African Journal of Agricultural Research Vol. 5(1), pp. 001-006, 4 January, 2010
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR09.595
ISSN 1991-637X © 2010 Academic Journals

Full Length Research Paper

Economic valuation of soil erosion in a semi arid area in Turkey

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Accepted 19 November, 2009

Economic valuation deficiency of soil erosion (because of its complex structure) is a well known matter. In this research it has been purposed to determine and calculate the economic value of the soil erosion event according to nutrient loss and their market prices as fertilizers, using the "market value of soil" method. The soil loss amounts were obtained from the measurement plots and the nutrient loss amounts from the eroded soils in the measurement plots with laboratory analyzes. Fertilizer prizes were collected from the regional fertilizer markets which are the lowest prizes in the market. The results show that an economic value loss because of soil erosion event in the research area occurs in average about 59.54 dollars (ha/year) in the pasture lands and about 102.36 dollars (ha/year) in the agricultural lands.

Key words: Soil nutrients, soil loss, market value of soil, fertilizers.

INTRODUCTION

Land may be described as a non-renewable (fixed stock) resource, although it has a renewable capacity to support most forms of biological life. Ciriacy-Wantrup defined topsoil as a renewable resource with a threshold level below which resource use renders it non-renewable. Many of the land-use practices adopted in the developing countries appear to be consistent with measures that transform topsoil into a non-renewable resource. The central characteristic of renewable resources is that they are thought to be capable of natural regeneration into useful 'products' within a time span relevant to man (Jayasuriya, 2003).

The natural resources (forests, wetlands, water resources, etc.) are being reduced to satisfy the food, fuel, industrial and other needs of the growing world population especially in the last century. The precaution and solution suggestions about the soil erosion are also being presented in the beginning of the last century. Application results of the soil erosion studies have shown that it has been taken a very long distance in this area which is not enough to solve the erosion problem completely. The need of research data and consciousness of the people is still necessary, to prevent the soil erosion damages and the economic and social problems (Richter, 1998).

According to ISRIC (International Soil Reference and Information Centre) very high water erosion is being reign in Turkey (Oldeman et al., 1991). Soil erosion is a great problem in Turkey which affects 79.43% of the total land surface in medium, high and very high grade (Anonymous 1, 1987). 500 million tons of eroded surface soils are yearly transported in to the dams, lakes and seas in Turkey. Some scientists estimate this value about 1 billion tons per year (Anonymous 3, 2001).

Physical events and socio-economic factors both are two main elements which are prompting the soil erosion. Moving from this point of view, it is necessary to analyze the soil erosion according to interactive relations between the soils, animals, plants and the human activities. These facts force the researchers in the physical and socio-economic area to work together (Toksoy and Hacisalihoglu, 2008).

The economic valuation of soil erosion centres round placing an economic value on soil. The value placed on soil depends on whose perspective it is that the analysis is being carried out. In the case of an agricultural Industry, two main soil user groups can be identified: the

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Figure 1. Location of the research area.

cultivators in the area and society as a whole (Jayasuriya, 2003).

The cost of soil erosion is not so much dependent on the physical amounts of soil lost. Soil erosion has both onsite and offsite effects. Loss of soil productivity is the main onsite effect, while enhanced productivity of downstream land, sedimentation and eutrophication of waterways and reservoirs are common offsite effects (Knut, 1996).

The knowledge about the soil erosion demonstrates that the output of these processes have very big negative effects. There is much different type of models using in determining the economic value of the soil erosion. Every model has its own perspectives and determines the results according to this perspective, but also these models have their own natural obstructions.

In this research, soil erosion amounts and nutrient loss amounts from eroded soils were determined in a semi arid area with terrestrial climatic conditions in interior part of Eastern Black sea Region of Turkey. The Economic value of erosion was calculated with the “market value of soil” method using these determined soil and nutrient loss amounts.

MATERIALS AND METHODS

Description of the study area

The study was carried out in Bayana in the county of Gumuşhane in Northeastern Turkey (40°23′40″ N, 39°18′50″ E) (Figure 1).

The altitude of the study area was about 1860 m above sea-level. The aspect of the study site was North-west (NW). In the study area, terrestrial climatic conditions exist, that is, winters are long, cold and snowy, whereas summers are short and warm (Anonymous 2, 2003). Seasonal and daily temperatures show big extreme values and precipitation is generally low. The weather data for 2003 (Gumuşhane Meteorology Station, at 1219 m) indicate that precipitation averages 400 mm annually). Average monthly temperatures range from 29°C in August to - 6°C in January. Differently sized andesite/quartz dikes are to be seen in the studied site (Anonymous 4, 1986).

Setting up experimental design and sampling

Three different land-use types and two different slope classes in each type were chosen to set up the experiments, namely, forest land, agricultural land and pasture land. Dominant tree type in the forest land was Scots pine (*Pinus sylvestris*). Scots pine stands were approximately 50 years old and the stand canopy closure was moderate (0.5 - 0.6). The agricultural land was used to grow some crops and fodders until 20 years ago, but since then it has been covered by grass. Only, at the beginning of the experiment, the soil in the plots of the agricultural land was tilled until the depth of 50 cm. Some parts of the pasture land were over-grazed and some parts had little vegetation cover. For each land-use type, two experimental sites (total 6) and 3 plots at each experimental site were taken (6 x 3 = 18 plots totally). Mean slopes of the plots were 20% (range 15 - 20%) and 40% (range 35 - 40%) (Hacisalihoglu, 2004). The diagrams of the experimental site (10 x 12 m) and the plots (2 x 10 m) are shown in Figure 2 (Richter, 1998).

The experimental sites were protected by a thorny cable to minimize the impact of wild-life and humans. Sampling plots were also protected by a galvanized sheet iron (15 cm height) to reduce the splash effect of the rain drops.

During the study period (2001 - 2003), the runoff and sediment measurements were carried out in each experimental site (totally 324 times). In winter, runoff and sediment measurements were not done, since the sampling areas were covered by snow.

Soil loss amounts from the plots and also total nitrogen, usable phosphorus, exchangeable potassium and organic matter from

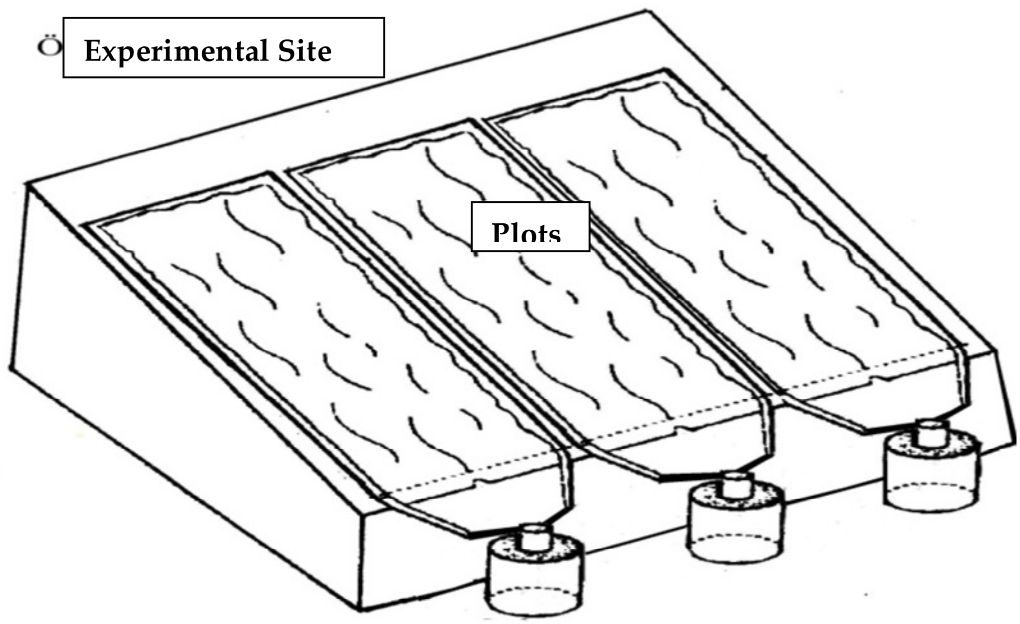

Figure 2. The diagram of the experimental site and the plots.

dried and sieved (< 2 mm) eroded soils was determined in the research area.

Soil analysis

Organic matter was determined by using the chromic acid method of Walkley and Black (Ozyuvaci, 1976; Irmak, 1954).

Total nitrogen (N) was determined with the LECO nitrogen measurement device by dry weigh method. Usable phosphorus (P) was determined according to the Bray and Kurtz (pH < 7.4) method in the Spectrophotometer device (Akillioglu and Direnc, 2002).

Exchangeable potassium (K) was determined in the Flame-Photometer device according to the one normal Ammonium Acetate method (if pH < 7 with Ammoniac; if pH > 7 with acetic acid) (Akillioglu and Direnc, 2002).

Soil pH was measured in a 1:2.5 mixture of deionized water and soil using a glass calomel electrode (Beckman H5 pH-meter), after equilibration for 1 h (Gulcur, 1974).

Economic valuation method of soil erosion

No single method for valuing soil has been established, but rather there are a number of different possible approaches (Clark, 1994). Each of these operates from different perspectives and has inherent drawbacks. Some of these methods are; replacement cost, rehabilitation cost, contingent valuation, hedonic pricing, market value of soil, production value of soil and opportunity cost etc.

The main reasons for using the "market value of soil" in determining the economic value of soil erosion can be collected as; appropriateness of the obtained data, usage of the market prices, practical application and almost correct results generation.

Jayasuriya (2003) explains the main specifications of this valuation method as follows: This method also attempts to estimate the cost of soil erosion to society as a whole. The approach adopted is based on soil erosion reducing the productive potential of the soil. This includes depletion of the soil's nutrient content, its physical structure and ecological qualities. Of these factors, only the soil's nutrient content can be valued in terms of marketed proxies (that is, artificial fertilizers). Therefore, the analysis estimates the value of reduction in soil's productive potential in terms of depletion of the soil's nutrient resource base. It is calculated as the market value of the difference in soil nutrient content between an eroding soil and uneroded soil. The method undervalues the soil from society's perspective. The soil nutrients are valued in terms of their least cost artificial fertilizer equivalents. The analysis is not based on the soil nutrient replacement cost approach (Jayasuriya, 2003).

RESULTS AND DISCUSSION

The average total nitrogen, usable phosphorus, exchangeable potassium, organic matter and pH values from the eroded soils which obtained in the measurement plots in the research area, are shown in the Table 1 (Hacisalihoglu, 2004, Hacisalihoglu, 2006).

In the forest part of the research area couldn't be determined enough eroded soil material to analyze. The obtained soil loss amounts from the measurement plots in the forest area were very low and neglect able. It is known that the forest are with their main specifications (interception, organic matter deposition, root activities, etc.) a barrier against the erosion and soil loss is.

The most total nitrogen amounts (0 and 14%) have been determined in the 20% slope gradient in the Agricultural lands. There couldn't find any differences according to the average total nitrogen values between the land use types, statistically. But also, it is conspicuous that the highest total nitrogen values are determined in the Agricultural lands with 20% slope gradient. This fact could be explained with the highest organic matter contents in these eroded soils. It is known that the nitro-

Table 1. Soil loss, some nutrients, organic matter and pH values of the eroded top soils.

Land Use	Slope (%)	Soil loss (Ton/Ha/Year)	Total nitrogen (%)	Usable phosphorous (ppm/ha)	Exchangeable potassium (ppm/ha)	Organic matter (%)	pH (1/2,5 H_2O)
Forest	20	-	-	-	-	-	-
	40	-	-	-	-	-	-
Pasture	20	0. 02	0. 11	16526. 00	149333. 33	2. 27	6. 91
	40	0. 16	0. 08	6531. 00	66991. 00	1. 76	6. 78
Agriculture	20	0. 06	0. 14	11119. 00	157083. 00	2. 64	7. 06
	40	0. 12	0. 12	10861. 00	124222. 00	2. 48	6. 91

Table 2. Total nutrient and organic matter loss values from the eroded top soils.

Land Use	Slope (%)	Total Nitrogen loss (Kg/Ha/Year)	Usable Phosphorous loss (Kg/Ha/Year)	Exchangeable Potassium loss (Kg/Ha/Year)	Organic Matter loss (Kg/Ha/Year)
Forest	20	-	-	-	-
	40	-	-	-	-
Pasture	20	0. 22	0. 33	2. 98	4. 54
	40	1. 28	1. 04	10. 71	28. 16
Agriculture	20	0. 84	0. 67	9. 42	15. 84
	40	1. 44	1. 3	14. 9	29. 76

gen holding capacity of the organic matter is very high.

Some differences have been determined according to land use types and slope gradients in the usable phosphorus amounts. As shown in the Table 1, the usable phosphorus amounts in the 20% slope gradient of the agricultural land is quite high than the values in 40% slope gradient. Especially in the pasture lands with 20% slope gradient are the usable phosphorus amounts very higher than the values in 40% slope gradient. This fact could be explained with the relative highest organic matter contents in the 40% slope gradient (especially in the 40% slope gradient in the pasture land). It is known that one of the usable phosphorus sources in the soils is the organic matter.

The highest exchangeable potassium amounts are determined in the 20% slope gradient both in the agricultural and pasture lands. Similarly, the highest organic matter amounts are determined in the same slope gradient. Organic matter is one of the main potassium resources in the soils.

Organic matter values in the agricultural lands are higher than pasture lands in the research area, as shown in Table 1. Especially, in the 40% slope gradient of the pasture lands was determined the lowest organic matter values, relatively. This fact is related with plant coverage in the research area where the lowest coverage amounts determined in the 40% slope gradient of pasture lands.

The total nutrient (total nitrogen, usable phosphorus, exchangeable potassium and organic matter) loss values from the eroded soils (Table 1) in the research area are calculated and given in Table 2.

The economic value of soil erosion (soil loss) in the research area was calculated by using the method “market value of soil”. The method dictates that the economic value of the soil erosion could be calculated with the lowest nutrients market prices. The lowest nutrients market prices have been determined as the lower fertilizer prices from the regional fertilizer sellers, in accordance to the method. Because of absence of the fertilizer separately in pure form in the fertilizer market, the mixed fertilizers prices (NPK = Nitrogen, Phosphorus and Potassium mixed in same proportions) has been used to calculate the erosion’s economic value as shown in Table 3. Table 3 also shows the land use forms, slope gradients and the calculated total nutrient loss prices as the lowest fertilizer prices in the regional market.

Total soil loss value was calculated with multiplication of the lowest fertilizer prices (Fertilizer prices are taken from the regional fertilizer sellers in the date of Dezember, 2008) (organic fertilizer: 3.3 cent/kg, Nitrogen:

Table 3. The economic price of the soil erosion.

Land use	Slope (%)	Price of total nitrogen loss ($/ha/year) ($T_1$)	Price of total usable phosphorous loss ($/ha/year) ($T_2$)	Price of total exchangeable potassium loss ($/ha/year) ($T_3$)	Price of total organic matter loss (cent/ha/year) (T_4)	Total soil loss prices ($/ha/year) ($T_1$+$T_2$+$T_3$+$T_4$)
Forest	20	-	-	-	-	-
	40	-	-	-	-	-
Pasture	20	0.78	1.16	10.52	14.98	12.61
	40	4.52	3.67	37.81	92.93	46.93
Agriculture	20	2.97	2.37	33.25	52.27	39.11
	40	5.08	4.59	52,60	98.21	63.25

*1 $ = 1.5 TL.

3.53 dollars/kg, Phosphorus: 3.53 dollars/kg and Potassium: 3.53 dollars/kg) and the total nutrient loss amounts.

The calculated value of the soil erosion in the pasture land with 20% of slope gradient is about 12.61 dollars (ha/year) and 46.93 dollars (ha/year) in the 40% slope gradient as shown in Table 3. Total value of the soil erosion in the pasture land in research area was calculated about 59.54 dollars (ha/year).

In the agricultural land with 20% slope gradient was calculated the soil erosion value about 39.11 dollars (ha/year), while in the 40% slope gradient about 63.25 dollars (ha/year) is. Totally, (both in 20 and 40% slope gradient) soil erosion value in the agricultural land is about 102.36 dollars (ha/year).

Conclusion

It is known that the semi arid areas cover a very big space in Turkey. It is also known that soil erosion a very big problem (in about 80% of the total land surface) in Turkey is. According to different resources, about 500 million to 1 billion tons of eroded top soils are being transported to the lakes, rivers and seas with the soil erosion event. These samples should help to explain the highness of the economic value of the soil erosion.

There are many different methods to calculation the economic value of the soil erosion event. But almost all of them have their restrictions and negative sides, like the used method (market value of soil) in this study.

The main reasons for using the “market value of soil” in determining the economic value of soil erosion can be collected as; appropriateness of the obtained data, usage of the market prices, practical application and almost correct results generation.

It is necessary to take in to account that this method attempts to estimate the cost of soil erosion to society as a whole. The method undervalues the soil value from society’s perspective. The fertilizer prices changes persistently in the market and therefore, calculated prices with this method evaluates the land values high while the fertilizer prices are high and low while the fertilizer prices are low.

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