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DESIGNING THE STRUCTURE OF AN INDEX FOR THE ECOSYSTEM SERVICES QUALITY ANALYSIS

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***Abstract*—The quality of ecosystems becomes a challenge, increasingly emphasized for the scientific community, in the sense of identifying viable ways of rehabilitating and maintaining them for a sustainable ecological coherence. The paper aims to develop an index of the quality of ecosystem services based on the analysis of the following components: plant production, animal production, livestock farming and tourism. For the construction of such index, a series of econometric models useful for quantifying the quality of ecosystem services, regarding the dependence between agricultural production, the number of bee families, the amount of natural fertilizers used, the agricultural surface, on the hand and the dependence between the number of nights, number of tourists, number of pensions, on the other hand, are developed.**

***Keywords*— ecological coherence, ecosystem services, statistical index**

I. Introduction

In terms of finding an index for analyzing the quality of ecosystem services, formulas can be made and checklists of availability and methodologies to protect ecosystem services can be made. In order to be able to analyze the statistical methodology, it is necessary: to verify the security conditions, to systematize the organizational function in time and in territorial profile, in order to transform into the specific indicator systems for chronic and territorial activities.

Due to the extensive literature on the quality of ecosystem services and the limitations of this material, we focused on three types of ecosystems: wetland ecosystems, forest ecosystems and agro-ecosystems (Boyd and Banzhaf, 2006; Ioan et al., 2010, MEA, 2005).

The goods and services offered by wetland ecosystems refer to:

- Animal breeding and agricultural crops;
- Fishing;
- Raw material for construction, handicraft production and firewood;
- Hunting;
- The aesthetic value of wetlands, recreation;
- Storm mitigation;
- Flood water storage and river flow regulation;
- Water drainage on slopes naturally;
- Sediments, nutrient recycling - improving water quality;
- Soil erosion control;
- Carbon capture and storage - climate change, adaptation and mitigation;
- Direct or indirect future use of the aforementioned goods and services;
- Existential value of wetland species and habitats;
- Culture and traditions.

The goods and services provided by forest ecosystems refer to:

- Forest products (construction material, fuel / coal, non-wood forest products);
- Genetic information (traditional medicine, pharmaceuticals, research);
- Recreation and tourism;
- Regularization of rainfall at regional level;
- Regularization of river and flood flows;
- Soil erosion control;
- Carbon storage and retention;
- Health;
- Direct or indirect future use of the aforementioned goods and services;
- Existential value, Culture and traditions.

Examples of goods and services offered by agrarian ecosystems may be:

- Plants / food; Animal breeding / feeding;
- The visual agreeability of agricultural landscapes;
- Pest and epidemic control;
- Processes at the soil level (nutrient recycling, maintaining soil structure and porosity, maintaining soil fertility), pollination, nutrient recycling;
- Water quality and quantity;
- Carbon storage;
- Genetic diversity;
- Future direct or indirect use of the above-mentioned goods and services;
- Existential value.

The steps involved in building a composite index, following the OECD guidelines (OECD, 2008) are: 1) establishment of a theoretical framework, 2) variable selection; 3) missing data imputation; 4) normalization of data; 5) removal of variables; 6) establishment of weights and 7) aggregation and computation of final scores and ranks (Neves Almeida T.A. and García-Sánchez I.-M., 2016; Strezov V., A. et.al., 2016, Van de Kerk and Manuel, A.R., 2008).

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II. Development of econometric models

In this phase of the research, a series of econometric models have been identified useful for analyzing the quality of ecosystem services.

A. *Dependence between agricultural production, the number of bee families, the quantity of natural fertilizers used, the existing agricultural area*

Variables used in econometric models:

- Total agricultural production at county level - dependent variable
- Number of bee families at county level - independent variable
- Quantity of natural fertilizers used - independent variable
- Existing agricultural area at county level - dependent variable.

The data related to these indicators have been downloaded from the TEMPO database, available on the website of the National Institute of Statistics (insse.ro). The value of agricultural production was deflated with the GDP deflator downloaded from the AMECO database.

Econometric model:

$$PROD\_AGR_{it} = \beta_0 + \beta_1 \cdot F\_ALB_{it} + \beta_2 \cdot INGR_{it} + \beta_3 \cdot SUPR_{it} + \varepsilon_{it} \quad (1)$$

The model will be estimated in three variants: no effects, random effects și fixed effects.

TABLE I. DEPENDENT VARIABILE: TOTAL AGRICULTURAL PRODUCTION

Period: 2001 - 2008			
Territorial units: 42			
	Model I	**Model II**	**Model III**
Independent variable	No effects	Random Effects	Fixed Effects
F_ALB	0,0381	0,091*	0,094*
INGR	0,0038*	0,0014**	0,00069
SUPR	0,0257*	0,0241*	0,0097
C	2820,30*	3152,03**	8408
R square	0,535	0,18	0,846
Adj R square	0,5308	0,17	0,822
Durbin - Watson	0,75	1,91	2,22

Note:* represents the level of statistical significance of 1%, ** of 5% and *** of 10%.

The Hausman test, at a significance level of 5% (Prob = 0.06) indicates that the Random Effects model cannot be considered to be inappropriate. Also, the fact that the DW test indicates the lack of autocorrelation supports the hypothesis of using this model. However, the main limitation of the model is given by the very small value of the coefficient R square and R square adjusted. Under these conditions, the Fixed effects model can also be taken into account (the Redundant Fixed effects test – Likelihood Ratio indicates that the fixed effects model is suitable to the detriment of the no effects).

The use of the fixed effects model as well as the very low value of the square R statistic for the random effects model indicates that there are a number of unobserved characteristics of the counties of Romania that explain to a much greater degree their agricultural production.

Important to mention is the fact that all independent variables have positive coefficients, in all living models, which clearly indicates that the counties with a high level of any of the independent variables will have a higher agricultural output.

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B. *Dependence between the number of overnights, the number of tourists, the number of pensions*

Variables used in econometric models:

- Number of overnights - dependent variable;
- Number of tourists - independent variable;
- Number of pensions - independent variable.

The data related to these indicators were downloaded from the TEMPO database, available on the website of the National Institute of Statistics (insse.ro). The data for the time series 2009 - 2013 were transformed by the following procedure, in order to eliminate the autocorrelation of errors:

$$X_{it}^{*} = X_{it} - 0{,}955 * X_{it-1} \quad (2)$$

By accomplishing this transformation, the data series was reduced by a period, the econometric models being run on the time series 2009 -2013. Out of the 42 territorial units, Giurgiu and Bucharest were eliminated, due to data unavailability

Econometric model:

$$NIG_{it} = \beta_0 + \beta_1 \cdot TUR_{it} + \beta_2 \cdot PENS_{it} + \varepsilon_{it} \quad (3)$$

The model will be estimated in three variants: no effects, random effects și fixed effects.

TABLE II. DEPENDENT VARIABLE: NUMBER OF OVERNIGHTS

Period: 2009 - 2013			
Territorial units: 40			
	Model I	**Model II**	**Model III**
Independent variable	No effects	RandomEffects	FixedEffects
TUR	1,835*	1,897*	1,91*
PENS	81,81*	80,32*	86,71*
C	-952,14	-1513,38	-1,885,7*
R square	0,957	0,942	0,993

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Adj R square	0,957	0,941	0,991
Durbin - Watson	0,258	1,28	1,6

Note:* represents the level of statistical significance of 1%, ** of 5% and *** of 10%.

The Hausman test, at a significance level of 5% (Prob = 0.49) indicates that the RandomEffects model cannot be considered to be inappropriate. Also, the DW test indicates that it is not possible to discuss a self-correction event of errors. The Fixedeffects model can also be taken into account (the Redundant Fixedeffects test - LikelihoodRatio indicates that the fixedeffects model is suitable to the detriment of the noeffects).

The use of the fixedeffects model indicates that there are a number of unobserved characteristics of the counties of Romania that explain to a much greater degree their agricultural production.

It is important to note that all the independent variables have positive coefficients in all three models, which clearly indicates that the high-level counties of any of the three independent variables will have a higher number of overnight stays.

III. Designing the structure of index

In order to analyze the quality of ecosystem services, the main challenge is the quality and availability of data. The quality of the recorded data represents the determining factor for obtaining real information about the ecosystem services on the Romanian territory. Preserving the character of total authenticity of the data is difficult to achieve because, even by observing all the scientific principles of preparation and organization of the recording, data cannot be recorded in full accordance with the real manifestations of the investigated phenomenon (Mayer, A.L., 2007). This means that errors are also recorded in the statistical observation. In general, statistical error (observation) means the difference between the result obtained by registration and the actual size of the characteristics (variables) observed. These differences (errors) are determined by the volume of the records, the accuracy of the recording media and various other sources (known or unknown).

In order to appreciate the possibilities of analyzing the quality of ecosystem services and highlighting the manifestation legitimacy, it is necessary to express quantitatively and to evaluate the evolution in time and space. Following the econometric analysis, the components of the index are proposed for the ecosystem services quality analysis:

- ✓ Agriculture – vegetale production (D1)
- ✓ Agricultura – animal production (D2)
- ✓ Forestry (D3)
- ✓ Turism (D4)

For each component, specific indicators are proposed that represent the input data in the index development for the ecosystem services quality analysis. These are:

- ✓ Agriculture - vegetable production
  - • Average fruit production per tree species
  - • The surface cultivated with the main crops, by property forms
  - • Average production per hectare, in the main crops - cereals
- ✓ Agriculture - animal production
  - • Livestock, by category of animals - Cattle
  - • Livestock, by category of animals - Sheep
  - • The number of animals, by category of animals - Poultry
  - • Animal herds, by category of animals - bee families
- ✓ Forestry
  - • The surface of the forest fund by category of land and forest species - Softwoods
  - • The surface of the forest fund by category of land and forest species – Hardwood
- • The volume of wood harvested by species
- ✓ Tourism
  - • Overnight stays in tourist reception structures
  - • Arrivals of tourists in tourist reception structures with tourist accommodation functions
  - • Tourist reception structures with tourist accommodation functions

Based on these indicators, the structure of the Ecosystem Services Quality Index was designed (ESQI). ESQI is an aggregate index that includes four dimensions. Each of the considered indicators is rescaled by the following procedure:

INDEX (i) = (Value (s) - MING) / (MAXG - min) (4)

The MAXG value is a value higher than the maximum value recorded for that variable, for all counties included in the analysis, throughout the entire period included in the analysis. MAXG = 1.2 * MAX, using MAXG is required so that individual indicators do not reach 1.

The MING value is a value lower than the minimum value recorded for the respective variable, for all counties included in the analysis, throughout the entire period included in the analysis. MING = 0.8 * MIN, using of the MING value is required so that the individual indicators do not reach the value 0.

The individual indices are aggregated into 4 dimensions, as follows:

$$D1 = I1.1*1/3+ I1.2*1/3+ I1.3*1/3 \quad (5)$$

$$D2 = I2.1*1/4+ I2.2*1/4+ I2.3*1/4+ I2.4*1/4 \quad (6)$$

$$D3 = I3.1*1/3+ I3.2*1/3+ I3.3*1/3 \quad (7)$$

$$D4 = I4.1*1/3+ I4.2*1/3+ I4.3*1/3 \quad (8)$$

The four dimensions are aggregated in ESQI, as follows:

$$D1 * 0.25 + D2 * 0.25 + D3* 0.25 + D4 *0.25 = ESQI \quad (9)$$

Ecosystem Services Quality Index.

IV. Conclusion

In order to find an index for the ecosystem services quality analysis, the formal procedures used were to make the checklists of the availability of the data and the methodologies for obtaining them for the ecosystem services. For their

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analysis, specific statistical methods were applied: data quality verification, systematization of data organized in time and in territorial profile, data transformation into information by using systems of indicators specific to the chronological and territorial series.

Due to the extensive literature on the quality of ecosystem services and the limitations of this material, we focused on three types of ecosystems: wetland ecosystems, forest ecosystems and agro-ecosystems.

The developed econometric models were estimated in three variants: no effects, random effects and fixed effects. The steps involved in building a composite index for ecosystem services quality analysis was establishment of a theoretical framework, variable selection, missing data imputation, data normalization, removal of variables, establishment of weights and aggregation.

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Giani Gradinaru is currently a full professor of Statistics and Econometrics Department from The Bucharest University of Economic Studies where he teaches classes of Econometrics, Microeconomic Statistics and Economic Forecasting. Following the endorsement of the habilitation thesis, starting with 2016, he becames a PhD advisor in the Cybernetics and Economic Statistics Doctoral School.