + \gamma_k \ln P_k + \frac{1}{2}\gamma_{11}(\ln P_1)^2 + \frac{1}{2}\gamma_{22}(\ln P_2)^2 + \ldots + \frac{1}{2}\gamma_{kk}(\ln P_k)^2 + \frac{1}{2}\gamma_{12}(\ln P_1 \ln P_2) + \frac{1}{2}\gamma_{13}(\ln P_1 \ln P_3) + \ldots + \frac{1}{2}\gamma_{1k}(\ln P_1 \ln P_k) + \frac{1}{2}\gamma_{23}(\ln P_2 \ln P_3) + \ldots + \frac{1}{2}\gamma_{2k}(\ln P_2 \ln P_k) + \vdots \; \frac{1}{2}\gamma_{k-1k}(\ln P_{k-1} \ln P_k) \quad (8)$$

where: E_{sediment} = off-site costs of soil erosion; P_i = costs generated by the process of removing sediment from bodies of water, per ton; i = various costs, from 1 to k (dredging sediment from sinks such as reservoirs, rivers, waterways, harbors and irrigation channels).

Sediments are considered the most important water pollutants, especially because nitrogen and phosphorus are adsorbed onto sediment particles. However, data is scarce making it difficult, for instance, to work out the treatment plant costs of removing P or N from the water. This means that, as a rule, only sediment dredging costs are included and this is why the valuation and assessment of off-site soil erosion costs are usually limited to a given type of damage or a specific set of impacts caused by this damage.

Final considerations

The economic valuation of the effects of soil erosion is very important for society. The suggested model provides a way of estimating how much soil erosion costs. The derived values can be used in two ways: a) to raise awareness to the need to implement policies encouraging the adoption of conservationist management systems, and b) to compare the cost-benefits of different agricultural systems. For a more accurate assessment of the real damage caused by soil erosion, applying the model empirically for estimating costs requires data on the problems caused by erosion on agricultural property and those caused outside the agricultural perimeter, and this data is often not available. In general, when a model is proposed, albeit theoretical, it does facilitate further studies on the topic and the economic valuation of the damage caused by soil erosion will allow us to assess the need to implement public policies to encourage the adoption of conservationist systems and practices, in the pursuit of sustainable development.

Acknowledgements

To the National Council for Scientific and Technological Development (CNPq) for fellowships and grants.

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