

Assessing the Impact of Land Use Changes on Ecosystem Services Value

Angela Pilogallo(✉), Lucia Saganeiti, Francesco Scorza, and Beniamino Murgante

University of Basilicata, Viale Dell'Ateneo Lucano 10, 85100 Potenza, Italy
angela.pilogallo@unibas.it

Abstract. Land use change significantly affects ecosystem services provision. This impact, however, is difficult to assess and thus often neglected in policy making. It is therefore the task of territorial planning discipline to explore methodological approaches capable of making explicit complex relationships in order to use them as tools for effectively designing the sustainable development.

In this paper, we report changes in land use over a 28-year period considering the territory of the Basilicata region. Our aim is to translate these changes in ecosystem services values, highlighting potentials of a framework able to integrate monetary figures into a larger approach based on the interactions between biomes and the meaning of human well-being more closely linked to the economics sector.

The results show that the greatest loss occurred at the detriment of wooded areas and agricultural mosaic while bare land and arable land increased. Several municipalities experienced significant changes involving above all the classes in the agricultural compartment. The growth of urban settlements took place everywhere affecting to a much greater extent the most important centers, the only ones not subject to depopulation.

Our estimate quantifies these changes in a total annual loss of ecosystem service delivery higher than €39 million with some municipalities where this loss corresponds to a significant part of GDP. Reversing the perspective, moreover, the internal areas emerge where, also due to depopulation, the monetization of ecosystem services leads to pro capita amounts equivalent to multiples of GDP per capita.

The study sets the basis for an approach oriented towards defining tangible criteria for assessing the sustainability of territorial transformations and land use change.

Keywords: Land use change · Ecosystem services values · Natural capital · Inner areas

1 Introduction

Providing a range of services essential for human survival, health and livelihood [1–3], ecosystems' contribution to human well-being has been widely deepened in science [4–7]. Although the relevance of this issue is also recognized by policy makers, there is

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still a need for full integration between the conceptual framework of ecosystem services (ES) and the effectiveness of decision-making processes.

Expressing the value of ES in monetary units can therefore be useful both because the decision-making process often uses a cost-benefit assessment to evaluate development strategies and planning alternatives [8], and because as also highlighted by Rodriguez-Loinaz et al. [9], most ES are outside the market system and this has often led to the degradation of non-marketed services as a result of measures implemented to increase the supply of ES marketed [10, 11].

The effort to monetize goods and both tangible and immaterial services is however all the more effective, the more appropriate the estimation method is in relation to the work scale [12, 13]: from the national scale to the local dimension, the contribution that the assessment of the ES value (ESV) can give, ranges from the estimation of the natural capital to the support in performing selections between project alternatives and transformation scenarios.

In this work, we estimate the ESV change in the Basilicata region following land use/land cover (LULC) modifications occurred over the period 1990-2018 derived from Corine Land Cover, and examine the comparison between these gain and loss and gross domestic product (GDP) at the municipal level. According to our assessment carried out using the values estimated by Costanza et al. [14], the changes over the 28 years considered resulted in an overall loss of capacity to generate ecosystem services of 39 million euros per year. At the municipal level, comparing these outcomes with the 2018 per capita gross domestic product highlights that the ESV is, in several inner municipalities, up to two times higher than the GDP.

A the regional level, this kind of outcomes could help to improve the territorial governance by measuring the performances of the transformation and to make decisions about allocating economic resources to promote sustainable development strategies capable to produce added value from natural capital while preserving the ESV for the future generations.

2 Materials and Method

2.1 Study Area and Land Use Changes

The Basilicata Region (Fig. 1) covers a total area of about 10,000 km^2 and is characterized by a prevalently mountainous territory. Only 8% of the total area is flat and it is mainly located along the Ionian coast.

Due to the presence of the Apennine chain that crosses it from north to south, two main sectors can be identified: a western one, characterized by higher altitudes and slopes and the eastern one where the hilly landscape prevails and slopes down to the low and sandy coasts of the Ionian Sea.

During the investigated time period ranging from 1990 to 2018 and according to Corine Land Cover, most of the changes in land use occurred in the semi-natural classes linked to agricultural use, although the loss of woodland is also significant.

As it can be seen from Fig. 2, the classes related to agricultural mosaic and pastures have decreased significantly while arable land, shrubs and bare land have expanded considerably.

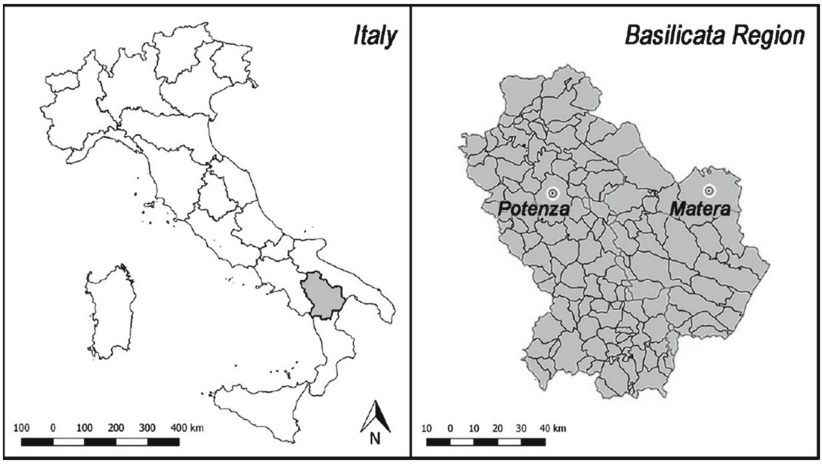

Fig. 1. Study area

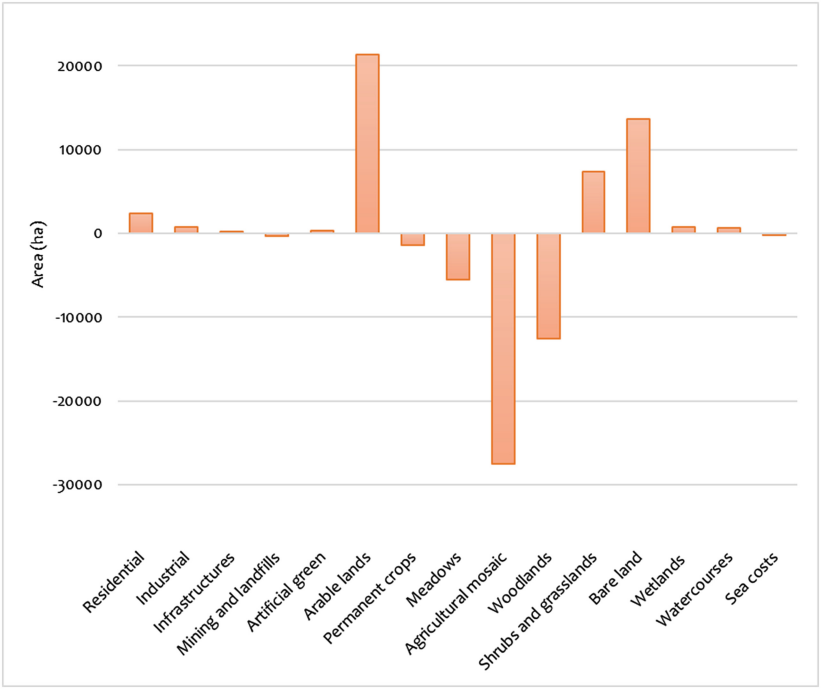

Fig. 2. Gain and loss for each LULC class resulting from changes occurred over the period 1990-2018.

Analyzing in detail the most significant transitions (Fig. 3), it emerges that most of the new arable land comes from the agricultural mosaic but also from previously wooded land. n a mirror-like way, the agricultural mosaic has given space mainly in favor of arable

land but also of orchards and permanent crops, even if the area for new urbanization, which amounts to about 2480 hectares and equal to 4% of the total transformations suffered by the class, is not entirely negligible.

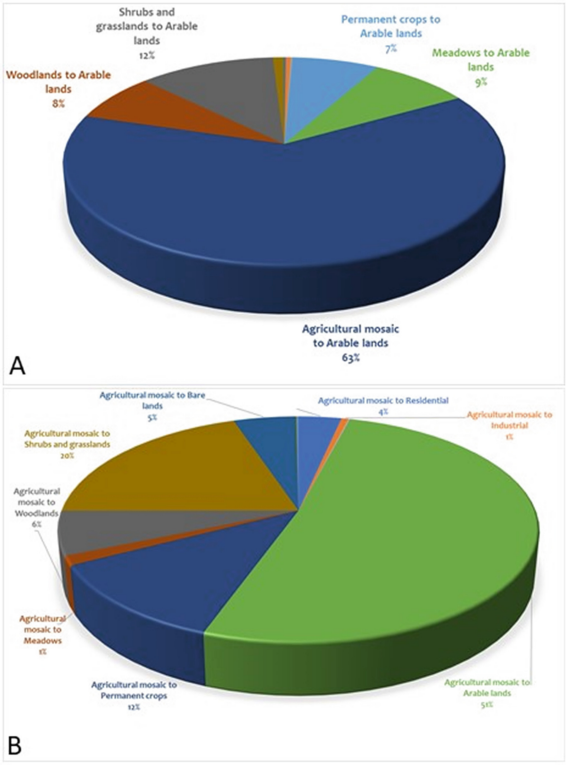

Fig. 3. Transitions from all LU classes to "Arable lands" (A) and from "Agricultural mosaic" to all LU classes (B).

2.2 Methods

The approach used to assess the ESV is shifted from the work developed [1] and carried out by Costanza et al. [14] which quantifies the economic value of the aggregated ecosystem services through the following formula:

$$ESV = \sum (VL_i \times A_i)$$

where A_i is the area (ha) of the biome i and VL_i represents the annual monetary unit value, in our case expressed in €/ha/yr.

This method assumes that every kind of biome produce a constant unit value per hectare, not considering any other features but the kind of the ecosystem. Starting with

Table 1. Unit value per hectare for each of the biomes

LULC class	Biome	VL_i (€/ha/yr)
Residential	Urban	6954.08
Industrial	–	0.00
Infrastructures	–	0.00
Mining and Landfills	–	0.00
Artificial green	Urban	6954.08
Arable lands	Cropland	5811.95
Permanent crops	Cropland	5811.95
Meadows	Cropland	5811.95
Agricultural mosaic	Cropland	5811.95
Woodlands	Temperate forest	3275.03
Shrubs and grasslands	Grassland	4349.30
Bare land	Rock	0.00
Wetlands	Wetlands	26810.96
Watercourses	Lakes/rivers	13062.53
Sea costs	Coastal	9337.54

the classification of Corine Land Cover, the classes were then aggregated into biomes and assigned the corresponding unit value (Table 1).

In order to assess the loss of capacity to generate ecosystem services following LULC changes over the 28 years considered, A_i was calculated in a GIS environment considering the extension of each kind of polygon (i.e. transition).

To deeply understand the relationship between ESV and socio-economic features of all the municipalities belonging to the study area, we considered the per capita GDP of the Basilicata region referred to 2018 and equal to 22,200 € [15] and population data provided by the Italian National Statistical Institute (ISTAT) [16].

3 Results and Discussion

According with this method, the LULC changes occurred in the last 28 years resulted in an overall loss of capacity to generate ecosystem services higher than 39 million euros per year. To this value conspicuously contribute both the artificialization of natural and semi-natural areas (e.g. the transition from agricultural to industrial land or the expansion of urban agglomerations [17] to the detriment of meadows or cultivated fields) and the processes of forest advancement in areas where pastures and agricultural land have been abandoned and renaturalisation has been allowed to proceed. This happens because, as can also be seen from the values shown in the table, the value of VL_i referred to temperate forests is lower than the biomes referring to cultivations and shrubs.

The most significant aspect of this approach lies in having an aggregate index (i.e. a significant number of different ecosystem services) which, however, maintains the spatial dimension, giving the possibility to identify the areas that have suffered the greatest loss due to the changes that have occurred but also to highlight hotspots at regional level, indicative of areas that are particularly functional from the perspective of ecosystem service provision [18].

The following Fig. 4 is a representation of land use changes expressed in monetary terms: areas in red correspond to a decrease in value (proportional to color gradation), areas in green indicate a gain in terms of capacity to provide ecosystem services.

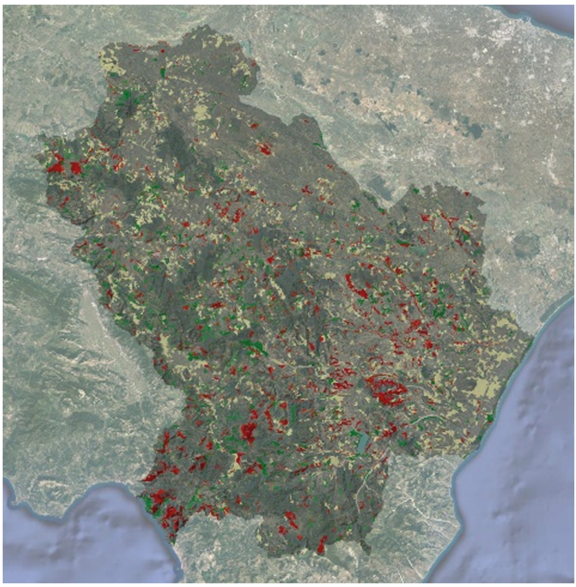

Fig. 4. Representation of land use changes in monetary terms: red correspond to a decrease of ESV, green to a gain.

Knowing the GDP per capita and population resident in each municipality in 2018, the municipal GDP was calculated. Comparing the change in ESV compared to this value, a distribution of municipalities where land use changes have had a more or less significant impact emerges. In the following Fig. 5 there is a representation of municipalities made winners or looser by land use transition: in green are represented municipalities where transition and transformation implied a gain in ESV value; on the other side, municipalities with colors ranging from light yellow to red are those in which LULC transitions correspond to a decrease in ES overall value.

As can be seen from Fig. 5, the municipalities located along the internal areas of the Apennine chain are those that have on average been most affected by the changes in LULC. The highest value, equal to more than 30%, is recorded in a municipality where in recent years there has been a significant decrease in agricultural land [19–21] due both to renaturation processes that have favored the conversion into shrubland and

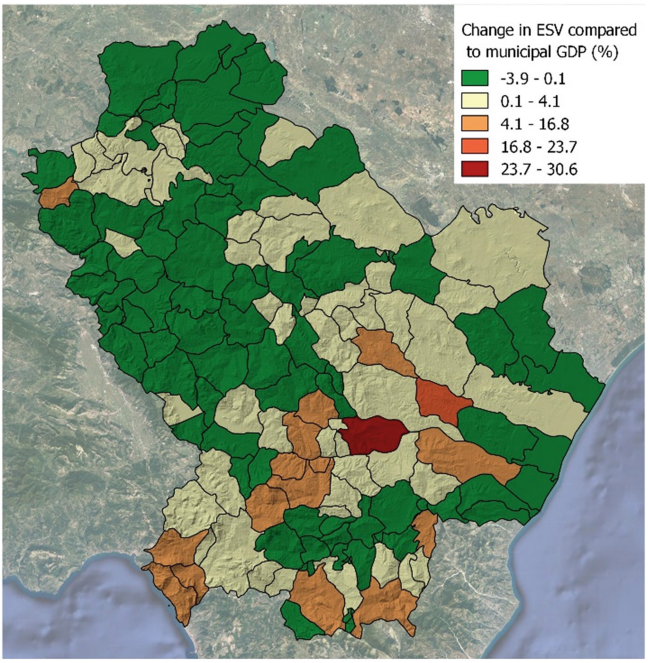

Fig. 5. Change in ESV expressed as a percentage of the GDP assessed at the municipal level (Color figure online)

to transformations in bare soil. It also emerges that, taking for granted the unit values assumed, there are quite a number of municipalities in which land use changes have had a positive impact, which, however, does not reach 4% of the municipal GDP.

Finally, the total value of ESV at 2018 was calculated for each municipality and then divided by the surface area of the territory and by the number of resident inhabitants (Fig. 6).

Analyzing the normalized data with respect to the extension (Fig. 6 – A), it emerges the role of municipalities with a significant percentage of territory dedicated to agricultural activity but also of those along the Ionian coast, with a high conservation value linked to the presence of habitats belonging to the dune and back dune environment. Equally significant is the representation of the ESV per inhabitant (Fig. 6 – B) which returns maximum values twice higher than the GDP per capita (€ 22,200). The municipalities where this value is higher correspond to the inner areas which, as shown in the figure above, are also those where land use changes lead to a significant decrease in ESV compared to GDP per capita. The reasons for this are related both to the scarce presence in these areas of industrial sites and artificial soils (which do not contribute to the ESV) but also to the small resident population, whose trend is considered, for some of those municipalities, irreversible.

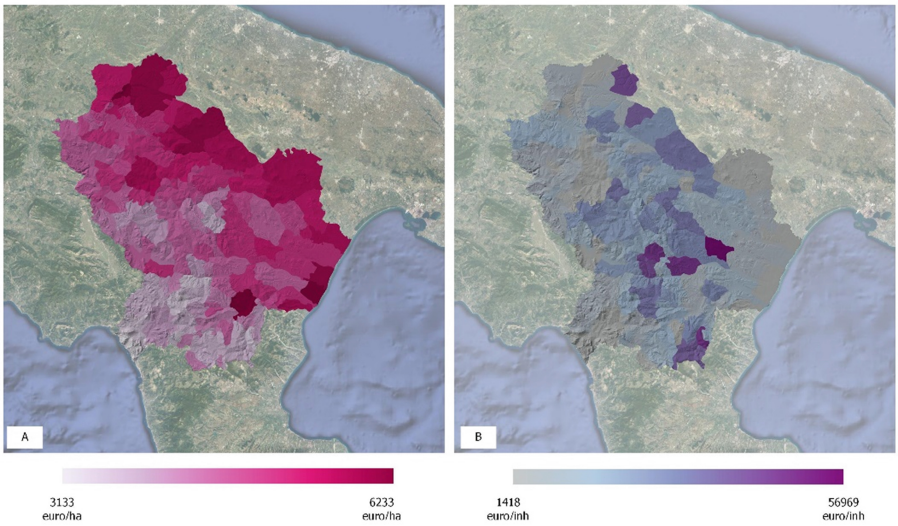

Fig. 6. 2018 ESV normalized with respect to surface area (A) and resident population (B)

4 Conclusions

The ES methodological framework represents a useful tool in interpreting changes in land use and in assessing the effects of territorial transformation. The aim of the paper was to show the potential of an aggregate index, representative of the capacity of a territory to provide simultaneously different ecosystem services. In this paper we used the ESV, calculated on the basis of the work done by Costanza et al. [1, 14] at the global scale. As also highlighted by Jiang [22], the accuracy of such kind of this assessment depends on the LULC data resolution and on the methodology applied for calculate the annual monetary unit value (VL_i) for each of the biomes present in the study area. This parameter is therefore very important because it derives from a market analysis characterized by dynamics and processes that certainly differ according to the working scale and, on an equal degree of detail, from the territorial components of the study area [23]. Therefore, replicating the ESV calculation methodology developed on a world scale, within a study area extending about 10,000 km^2, brings with it non-negligible margins of error. In addition to these are to be considered the simplifications deriving from the Corine Land Cover Map whose resolution fails to capture the detail of certain transformations which, however, even with the same surface area involved, have different impacts in terms of ecosystem services. This is the case, for example, of the phenomena of urban growth already studied by the authors [24–26] and that highlight the inefficiency of the sprinkling process with which urban settlements continue to grow despite the marked depopulation that characterizes the overwhelming majority of municipalities. However, as highlighted in previous works [22–24], the ecosystem services approach is particularly effective in interpreting territorial transformations by providing useful tools both in the ex-ante planning phase [27] and in the assessment of cumulative impacts [28, 29]. Although the strength of this approach lies in the possibility of expressing the values

of individual territorial components at different scales, the use of aggregate indices of the overall capacity to provide ES is useful in identifying hotspots or, conversely, in defining regeneration priorities for particularly degraded areas. The use of synthetic indicators can certainly be included in that toolkit [30–32] useful for decision makers and policy designers to pursue sustainability objectives in the evaluation processes. The comparison with socio-economic parameters makes explicit the relationship of the population with ecosystems, thus allowing to assess the demand for ES and to orient regional programming more effectively.

Future developments will certainly have to remedy the weak points of this work, namely that a globally developed evaluation methodology is not scalable on a regional level. Therefore, further studies and research are needed for the evaluation of ES unit values according to a place-based approach.

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