Short communication

Criticism on elasticity-sensitivity coefficient for assessing the robustness and sensitivity of ecosystem services values

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Abstract

The Coefficient of Sensitivity *CS* (or coefficient of elasticity) is used to determine the sensitivity and robustness of prices (coefficients) in the analysis of Ecosystem Services (ESs). The common *CS* approach is applied based on a specific % change of an ES coefficient keeping constant the coefficients of the remaining ESs. This approach assumes that when *CS* value is >1 then the estimated ES value is non-robust because it is elastic. The aim of this study is to show that the common approach of *CS* used in ESs studies is erroneously applied and interpreted. A simplistic calculus is provided which shows that the *CS* values of ESs a) are always in the range between 0 and 1 leading always to the conclusion that the applied coefficients by the users are robust, and b) are always independent by the % change of an ES coefficient defined by the user. Other reasons which question the validity of the common approach are that the *CS* values a) are always positive which is unrealistic in real market since it always violates the "law of demand" and b) can be manipulated by the user by changing the boundaries of the study area.

Keywords: elasticity coefficient, sensitivity analysis, robustness of ecosystem services values

1. Introduction

The inclusion of Ecosystem Services (ESs) approach (Costanza et al., 1997; 2014; De Groot et al., 2012) to assess the direct and indirect economic contribution of ecosystems to human welfare has given significant merit in decision making related to environmental management (Kareiva et al., 2007; Fisher et al., 2009; Maes et al., 2012). The robustness of the approaches used for ESs assessment is strongly based on the use of realistic ESs prices (coefficients) provided by the researchers. Due to the large uncertainty of these coefficients (Schmidt et al., 2016), the simplistic approach of the Coefficient of Sensitivity *CS* of Mansfield (1985) as proposed by Kreuter et al. (2001) has been adopted in many ESs studies for analyzing coefficients' sensitivity and robustness (Li et al., 2007; Hu et al., 2008; Tianhong et al., 2010; Yoshida et al., 2010; Hao et al., 2012; Wang et al., 2014a, b; Zhang et al., 2015a, b; Fu et al., 2016; Crespin and Simonetti, 2016; Fei et al., 2016; Kindu et al., 2016).

The *CS* is based on the concept of elasticity, which is used in economics to describe the sensitivity in demand of a specific good or service in response to changes in its price (Gwartney et al., 2006). The analysis of elasticity is based on the ratio between the percentage change in quantity demanded and the percentage change in price of a good/service (this ratio is equivalent to *CS*). When the absolute value of the ratio is <1, then the demand is considered inelastic, which indicates that changes in price have a relatively small effect on the quantity of the good/service demanded. When the absolute value of the ratio is >1, then the demand is considered elastic, which indicates that changes in price have a relatively large effect on the quantity of a good/service demanded. The aforementioned approach is applied in the case of ESs where the threshold of unity is considered as a measure of robustness for the ESs values (*CS*<1 defines robust and inelastic coefficients) (Kreuter et al., 2001) but the use of this approach in the ESs studies leads always to *CS* values in the range between 0 and 1 (Li et al., 2007; Hu et al., 2008; Tianhong et al., 2010; Yoshida et al., 2010; Hao et al., 2012; Wang et al., 2014a, b; Zhang et al., 2015a, b; Fu et al., 2016; Crespin and Simonetti, 2016; Fei et al., 2016; Kindu et al., 2016) because the effect of price in the demand is not considered.

The aim of this short communication is to present a simplistic calculus and other justifications, which show that the common *CS* approach used in ESs studies is erroneously applied and interpreted.

2. The common *CS* method for ESs sensitivity analysis

The *CS* is usually applied based on a specific percentage change of an ES coefficient keeping constant the coefficients of the remaining ESs. In the context of ESs framework, the *CS* is calculated by the formula (Kreuter et al., 2001; Mansfield, 1985):

$$CS = \frac{\left(ESV_j - ESV_i\right) / ESV_i}{\left(VC_{j,k} - VC_{i,k}\right) / VC_{i,k}} \quad (1)$$

where *ESV* is the total estimated value of all ESs (in monetary units per year), *VC* is the value coefficient (monetary units per year per unit area), *i* and *j* represent the initial and adjusted values, respectively, and *k* represents the land use category. For the calculation of Eq.(1) a predefined % change is usually used for all coefficients (e.g. ±50%). In this study, the fixed value of % change was substituted by a general value equal to *x*. The value of *x* is applied as a coefficient and not as percentage (e.g. -30% change of *VC* corresponds to x=0.7 while for +30% of change x=1.3).

3. Results

If we assume that the initial $VC_{i,k}$ of a land use category k is changing based on the x coefficient and the VC values of the remaining land uses are constant, then the adjusted values of $VC_{j,k}$ and ESV_j of Eq.1 are equal to:

$$VC_{j,k} = x \cdot VC_{i,k} \qquad \text{and} \qquad ESV_j = ESV_i - (1-x) \cdot VC_{i,k} \cdot A_k \tag{2a,b}$$

where A_k is the area of land use k (in area units).

Taking into account Eq.(2a,b), then Eq.1 is readjusted according to the following:

$$CS = \frac{\left(ESV_j - ESV_i\right)/ESV_i}{\left(VC_{j,k} - VC_{i,k}\right)/VC_{i,k}} = \\ \frac{\left[\left(ESV_i - (1-x)\cdot VC_{i,k} \cdot A_k\right) - ESV_i\right]/ESV_i}{\left(x \cdot VC_{i,k} - VC_{i,k}\right)/VC_{i,k}} = \frac{-(1-x)\cdot VC_{i,k} \cdot A_k}{(x-1)\,ESV_i} = \frac{VC_{i,k} \cdot A_k}{ESV_i} \tag{3}$$

The final result of Eq.3 has the following attributes: a) is independent by x and consequently independent by the % change of the VC value selected by the user and b) is always in the range between 0 and 1.

4. Discussion

The use of Eq.1 in the ESs framework either as elasticity or simply as sensitivity index should no longer be used following the approach of section 3 for the following reasons:

- when Eq.1 is used to examine the elasticity of the VC coefficients, the CS values range always between 0 and 1 leading to the conclusion that the used *VCs* are inelastic and consequently robust. This finding questions by itself the validity of the formula for this purpose.
- According to economic theory, CS application to real market conditions usually yields a negative value, due to the inverse nature of the relationship between price and quantity demanded, as described by the "law of demand" (Gwartney et al., 2006). In real market

the "law of demand" can be violated in some exceptional cases like Veblen and Giffen goods. In the first case (Veblen goods), consumers of higher income may prefer a good to be more expensive as a status symbol (e.g. luxury goods like expensive cars, jewels, original works of art etc) (Jain and Khanna, 2010). In the second case, Giffen goods are usually inferior products, usually preferred by low income consumers, whose demand falls even when their price falls (rare and almost theoretical case). An example of this case was given by Jain and Khanna (2010) and concerned the bajra (type of millet) product. When its price falls the real income of consumers rises and so they may demand more wheat (case where the income effect dominates the substitution effect). On the other hand, the "law of demand" is always violated in the ESs framework since *CS* is always positive. This suggests that the results of the common *CS* approach in the ESs studies are unrealistic especially for those services directly related to the market (e.g. food production).

- when Eq.1 is used to examine the sensitivity of the *VC* coefficients, the *CS* values are always independent by the % change of the *VC* coefficient selected by the user as indicated by the final form of Eq.3. Eq.1 can not be considered as sensitivity formula in ESs framework but only as a ranking index that defines which land use is more important in the total *ESV*.
- Eq.1 can be manipulated by the user because its results are related to the geographic extent of the land uses. When one land use has an extremely large % coverage in a study area or a large *VC* coefficient, its *CS* value is expected to be proportionally high. The user can reduce the extent of this land use by changing the boundaries of the study area in order to manipulate the *CS* values. Again, this suggests that the *CS* approach can not be used for assessing the robustness of ESs values. The arbitrary delineation of the boundaries of the study areas used in ESs services affects not only the results of the *CS*

but also the results of all the other compartments related to ESs analysis. For this reason, rules for the delineation of the study areas should be adopted in the ES framework. Some suggestions to avoid such criticism could be the use of boundaries related to administrative units (e.g. provinces, prefectures, cantons etc) (Gaglio et al., 2016; Gissi et al., 2016), because they constitute economic entities of the states, or physical boundaries such as natural hydrologic basins (Tian et al., 2016) because they constitute the most common base for development of environmental management strategies.

5. Conclusion

This study provided proofs and justifications, which show that the common approach of elasticity-sensitivity coefficient used in many ESs studies is erroneously applied and interpreted. Our observations suggest that this approach can be used only for ranking the importance of land uses based on their contribution to the total ESs value, while it should be abandoned for assessing the robustness and sensitivity of the ESs coefficients.

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