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Cost–benefit analysis of the Zonal Program of Castro Verde (Portugal): Highlighting the trade-off between biodiversity and soil conservation

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Abstract

We address the effects of erosion on the environmental services provided by the soil and explore possibilities for integrating soil erosion impacts in cost–benefit analyses of agri-environmental policies. As a case study, we considered the continued soil erosion caused by the traditional cereal farming system which is financially supported by the Zonal Program of Castro Verde. This case study illustrated the conflict between the preservation of biodiversity habitat requirements and the maintenance of soil productivity. We conclude that soil erosion is currently a major threat to the long-term sustainability of the Cereal Steppe of Castro Verde and largely reduced the cost-efficiency of public expenditure in local biodiversity conservation. Although replacement cost has proven to be a suitable method to determine the cost of soil productivity loss from erosion, we argue that there is a need to frame the erosion cost estimate obtained within more integrative approaches of assessing erosion costs.

Keywords: Environmental services; Soil erosion; Replacement cost method; Agri-environmental policy cost-efficiency; Cost–benefit analysis

1. Introduction

The current and potential benefits humans can, directly or indirectly, derive from the soil are diverse yet many soil services are affected by mismanagement leading to loss of soil quality and soil erosion (Singer and Munns, 1996; Merrington et al., 2002). Many of the environmental services provided by soil are not priced in conventional markets and thus many of the consequences of irresponsible soil management are not captured by any analysis of farms' financial performance or taken into account by farmers in their land allocation decisions. Economic valuation can help to develop more sustainable soil management because monetary estimates of the impacts resulting from soil mismanagement allow their comparison with other conventional goods once they become expressed in the same units. A wide range of monetary valuation methods and techniques for environmental assets are described in the literature (see e.g., Garrod and Willis, 1999, and Turner et al., 2003, for an overview of economic valuation methods). Improvement of monetary valuation methods of environmental assets was crucial in broadening the use of cost–benefit analysis

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(CBA) for appraisal of policies and projects that affect the environment. Within the European Union (EU), there has been a notable absence of institutional guidance for its application to environmental issues and policy appraisal (Bonnieux and Rainelli, 1999; Pearce and Seccombe-Hett, 2000). Moreover, use of CBA in agri-environmental policies evaluation and cost-efficiency appraisal among the EU member states has been restricted to a few studies conducted mainly in the United Kingdom (Kleijn and Sutherland, 2003).

We explored the role of economic valuation of soil mismanagement impacts in the appraisal of agri-environmental policies based on the Zonal Program of Castro Verde (ZPCV). This agri-environmental program was implemented in 1995, within EUs agri-environmental regulation, over an extension of 64,000 ha in Southern Portugal (Fig. 1), mostly within the Municipality of Castro Verde. The area under the ZPCV is dominated by a mosaic landscape often referred to as cereal steppe. The traditional management of this mosaic landscape, consisting mainly of cereal fields, fallow land, pastures and ploughed fields, is based on extensive cultivation of cereals in a rotation scheme. Although an economically marginal farming system, the importance of the Cereal Steppes of Castro Verde as one of the last refuges for many steppic birds with unfavorable conservation status, such as the great bustard (*Otis tarda* L.), the little bustard (*Tetrax tetrax* L.), and the lesser kestrel (*Falco naumanni* Fleischer) is well known (Delgado and Moreira, 2000).

The ZPCV was designed to avoid the loss of suitable habitat for such bird species by financially compensating those farmers who voluntarily agreed to maintain the farming practice described. In spite of the reported positive effects of the ZPCV on target bird populations (Borralho et al., 1999), the occurrence of soil erosion caused by cereal farming is an important drawback of this program, which has not been taken into account in past program evaluations.

The paper is organized as follows: in Section 2, a systematic description of the functions performed by an undisturbed soil as well as the potential flow of benefits delivered to humans is provided. An overview of the impacts of soil erosion on the flow of benefits, and also on adjacent systems, is described. In Section 3, we present the case study of the ZPCV and an application of the replacement cost method to estimate the costs of soil productivity loss due to erosion. The conflict between biodiversity and soil conservation is highlighted in Section 4 through a simple cost–benefit analysis of the ZPCV. We conclude in Section 5 by drawing policy recommendations and listing further research needs.

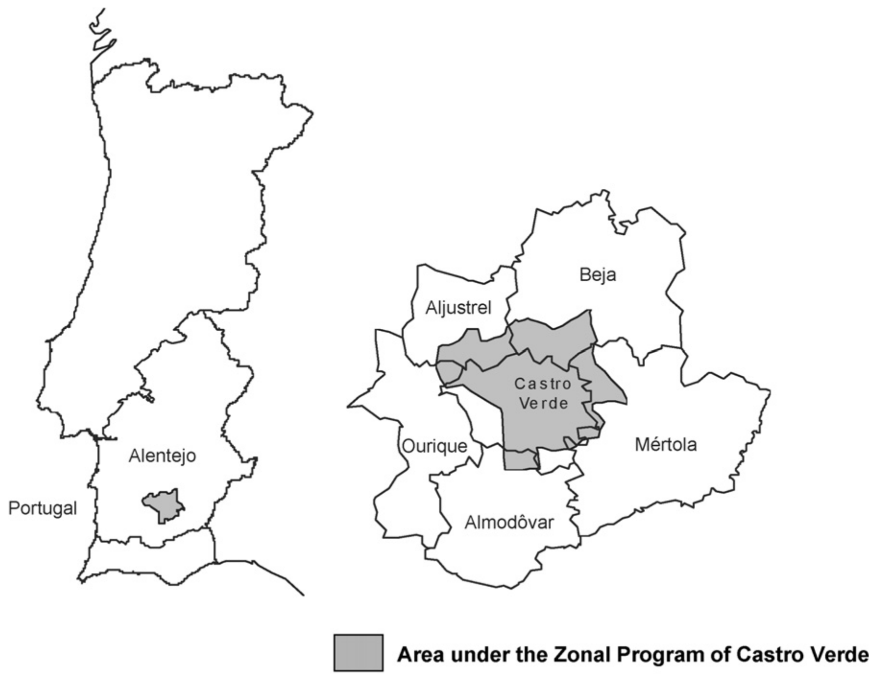

Fig. 1. Study area location and geographical limits of the Zonal Program of Castro Verde.

2. Soil services and effects of erosion

This section describes the potential spectrum of environmental services that can be delivered by a natural, relatively undisturbed soil ecosystem, and how conversion to agricultural purposes affects these services through erosion.

2.1. Flow of environmental services provided by an undisturbed soil ecosystem

Soil is a terrestrial ecosystem located at the interface between the Earth's surface and the bedrock, with biotic and abiotic components linked through biogeochemical processes. Humans have influenced the evolution of soil ecosystems through their exploitation for such different purposes as settlements, roads, and agriculture. However, soil is much more than just a substrate for infrastructure, and to achieve more sustainable use, there is a need to depict the flow of environmental services provided by soil in a systematic way. Environmental goods and services are the current or potential benefits humans derive from the ecological functioning of ecosystems. These benefits can be expressed through their economic value and also through their socio-cultural value (de Groot et al., 2002). According to de Groot et al. (2002) the capacity (function) of any ecosystem to provide goods and services depends on the underlying natural components and processes and can be grouped into four major categories: regulation functions, habitat functions, production functions and information functions.

In Table 1, we describe the flow of environmental goods and services generated by a well-functioning soil, following this typology. The description is not exhaustive and the magnitude of some services depends very much on soil cover type and density, as well as on soil structure itself.

2.2. Overview of the impacts of farming induced erosion on soil functioning

The direct benefits humans can derive from soil production functions have been the main driving force for conversion of natural ecosystems into agricultural fields. The nature and extent of the impacts of farming on the soil depend very much on the intensity of farming, the farming practices adopted and the soil's suitability for crop production (Lal, 1993; Warkentin, 2001). Positive environmental impacts of farming are in general associated with low input farming systems. Without denying the beneficial role of agriculture in creating landscape diversity and enhancing biological diversity in some cases (Pretty, 1998; Bignal and McCracken, 2000), agricultural activity has many negative effects, including, in many cases, (increased) soil erosion. Soil erosion is the detachment or breaking away of soil particles from a land surface by some erosive agent, most commonly water or wind, and the subsequent transportation of the detached particles to another location (Flanagan, 2002). Erosion is a natural process occurring at relatively low rates but which may be accelerated by human activity, such as farming. Induced or accelerated soil erosion can have major impacts both on-site and on adjacent areas (Lal, 2001).

On-site impacts of erosion refer mainly to the disruption of soil functioning, perceived in farmland through the loss of soil productivity. The topsoil lost by erosion is the most fertile, as it contains soil organic matter and nutrient reserves, and offers the optimal seedbed for germinating and emerging plants (Hatfield, 2002). Loss of organic matter resulting from soil erosion can generate an imbalance of soil functions. It generates compaction, therefore less gas exchange with the atmosphere, less possibility for water infiltration and more surface runoff, less sorptive capacity for nutrients and toxic materials, less biological activity, and less potential for biological detoxification (De Kimpe and Warkentin, 1998). See Table 1 for an overview of soil functions that may be affected by soil erosion.

Off-site impacts are those linked with the transport and deposition of soil from production fields to adjacent or downstream areas. The eroded sediments can cause a number of off-site damages, including sedimentation of dam lakes, siltation of harbours and channels and pollution of watercourses, which are costly in both environmental and socio-economic terms. The eroded sediments entering water bodies cause harm to aquatic living organisms by contaminating the water with soil particles along with fertilizer and pesticides. Damage to public health has also been reported (Pimentel et al., 1995).

3. Case study

The cereal steppe is the main landscape unit within the Municipality of Castro Verde, Southern Portugal, comprising about 82% of the agricultural area. The origin and expansion of the Cereal Steppe of Castro Verde is rooted in the recent past economic and political history of Portugal, which brought to cereal production many unsuitable soils for agriculture, in an attempt to make the country self-sufficient in wheat production. This agricultural rush (Wheat Campaign) took place

Table 1
The provision of environmental goods and services by the soil ecosystem[a]

Soil Functions [b]	Goods and services	Examples of economic and socio-cultural benefits [c]
Production		
Conversion of solar energy into biomass	Food and Fiber Fuel and energy Raw materials Drugs and pharmaceuticals	Soils are used primarily for production of food, fuel and fiber **(4)**. Approximately 11% of the land area, or 1461 million ha of the world, are presently cultivated **(3)**. Soils are used directly as raw materials for constructing dams and foundations. Some ingredients are used for bricks and ceramic products **(4)**. Soils also contain organisms which are useful in pharmaceutical production: penicillin and cyclosporin are two well known fungal products **(8)**
Regulation		
Nutrient cycling Formation and retention of organic matter	Maintenance and renewal of soil fertility	The processing by soil organisms of dead organic matter and waste replenishes the nutrients required for primary production and thus fuels the cycle of life**(1)**. Once natural fertility declines (a tonne of fertile agricultural topsoil typically contains 1 to 6 Kg of Nitrogen, 1 to 3 Kg of phosphorus and 2 to 30 kg of potassium), **(2)** external inputs of inorganic fertilizers are needed.
Water regulation Water supply	Buffering and regulation of hydrological flows Groundwater pollution control	Like a sponge, soil absorbs precipitation and gradually releases it to plants and into subterranean aquifers and surface streams **(1).** Extra costs for artificial flood prevention and irrigation are avoided. Soil also acts as a filter and absorbant for chemicals, thus contributing to improved water availability to human consumption **(3)**.
Gas regulation	Influence on Greenhouse effect & climate change	Soil is a sink for carbon, nitrogen and other gaseous elements that may be converted to volatile forms and released into the atmosphere **(3)**. The debate surrounding climate change effects still remains as well as uncertainty about the society adaptations costs **(9)**.
Waste treatment	Pollution control ; environmental detoxification	Soil can contribute to the detoxification of pollutants on a global and a local scale, for instance, detoxifying the pollutants in our yards, farms, golf courses and parks. Bioremediation is a growing industry **(6)**.
Habitat		
Suitable living space	Maintenance of biological and genetic diversity	Soils are the habitat for millions of organisms, ranging from cellular bacteria to burrowing animals. Because soil is a suitable habitat for so many species, it is a repository for a great deal of genetic material **(3)**. Although the role of most of the organisms in soil functioning remains unknown there are evidences of their ecological and economic importance **(5).**
Information		
Archeological records Seeds banks Pollen storage Field laboratory	Scientific knowledge Natural history knowledge	Soil sciences contributes much to the understanding of natural and human history **(3)**. Soil is a source of paleontological and archeological evidence, relevant for the understanding of the evolution of earth and mankind **(7)**. Although we are connected to the land and soils in ways that most of us do not readily comprehend, we do recognize the sense of belonging and the feeling of renewal associated with our contacts with the natural world **(4)**.

[a]The table only describes those functions provided by a relatively undisturbed soil and therefore does not include the use of soil as a substrate for human infrastructure (e.g. buildings, roads, etc). [b]Classification of function, goods and services is based on de Groot et al. (2002). [c]Examples are based on (1) Daily et al. (1997), (2) Pimentel et al. (1995), (3) Larson (2002), (4) Arnold (2002), (5) Andren and Balandreau (1999), (6) Sayler (1991), (7) EEA (1999), (8) Hagvar (1998) and (9) Tol et al. (1998).

during the 1930s and resulted in the clearing of existing vegetation and trees, ploughing of all types of soils, on all types of slopes, causing widespread soil erosion. Soil productivity soon collapsed and led to a shift from an intensive cereal cultivation system to an extensive mixed system characterized by cereal and livestock farming.

Structurally the Cereal Steppe is an open mosaic landscape, consisting mainly of cereal fields, stubble, ploughed and fallow land (usually grazed) and is based on extensive cultivation of cereals under a rotational scheme. Under the dominant rotation scheme, each farm is divided into plots, each of which lies under cereal cultivation for one or two years, after which land is left fallow for a period of 2–3 years. After this period, the plot is ploughed, re-initiating the rotation (Fig. 2). Fallow land is mainly grazed by sheep and to a lesser extent by goats and beef cattle.

Although marginal, with yield less than half the average yield in the European Union (Suárez et al., 1997), this low intensity dry land cereal farming holds a large proportion of steppic bird species threatened at their global scale of distribution. The importance of this human dominated landscape, as one of the last refuges for many steppic birds, such as the great bustard (*O. tarda*), the little bustard (*T. tetrax*), and the lesser kestrel (*F. naumanni*) is widely recognized (Tucker and Heath, 1994; Delgado and Moreira, 2000).

In 1995, a management program for this landscape (ZPCV) was implemented within the EU Agri-environmental measures. The program was implemented to prevent the anticipated land use changes to agro-forestry activities, thus avoiding the loss of suitable habitat for bird species with unfavorable conservation status. This was accomplished by financially compensating those farmers who keep their land under extensive cereal cultivation. Besides maintaining their current farming practices, farmers who signed up for the program were obliged to adapt some of the usual farming practices according to the bird species' life cycles. For instance, the time interval for cutting fodder and harvesting cereal may be adjusted annually in order to minimize the disturbance during the nesting period of the target species. Although management agreements contain some constraints that contribute to soil protection (maintenance of crop rotations, long fallow periods, prohibition of burning stubble), they do not prevent the continuing erosion of the very thin and shallow soils brought into cereal cultivation. Any tillage of soil will promote soil disaggregation and consequent erosion.

Within the Municipality of Castro Verde soils are mostly derived from schist and are characterized by their thinness and deficient drainage. Only a small proportion of soils are suitable for agricultural use. According to the Portuguese classification of soil capacity, of the total area under agricultural use in Castro Verde, 17.5% is within Classes A, B and C while 82.5% belongs to Classes D and E (Fig. 3). Soils belonging to Class D have very low use capabilities and very high erosion risk, mainly suited permanent pastures, brushwood, and forest. Soils under Class E are not suitable for any economic use and subject to severe erosion risks. Classes A, B and C are less affected by erosion risks than soils under Classes D and E (see the legend for Fig. 3 for a detailed description of each category).

The occurrence of soil erosion in the southern region of Portugal is well-documented (D'Araújo, 1974; Poeira et al., 1990; Kosmas et al., 1997; Bergkamp et al., 1997; Sequeira, 1998). The high erosion rates occurring in Mediterranean areas are attributed to the climatic regime and the lack of vegetation cover. This cause-effect relationship has been demonstrated by Kosmas et al. (1997) for different land uses and holds also for the region of Castro Verde. The climate of this

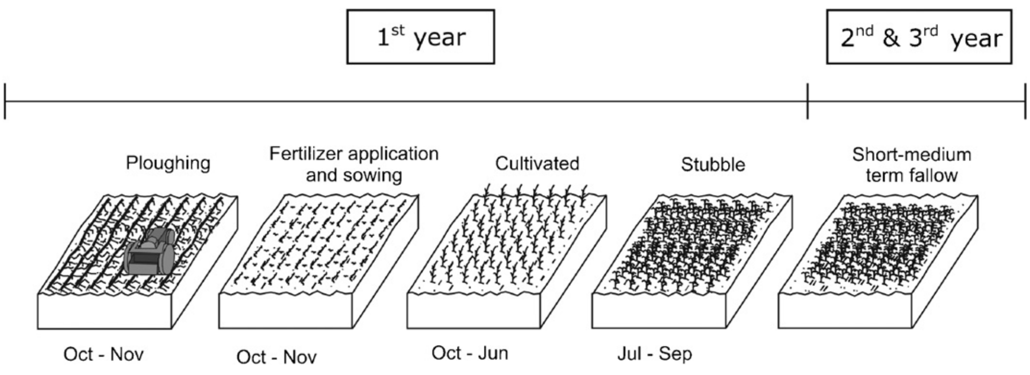

Fig. 2. Calendar of winter cereals' farming in the study area.

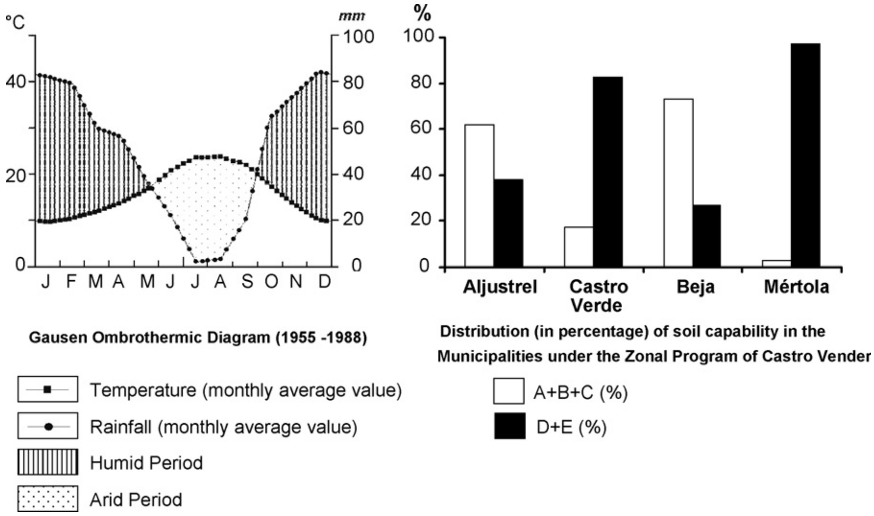

Fig. 3. Climatic and edaphic characterisation of the study area. Class A: very high use capability, no limitations and erosion risk, adequate for intensive cultivation; Class B: high use capability, some limitations and erosion risk, adequate for intensive cultivation; Class C: medium use capability, accentuated limitations and possible high erosion risk, conservation practices required; Class D: low use capability, high proportion of coarse elements in the soil, high erosion risks, only indicated for pastures, brushwood or forest; Class E: not suitable for any economic use, very thin soils, close to parent rock, severe risk of erosion, accentuated slopes, water deficiency throughout the year.

region is typically Mediterranean, with a very hot and dry summer and a moderate winter. The annual average rainfall is low (about 580 mm), occurring essentially during winter and fall (Fig. 3). Most rainfall and associated runoff events occur from early October to late February when the soils are almost bare, or the vegetation cover is not enough to protect the soil, due to the tillage calendar adopted in this region (Fig. 2). Studies reporting on the impacts (both on-site and off-site) of such erosive events in this region have been scarce and have not quantified the impacts in monetary terms. Rocha (1998) suggested that this region was very prone to soil erosion and identified sedimentation of water reservoirs as one of its impacts, but did not mention the economic impacts.

Although the occurrence of soil erosion caused by cereal farming is an important drawback of the ZPCV, its impact on the cost-efficiency of the program has not been taken into account in past program assessments. Past assessments of the program have been restricted to monitoring the effects of adopted measures on the target bird species' populations. These ecological assessments in general report positive results (Borralho et al., 1999). To the best of our knowledge, there have been no studies that attempted to provide information for the cost–benefit analysis of the program, other than Marta et al. (2005). Marta et al. (2005) used the contingent valuation method to estimate individuals' willingness to pay (WTP) to preserve the Cereal Steppe of Castro Verde and thus provide a benefit measure of the program. Individuals' WTP to preserve the Cereal Steppe of Castro Verde were obtained as voluntary contributions (one time payment) in an open-ended question format. A total of 422 Portuguese employed individuals were surveyed using two different approaches, in-person (230 individuals) and through the internet (192 individuals). The valuation scenario presented to respondents was based on a hypothetical situation in which the ZPCV would be cancelled. Respondents were told that it would mean that the current financial compensation given to farmers who agreed to maintain their land under traditional cereal cultivation would be suspended. So, the scenario of land use changes to agro-forestry would become the most profitable option for local farmers. Facing this hypothetical situation, the preservation of 1/3 of the area of the Cereal Steppe within the Municipality of Castro Verde would be possible if an environmental non-profit organization were financially supported by citizen's donations to acquire such an area. Individual Portuguese WTP was found to be 30 €.

3.1. Erosion cost estimation: an application of the replacement cost method

To include soil erosion impacts in the CBA of the ZPCV, a monetary valuation of the observed or expected impacts was required. Although the effects of soil erosion are well recognized, considerable difficulties arise in their valuation. There is no single method generally recognized for the valuation of soil erosion effects. Currently, productivity change and replacement cost are the most used methods in the economic literature for the valuation of soil services and estimation of the costs of erosion effects. Both methods of valuation are not exempt from criticisms (Enters, 1998). The productivity change method is of interest when the effects of erosion can be measured through the change in crop yields due to erosion, which are assumed to be a monetary measure of the costs of erosion. The replacement cost method (RCM) is used when the focus of the study is on erosion effect on soil properties (e.g. nutrient content loss) which directly influence, among others, soil productivity. We used RCM rather than productivity change because the change in productivity is an important on-site cost of erosion when the main function of agricultural land is food and fiber production. In our case study the maintenance of soil productivity conditions is needed to ensure the provision of many other services than production functions, namely biodiversity preservation. Thus the use of productivity change would not be adequate. Notice that the agricultural system of interest is a marginal system with yield less than half the average yield in EU.

The basic premise of the RCM is that the costs incurred in replacing productive assets damaged by a certain economic activity can be measured and interpreted as an estimate of the benefits presumed to flow from measures taken to prevent those damages from occurring (Dixon et al., 1996). The rationale for RCM application in our case study comes from the assumption that soil productivity can be maintained: (a) if lost nutrients and organic matter are replaced artificially at levels prior to the erosive events and (b) if soil depth is maintained above a critical value, through the replacement and stabilization of the eroded sediment. This is a rather restrictive assumption since: (1) soil productivity depends on many other factors and (2) soil nutrients are lost through means other than soil erosion (Gunatilake and Vieth, 2000). In spite of these constraints, RCM is known to be a reasonable provider of a lower bound to the on-site costs of soil erosion. Overestimation of such costs can occur if the soil has deep and fertile layers (Hufschmidt et al., 1983). This caution does not apply to our results since soil in the study area has an average depth of only 15 cm and has low fertility.

The validity of the RCM is still subject to the fulfilment of two additional conditions (Freeman, 2003): (a) replacing the eroded sediment and nutrient contents as engineered would be the least costly option for restoring soil productivity (b) individuals in aggregate would be willing to incur the replacement costs if the soil productivity capacity was no longer available. As to the first condition, and at least concerning the replacement of the eroded sediment, there would be alternative techniques expected to be less costly than dredging the eroded sediment accumulated downstream as we consider in our estimation. Settling on vegetation strips or other fences along a topographically controlled distribution would be among the least costly strategies that could be used at the farm scale to detain overland flow of sediment (Merrington et al., 2002). These options should not be considered in Castro Verde because landscape openness, a main habitat requirement for the target birds of the ZPCV, would be compromised by vegetation strips and fences. The second condition, the existence of willingness to incur the costs of replacement, is addressed based on the existing information on individuals' willingness to pay to preserve the Cereal Steppe of Castro Verde. Marta et al. (2005) provided evidence that maintenance of soil productivity and current cereal farming is desired from a societal perspective for reasons other than the supply of cereals by estimating the willingness to pay to preserve it.

Therefore, by applying the RCM, the cost of replacing soil productivity to similar levels prior to erosive events was estimated by calculating the cost of replacing nutrient losses (organic matter, P and K) and the cost of returning the eroded sediment to the farmland as a proxy. Although these losses occur simultaneously, they were considered as separate elements since the complete loss of the soil's arable layer can effectively occur (due to its thinness) in a short to medium time span.

Loss of soil nutrients was indirectly estimated by multiplying the nutrient content in the non-eroded soil[1] (organic matter, P and K) by the quantity of soil eroded, as suggested by Gunatilake and Vieth (2000). Replacement costs of nutrients losses were estimated using their market prices obtained from the company ''Adubos de Portugal'', which is the leader in the Portuguese fertilizer market. The costs of spreading fertilizers were not included in our analysis because spreading was assumed to be undertaken during annual routine fertilizer applications by local farmers.

[1] For the purpose of quantification of soil nutrients, five soil samples were collected at 15 cm soil depth after the completion of the rotation, i.e., after 2 years of fallow. The collection sites were chosen randomly within the study area. The mean value was used as an estimate of nutrient content.

We assumed that all the sediment eroded accumulated in the same water reservoir and thus its recovery was technically feasible. Our cost estimate of replacing the sediment only included the cost of dredging operations, which was calculated based on the market price for the removal of 1 m^3 of sediment using a track-type excavator. The price was obtained from the company ''Isidoro Correia Silva, Lda''. It should be noted that a complete cost estimation of returning the eroded sediment to farmland would include also, the transportation costs to farmland and the costs of sediment spreading and stabilization. There is no information available on the costs of such operations.

The model used for the replacement cost calculation was adapted from Dixon and Hufschmidt (1986):

$$RC = (S_t - S_{t+1})\left[\sum_{j=1}^{K} N_j P_j + \frac{P_r}{B_d}\right]$$

where RC is the replacement cost of nutrients and eroded sediment removal (€ ha^{-1}), $S_t - S_{t+1}$ the soil loss from time t to $t + 1$ (tonnes ha^{-1}), N_j the quantity of the jth nutrient in the soil (kg $tonne^{-1}$), P_j the price of the jth nutrient (€ kg^{-1}), $j = 1, \ldots K$, B_d the soil bulk density (tonnes m^{-3}), and P_r is the cost of dredging 1 m^3 of sediment (€ m^{-3}).

The model was applied to estimate the yearly replacement cost of soil nutrient losses and the recovery of the eroded sediment for the range of erosion rates occurring in Castro Verde. Erosion rates were obtained from the erosion map for Castro Verde, produced by the Governmental Department for Land Use Planning (Fig. 4). This map was originally produced by quantifying the parameters of the Universal Soil Loss Equation (USLE) spatially. We also included in our estimation, as an indicative value, the findings by D'Araújo (1974) on erosion rate attributable to winter cereals tillage: 3.7 tonnes ha^{-1} yr^{-1}, which was based

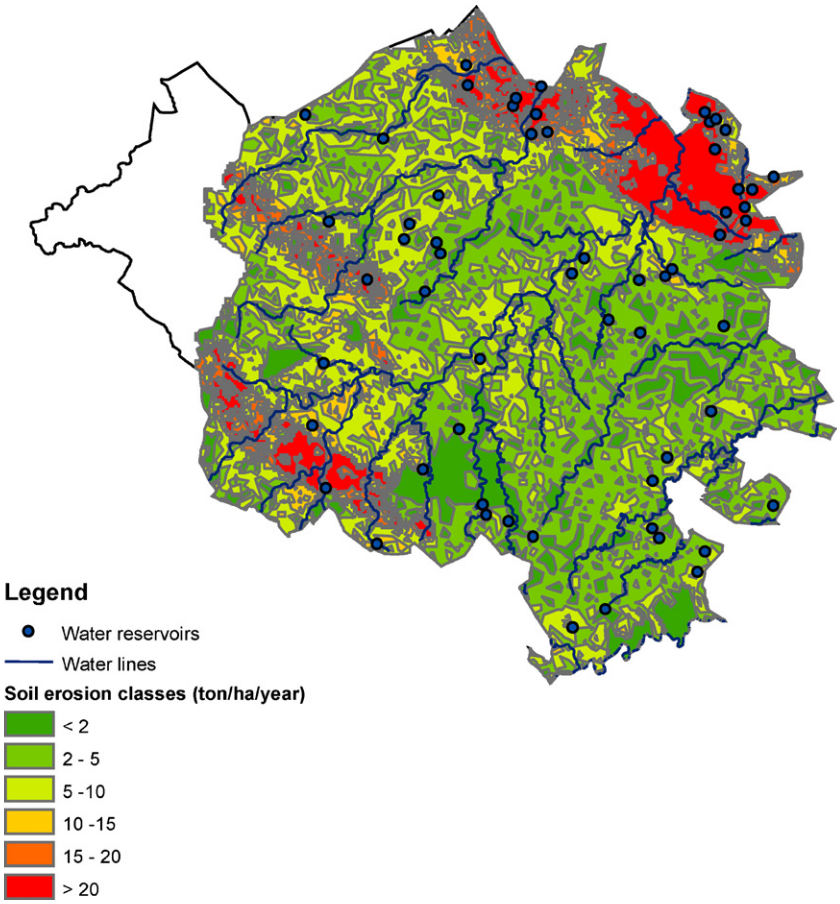

Fig. 4. Soil erosion map for the Municipality of Castro Verde. *Note*: The area of the Municipality of Castro Verde that is part of the Hydrological Basin of the Sado River is not shown. Soil erosion map was obtained using the USLE equation. Data was obtained from INAG (Instituto Nacional da Água).

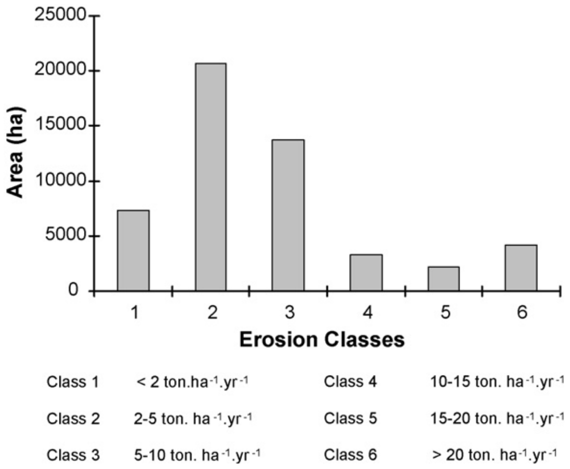

Fig. 5. Area of soil erosion classes within the Municipality of Castro Verde.

on the quantity of sediment trapped during 20 years in Albufeira de Vale Formoso (Southern Portugal). During that period, the catchment's area (192 ha), was dominated by winter cereal cultivation (under the rotation of interest for our purpose) mainly in soils derived from schist. The value of 3.7 tonnes ha^{-1} yr^{-1} reflects the temporal variability of parameters determining soil erosion (e.g., variability of precipitation values along a 20 years period) and as observed in Fig. 4 this value is approximately the midpoint of the erosion class 2 (2–5 tonnes ha^{-1} yr^{-1}), which is the most representative in terms of the area mapped (Fig. 5).

By applying the RCM, under the assumptions and data constraints described, the on-site cost ranged from 9 to 87 € ha^{-1} yr^{-1} (Table 2). Estimates represented the cost farmers would incur if soil productivity were to be maintained. As described before in Section 2, the benefits society derives from soil are diverse and cannot be restricted to its productivity (e.g. carbon sink and groundwater pollution control). There is also evidence in the literature that off-site impacts, such as sedimentation of dam lakes, siltation of harbours and pollution of rivers, can be very costly to society (Pimentel et al., 1995). The full societal cost estimation should include all these effects and would thus be much higher than the monetary damage calculated in this paper.

4. Cost–benefit analysis of the ZPCV: biodiversity versus soil conservation

The estimated costs (9–87 € ha^{-1} yr^{-1}) would be a strong underestimation (see Section 2.2) of the real cost of soil erosion occurring in the study area. Nevertheless several inferences on the ZPCV's cost-efficiency can be drawn based on our findings and also some of the trade-offs coming from the provision of public goods in private land can be addressed.

Maintenance of this tillage system is being financially supported through compensation payments given to those farmers who sign up for the ZPCV. The compensation payments were meant to maintain farmers' income under the current farming option: extensive cultivation of winter cereals avoiding the adoption of either more short-term profitable activities or land abandonment. Both land use options would have negative effects for the steppic birds' populations because their conservation relies on the maintenance of the current tillage and cultivation pattern. Note that agro-forestry use, against which the ZPCV is being compared, would likely lead to increased soil protection. We assumed when comparing the benefits and costs of the ZPCV that the erosion rate would be negligible under agro-forestry. This assumption is supported by empirical evidence gained in the region.

The financial compensation given to those farmers signed up for voluntary agreements[2] was 73 € ha^{-1} yr^{-1} (MA, 2001). The reasoning for the public expenditure comes from the assumption that maintenance of extensive cereals farming is needed to ensure local biodiversity. Nevertheless it must be noted that there is a trade-off between bird species conservation and long-term maintenance of soil productivity. The yearly cost of replacing soil productivity is about 22% of the compensation payments given to farmers (considering the indicative erosion value of 3.7 tonnes ha^{-1} yr^{-1}). For the case of the two highest erosion rates considered in our analysis the cost of soil productivity maintenance would be higher than the compensation received. Thus we cannot expect that the replacement of soil productivity would be routinely performed by farmers on their land without an increase in payment received. Currently, soil replacement is not undertaken by farmers and it seems reasonable to admit that, without public investments in soil productivity maintenance, soil loss as a consequence of erosion will continue. Thus the expected efficiency and success of the government intervention to protect the bird populations, through the compensation payments given to farmers, is subject to the following constraints: (a) no effective measures for the mitigation of soil productivity loss, caused by erosion, are being undertaken by

[2] Compensation payment for the average farm size of 160 ha until the year 2001.

Table 2
Yearly cost estimates to replace nutrients and eroded sediments from farmland in the Municipality of Castro Verde

	Soil content[a] (kg tonne^{-1})	Loss (kg ha^{-1})						Cost (€ ha^{-1})					
		(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)
Nutrients													
Organic matter	10	37	20	75	125	175	200	1.92	1.04	3.90	6.50	9.10	10.40
P	0.008	0.03	0.02	0.06	0.10	0.14	0.16	0.02	0.01	0.05	0.08	0.12	0.13
K	0.066	0.24	0.13	0.50	0.83	1.16	1.32	0.09	0.05	0.17	0.29	0.41	0.46
Sediment[b]		3700	2000	7500	12,500	175,000	200,000	14.02	7.58	28.41	47.35	66.29	75.6
€ ha^{-1} yr^{-1}								16.50	8.68	32.53	54.22	75.91	86.75

(1) 3.7 tonnes ha^{-1} yr^{-1} (D'Araújo, 1974).
(2) 2 tonnes ha^{-1} yr^{-1} [upper bound for erosion Class 1].
(3) 7.5 tonnes ha^{-1} yr^{-1} [interval mid point for erosion Class 3].
(4) 12.5 tonnes ha^{-1} yr^{-1} [interval mid point for erosion Class 4].
(5) 17.5 tonnes ha^{-1} yr^{-1} [interval mid point for erosion Class 5].
(6) 20 tonnes ha^{-1} yr^{-1} [lower bound for erosion Class 6].
[a] Average nutrient content of five samples soil collected at 15 cm soil depth.
[b] Bulk density = 1.32 g cm^{-3}; the cost of dredging the eroded sediment, which is assumed to be trapped in the same water, reservoir is 5 € m^{-3}.

farmers; (b) the continued and irreversible soil loss is being promoted by current government intervention and it represents a big cost to society as a whole.

Long-term soil erosion can be a major threat to steppic bird's species preservation as well as countryside maintenance. As emphasized before, the complete depletion of soil productivity is likely to occur under the current land use in the absence of erosion mitigation measures. The sustainability of this human-dominated ecosystem, both ecologically and socio-economically, is firstly dependent on the maintenance of soil as a productive resource and secondly on the attractiveness of compensation payments given to farmers. Public expenditure is justified, from a societal perspective, if the benefits flowing from the current land management might exceed the costs of maintaining it under sustainable levels. Hence, there is a need to perform CBA of public expenditures (including public investment in agri-environmental programs).

Marta et al. (2005) provide evidence that maintenance of soil productivity and current cereal farming is desired from a societal perspective for reasons other than the supply of cereals by estimating the willingness to pay to preserve it (see Section 3.1). The aggregated willingness to pay figure estimated by the mentioned authors was converted by us into annuities in a per

Table 3
Simple cost–benefit analysis of the Zonal Program of Castro Verde

Environmental Impacts	**Costs (€ ha^{-1} yr^{-1})**	**Benefits (€ ha^{-1} yr^{-1})**
Physical soil loss	14 – 76	—
Nutrient loss	2 – 11	—
		—
Species preservation / Landscape identity	73	446
	Estimated Net benefit	357- 286

hectare basis for the purpose of the cost–benefit analysis of the ZPCV (Table 3). Annuities (446 € ha^{-1} yr^{-1}) were obtained considering a time horizon of 40 years and a discount rate of 5% for the purpose of converting a one time payment to constant annuities (Dixon and Hufschmidt, 1986). The costs and benefits of maintaining the Cereal Steppe of Castro Verde leading to a positive CBA between 286 and 357 € ha^{-1} yr^{-1} reduced the cost-efficiency of the ZPCV by almost 30%. The outcome of the rough CBA should be regarded with caution due to the data constraints and simplifications used in cost estimation.

5. Conclusions

Our analysis aimed to assess the costs of soil erosion due to continuation of traditional cereal farming as encouraged by the Zonal Program of Castro Verde (ZPCV) and to contribute to the cost–benefit analysis (CBA) of this program. Although CBA is appealing for policy appraisal, its usefulness is often limited by the lack of monetary values for environmental assets. In spite of the data constraints and simplifications used in cost erosion estimations, our study showed that the efficiency (in terms of monetary benefits versus costs) of the ZPCV was much reduced due to soil erosion.

The ZPCV is based on the premise that maintaining the current tillage system is a basic condition to preserve target bird species habitat requirements. Thus, we focused on mitigation measures of soil erosion under the current tillage system. Due to the uncertain effectiveness of such measures and their costs, further research is needed on the impact of conservation tillage on local biodiversity. There is evidence from previous studies that no-tillage cereal farming can reduce soil erosion in this region (Basch et al., 1996; Barreiros et al., 1996). A better understanding of the impact of the adoption of no-tillage systems on the steppic birds' habitat requirements would be a valuable contribution to sustainable regional planning.

Also, more research is needed on defining indicators to assess the overall impact of soil erosion that can be rapidly measured in monetary terms and incorporated in CBA. These research efforts are critical to improve land use decision-making and the cost-efficiency of the Zonal Program of Castro Verde.

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