

From Cost Benefit Analysis to Spatial Indicators: The Use of CO2 Segregation and Carbon Footprint for the Evaluation of Sustainable Land Use Transitions

Carmelo Maria Torre(✉), Pasquale Balena, Alessandro Bonifazi, and Ludovica Vitale

Department of Civil, Environmental, Land, Building Engineering and Chemistry, Polytechnic University of Bari, 70126 Bari, Italy
carmelomaria.torre@poliba.it

Abstract. The paper shows the first result of a research project, aiming at considering new useful environmental indicators that will be useful to describe, such as a unique parameter, the environmental impact of spatial artificialization of land. The well known concept of "soil take" can support the evolution towards new concepts, related to global environmental phenomena, such as the increase of "Global Warming" and of "Carbon Dioxide". Land transition from an existing natural category of soil coverage to a new artificial one is one of the main negative contribution to the increase of the temperature in the earth's atmosphere. Some recent studies developed by scholars in environmental economics, put on evidence the function of "cost of carbon dioxide segregation" as a relevant indicator of Heart's Global Warming. The paper highlights a double function of such kind of measures: "synthetic environmental indicators" on one hand represent the measure of a continuous check of global change in the atmosphere, and on the other hand consider the economic value of carbon segregation as an "easy" alternative to cost benefit assessment, able to describe in a unique dimension the trend of global phenomena.

Keywords: Environmental synthetic indicators · Cost-benefit · CO2 footprint · Soil take · Transition matrix · Multidimensional spatial assessment

1 Introduction

In the history of city and regional development, environmental issues due to soil take represent the most common example of a never-ending conflict among urban growth and nature preservation.

The need of using environmental resources and – in the same - of saving ecosystem services, always in order to increase human welfare, drive nowadays to the seek for new needful evaluative approaches regarding the impact due the increase of urban settlement on the natural environment [1, 2].

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In this continuously evolving context, since the past to nowadays Cost-benefit analysis (CBA) represent the "business as usual" approach for assessing advantages/disadvantages, in many social and private disciplinary activity. CBA (at the same time) is looking at balancing the reduction of natural capital due to the urban and economic growth, accompanied by the aim at understanding if the issues of an increase of welfare can balance the loss of some environmental resources.

Starting from the milestones of the Serageldin Triangle (Economy, Environment and Society) authors analyzed possible evaluative paths towards a more effective assessment of the sustainability of plans and programs.

This assessment has been often based on multiple indicators of performance, valuation criteria, multifunction formulas etc.

The debate "Cost Benefit Assessment (CBA) versus Sustainability Multidimensional Evaluation (SME) started in the Eighties, and still exists in the nowadays: the two approaches have been overtaken by several synthetic indicators of sustainability (SIS) having some peculiar issues [3–5].

Just to be more understandable the shift from a complex communicative result to a simplest, SIS have an educational scope, and invite people to understand more easily the limit of urban World Growth.

The task is based on making people more concerning about the ratio at the World scale, between the economic growth vs the reduction of environmental resources. Resources are usually measured by the "Ecological Footprint", "Ozone Hole", "Global Warming", "atmosphere CO2" etc.

In the most recent and contemporary era, the evolution of environmental economics coupled with the increased relevance of social communication, favored as consequence the idea to communicate with understandable indicators the state of the environment [6–8].

The relevance of such "universal indicators" [9] is due to the understandability that a unique estimate of global environmental changes, make people easily concerning about the importance to adopt a more sustainable lifestyle. The newest indicator of sustainability is related with the "Carbon Segregation" [10–12].

2 Aim of the Research

Starting from the idea that data about pollution, artificialization of soil, consumption of not-renewable resources, in the light of "environmental democracy" (aside the traditional technical approach based on the practice of environmental impact assessment) should communicate effective information to non-expert arenas, environmental planners and economists propose readable measures, such as the ecological footprint, the percentage of artificialization of Hearth surface, the global climate warming, and so on, as a fast communicative measure of environmental changes.

In the recent years, further scholars have been posed a new attention on the increase of CO2 in the atmosphere, just to support the environmental information to "non-expert" contexts by a simple parameter (represented by the increase of carbon dioxide and global temperature).

The need to stock "also but not only" Carbon dioxide, becomes therefore the new horizon for assessing global sustainable actions in the field of Urban and Spatial Planning (USP), Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA).

The diffusion and segregation of CO2, therefore, represent now a joint/global indicator of global warming and surface pollution.

Many scholars just in the recent time started studying effect of soil take, in official institutional researches, looking at artificial coverage and imperviousness, as one of the causes of global environmental issues as hearth climate changes.

3 Synthetic Indicators vs Cost Benefit Analyses for Environmental Impact Assessments

The aim of this paper is to test a new way of mapping the transition of soils from the previous coverages to new ones, and of calculating the effect of change the carbon stock as a complement of the most famous measures of soil take. The paper illustrates an example of a research about the potential absorption of CO2 emission, based on geographic mapping and GIS-supported multidimensional assessment at the local scale, that can demonstrate the possible usefulness of measure deriving form carbon segregation as measure of environmental issues.

The research started with the seek for a "measure" about effects of the transition from the existing natural/artificial soil towards new ones [13, 14]. The measure starts from the spatial analysis of Carbon segregation (CS) and Carbon Bi-oxide diffusion of soil (CO2), related to the peculiar characters of all land surfaces. Finally, the effect of CO2 segregation in land-use has been represented in the spatial and monetary dimension, as a result of the loss and revenue deriving from the measure of CO2 segregation cost and savings. The authors think that this study, looking at the evolution of land uses [15] [16], will contribute to a deeper research on the use a spatial indicator of the effectiveness man-driven CO2 segregation.

Different methods can be used to evaluate externalities: it is possible to approach by qualitative evaluation, weighting and ranking, cost-benefit, damage estimation and monetization of issues, multiple criteria analysis (sometime combined with cost-benefits) and so on.

The most frequently applied is still the Cost Benefit Analysis (CBA), especially in the ruling system.

CBA takes place by the identification of a cash-flow of costs and benefits (benefits, for instance are considerable as public/social revenues) brought to the community as consequence of land-use changes. A territorial transformation therefore is assessed by the use of a time-actualization of all (positive and negative) money quantities at the initial instant of flow, in order to make them comparable, and to obtain by a difference between benefits and costs, the overall net benefit. A wider application of the method has been considered preferable, from the past until nowadays, thanks to the apparent simplicity of the economic indicators that measure advantages and disadvantages of a given choice. Among these, the most known is the net present value (NPV).

NPV is characterized by its communicative power, that is based on the definition of a judgment through a single monetary measure: such measure can result positive or negative, and can refer to a farer or nearer future horizon.

The so-called "Extended CBA", refines the results of the "traditional" CBA (that refers on financial Cost and benefit in a social arena) by adding the evaluation of those overall social/environmental costs and benefits that will be generated by transformations [14].

CBA therefore, can base its judgment of appropriateness not only on the assessment of a financial cash flow, but also on a wider evaluation that collect both financial accounts and socio-environmental accounts, looking towards a wider cost-effectiveness balance.

As regards the monetary equivalence of social and environmental issue due to a land transformation (a project or a plan):

– on one hand, it can express positively the increase of the financial dimension of resources/revenues, and on the other hand the consequent expected advantage enjoyable for the community.
– on the other hand, it can express negatively the financial dimension of the disadvantage due to an unlucky or fallacious implementation, with a consequent difficulty for community, due to the deprivation of lost resources.

Last but not least, CBA also represented, in the recent past times, a complementary tool to Environmental Impact Studies.

Cost Benefit Analysis has often been criticized by the scientific community of environmental economists for decades, due to some well-known limits: the remoteness of time horizons of environmental issues, that makes ineffective the measure of costs and benefits. The balance between cost and benefit becomes "smaller" after the discounting from remote futures to nowadays. The cost-benefit analysis, however, has a very broad scope and is frequently indicated as relevant methodology in the law system, due to some technical approaches related with the evaluation of impacts/transformation inside the development and implementation of plans and projects.

A further limitation of CBA is due to the difficulty to manage several and multi-dimensional information, in the light of an accounting related with: land use changes, cost and revenues, social effects, environmental resources, enhancement/reduction: all are always measured with homogeneous money units that sometimes make a non-sense final determination of values. The balance, when based on the expression by money units, describing a multiple dimension of effects, implies several financial calculations with a high character of uncertainty.

Last but not least, the support of Cost-Benefit studies in decision-making processes, and many further complex evaluative approaches (e.g. Multicriterial or Environmental Impact Assessment) is politically useful, but in the same time it is not so easy to be explained to the community.

For these reasons, indicators and descriptors of impacts generated by the transformations and the evolution of a given environment, have been combined with the steady technique of cost-benefit analysis. The description of the effects of the environment generated by a "unique global indicator" is represented, for instance by the "ecological

footprint" (EF). Ecological Footprint means "the measure of the resources needed to ensure the usual lifestyle of a community".

Claiming that the Ecological footprint is the measure of a consumption of environmental resources so that "three times bigger of the earth", for instance, represents easily that the level of consumption of resources has to be considered three times the sustainable one.

The use of the so-called "synthetic indicators', therefore, favors the application of the concept of "environmental democracy" based on the principles of the Aharus Convention, which establish the obligation to inform the community of the environmental impacts generated by territorial transformations.

The advantage of synthetic indicators lies in the ease of understanding the relevance of the environmental risk generated by human activities. The difficulty, instead is represented by upstream procedure that identifies the value of the indicator.

The aim of the experimentation is to verify the communicability of indicators that are represented with a monetary measure, which is very easy to communicate. In the case in question, we are talking about the cost of "Carbon segregation", measured with respect to changes in land use.

The cost of "Carbon Segregation" (CSC) is not only an easy communicative monodimensional measure: it represents also a synthetic money estimate of compensation of environmental issues, due to the evolution of settlements and activities on the Hearth surface. According with these premises, the paper will show a possible method of assessment that can be extended from a small piece of land to an entire regional or sub-regional context.

Last but not least, the assumption by the European Commission, concerning about the relevance of climate changes, amended the Regulation (EU) 2018/842 on "binding" annual greenhouse gas emission reductions from 2021 to 2030 in order to give a further contribution to action for climate regulation, according with the commitments coming from the "Paris Agreement".

The European Commission already from 2020 as part of the so-called "European Green Deal, had proposed to increase the minimum acceptable threshold for 2030, relating to the reduction of greenhouse gas emissions, to at least 55% compared to 1990".

Paris Agreement - COP 21, as well, produced the first universal agreement to reduce the atmospheric temperature by 2 degrees, below the levels of the first industrial revolution (1861–1880) from 2015 to 2100. Such reduction is equivalent in terms of Carbon Footprint, to the elimination of 2,900 billion tons of Co2, by 2050: the reduction is equal to a cut of emissions between 40% and 70%.

More in detail, the existing ambition for 2030 climate and energy framework are represented by the following Key targets: at least 40% of cuts in greenhouse gas emissions (from 1990 levels), 32% to share for renewable energy, 32.5% improvement in energy efficiency.

The minimum target for the 2030 is anyway represented by the reduction of greenhouse gas emission at the 55% respect to 1990, according with the forecast and the actions of the "European Green Deal".

In the light of these international agreements, it should be interesting to consider as a new approach the "economic measure" of "carbon footprint" as the base of a new "exercise of evaluation" aiming at translate in money dimension, the effect of carbon segregation changes, in the territorial structure.

4 The Case of Study

As already explained the story starts from an experimental approach aiming to find, test and propose a synthetic (one-dimensional) indicator of environmental impacts that can be implemented within an EIA procedure applied to a set of projects, and which acts for a new offer of rural leisure in the countryside of the Puglia Region. Rural contexts in Puglia are, - sometimes and partially - included inside "Sites of Interest for the Community" (SIC) by decree of the European Union (EU).

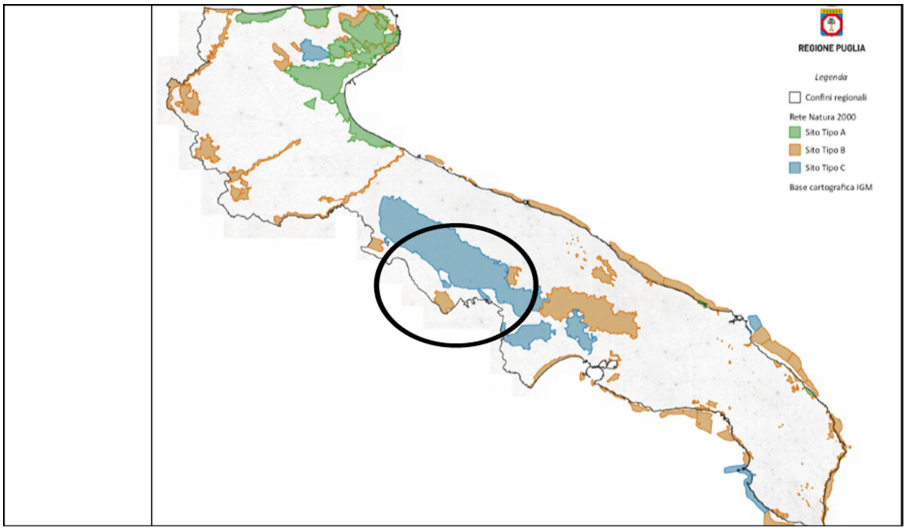

Fig. 1. Map of European "Sites of Interest for the European Community" in Apulian Region. The case study refers to the undersigned area inside the ellipse (Source: Apulian Region Geographic Information System)

The classification of SIC starts from the recognition of the environmental context, in those areas that guest listed species according with criteria of "EU Habitat Catalogue". This constrain requires maintaining a good conservation status of "habitat types" and "species" within the "Nature 2000" program (see Fig. 1).

Italian natural terrestrial sites included in the "Nature 2000" Repository (the so-called SIC-Sites of interest for the EU Community) cover 5.843.817 Hectares (more-less the 20% of the whole national surface).

In Apulian Region "SIC areas" cover an extension of 402.512 Hectares. In detail, the SIC area named "Murgia dei Trulli" is one of the biggest in the regional and national context.

All EU Member States, according with the Habitats Directive, must periodically monitor the status of "habitat types" and "listed species", just to confirm or to modify the perimeters of such special environmentally protected areas. Finally, the assessment of the state of conservation is mandatory, and all real modification or transformation project regarding Habitat Sites are subjected to a peculiar impact assessment procedure.

5 The Approach to Evaluation

The first test has been experimented in the core area of Apulia Region (put on evidence in Fig. 1), that contains a main "Site of Community Interest". Such environmental context is well identified by the presence of hilly and oak wooded highlands (see Fig. 2) and avian species, both listed in the Natura 2000 repository, also hosting the presence of the famous and peculiar rural houses named "Trulli" having the typical circular plant and the conic stone roof.

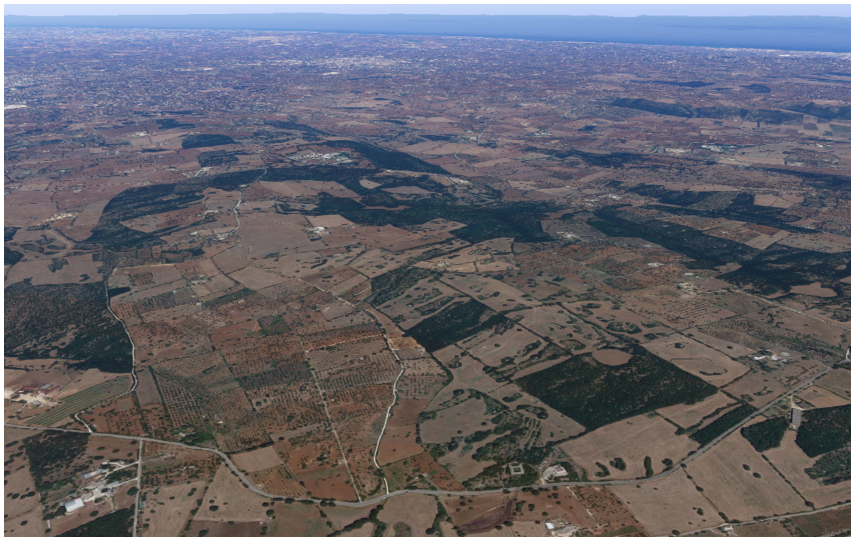

Fig. 2. Overall view of the countryside interested by projects of new rural settlements. In the far horizon the Adriatic Coast is visible (source: 3D vision - Google maps)

The area of study was analyzed, in order to discover the possibility of transition from the current land use to new ones. It takes necessary the assessment of environmental effects, just by simple indicators, according with norms. Just to experiment an innovative approach, a new set of indicators was provided. The peculiarity of new measures is based on the assessment of effects of transition from old land uses to the new ones. The impact of transition was measured in terms of variation of CO2 segregation connected with to the change of land uses. All typologies of surface can be classified in terms of CO2 segregation: as a consequence, the measure of CO2 segregation of a soil, looking at land use changes, changes as well. In the observed contexts the transition regarded mainly

the shift from agricultural land-uses to the touristic ones, accompanied with new leisures and new complementary activities.

According to the EU legislation, the environmental issues due to the forecasts of new settlements provided by plans should be submitted to "Strategic environmental assessment" (SEA); in the same time the more detailed project should be submitted to "Environmental incidence assessment" (EIA).

In order to justify the usefulness of the new activities, when discovering environmental issues related to the implementation of plans/projects, it becomes necessary to make a balance between costs and benefits.

According to such approaches, the valuation of costs should consider environmental issues, and in the same time, the valuation of benefits should include "added values", due to the creation of new activities and jobs, and furthermore, to the increase of gross profit. The positive economic issues should be represented (as already underlined) by the net present value deriving from previous balances.

As regards economic literature, many researches put continuously on evidence the weakness points of Cost Benefit Studies.



Fig. 3. A possible project of new settlements inserted in the countryside.

Social costs, generally are referable to long-term time horizons, unlike the financial costs of intervention referring to the short term, consequently have a minimal impact on the cost-benefit balance, because they are greatly reduced by the high uncertainty they undergo in discounting.

Starting from the assumption of some weakness point in applying a traditional cost-benefit balance, the more recent thoughts about the study of environmental impacts due to the human activities suggest to use universal indicators, that have a technical and a social characterization. The most relevant technical aspect of an universal indicator is represented by its synthetic character: for instance, global warming can be measured by the increase of temperature or by the sea level rise; soil take can be measured by hectares of artificial soil, or by imperviousness; the loss of natural resources is measured by the reduction of biomass, and so on [16, 17].

As previously announced, the experiment related with the case-study consists in substituting the traditional cost-benefit analysis with the assessment of derived values from CO2 segregation due to the variation of surfaces, in the transition from the early land use to the new one, with consequent coupled transition from an initial money value to

the final one, expressing the economic dimension of carbon segregation [18, 19]. Among basic systems of carbon recapture and segregation, the Carbon Dioxide Removal (CDR) is mainly relevant. CDR is accompanied by several strategies [20]:

– reforestation, aiming at the creation of "carbon sink", useful for biofuel production,
– bio-energy with carbon capture and storage (BECCS),
– direct air capture (DAC) by air scrubbing,
– use of dedicated solvents ready to be used for solution.
– sequestration for soils increase, to be obtained by suitable techniques based on the content of organic compounds in rhizosphere.

When looking at the monetary dimension, furthermore, the value of CO2 segregation has been increasing during the time (Fig. 4). Such trends show a progressive increase of performance testified by cost-benefit balance of carbon segregation (Fig. 4). The table in Fig. 5, instead, shows the variation of of land coverage before and after the implementation of the project.

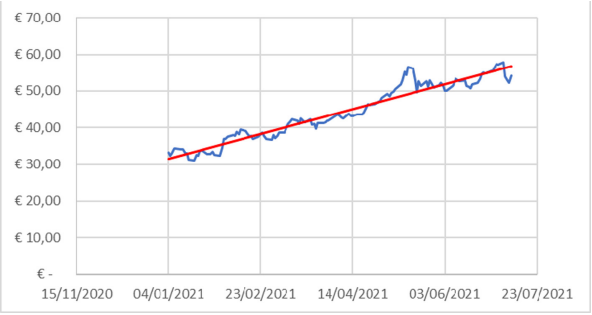

Fig. 4. Trend of value of CO2 segregation (euros per square meters)

SAMPLE n.3	m²	m²	m²	m²	m²	m²	m²
Uncultivated land	201.720						-42.770
Rare widespread wooded soil	20.250					-6.560	
Oaks	53.030				0		
Ornamental saplings	0			+51.280			
Wooded Soil	47.100		-27.080				
Built Environment	1.350	+25.130					
New Surfaces		26.480	20.020	51.280	53.030	13.690	158.950
	Past Surfaces	Built Environment	Wooded Soil	Ornamental saplings	Oaks	Rare widespread wooded soil	Uncultivated land

Fig. 5. Transition among different typology of land use (before and after land use change)

Balance of CO_2 segregation	m^2	m^2	m^2	Kg_{CO2}/m^2	Unit Price of CO_2 kg	Total Kg_{CO2}	Cost of CO_2 Segregation
Uncultivated land	201.720	158.950	**-42.770**	0,35		-14.970	
Rare widespread wooded soil	20.250	13.690	**-6.560**	0,5		-3.280	
Oaks	53.030	53.030	**0**	1,99	€ 23,38		
Ornamental saplings	0	51.280	**+51.280**	4,33		222.042	
Wooded Soil	47.100	20.020	**-27.080**	0,98		- 26.538	
Built Environment	1.350	26.480	**+25.130**	1,1		27.643	
						204.897	€ 4.790.492

Fig. 6. Final money accounting of CO2 segregation

6 Last Remarks

The paper shows an experimental/pioneer proposal to assess the impact of composite land-use change due to the birth of new settlements. The economic dimension of carbon segregation has been used as "dummy" measure of a benefits/costs balance, associated to progressive urban and countryside evolutions. Similarly to various experiments, the case of study shows the relevance of innovation in environmental assessment, joint as well a new philosophy in environmental economic evaluation.

The reader can notice that the Balance of Co2 Segregation, as regards the dimensional aspect of the amount (about four million euros), can be comparable, from the formal point of view with the assessment of a net present value due to an economic recreational activity, as considered as traditional approach to benefit and costs analysis.

Just to foster this assumption, the amount is similar to the net present value that an ordinary construction company can estimate in a cash flow of more-less ten years.

Last but not least, a further reasoning can be connected with the double dimension of cost of carbon segregation. On one side, the monetary dimension of carbon segregation can be considered a measure of the capability of an economic activity (related with the transition from a natural environment to a built environment), of maintaining a low impact in terms of contribution to global warming. On the other side, monetization of carbon footprint can also represent a way of measuring the dimension of the interaction between the residential activity and the environmental context.

References

1. Attardi, R., Cerreta, M., Sannicandro, V., Torre, C.M.: Non-compensatory composite indicators for the evaluation of urban planning policy: the land-use policy efficiency index (LUPEI). Eur. J. Oper. Res. **264**(2), 491–507 (2018)
2. Berto, R., Stival, C.A., Rosato, P.: Enhancing the environmental performance of industrial settlements: an economic evaluation of extensive green roof competitiveness. Build. Environ. **127**, 58–68 (2018)

3. Morano, P., Guarini, M.R., Tajani, F., Anelli, D.: Sustainable redevelopment: the cost-revenue analysis to support the urban planning decisions. In: Gervasi, O., et al. (eds.) ICCSA 2020. LNCS, vol. 12251, pp. 968–980. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-58808-3_69
4. Morano, P., Tajani, F.: Break Even Analysis for the financial verification of urban regeneration projects. Appl. Mech. Mater. **438**, 1830–1835 (2013)
5. Morano, P., Tajani, F.: Saving soil and financial feasibility. a model to support public-private partnerships in the regeneration of abandoned areas. Land Use Policy **73**, 40–48 (2018)
6. Sullivan, E., Ward, P.: Sustainable housing applications and policies for low-income self-build and housing rehabilitation. Habitat Int. **36**(2), 312–323 (2012)
7. Torre, C., Morano, P., Tajani, F.: Saving soil for sustainable land use. Sustainability. **9**(3), 350 (2017). https://doi.org/10.3390/su9030350
8. Foster L.S., Gruntfest I.J.: Demonstration experiments using universal indicators. J. Chem. Educ. 274–276 (1937)
9. Greenwood-Smith, S.L.: The use of rapid environmental assessment techniques to monitor the health of Australian rivers. Water Sci. Technol. **45**, 155–160 (2002)
10. VV.AA.: Interpretation Manual of European Union Habitats. European Commission - DG Environment Nature Env B3 (2013)
11. Solarin, S.A.: Convergence in CO 2 emissions, carbon footprint and ecological footprint: evidence from OECD countries. Environ. Sci. Pollut. Res. **26**, 6167–6181 (2019)
12. Pilogallo, A., Saganeiti, L., Scorza, F.M., B. : Ecosystem services' based impact assessment for low carbon transition processes. TeMA-J. Land Use Mobil. Environ. **12**(2), 127–138 (2019)
13. Mazzariello, A., Pilogallo, A., Scorza, F., Murgante, B., Las Casas, G.: Carbon stock as an indicator for the estimation of anthropic pressure on territorial components. In: Gervasi, O., et al. (eds.) ICCSA 2018. LNCS, vol. 10964, pp. 697–711. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-95174-4_53
14. Perchinunno, P., Rotondo, F., Torre, C.M.: The evidence of links between landscape and economy in rural park. Int. J. Agricult. Environ. Inf. Syst. **3**(2), 72–85 (2012)
15. Attardi, R., Cerreta, M., Sannicandro, S., Torre, C.M.: The multidimensional assessment of land take and soil sealing. Lect. Notes Comput. Sci. **9157**, 301–316 (2015)
16. Castella, J.C., et al.: Effects of landscape segregation on livelihood vulnerability: moving from extensive shifting cultivation to rotational agriculture and natural forests in northern laos. Hum. Ecol. **41**, 63–76 (2013)
17. Feld, C.K., Sousa, J.P., Martins da Silva, P., Dawson, T.P.: Indicators for biodiversity and ecosystem services: towards an improved framework for ecosystems assessment. Biodiversity Conserv. **19**(10), 2895–2919 (2010)
18. Motavalli, P., Nelson, K., Udawatta, R., Shibu, J., Sougata, B.: Global achievements in sustainable land management. Int. Soil Water Conserv. Res.h **1**, 1–10 (2013)
19. Pontius, R.G.J., Shusas, E., McEachern, M.: Detecting important categorical land changes while accounting for persistence. Agr. Ecosyst. Environ. **101**, 251–268 (2004)
20. Vauhkonen, J., Packalen, T.: Shifting from even-aged management to less intensive forestry in varying proportions of forest land in Finland: impacts on carbon storage, harvest removals, and harvesting costs. Eur. J. Forest Res. **138**(2), 219–238 (2019). https://doi.org/10.1007/s10342-019-01163-9