Soil Loss, Productivity and Cropland Values GIS-Based Analysis and Trends in the Basilicata Region (Southern Italy) from 1980 to 2013

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Abstract. This paper concerns the trends assessment of the productivity values and croplands values of specific crops (*cereals (arable cereals land), vineyards, olive-growing lands)* in the Basilicata region at regional scale, from 1980 to 2013, in relation to the soil loss evaluated through the USPED method. The comparative analysis shows the interrelations between the soil loss by erosion and the economic value deriving from the erosive phenomenon affecting the croplands considered.

Keywords: Soil consumption · USPED · Land value · Erosion · GIS · Basilicata · Southern Italy

1 Introduction

Soil erosion is one of the major environmental and agricultural problem worldwide. Although erosion has occurred throughout the history of agriculture, it has intensified in recent years, also due to climate changes and extreme climatic events [1–3]. Each year, 75 billion metric tons of soil are removed from the land by wind and water erosion, with most coming from agricultural land [4]. The loss of soil degrades arable land and eventually renders it unproductive. Worldwide, about 12×10^6 ha of arable land are destroyed and abandoned annually because of non sustainable farming practices, and only about 1.5×10^9 ha of land are being cultivated [4]. The use of large amounts of fertilizers, pesticides, and irrigation help offset deleterious effects of erosion but have the potential to create pollution and health problems, destroy natural habitats, and contribute to high energy consumption and unsustainable agricultural systems. The eroded soil is mobilized to other places even outside from the cultivated areas, producing often widespread damages. In fact, erosion, not only damages the immediate agricultural area where it occurs, but it also negatively affects the surrounding environment. Off-site problems include roadway, sewer, and basement siltation, drainage disruption, undermining of foundations and pavements, gullying of roads, earth dam

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failures, eutrophication of waterways, siltation of harbors and channels, loss of reservoir storage, loss of wildlife habitat and disruption of stream ecology, flooding, damage to public health, plus increased water treatment costs. The most serious of off-site damages are caused by soil particles entering the water systems and being deposited in streams and rivers [4].

In relation to these possible damage scenarios, in this study, we have considered the potential soil erosion assessed by empirical methods well-known in literature (Unit Stream Power – Erosion Deposition or USPED) and applicable in the contexts of study examined [5]. So, in this paper, we propose a methodology to assess the economic costs of soil erosion applied to arable cereals lands, olive growing lands and vineyards considering the study sample area of the Basilicata region (southern Italy). These crops have been selected because the territory of the Basilicata region is characterized by a historical agricultural vocationality based primarily on these three types of crops.

It is proposed also to verify the possible economic impact of soil erosion under a general regional trend, from 1980 to 2013, of decrease of agricultural areas, with particular reference to the arable areas in cereals and productivity. In fact, the estimation of costs of soil erosion is an issue of fundamental importance in view of the current worldwide discussions on sustainability.

2 Materials and Methods

In order to perform the croplands and productivity values trends assessment, datasets analysis was carried out by utilizing the time frame containing the smallest data gap within each database used in this work. Using the different datasets - related to the databases realized in order to correlate the historical data and the recent ones – an analysis of the trends and the valued soil loss in the regional territory located in the Mediterranean area was performed. The datasets used have been divided in relation to the different sources and contents of the themes addressed by making them concern into specific following databases:

- **Database (1): Land Values and Croplands quotation price** and available period:
  - ***Land Values Trends (Basilicata)*** – dataset coming from INEA – *National Institute of Agricultural Economy* – available period: 1960 – 2014;
  - ***Croplands quotation price*** **(Basilicata)** – dataset coming from *Italian Yearbook of Agriculture, Vol. XLIV - L, 1990 – 1996.*
- **Database (2): Utilised Agricultural Area (UAA)** and available period:
  - ***Utilised Agricultural Area (UAA)*** **(Basilicata)** – dataset coming from ISTAT (National Institute of Statistics) - *Italian Agricultural Censuses* – available period: 1970 – 2014;
  - ***Utilised Agricultural Area (UAA) – Arable cereal lands, vineyards, olive-growing lands*** **(Basilicata)** – dataset coming from ISTAT – National Institute of Statistics - from *3rd Italian Agriculture Census* to *6th Italian Agriculture Census* – 1980, 1990, 2000, 2010.

- **Database (3): Croplands - Agricultural Surface and Production** – utilised in order to evaluate the Productivity value at regional scale. The resulting datasets are the following:
  - ***Utilised Agricultural Area*** – *Arable cereal lands (1999 – 2012), vineyards (1990; 1999 – 2012), olive-growing lands* (1990; 1999 – 2011) (Basilicata) – dataset coming from ISTAT (National Institute of Statistics) – *Agriculture section: "Surface and Production", 1999 – 2011.*
  - ***Utilised Agricultural Area (UAA)*** **(Basilicata)** – *Arable cereal lands* (2013), *vineyards (1990; 2013), olive-growing lands (2012 – 2013)* – data coming from INEA – National Institute of Agricultural Economy;
  - **Productivity values -** ***Arable cereal lands***:
    time frame: 1997 – 1998: data coming from INEA dataset;
    time frame: 1999 – 2011: data resulting from evaluation deriving from ISTAT *dataset;*
    time frame: 2012 – 2013: data coming from AGRIT - Statistic Program by Mipaaf (Ministry of Agriculture, Food and Forestry Policies), Italy.
  - **Productivity values –** ***Vineyards***:
    time frame: 1990; 1999 – 2011: data resulting from evaluation deriving from ISTAT dataset;
    time frame: 2012 – 2013: data coming from INEA dataset.
  - **Productivity values –** ***Olive growing-lands***:
    time frame: 1999 – 2012: data resulting from evaluation deriving from ISTAT dataset;
    time frame: 2012 – 2013: data coming from INEA dataset.
- **Database (4): Average Agricultural Values** for the following croplands:
  - *arable cereal lands* (intensive and extensive crops), *olive growing-lands* and *vineyards* – dataset coming from the Basilicata Region – Department of Agriculture, Rural Development, Mountain Economy – *Provincial Commission for determining compensation for expropriation and the average agricultural land values* – Available period: 2008 – 2013.
- **Database (5): GIS geodatabase: Corine Land Cover 2012 – 4th level -** shapefile coming from ISPRA – *Superior Institute of Environmental Protection and Research,* Italy.
  - Layer derived: layer of the Basilicata region used to extrapolate the different croplands areas/polygons of arable cereal lands, olive growing-lands and vineyards.

In order to carry out a spatial analysis of the amount of land subjected to erosion phenomenon, a quantitative analysis has been based on either the spatial and economic aspect. Indeed, the Corine Land Cover 2012 – 4th hierarchical level – has been used to define the areas interested by the different crops considered in this study, in which the USPED method has been applied to show the amount of land subjected to the potential erosion phenomenon in 2012. From this analysis, a comparative economic analysis has been carried out in order to evaluate the variation of the crop-productivity and then, consequently, of the land value by comparing the trends land values assessment from 1980 to 2013 with the scenario represented by the analysis of 2012.

2.1 Methodology - USPED

The Unit Stream Power Erosion and Deposition model (USPED) has the basic model structure of the USLE and RUSLE [6, 7].

$$A = R \times K \times (LS) \times C \times P \tag{1}$$

where, A is the computed site soil loss (Mg ha^{-1} $year^{-1}$), R is the rainfall erosivity factor (MJ mm ha^{-1} h−1 $year^{-1}$), K is the soil erodibility factor (Mg h MJ^{-1} mm^{-1}), L is the slope length factor that is often combined with S, a slope steepness factor, to yield a dimensionless terrain factor (LS), C is the dimensionless vegetation cover factor and P is the dimensionless erosion control practice factor.

Equations for the computation of the LS factor are based on upslope contributing area and have been developed by [8]:

$$LS = A^m (\sin \beta) \tag{2}$$

where A is upslope contributing area, β is slope angle, and *m* and *n* are constants depending on the type of flow and soil properties; where rill erosion dominates these parameters are usually set to m = 1.6 and n = 1.3, whereas where sheet erosion prevails, they are set to m = n = 1.0 [9]. This LS factor is equivalent to the traditional LS factor on planar surface but has the added benefit of being applicable to complex slope geometries [9, 10]. Then, for the estimation of the erosion and deposition (ED), which are both computed as a change in sediment transport capacity across a GIS grid cell, the following equation has to be computed:

$$ED = d(A \cos \alpha)/dx + d(A \sin \alpha)/dy \tag{3}$$

where α is the slope aspect of the terrain in degrees in the direction of the steepest slope. Net erosion areas coincided with areas of profile convexity and tangential concavity (flow acceleration and convergence), and net deposition areas coincided with areas of profile concavity (decreasing flow velocity).

The USPED model was critically applied by using an integrated GIS approach in a raster environment to obtain maps for each factor.

3 Data Analysis and Results

In relation to the Database 1, an analysis has been carried out aimed at observing the temporal trend of the agrarian and economic development in the Basilicata region from 1980 to 2013 by considering the dataset coming from INEA – *Land Values Database*. From data analysis it was possible to verify that, during the period considered, the trend of land values has steadily grown with values ranging from a minimum of 3200 €/ha in 1980 to 7000€/ha in 2013 (Fig. 1).

The Database 2 analysis has been carried out by surveying the *Total Utilised Agricultural Area* [ha] (TUAA) – at the regional scale - in relation to a large time frame – from 1980 to 2013 – in order to assess the related trend shown in Fig. 1. The same

Fig. 1. Land values trend in the Basilicata region with particular attention on the time frames from 1980 to 2013. Source: INEA, Italy.

dataset analysis has been carried out by surveying the following time frame: 1980, 1990, 1992, 2000, 2003, 2008, 2010, 2013 - for evaluating particular changes in relation to the CAP Reform and Development from 1980 to 2013:

- From 1980, well-known as the *3rd phase of the CAP Structural Policy*, to 1992 – known as *McSharry's Reform* - it is possible to evidence an increase of the land values due to the central element deriving from the 'ratio' related to the compensation strongly related to the 'land' considered as a *production factor* and so this compensation of the farmers with a payments system related to the number of cultivated or non-cultivated hectares has favored an increase of the land value because of the '*production factor*'.
- In 1993 – 2nd *Structural Policy Reform* (after the first one happened in 1988) – the vision of the Agricultural enterprise was renewed as Agricultural-Multifunctional Company. This new vision provides for the safeguard of the environment and landscape, economic and social development and promotion of culture.
- In 2000 – well-known as *Agenda 2000* – was a reform conceived in anticipation of a Mid-Term Review (MTR).
- In 2003 – *Fischler's Reform* – new goals have come into a play into the CAP's scenario, such as improving the European agricultural competitiveness, re-orienting the production to the market, promoting a sustainable agriculture socially acceptable and reinforcing the rural development. In this period, conditionality represented one of the principal tools used by European Union for including the environmental thematic about the CAP – Reg. Ce. 1782/2003. In relation to the annexed document attached to this Reg. No. 1782/2003 (Annex 4), it is important to consider a significative aim, such as keeping agricultural land in good agricultural and environmental conditions.
- In 2008, the well-know *Health Check* CAP – *Fisher Boel's Reform* -, refers the proposals of the CAP changes: result of a detailed analysis on health check of CAP. Health Check based on three principle rules, such as:

1. Reg. No. 72/2009 – *Market Tools*
2. Reg. No. 73/2009 – *Direct Payments*
3. Reg. No. 74/2009 – *Rural Development Policy.*

New environmental and climatic challenges and risk management belong to the elements coming from Health Check.

An additional correlated analysis has been carried out – on the same parameter, *Utilised Agricultural Area* [ha] (UAA) – by considering the three croplands types, such as *arable cereal lands*, *vineyards* and *olive-growing lands* at regional scale.

At the temporal scale, this analysis has been carried out for the 1980, 1990, 2000, 2010 years, related to the Italian Agricultural Censuses – *from 3^rd^ to 6^th^ Italian Agricultural Census* - analyzed over time until 2013 (Fig. 2).

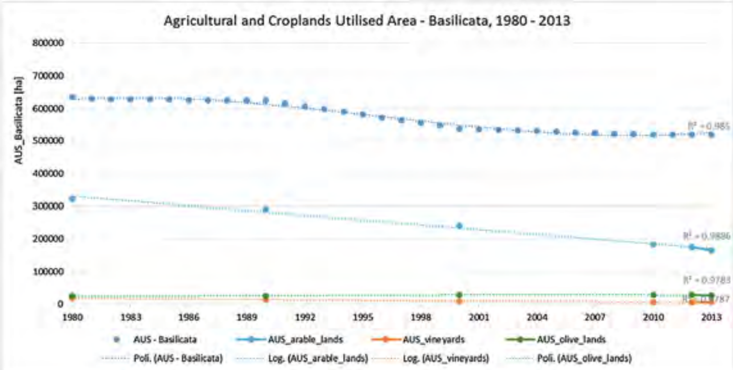

Fig. 2. Agricultural and croplands utilised surface (Agricultural Utilised Surface - AUS) trends [ha/year] in the Basilicata region from 1980 to 2013. (Color figure online)

The next step of the data analysis and the related trends assessments concerned the calculation of a new parameter, such as the *Productivity* [quintals/hectares] of the three crops considered in this work: *cereals*, *vineyards* and *olive trees*. This evaluation has been carried out by considering two data coming from the production scope, such as the *productive surface* (cropland) [ha] and the related *crop production* [quintals] *(ISTAT – Agriculture section: Surface and Production*). By calculating the division ratio between both of them – *Production* [q]/*Productive Surface* [ha] – it has been calculated the *Productivity value* for each crop. Thus, in order to observe the productivity trend, it has been necessary to work on spreadsheets for developing the graph of the series of data evaluated in the time frame considered. Figure 3 shows a complete framework of the three linear trends.

In relation to the data gap related to the surface and the production from 2012 to 2013 coming from ISTAT datasets, it has been considered the data coming from INEA database.

In order to analyze and evaluate the economic-agrarian aspect related to the *Agricultural Land Values*, has been carried out an analysis of the *Agricultural Average Values* – well-known as VAM – primarily used in the context of expropriation

Fig. 3. Trend Line application to the croplands productivity - arable cereal lands, vineyards, olive-growing lands trends – in the Basilicata region – from 1999 to 2013. (Color figure online)

procedures for public use of non-building areas of pursuant to the Italian Presidential Decree No. 327/2001.

The first step of the following analysis has been to calculate the average agricultural value by using the database of the 21 *Agrarian Zones* of the Basilicata region, evaluating an unique Average Agricultural Value in relation to each cropland for every year of the time frame considered – from 2008 to 2013 (Fig. 4).

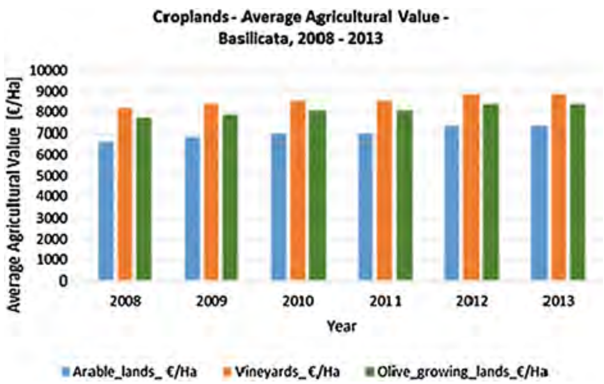

Fig. 4. Average Agricultural Values - arable cereal lands, vineyards, olive-growing lands trends – in the Basilicata region – from 2008 to 2013. (Color figure online)

3.1 USPED Method Application

Estimates of the factors related to the USPED model relative to the Basilicata region have been drawn as follows. For the support practice factor (P), which is the soil loss ratio with a specific support practice to the corresponding soil loss with up–and–down slope tillage, we adopted a unitary value, as is usually the case for natural slopes with no conservation practices.

3.1.1 Rainfall Erosivity

The R factor has been calculated by applying the equation developed by Capolongo et al. [11] for Basilicata, derived from 20-min and hourly precipitation data. It takes into account daily precipitation $\geq$ 10.0 mm:

$$EI_{30} = 0.0009 \cdot \left[P_k \cdot \left(9.0 + 3.0 \cdot \cos\left(2\pi \left(\frac{J - 3\sqrt{P_k}}{365} \right) + 3.0 \right) \right) \right]^2 \quad (4)$$

where EI_{30} is the rainfall erosivity in MJ ha^{-1} mm h^{-1}, Pk the daily total rainfall in mm and J the Julian day number. To extract the spatial distribution of erosivity in the whole region, we have considered the average erosivity values of 53 pluviometric stations calculated for 2012. Thus we have drawn an erosivity map by adopting the kriging geostatistical method, as suggested by [12] (Fig. 5d).

3.1.2 Soil Erodibility

The soil erodibility factor (K) map (Fig. 5a) has been calculated by using the USLE equation [6]:

$$K = [2.1 \times 10 - 4\,(12 - M)[(Si + fS)(100 - C)]1.14 + 3.25(A - 2) + 2.5(P - 3))]/100 \quad (5)$$

where M is the organic matter content (%), Si is the silt content (%), 2 to 50 μm, fS is the fine sand content (%), 50 μ to100 μm, C is the clay content (%), less than 2 μm, S is the sand content (%), 50 μm to 2 mm, A is the structure and P is the permeability class (within top 0.60 m). Soil data were derived from different sources. Texture, structure and permeability data derived from soil map of Basilicata [13]. This soil map, based on more than 1750 direct observations from 2002 to 2004 or on observations drawn from previous studies, laboratory analyses, drill holes and profiles, allowed researchers to obtain information on the physical characteristics of each soil type in the region. Organic matter data were derived from the European Soil Database [14].

3.1.3 Slope-Length Factor

The LS factor measures the impact of slope-length on soil erosion under steep slope conditions. In the traditional USLE and RUSLE methods it is evaluated as the horizontal distance from the overland flow origin to the point where either the slope gradient decreases to a point where deposition begins, or runoff becomes concentrated in a defined channel. As clearly explained by Garcia Rodriguez and Gimenez Suarez (2012) [15], in a real two-dimensional landscape, overland flow and the resulting soil loss do not actually depend upon the distance from the divide or upslope border on the field, but rather on the area per unit of contour length contributing runoff to that point, which is strongly affected by flow convergence and/or divergence [16].

Thus the slope-length unit (L) is replaced by the unit – contributing area. Digital Elevation Models of 1955 (20 × 20 m raster cell resolution) from the Istituto Geografico Militare Italiano has been used. Here the upslope contributing area is calculated by using the SINMAP extension in ArcViewGIS [17], which employs the D-∞ algorithms proposed by Tarboton (1997) [18].

3.1.4 Cover and Management Factor

The cover and management factor (C), which reflects the effects of cropping and management practices on soil erosion rates, has been calculated by using data from the fourth level of the land use map Corine Land Cover 2012 (Fig. 5c), which is available from the *Network of the National Environmental System of the Superior Institute for Environmental Protection and Research* (ISPRA, SINANET).

3.1.5 Model Application and Validation

The USPED Model was applied to the Basilicata region for the year 2012 (Fig. 6). Results from each raster cell were separated into seven classes of erosion and deposition as listed below:

1. High erosion (< − 20 Mg ha^{-1} y^{-1})
2. Moderate erosion (−12 to −20 Mg ha^{-1} y^{-1})
3. Low erosion (−1 to −12 Mg ha^{-1} y^{-1})
4. Very low erosion (−1 to 0 Mg ha^{-1} y^{-1})
5. Very low deposition (0 to 1 Mg ha^{-1} y^{-1})
6. Low–Moderate deposition (1 to 20 Mg ha^{-1} y^{-1})
7. High deposition (> 20 Mg ha^{-1} y^{-1}).

This classification was derived by adopting (i) the erosion risk classes used for Italy by van der Knijff et al. (1999) [19], (ii) the concepts formulated for Mediterranean environments by Morgan (1995) [20] and (iii) the criteria of tolerable erosion that established the soil losses at 1 Mg ha^{-1} y^{-1} [21].

Starting from the USPED raster image (Fig. 6), the values of the erosion classes, included in the Corine Land Cover polygons relative to the most economically significant for the Basilicata region (arable cereals lands, olive growing lands and vineyards) have been considered. For each cultivation has been evaluated the *Potential eroded surface* [ha] obtained through USPED method by considering only the first three classes of erosion in relation to the following range: < – 20 Mg ha^{-1} y^{-1} ÷ < – 1 Mg ha^{-1} y^{-1} – from high erosion to low erosion. This parameter has been related to soil loss average erosion to obtain/assess the potential economic loss for each cropland considered, so that the economic result – defined as "Potential Economic Loss" (PEL [€/ha]) – could be put in relation with the outputs coming from the USPED method application (Fig. 7).

Proceeding, it has been necessary to consider the soil density (C_Mg/m^3) parameter, in order to obtain the weight of eroded soil (P_Mg) and, consequently, the relative volume (V_m^3). Obtained these results, it has been possible, after having calculated the relative surface (Area m^2), imposing the average value of the topsoil width of 0.1 m [22], to assess two economic parameters reported in Table 1 (PEL – *Potential Economic Loss* [€] – and PEL/B €/ha – *Potential Economic loss*), put in relation to the potential eroded surface (B) related to the three selected croplands. This last result provides the economic value, evaluated in Euros per hectare, potentially lost in condition of eroded surface, in this case, in relation to the three croplands surface evaluated

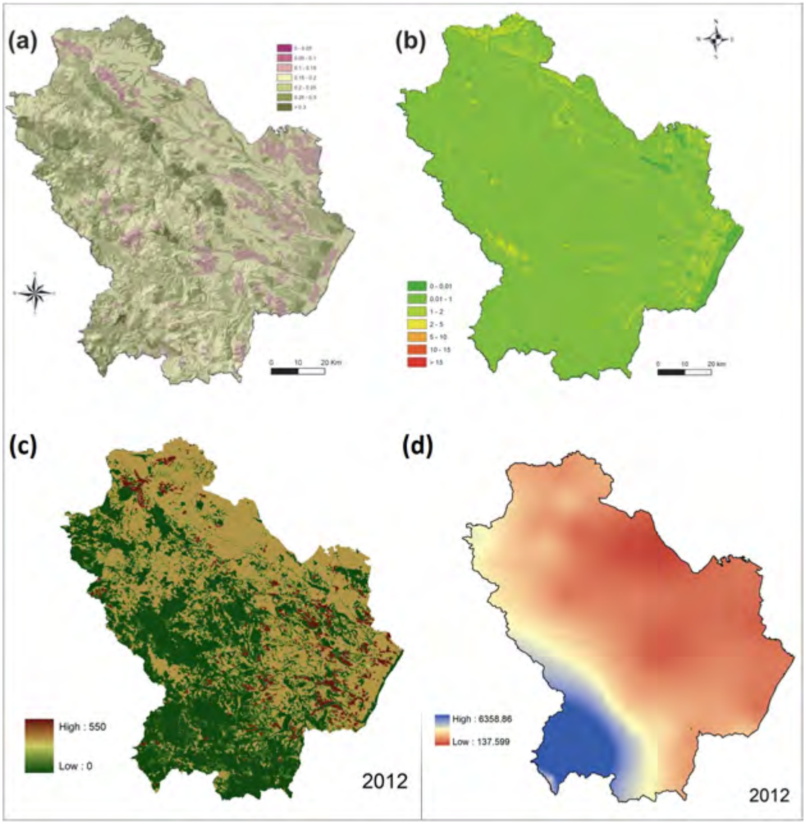

Fig. 5. Legend: 5(a) Soil erodibility factor map in the Basilicata region in 2012 (K factor); 5(b) Topographic Index Map, 2012; 5(c) Land cover and management factor map (C factor), 2012; 5 (d) Erosivity map (R factor), 2012. (Color figure online)

by considering the Average Agricultural Values (D €/ha) of the year 2012, coming from the database of the Basilicata Region Department (Table 1)

The Table 1 permits to define:

- *Potential Economic Loss* (PEL) €: parameter calculated by correlating the Area value [ha] with the Average Agricultural Values of the year 2012 for the three croplands selected. It has been defined a *potential value* because the soil loss values (average erosion [Mg/ha/y]) are considered as 'potential': indeed, the surface obtained through the USPED method application is a *potential eroded surface* [ha].
- *Economic erosion value* (PEL/B) €/ha: it is possible to notice these results in potential erosion conditions (economic value in relation to the Agricultural Average Values of the year 2012):
  - the arable lands would lose 1.50 Euros per hectare;
  - the olive growing lands would lose 0.80 Euros per hectare;
  - the vineyards would lose 1.88 Euros per hectare.

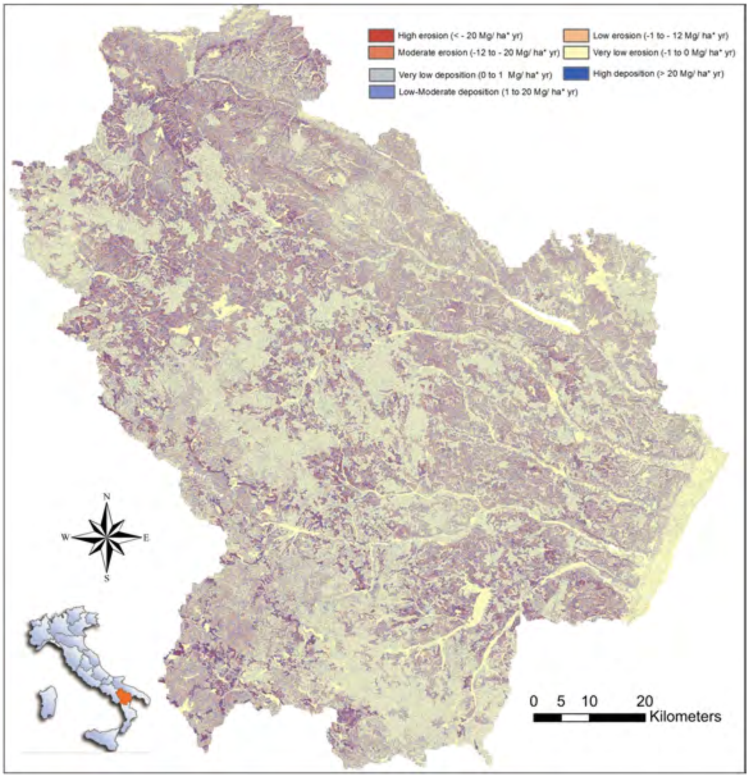

Fig. 6. USPED method application. Erosion and deposition map in the Basilicata region in 2012. (Color figure online)

Proceeding to the characterization of the environments occupied by cultivated areas of three croplands, in order to determinate the surfaces related to the total and the non-potential eroded ones, respectively, the estimation of the mean erosion has been carried out through the USPED method application – as reported into the following table (Table 2).

The results concerning *not potential eroded surface* [ha] has been obtained by calculating the difference between the *total surface* [ha] and the *potential eroded surface* [ha] (reported into the Table 1).

The percentage of potential eroded surface for every cropland considered, obtained by the ratio *Potential Eroded Surface (B) [ha]/Total Surface [ha],* show a strong potential eroded surface, around 99 % of the total (Table 2).

Table 1. Calculation of soil loss caused by erosion – USPED method application outputs. Legend: (A) *Soil Loss – average erosion* [Mg/ha/y]; (B) *Potential eroded surface* [ha] obtained through USPED method by considering only the first three classes of erosion in relation to the following range: < – 20 Mg ha^{-1} y^{-1} ÷ < – 1 Mg ha^{-1} y^{-1} – from high erosion to low erosion); (C) *Soil density* [Mg/m^3] = 1.9; (D) *Average Agricultural Values* [€/ha]; (P) *Weight of eroded soil* [Mg]; (V) *Volume* [m^3] = P/C; Area [m^2] = V/H (h = 0.1 m); PEL*: Potential Economic Loss* [€] = Area [ha] * D [€/ha]; PEL/B*: Economic erosion value - soil loss value* [€/ha].

Croplands	(A) [Mg/ha/y]	(B) [Ha]	(C) [Mg/m^3]	(D) [€/Ha]	P (Mg)	V P/C [m^3]	Area [m^2]	PEL [€]	PEL/B [€/Ha]
arable_lands	2.56	372385.62	1.9	7334	145463.13	76559.54	765595.44	561487.69	1.51
olive growing_lands	5.34	27945.29	1.9	8365	5233.20	2754.32	27543.16	23039.85	0.82
vineyards	2.48	1119.73	1.9	8841	451.50	237.63	2376.34	2100.92	1.88

Table 2. Characterization of the environments related to the croplands in relation to the USPED method application.

CROPLANDS	ENVIRONMENTS	Surface [ha]	Mean erosion USPED method	Total surface [ha]	Not potential eroded surface [ha]	Potential eroded surface
Arable lands	Mountain	65998.12	4.06	376444.78	**4059.16**	**0.99**
	Hill	176537.70	2.72			
	Plain	133908.96	1.59			
Olive growing lands	Mountain	726.24	8.96	28122.45	**177.16**	**0.99**
	Hill	17892.98	6.16			
	Plain	9503.23	3.67			
Vineyards	Mountain	0.00	0.00	1151.50	**31.77**	**0.97**
	Hill	694.09	3.28			
	Plain	457.41	1.14			

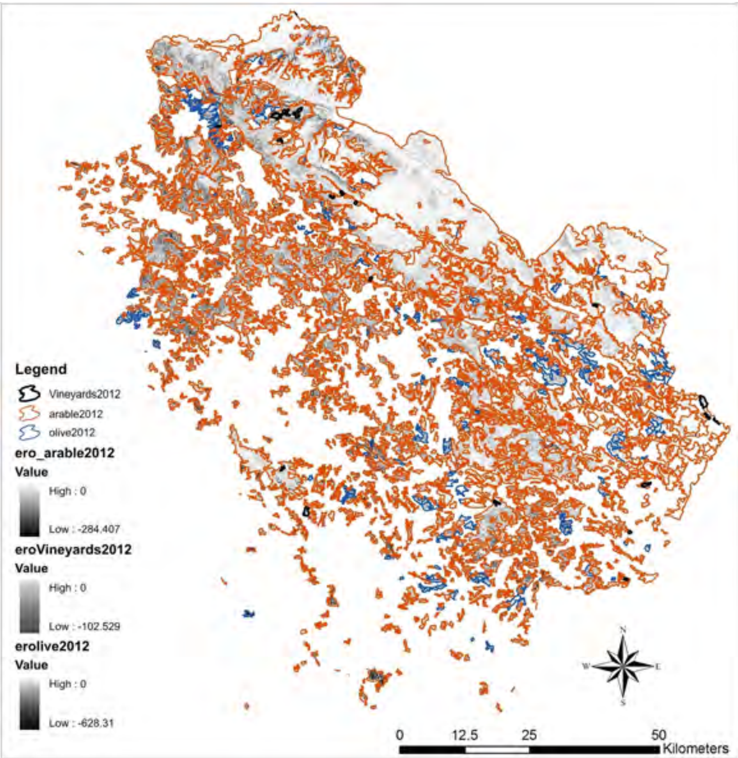

Fig. 7. Distribution of the three selected croplands, according to the Land Use map - Corine Land Cover 2012 – 4th hierarchical level, in combination with the USPED method application related to the erosion assessment (Color figure online)

4 Discussion and Final Remarks

In relation to the *Average Agricultural Values* (VAM - 2012) – coming from the Region of Basilicata - Department of Agriculture, Rural Development, Mountain Economy – *Provincial Commission for determining compensation for expropriation and the average agricultural land values* (available period: 2008 – 2013), it is necessary to premise that the value used in this study has been obtained by calculating the Average Value of each cropland considered, since the values, coming from the Table deriving from the abovementioned source, are divided into agrarian areas of the Basilicata region. This choice has been made because of the different spatial scale, as this study doesn't deal with the data at agrarian areas scale but at regional scale.

According to Bakker et al. (2004) [22], in order to obtain a clear framework of the structural analysis of the variables playing an important role into the erosion-productivity scenario, it is necessary to consider the following cases:

(a) topsoil removal may often result in a nutrient deficit;
(b) erosion may also lead to physical hindrance to root growth.

Regarding erosion-productivity relationship, it is important to consider that erosion reduces productivity so slowly that the reduction might not be recognized until crop production is no longer economically viable [22].

Moreover, putting in relation the geomorphological role with the economic one, it is interesting to mention the importance of considering the erosion and productivity, because - according Pimentel et al. [4]; El-Swaify et al. [23] and Troeh et al. [24] erosion by water and wind negatively affects soil quality and productivity by reducing infiltration rates, water-holding capacity, nutrients, organic matter, soil biota and soil depth.

The economic loss values calculated in Table 1 are comparable with those calculated for other sites synthesized by Telles et al. (2011) [25], considering that, in most of those papers, the methods used to assess the erosion were the USLE and RUSLE, which tend to amplify and emphasize the measured data and those generated by the application of USPED method [5].

The soil exposure to the erosion equal to 99 % of their surface, as is apparent by the USPED map, produces an economic loss, preliminarily estimated in €/ha (Table 1), which does not result in terms of physical removal of the soil particles by water, wind or anthropogenic land use for urban sprawl, but in a gradual destruction of the soil properties and pauperization of nutrients, organic matter and productivity.

The action of linear and areal erosion exerted by the water produces, however, a re-deposition and accumulation of the soil in other areas, but penalizing those of origin.

In this context, in this paper the estimation of costs due to soil erosion was made on the basis of on-site and not of those off-site, linked to sedimentation, flooding, flash floods, landslides and so on. By analyzing the on-site effects' framework related to erosion on crop yield, according to Lal (1998) [26], these effects might be induced by several interacting factors, such as reduction of soil organic carbon (SOC), loss of plant nutrients, decline in soil structure, loss of effective rooting depth and decrease in available water capacity (AWC). These factors, obviously, play an important role in causing a decline in soil quality and productivity. Also, reasons of decline in soil quality include edaphological factors affecting crop growth, decrease in soil structure and reduction in effective rooting depth [26].

Soil loss by erosion tends to increase production costs in the medium and long term, with an increasing demand for liming and fertilizer applications and reduce operational efficiency of machines, incurring costs to control the situation [27].

Soil erosion has, therefore, evident effects both on and off production sites, which have economic consequences on agriculture and on the land use policy. This paper provides a scenario that draws attention to the urgent need to prevent and control soil degradation processes. Considerable applied research on erosion control techniques has been done, for example, in the U.S. and elsewhere and can be grouped into two broad categories: (1) soil management techniques that improve infiltration rate, and (2) runoff management techniques that permit safe management/removal of surplus runoff. Conservation tillage [28], use of cover crops (e.g., crimson clover) to restore productivity of degraded soils [29], and summer fallowing [30] are common examples of soil management techniques. Constructing terracing, installing waterways, and other engineering devices are some examples of runoff management techniques.

For this propose, the data on erosion cost are of fundamental importance, especially in a region like Basilicata, whose economy depends by farming.

Database and Archive Sources

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