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Soil Loss Due to Erosion and its Relation to the Economic Cost

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ABSTRACT

Soil loss as a result of soil erosion has an impact on the economy, specifically when it occurs in agricultural site. The economic impact can be on-site or off-site. The on-site impacts are in the form of nutrient loss, loss of existing production and less yield, while off-site effect consists of flooding, sedimentation and damage plantation. This study focuses on some of the economic aspects of soil loss as they apply to "in-the-field" practices. The research was carried out using current data from existing literature. The data were then interpreted statistically and comparisons between various factors were made. The results indicated that the contribution of rainfall to soil loss varied and depended on some other factors such as type of vegetation cover and soil slope. In terms of economic cost due to soil loss, the off-side cost which included indirect cost such as agricultural productivity was calculated as $176.33 per ton/ha/year. This indirect cost was about more than three times of the direct cost which was $53.35 per ton/ha/year.

INTRODUCTION

In the production of food and crops, continued soil availability is fundamental. The erosion of soil, therefore has far-reaching consequences, and the loss of this non-renewable resource has been an issue of concern to researchers for some time. Soil erosion affects a country's economy by adding considerable costs to the chain of production and therefore to consumer products. According to Moore & McCarl (1987), soil erosion both on and off-site causes a variety of problems. However, off-site issues affect society and its welfare to a greater degree than on-site issues.

There have been numerous studies conducted with regard to explore the occurrences of soil erosion, soil loss and the effects of those phenomena along with specific studies of long-term soil-loss (Gunatilake & Vieth 2000, Verstraten & Poesen 2002, Ramos & Marti'nez-Casasnovas, 2004). Despite this, few investigations have been carried out to explore its economic effects alone. According to Moore & Mc Carl (1987), erosion impacts upon the income of farmers, as more and more fertilizers must be purchased to improve declining crop quality. Crop acreage is also damaged by sedimentation.

Thus, this study aims to examine the relationship between soil erosion and cost by applying a statistical method using current data from existing literature. The results should assist farmers and decision makers to formulate more effective policies to find solutions to the costs of erosion.

MATERIALS AND METHODS

This study uses data obtained from previous research undertaken in several locations in four different countries, namely, Spain, Greece, Italy and Portugal. The locations were chosen according to their type of vegetation which are vineyard, eucalyptus and olive.

Anoia (Spain) and Spata (Greece): The erosion data of the county of Anoia in The Penedes, Spain, and the town of Spata in Greece, were chosen to represent the area with vineyards. The Penedes land is located 200 m above sea level in the autonomous region of Catalonia, Spain. It has an average 15°C of air temperature with an average rainfall of 550 mm per year. The slope of the land is 4% - 20% (Ramos & Porta 1994). Meanwhile, Spata, a town in Greece is located 20 km east of Athens. This location has the average altitude of 140 m and it has a thermo-Mediterranean climate. The average air temperature is about 17.8°C with 496 mm annual rainfall. The vines are planted in an area with a 7% - 12% slope while the olive trees are grown in area with a 16%-23% slope (Kosmas 1997).

Forada Is Olias (Italy) and The Agueda Basin (Portugal): The erosion data of the village of Forada Is Olias and The Agueda Basin were chosen to represent areas mainly covered with eucalypts. Forada Is Olias is located in Cagliari on the island of Sardinia; an autonomous region of Italy. The average rainfall is approximately 540 mm while the temperature in the region is about 17°C. The region also has a Mediterranean climate, an average altitude of 156 m and the land slope ranges from 12%-18% (Kosmas et al. 1997). Meanwhile, the Agueda Basin is located in the lower area of the Caramulo mountains, close to the cities of Lourizela and Falgorosa in Portugal. It has an annual rainfall rate of around 1300 mm to 1900 mm. The soil characteristics in this area are dominated by sand and silt (Thomas et al. 1999).

La Conchuela (Spain): The erosion data of La Conchuela were chosen due to olive trees being the dominant land cover. La Conchuela is situated about 10 km from Cordoba City in Spain. This area has an average rainfall around 655 mm per year. The land here has an average slope of approximately 13.4%. The soil contains mostly clay and silt (Gómez et al. 2004).

Statistical analysis: The aim of this paper was to test the correlation between rainfall, vegetation type and slope and their contributions toward soil loss. The data obtained was analysed using the program IBM SPSS 21 to define the correlation between the independent and dependant variables defined in this study. The testing methods used were the normality test, and regression and correlation methods. The normality test is employed to examine whether the data generated are normally distributed (Weinberg & Abramowitz 2008). The data were then analysed using the correlation test. Correlation analysis aims to determine the pattern of the relationship between two or more variables. The correlation coefficient (R) states the value of the relationship, and the direction of the relationship between one variable and another. The correlation coefficient is the root of the coefficient of determination (R^2) (Tabachnick & Fidell 2007).

RESULTS AND DISCUSSION

The data collected from the previous research on soil erosion provided two main variables. The first one functioned as a dependant variable with the second variable being the independent variable. In this case, the dependant variable was the soil loss as the result of rainfall. In this paper, the effect of rainfall on soil loss is discussed in detail, and the influence of other factors such as vegetation type and the slope of the area are also considered.

The contributions of rainfall and vegetation type to soil loss are shown in Fig. 1. The correlation of rainfall to soil loss in the vineyard region (see the blue trend line in Fig. 1) is shown by the following equation: $y = 1.4428x - 442.61$. The R^2 of the equation is 0.5691 which means that there is a correlation between rainfall and soil loss in the vines area even though it is not a strong correlation. This means that there is another significant factor which has influenced the amount of soil loss in the vines area, apart from the rainfall.

In areas which were mainly covered with eucalypts, the correlation between rainfall and soil loss was stronger than the vines/rainfall correlation. The eucalypt/rainfall correlation is shown by $R^2 = 0.6634$, which is higher than the result obtained for the vines area. It also can be shown by the equation for the rainfall/soil loss relationship in this area which is: $y = 0.0346x - 5.2871$ (see the red trend line in Fig. 1).

The strongest correlation between rainfall and soil loss was in the area covered by olive trees. The correlation of both factors is shown by: $y = 0.0129x - 4.4946$ with $R^2 = 0.815$. The high value of R^2 in this area shows that the rainfall factor is the dominant factor in the region which is mainly planted with olive trees. It does not mean that other factors such as slope and type of soil do not make any contribution. Those two factors still have some influence on the loss of soil, although they do not make as strong a contribution as the rainfall.

Table 1 gives the common parameters which were used by Telles et al. (2001) to calculate the estimated cost of soil erosion. However, there are some factors which are still under discussion, whether be categorized as on-site or off-site cost, such as productivity and yield drop.

In this paper, the estimated onsite cost data were chosen based on nutrient and soil loss only to avoid any bias calculation on the other parameters such as production loss, yield drop, etc., which were dependent on many other factors besides soil erosion itself. For example, production loss and yield drop are directly affected by nutrient in the soil which is because the estimation of the cost can vary. However, some research also considered other factors, for example, plantation damage and organic matter.

Fig. 2 illustrates the estimated costs of soil loss in three different categories. The first is on-site costs, which are the direct costs generated at the time when the soil erosion occurs. The second is off-site costs, which are the indirect or hidden costs of soil erosion. The example of off-site cost is the loss of soil nutrients which affect agricultural productivity. The last category is a combination of both on and off-site costs. The bar chart in Fig. 2 shows that the off-site costs of soil erosion are much higher than on-site costs. The estimated indirect cost of soil erosion per ton is about \$176.33 while on-site cost of soil erosion calculation per ton is approximately \$53.35 which is less than one-third of the off-site cost. The estimated combination cost (on-site and off-site) based on the previous data is \$395.83 per ton,

Table 1: Some parameters for measurement of on-site and offsite cost (Telles et al. 2001).

On-site	Off-site
Soil loss	Flooding
Nutrient loss	Overflow
Organic matter	Landslides
Production loss	Water quality
Yield drop	Sedimentation
Damage plantation	Drop in food supply

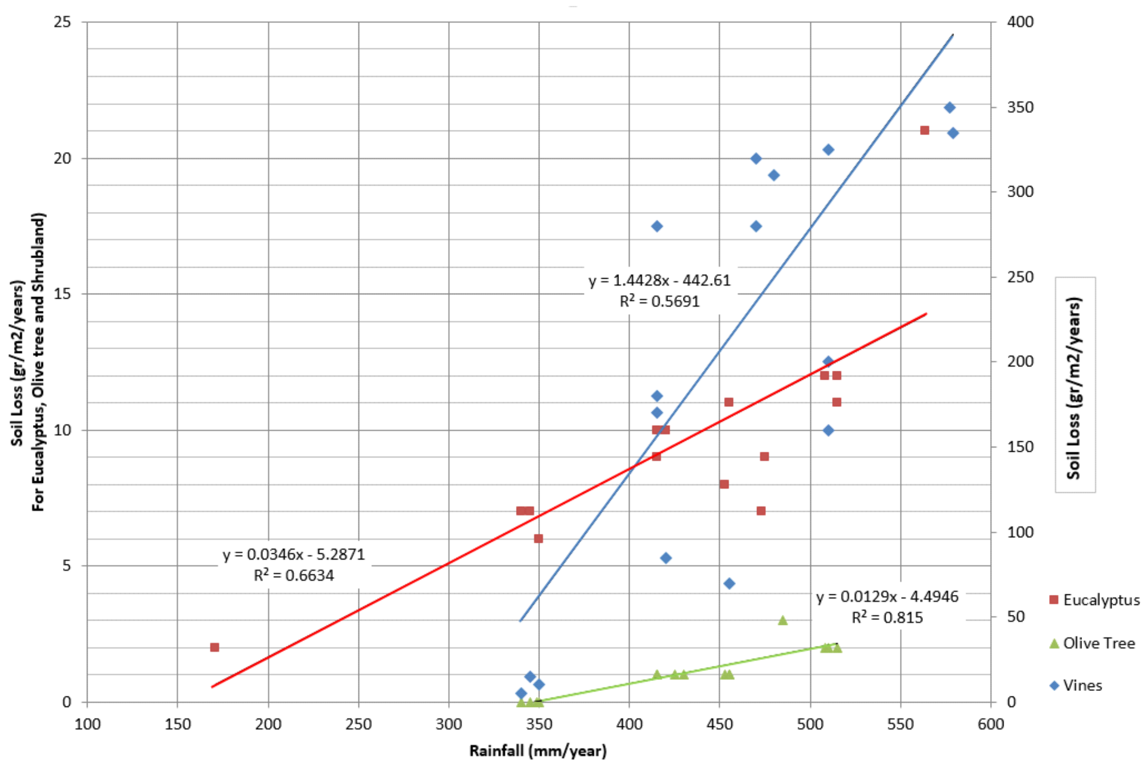

Fig. 1: The correlation between rainfall and soil loss from three different types of vegetation.

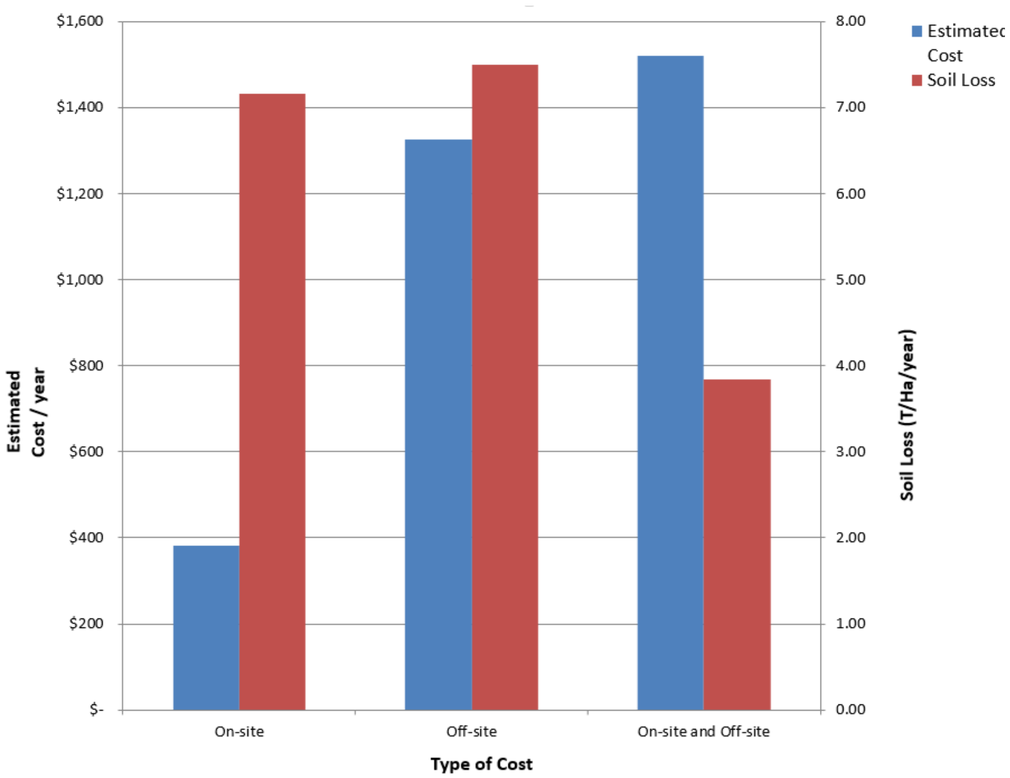

Fig. 2: Cost estimates of soil losses per year at three different cost-sites (on-site, off-site and at a combination of both).

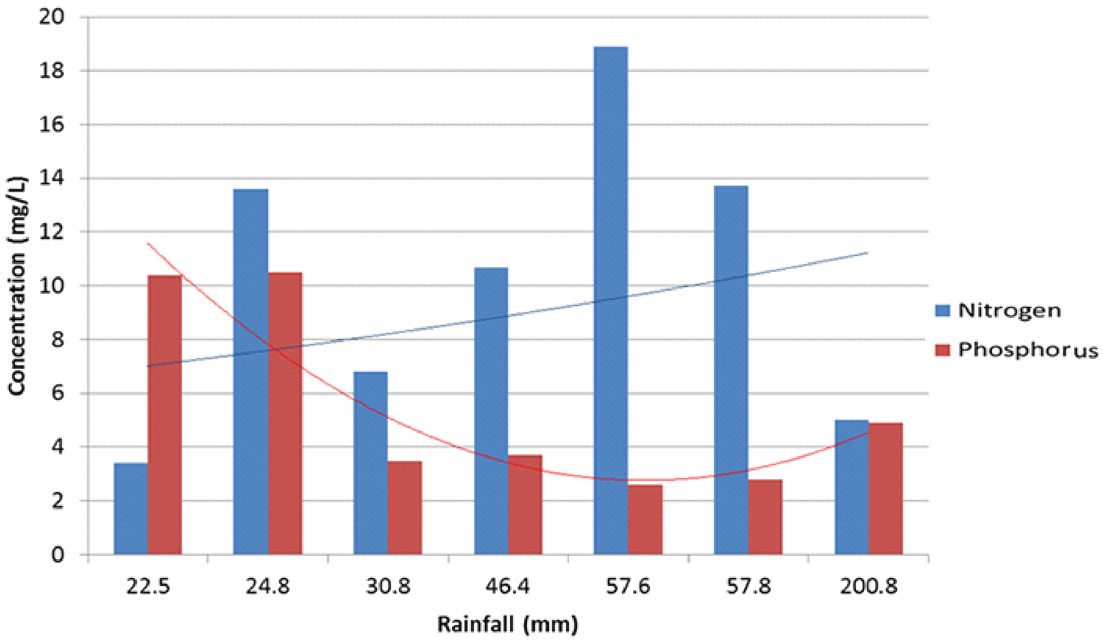

Fig. 3: The correlation between rainfall and nutrient loss on vineyard area in Penedes, Spain.

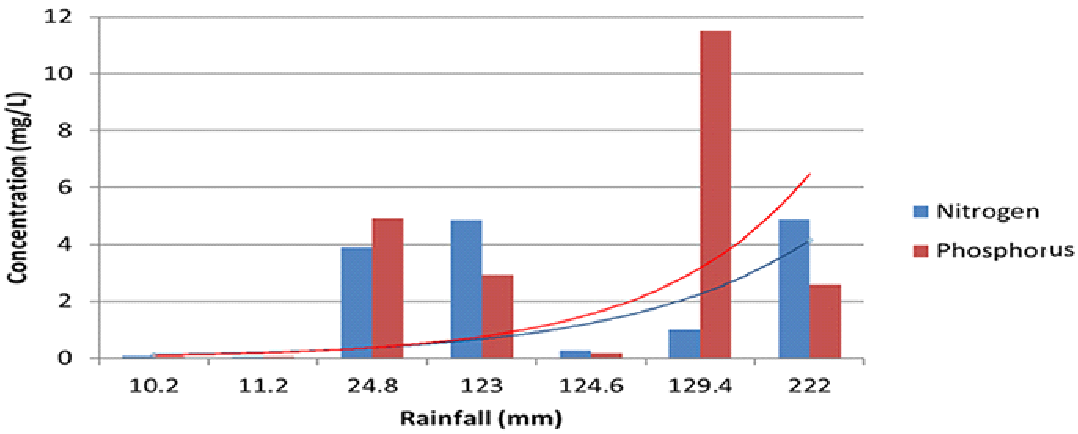

Fig. 4: The correlation between rainfall and nutrient loss on vineyard area.

which is more than double, compared to the estimated off-site cost.

Nutrient loss: The data used for nutrient loss discussion was based on the soil erosion experiment in the vineyard area located in Penedes, Spain. Nitrogen (N) and phosphorus (P) are measured as indicators of nutrient loss. Fig. 3 shows the amount of nutrient loss and also the trend of those parameters. Surprisingly, the maximum nutrient loss did not occur during the highest rainfall. The maximum nitrogen loss was 18.9 mg/L which was when the rainfall rate was 57.5 mm. On the other hand, according Ramos & Martinez-Casasnovas (2006), when the rainfall reached 200.8 mm, the nitrogen loss was only 5 mg/L. At the same time, based on a statistical approach, the trend of nitrogen loss cannot be demonstrated using standard equations such as, linear, exponential, logarithm or even polynomial. When the nutrient data were plotted using polynomial with two order equation, the R^2 value is only 0.4481 and resulting in the following: $y = -0.9274x^2 + 8.0298x - 3.2714$.

The similar pattern also appeared to another parameter. The maximum loss of phosphorous was 24.8 mg/L which happened when rainfall was 49 mm. Ramos & Martinez-

Casasnovas (2006) also reported that at the highest rainfall period, which reached 200.8 mm, the phosphorous loss was only 10.5 mg/L. Statistically, the trend of phosphorous loss can be illustrated with a polynomial with two order equation as follow: $y = 0.5167x^2 - 5.3048x + 16.371$. This equation seems to be able to represent the phosphorus loss since the R^2 value is 0.8415.

Another research was conducted by Martínez-Casasnovas & Ramos (2006) in vineyard located in the same region with the previous research results in different pattern (Fig. 4). The maximum nitrogen and phosphorous losses did not take place during the highest rainfall period as well as the lowest nitrogen and phosphorous loss which also did not occurred during the lowest rainfall.

The trend of nitrogen and phosphorous loss can be represented using an exponential equation rather than polynomial one. The nitrogen loss trend equation is $y = 0.0592e^{0.607x}$ with $R^2 = 0.4026$ while the phosphorous loss trend equation is represented by $y = 0.0435e^{0.715x}$ with $R^2 = 0.4403$. However, both results are not quite reliable to make any prediction of soil loss in other regions since the correlations between all variables are not strong enough. There must be other factors that should be considered when using the equations.

Cost of nutrient loss*:* According to USDA/NRCS (2010), the estimation of nutrient loss in 2011 which was represented by the loss of nitrogen and phosphorous parameter was approximately US $1.1 per kg of nitrogen and US $1.3 per kg of phosphorous. It was also assumed that the cost of nutrient is about US $1.77 per ton of soil loss. Referring to previous discussion, the total cost of onsite cost is $53.35 per ton, which means that the nutrient cost mainly for nitrogen and phosphorous parameter is about 2 %. However, this result can be varied since the initial nutrient content in soil in every site may be significantly different.

CONCLUSION

Soil erosion and losses can have a major effect on the economy of any region and on the income of its farmers. On-site and off-site costs have been found to be two important parameters in the economic plans for the area and its wider community. The results from different regions were gathered from existing literature, analysed and statistically investigated. Statistical methods were applied to the data and the graphing of the results presented in this study. The results prove that regardless of vegetation and cover, rainfall and precipitation will increase the amount of erosion. The final evaluation was made through comparisons of the effects of soil loss with regard to different areas along with on-site and off-site costs. The result showed that the indirect costs of soil erosion was much higher compared to its direct cost. While in total, the combination cost of soil erosion was $395.83 per ton/ha/year. Even though the cost of nutrient loss as part of the direct cost of soil erosion was only 2% of the total direct cost which was $53.35 per ton/ha/year, the nutrient loss will trigger indirect cost escalation once it came to the agricultural productivity.

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