Economic losses from soil degradation in agricultural areas in Albania

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Abstract: Soil degradation is a serious and widespread problem in Albania. It manifests itself in many forms and causes a range of effects. The aim of this study was to analyze the economic losses from soil erosion and compaction in relationship to agriculture in Albania. On-site effects of these two degradative processes affect farmers directly through reducing production and increasing the costs of farming. Calculation of economic losses was performed by using the replacement and lost production methods. According to our assessments, the wheat and maize yield losses due to the soil compaction are 112 164 tons or US$ 40.2 million, and the plant nutrient losses due to the water erosion are 69 609 tons or US$ 98 million. Economic losses from the erosion and compaction in the agricultural area in Albania are at least US$ 138.2 million per year or about 5.5% of the agricultural GDP. Based on the assessed economic losses from soil degradation, it can be concluded that the soil conservation in Albania is economically viable.

Key words: nutrient loss, replacement cost, soil compaction, soil erosion

Soil degradation has important socio-economic and environmental implications. It will remain an important global issue for the 21st century (Eswaran et al. 2001). The rate of soil degradation depends on many factors, including the changes in the land use and land cover. However, Šarapatka et al. (2010) found no differences in the rate of degradation for both categories of the protected and non-protected land.

According to Oldeman (1994), two categories of soil degradation processes are recognized: the water and wind erosion and the in situ physical and chemical degradation. In Albania, soil resources suffer from varying degrees and forms of degradation. Most of the degradation is due to the soil erosion, in which a major role plays the improper soil management, including deforestation, overgrazing, construction activities, etc. (The World Bank 2007). Other forms of soil degradation are flooding, landslides, salinization, contamination, urbanization on a high-quality agricultural soil, etc. (Bockheim 2001). With little arable soil available for the cultivation (about 24% of the total land area), the impact of soil degradation in Albania is significant, particularly in poor rural areas. Soil degradation especially affects the Northeast and Southeast of the country, but it is important everywhere. Albania is among the most affected countries in the Europe in terms of the extent and intensity of soil degradation. Experimental stations report soil losses of 10.9–15.1 tons/ha per year (MAFCP 2010) and farmers report a declining agricultural productivity of their farms. In Europe, the figure is 10–20 tons/ha/year (Pimentel et al. 1993). In Albania, although detailed soil surveys have been carried out, there are few studies on soil degradation, which are mainly restricted to soil erosion, and only in the terms of its effect (extent and intensity) (Xinxo 1986; Kovaçi et al. 1996; Gjoka and Cara 1999; Zdruli and Lushaj 1999). Assessing the costs of soil degradation is crucial for understanding how farmers and policy-makers respond to soil degradation. The aim of this paper was to determine the economic losses caused by soil degradation due to the erosion and compaction in the agricultural area in Albania.

METHODOLOGY

We reviewed the available information on the land use changes and the soil degradation processes, and other resources base for agriculture like plants, livestock, and the use of agrochemicals. The data are derived from the Statistical Yearbook of the Ministry of Agriculture, Food and Consumer's Protection (MAFCP), the Institute of Statistics (INSTAT), the World Bank, project reports of the Institute of Soils Study, scientific journals and the additional scientific investigations of Albania soils.

To evaluate the trend over time in the soil property change like the organic matter, N, P and K, a simple regression analysis is applied. For this purpose, the data of the selected soil parameters to four cycles of study were used.

The loss in the maize yield due to the soil compaction is assessed using the linear form of the relationship between the plant yield and the soil bulk density. This study adopted a model proposed by Houk, et al. [2004]. The adopted model has the following form:

$$RY_{SC} = 100 - g(BD - f) \text{ for } BD \geq f \quad (1)$$

where RY_{SC} is the relative maize yield as the result of soil compaction; g is the slope of the compaction response curve; f is the bulk density threshold value at which the plant yield begin to be affected; and BD is a common measure of the bulk density. The g parameter is the constant a in the linear function ($y = ax + b$), that expresses the relationship between the plant yield and the soil bulk density (Figure 4), the f parameter is obtained by solving the above function by using the formula:

$$f = (b - 100)/a \quad (2)$$

The above function is derived from the data of our previous study Gjoka (1994). The loss in the wheat yield was assessed by comparing the normal yield with the yield obtained on the compacted soil by using the existing data (Dabulla et al. (1989). The economic loss resulting from erosion is valued at the cost of replacing the plant nutrients by fertilizers (Eswaran et al. 2001).

RESULTS AND DISCUSSION

Land use

Albania is the 8th smallest country in Europe, where the agricultural land covers about 39% of the total land area (1 137 000 ha) (Table 1). Approximately three-fifths of agricultural land is arable land, and the rest is pasture land. Of the remainder, 36% are woodlands and forests, and 25% other land including lakes, the urban and unproductive area (MAFCP 2010). The agricultural land has increased during 1950–1990 by nearly 80%, reaching the limits of the land available. The country has a resident population of about 2.8 million, of which about 1.3 million lived in rural areas (INSTAT 2012). Agricultural land per-capita is 0.22 ha. Because of the slope (83% of the land has a slope over 8%), the land is operated at a high risk of erosion. This risk is assessed at 1.7 million ha (or 62% of the land) (FAO 2000). The distribution of agricultural land in Albania by the ground slope is given in Figure 1.

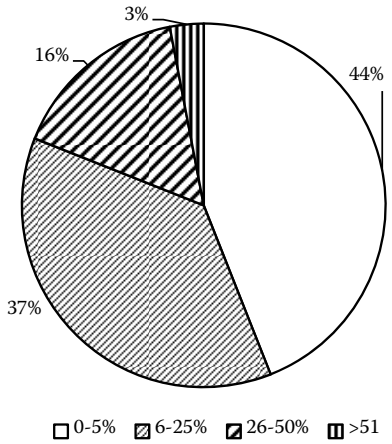

Figure 1. Arable land by ground slope

Changes in the land cover

Changes in the land cover in Albania are well documented (Table 1). The reduction of forests has happened during 1950–1990 with about 18%, but it has continued until 2001. Of a great importance is the total deforestation in the lowland area of elm forest

Table 1. Land-use change in Albania for the period 1950–2009 (1000 ha)

Classification	1950		1990		2001		2009	
	1000 ha	%	1000 ha	%	1000 ha	%	1000 ha	%
Land, total	2875	100	2875	100	2875	100	2875	100
Agricultural soil	1207	42	1121	39	1139	39	1137	39
– arable soil	391	14	704	24	699	24	696	24
– pastures	816	28	417	15	440	15	441	15
Forests	1282	45	1045	36	1024	36	1041	36
Other land	386	13	709	25	712	25	712	25

Source: MAFCP (2010)

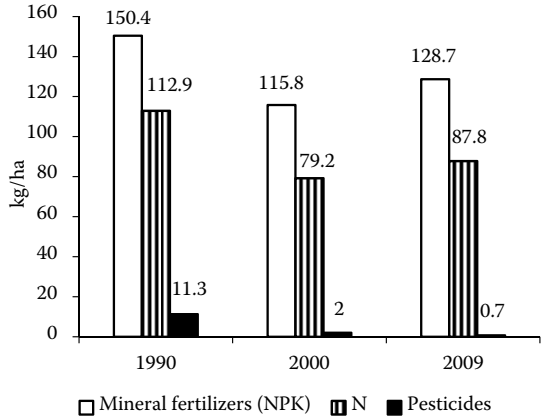

Figure 2. Consumption of agrochemicals

Source: MAFCP 1990, 2002, 2010

(Ulmus foliaceae), ash forests (Fraxinus angustifolia), English oak forests (Quercus robur) and the large-scale deforestation for the plant production of oak forest in the hill areas of Hasi (Kukës) and Dumre (Elbasan). About 15 000 ha of shrub area have been converted to cultivated pastures that led to intensive soil erosion (Marku and Gjoka 1999). During this period, about 200 000 ha of swamps and wetlands are converted to cultivation, and the pastures have dramatically decreased from 816 000 to 417 000 ha and degraded for the same reasons. This has led to the reduction in the production potential. In 2009, there was nearly 0.1 ha per sheep (sheep units). The unsustainable soil management practices have led to a significant decrease in biodiversity.

Use of agrochemicals

The use of mineral fertilizers in Albania is lower than in the other countries of the region and Europe, and it has been drastically reduced since 1990. The level of the mineral fertilizer used in 2009 amounted to 134.6 kg of active substances per ha of agricultural land, versus 150.4 kg/ha consumed in 1990 (Figure 2). The N : P_2O_5 ratio has been and is still unbalanced (close to 2), and the potash fertilizers are mostly not used. The mineral fertilizers are used in about 386 148 ha of agricultural land and the agricultural land untreated with fertilizers and pesticides is nearly 35 000 ha and 166 784 ha, respectively. Organic manure is an important source of the essential nutrients for plants in Albanian agriculture. The production of organic manure in 2009 was 5.95 million ton, equal to 8.6 t per ha of agricultural land (Figure 3). The average NPK amount from organic manure was 102.8 kg, from which 17.2 kg was N. Mineral fertilizers are considered by farmers as a major input constraint in the plant production in Albania. The use of pesticides in agriculture is also lower. According to the official data, the total amount of pesticides used in 1990 was 8000 ton, in 2000 242 ton, and in 2009 294 ton, corresponding to about 11.3 kg/ha, 2 kg/ha and 0.7 kg/ha of the treated agricultural land. The major part of pesticides is used for maize, vegetables and fruit trees.

Livestock raising

In the livestock sector, there are especially managed cattle, small ruminants, poultry and pigs (cattle and poultry in the lowland areas, and sheep and goats in the hilly and mountainous areas). The total number of livestock in 2009 amounted to 11.61 million heads or 0.99 million livestock units, corresponding to an average livestock density (number of livestock units/ha) of 1.42 (Figure 2). These data show that the livestock pressure on agricultural land is comparatively high. In 2000, the number of livestock units was still higher.

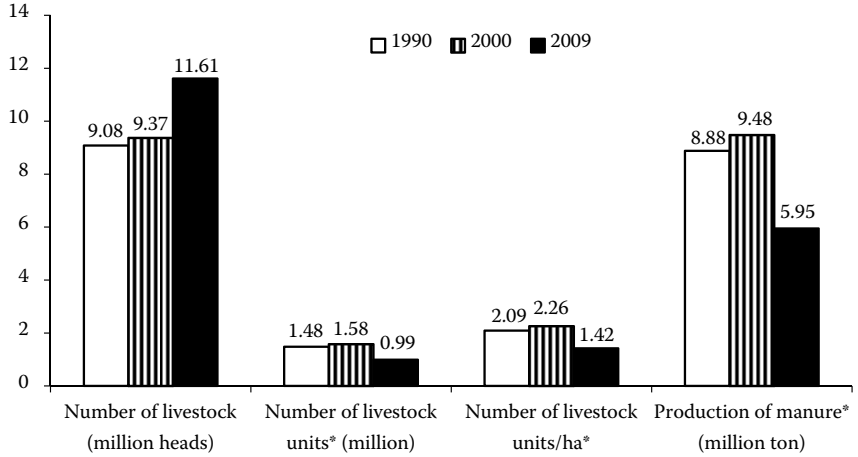

Figure 3. Livestock population and the manure production

Source: MAFCP 2002, 2010; *our own calculations

Soil degradation

The major forms of soil degradation in Albania are the soil erosion, compaction, the depletion of nutrients, the loss of organic matter, salinity, etc.

Soil erosion: It is caused by the combination of the Mediterranean climate, the dissected topography and the poor agricultural practices. Soil erosion affects about 350 000 ha of agricultural land, with a total loss of 60 million tons of solid materials (World Bank 2007). While the total nutrient loss from erosion is assessed at about 100 000 tons of N, 60 000 tons of P and 16 000 tons of K (Kovaçi et al. 1996), agricultural land damaged by both the erosion and gravelling is assessed at 6780 ha (MAFCP 2010).

Soil compaction: It is related with the adoption of mechanized agriculture, thus affecting all the agricultural land. However, the soils with a fine texture (251 000 ha) are very highly prone to this phenomenon. Reductions in the plant yields are about 16% in wheat (Dabulla et al. 1989) and 17% in maize (Gjoka 1994).

Loss of organic matter: The soil surface rich in organic matter is strongly reduced (about 35%) from 1971 to 1985, while the soil surface medium and poor in organic matter is significantly increased (about 5%). Within the study period, the trend in the soil surface poor in organic matter can be explained by the function given in Table 2. The data indicate that 285 000 ha or 42% of agricultural land suffer from the loss of the soil organic matter. The reasons for this are the intensive cultivation of soils and soil erosion.

Depletion of nutrients: A large body of information on plant nutrients in the soils of Albania is available. However, the data on micronutrients is still limited. A decrease in the soil surface poor in the nitrogen and phosphorous contents was identified (3.7% and 14.6% respectively). This trend could be related to the use of NP fertilizers (112.9 kg N/ha and 34.3 kg P/ha) (Angé 1994) and the mineralization of the soil organic matter. On the contrary, a slight trend towards the increase in the soil surface poor in available potassium (0.2–1%) appears to have arisen due to the intensive cultivation of land and the low level use of potash during about two decades (1970–1990). Functions that explain the trends within the study period in soil surfaces poor in the total nitrogen, the available phosphorus and potassium are given in Table 2.

Salinization: Soil salinity is a major abiotic factor limiting plant production. The accumulation of salts in the soils of Albania is related mostly to the pedogenetic processes and the sea-water infiltration. The contribution of agriculture through the irrigation to the soil salinization is unknown yet. Salinization affects about 35 000 ha of land in the Western coastal area and the inland valleys of the country producing saline soils (Spaho 2003). About 12 765 ha of saline soils have been reclaimed and used in agriculture during the past 40–50 years. Of these soils, nearly 3800 ha are damaged due to severe salinization. Other forms of soil degradation in Albania are the salinization (about 2000 ha), the acidification related especially to the pedogenic processes (74 000 ha), flooding (40 000 ha) and the waterlogging (2031 ha), sliding (110 000 ha of which about 4000 ha are really affected), deformation (about 27 ha only in Tirana area), contamination (about 503 ha), and urbanization (about 512 ha, including soil excavation).

Economic losses from soil erosion and compaction

The assessment of soil degradation in Albania has been carried out by the national experts in the terms of effect, but not in the terms of cost. The following analysis is to determine the economic losses through soil erosion and compaction in the agricultural area in Albania by using the methods of the replacement cost and lost production, respectively. This is the most original and interesting part of the study. The economic losses related to soil compaction are calculated for two main plants, maize and wheat. To assess the losses in the maize yield, the relative yield

Table 2. The trends in the soil surfaces poor in organic matter, the total N, available P and K

Soil property	% of poor soil to the total agricultural soil				Function
	1971	1975	1979	1985	
Humus	42	37.5	38.9	44.6	$y = 0.1081x^2 - 1.2979x + 41.727$; $R^2 = 0.96$
Total N	40.6	33.8	33.1	36.9	$y = 0.1233x^2 - 1.9641x + 40.359$; $R^2=0.98$
Available P	47.6	39.9	34.1	33	$y = 0.1006x^2 - 2.468x + 47.748$; $R^2=0.9$
Available K	8	7.9	9	8.2	$y = -0.0105x^2 + 0.1806x + 7.8279$; $R^2=0.42$

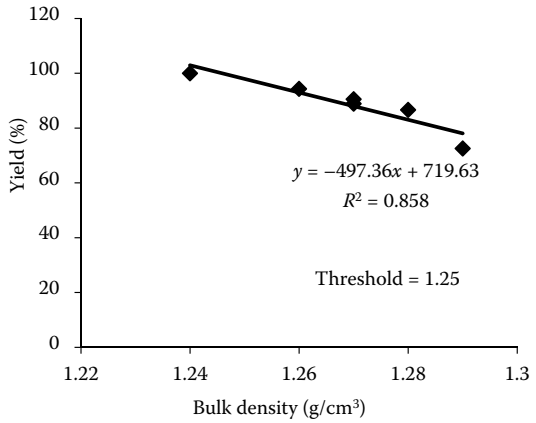

Figure 4. The relationship between the maize yield and the bulk density

(the relative yield factor RY_M) of this plant is determined. For this, the slope of the yield response to soil compaction (g) and the threshold value of the bulk density (f) are calculated. These two statistical parameters are obtained by solving the linear function ($y = -497.36x + 719.63$) (Figure 4) that expresses the relationship between the plant yield and the soil bulk density, as follows:

$g = a = -497.36$

$f = (b - 100)/a = 1.25$ for $y = 100$

$BD = 1.28$ g/cm^3 (data is sourced from Gjoka 1994).

The relative yield (%) for maize is determined with the following formula, and it is 85.

$$RY_M = 100 - g(BD - f) \quad \text{for} \quad BD \geq f \tag{3}$$

The potential yield (PY_M, ton/ha) for maize is calculated using the formula, and is 6.20 ton/ha:

$$PY_M = AY_M/RY_M \tag{4}$$

where AY_M is the actual yield in ton/ha (5.27 ton per ha) (data are sourced from the Statistical Yearbook of the MAFCP 2010).

The loss in the maize yield (LY_M, ton/ha) is calculated by comparing the potential yield with the actual yield by using the formula, and it is 0.93 ton/ha:

$$LY_M = PY_M - AY_M \tag{5}$$

while the economic loss (EL_M) is calculated with the formula, and is US$ 15.1 million:

$$EL_M = LY_M \times S_M \times P_M \tag{6}$$

S_M = cultivated area (ha)
P_M = market price for maize (US$)

The loss in the wheat yield is calculated by using the same formulae as for maize (4, 5, 6), but the relative yield for wheat (RY_W) is derived from the available experimental data (Dabulla et al. 1989). According to these data, the loss in the wheat yield due to soil compaction is 17%. As a result, the RY_W is 83. Production losses for both plants are given in Table 3. The calculations indicate a total loss of 112 164 tons, equal to US$ 40.2 million, or about US$ 35 per hectare. In the USA, the on-site losses through soil compaction are estimated at US$ 1.2 billion per year (Gill 1971, quoted by Eswaran et al. 2001) or about US$ 7/ha. For the EU, no assessment of soil compaction is currently available.

Losses of nutrients by erosion from the total area (Kovaçi et al. 1996) are corrected for the agricultural area, giving an annual loss of 69 609 tons nutrients (39 551 tons N; 23 730 tons P; 6328 tons K), which is by about 40% greater than the amount of nutrients added to the soil by fertilizers (fertilizer use in Albania was 49 717 tons of nutrients in 2010). In other words, farmers will need to increase the fertilizers use by 40% each year just to replace the nutrients lost through erosion. Its value is approximately US$ 98 million or US$ 82/ha/year, and it can be considered as an additional cost for the agricultural production. Although few studies have been made to know the economic implications of erosion (Martınez-Casasnovas and Ramos 2006), the stud-

Table 3. On-site losses by soil erosion and compaction in the agricultural area in Albania

Crop	Actual yield* (ton/ha)	Relative yield factor	Potential yield (ton/ha)	Loss in crop yield (ton/ha)	Cultivated area* (1000 ha)	Loss in crop production (ton)	Value of lost production (US$ million)
Wheat	4.02	83	4.84	0.82	82.8	67 896	25.1
Maize	5.27	85	6.20	0.93	47.6	44 268	15.1
Total						112 164	40.2

*Source: MAFCP 2010 (www.mbumk. gov.al)

ies done by Montanarella (2006) and the European Commission (2004) indicated that the annual cost of soil erosion is € 4 per hectare in the EU and about € 41 per hectare in France, respectively. This means that economic losses from soil erosion in Albania are indeed much higher. The on-site losses through soil erosion and compaction in the agricultural area in Albania are at least US$ 138.2 million per year or about 5.5% of the agricultural GDP in 2011.

CONCLUSIONS

Soil degradation in Albania could be considered a national threat. It occurs mainly in the form of soil erosion, though compaction, depletion of nutrients, loss of organic matter, salinization and urbanization have also had an effect. Erosion is the main factor of soil degradation, causing an annual loss of three essential nutrients (NPK) of 69 609 tons, or by 40% greater than the amount of the fertilizer used. Thus farmers should increase by 40% the actual amount of fertilizer used to replace the nutrients lost by erosion. This can be converted into an economic loss of US$ 98 million. Soil compaction is also an important factor of soil degradation, especially for heavy textured soils. It is responsible for 112 164 ton of the annual loss of wheat and maize, with the value of US$ 40.2 billion. The total economic losses caused by erosion and compaction associated with agriculture are assessed at U.S.$ 138.2 million per year, or at about 5.5% of the Agricultural Gross Domestic Product (GDP). However, the total overall economic loss would be greater if the losses from other forms of land degradation such as salinity, water logging, etc. are be calculated. Therefore, this work will continue to assess them.

Based on these assessments, it could be concluded that the soil conservation in Albania was economically viable.

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Received: 13th February 2013
Accepted: 12th November 2013

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