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Natural Capital Changes in Poland – Integrating Spatial and Economic Approach

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Abstract: In the context of decision making, the main challenge is the assessment of changes in natural capital stocks due to conversion of ecosystems for development purposes. Ecosystems are basically a spatial concept, so the natural approach is to use GIS to evaluate land cover changes. Basic economic model of competing land uses allows us to formulate the criteria of economic rationality in the management of natural capital. The goal of this paper is a preliminary application of the criteria coming from the economic model of land uses to assess changes in land cover in Poland in the years 2000-2012.

Keywords: land management, ecosystem services, natural capital, Corine Land Cover, sustainability, dynamic optimization.

JEL codes: Q57, C61

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1. Introduction

In modern economics, the principle of sustainability is interpreted as the principle of preserving the resources of basic capital enabling the creation of well-being for present and future generations. Capital is understood broadly here, it is a stock that yields a flow of benefits into the future. However, there is a distinction between material (manufactured), human, social and natural capital. Natural capital is an extension of the economic concept of capital on environmental goods and services (Constanza and Daly, 1992: 38). Natural capital in the form of ecosystems yields numerous and diverse ecosystem services for both production and consumption but, above all, for the maintenance of life on the earth (Constanza et al., 1997; Wilson, 2002). In addition to natural

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resources, ecosystems provide, to name just a few, life-support, regulatory, cultural and aesthetic benefits. (Daily, 1997). Loss of biodiversity threatens the sustainability of ecosystems and can have a significant impact on the ability of the ecosystem to provide the services (Diaz et al., 2006; Cardinale et al., 2012).

The Millennium Ecosystem Assessment (2005: 40) distinguishes 31 ecosystem services assigned to four categories: provisioning, regulating, cultural and supporting**.** As noted over the past 50 years, 15 out of 24 assessed ecosystem services have been degraded or used in ways that threaten sustainability, for instance drinking water supply, fish populations, air and water purification, climate and natural hazards regulation.

Taking into consideration the above mentioned facts, the fundamental problem is the assessment of changes occurring in natural capital resources. A considerable difficulty though, is the development of criteria as well as the assessment tools. Since ecosystems belong to a spatial category, the natural approach is to evaluate changes in space based on the concept of a distinctive spatial unit (the so-called *ecological landscape*) (Barbier, 2011). GIS tools can be used to assess changes in land use or land cover, and thus to identify changes in the availability of natural capital resources.

Also, the rational policy of ecosystem preservation should be based on economic criteria, thus maximizing the welfare of present as well as future generations. However, the valuation of ecosystem services (TEEB, 2010) is a major problem. In spite of these difficulties, the use of the basic economic model of changes in land use allows us to formulate criteria for economic rationality in the management of natural capital.

The aim of this paper is preliminary application of the criteria stemming from the economic model of land use changes (competing land uses) to the assessment of land cover changes in Poland in the years 2000 - 2012 analyzed with GIS tools. Successful management of natural capital requires an interdisciplinary approach integrating spatial and economic analysis.

The first chapter discusses the basic economic model of land use. The second chapter enumerates the possibilities of using GIS tools to assess changes in natural capital resources, whereas the third chapter presents the results of empirical research - a preparatory assessment of changes in natural capital resources in Poland using GIS tools. Final chapter includes preliminary conclusions and recommendations for future research.

2. Ecosystems in the Land Use Model - Economic Criterion

Natural capital perspective allows for the analysis of economic processes, which result in the conversion of natural ecosystems in the process of socio-economic development. The preservation of remaining resources of natural capital in the context of growing ecological scarcity is largely conditioned by the inclusion of natural capital in the economic account, similarly to other forms of capital. As observed, the main cause of the destruction and degradation of natural ecosystems is the lack of consideration of the value of ecosystem services in decision-making and development policy formation (Millenium Ecosystem Assessment, 2005).

Treating ecosystems as a type of capital enables to determine their social value in the form of discounted net present value (NPV) of the flow of benefits (ecosystem services). Simultaneously, the identification of ecosystems with distinctive ecological landscapes enables the formulation of economic criteria for the optimal development of such an area using a competing land use model (Barbier, 2011: 89).

The conversion of a natural area can be of a one-time or continuous type. In the case of a one-off change in the use of the area, the economic criterion determining the optimum conversion moment is fairly standard - the benefits of maintaining the area in the natural state with the opportunity cost are compared. Let us denote the rent obtainable by converting the area at time t by $R(t)$, where $R'(t) > 0, R''(t) < 0.$ Let $B(t)$ denote the value of the stream of ecosystem benefits. Then the economic criterion consists in maximizing the present value of the benefits of the given area:

$$V = R(t)e^{-rt} + \int_0^t B(s)e^{-rs}ds$$

where r is the discount rate. Then

$$\frac{dV}{dt} = e^{-rt}(R'(t) - rR(t) + B(t)) = 0 \Leftrightarrow R'(t) + B(t) = rR(t)$$

T

he natural area should be developed at time t, where the advantages of the delaying of the conversion (increase in rental value of developed land $R'(t)$ and the obtained ecosystem benefits $B(t)$) are equal to the value obtainable after the investment of the amount $R(t)$ received from the conversion. Therefore, the key parameters are the rate r and the value of $B(t)$. Higher discount rate accelerates the conversion moment. At the same time, taking into account the value of ecosystem services delays this moment[1].

If $R(t) = R$ is constant, then $\frac{dV}{dt} = e^{-rt}(B(t) - rR)$. If $B(t) < rR$, then conversion should be "immediate" - the benefits of the ecosystem do not compensate for the waiting time. On the contrary, $B(t) > rR$, then the ecosystem should be preserved. Again, the interest rate r is a key parameter here. Conversion will also be economically justified if $B(t)$ decreases, e.g. due to ecosystem degradation resulting from environmental pollution. Note that B (t) may also increase owing to the increasing scarcity of ecosystem services.

In most cases, the process of changes in land use is gradual[2]. Let us assume that the changes are continuous – i.e. the natural area is subject to continuous anthropogenic conversion processes, e.g. farming, infrastructural, housing processes, etc. Considering technical limitations and high costs, conversion can be considered irreversible. When $A(t)$ is the area of the natural ecosystem at time t, $A(0) = A_0$, $D(t)$ is the developed land, and $c(t)$ - the area of the ecosystem being converted at time t. Then[3]

$$A(t) = A_0 - \int_0^t c(s)ds\,,\ \dot{A} = -c(t) \qquad (1)$$

$$D(t) = D_0 + \int_0^t c(s)ds\,,\ \dot{D} = c(t)$$

Both natural and anthropogenic land is the source of certain benefits. Let $B(A(t))$ and $R(D(t))$ denote respectively the value of the flow of ecosystem benefits and the rent to developed land. Conversion (development) costs are $C(c)$. The value of the stream of rent can be expressed as $R\big(A(t)\big)$ and $\frac{\partial R}{\partial A} = -\frac{\partial R}{\partial D}$. The problem can be simplified to maximizing the net present value of a given area with following constraints (1), i.e.:

$$V = \int_0^{\infty} (R(D) - C(c) + B(A))\, e^{-rt} dt$$

[1] As noted, in a situation of increasing scarcity of ecosystem services, which implies an increase in $B\ (t)$, the conversion of a given area may never be profitable, i.e. the area should remain in its natural state.
[2] Clearly, it depends on the adopted scale.
[3] After Barbier (2011).

The discounted Hamiltonian for the problem (where A is the state variable and c control variable) is in the form

$$H = R(A) - C(c) + B(A) - \mu c,$$

$\mu(t)$ is a so called *shadow value* of the ecosystem area[4]. According to maximum principle, first-order conditions are as follows:

$$\frac{\partial H}{\partial c} = 0 \leftrightarrow \ \mu = -C'(c) \quad (2)$$

$$-\frac{\partial H}{\partial A} = \dot{\mu} - r\mu \leftrightarrow \dot{\mu} = r\mu - B'(A) - R'(A).$$

By joining them we will receive

$$R'(D) - rC'(c) = B'(A) + \dot{\mu} \quad (3)$$

Condition (3) means that the optimal development of the natural area requires the marginal net benefits of conversion at any given moment t (the marginal change of the rent flow $R'(D)$ minus the conversion costs $rC'(c)$) to be equal to the marginal benefits of preservation of the natural area (marginal change of the ecosystem services flow plus $\dot{\mu}$, i.e. marginal change in unit value (shadow price) of natural areas A). Condition (3) can be formulated as follows:

$$-\mu(t) = \frac{R'(D)}{r} - \frac{B'(A)+\dot{\mu}}{r} = C'(c). \quad (4)$$

Increasing the size of an area D at time t means increasing the stream of income $R'(D)$. For every t, the capitalized value of that increase $\frac{R'(D)}{r}$ minus the capitalized value of the marginal change of the stream of ecosystem benefits and the value of the ecosystem unit determines the marginal net benefit of the development of the area (ecosystem conversion). The optimal conversion process should be carried out in such a way that the marginal cost of conversion is equal to the net benefits of the conversion[5].

In the long term[6] $c(t) = 0$ and $\mu(t) = 0$. Natural areas tend to a constant magnitude A^*, for which $R'(D) = B'(A)$. Of course, if $A_0 > A^*$. It is worth noting that if $B\big(A(t)\big) = 0$, i.e. the value of ecosystem services is not taken into account, then the conversion will cover the whole area. See (Barbier, 2011) for more details.

[4] Variable μ is similar to Lagrange multiplier and has similar interpretation in terms of economics. Since we are considering current value Hamiltonian, then $\mu(t)$ is the shadow price (marginal valuation) of the state variable. If $\lambda(t) = \mu(t)e^{-rt}$, then $\lambda(t)$tells us how much will V change as a result of the change of A by unit at time t. (Chiang, 2002; Kamien and Schwartz, 2012:138).

[5] In principle, this is a classic requirement for marginal cost and benefit equality.

[6] To (1) and (3).

Let us observe that accepting a simplifying assumption that the annual value of the benefits produced by one hectare of particular biomes is constant in time, the discussed Barbier's model undergoes considerable simplification and deciding how to use the given area comes to comparing the two NPV alternatives. Let $B(A) = nA$ and $R(D) = dD,$ where n is the annual value of the benefits of the ecological landscape, and $d\ is$ the annual rent obtained from the developed ecological landscape (after conversion). If the conversion costs are relatively low and the following condition is met

$$C(A_0) < \int_0^\infty A_0(d-n)e^{-rt}dt = A_0\frac{d-n}{r},$$

i.e., the net present value of the conversion is greater than the conversion cost of the entire area A_0, then the total conversion is economically justified. Of course, since $C(A_0) > 0$, the condition $d - n > 0$ should also be fulfilled.

Conversion may take place in a gradual manner. Let us assume that the control variable c is limited, i.e. $0 \leq c \leq c_1$. Then the hamiltonian for the problem of optimal land development takes on the form of

$$H = pD - C(c) + nA - \mu c,$$

Since $\mu(t)$ is the shadow price of the ecosystem unit, then for every t

$$\mu(t) = \int_t^\infty (n-d)e^{-r(s-t)}ds = \frac{n-d}{r},$$

Therefore, $\mu(t)$ is constant and $\dot{\mu} = 0$. Thus, Condition (4) can be presented as following

$$-\mu(t) = \frac{d}{r} - \frac{n}{r} = C'(c).$$

If $C(c)$ is increasing and strictly convex, i.e. $C'' < 0$, then c must be constant and set to $0 \leq c^* \leq c_1$, satisfying the above condition. The second possibility is to assume that $C(c)$ is a linear function with respect to c. Surely, then $C'(0) \neq 0$. In this case, the hamiltonian H is linear with respect to c with a slope equal to $-C'(c) - \mu$. Since the control set c is a closed set, from maximization of H, we obtain a boundary solution. If $C'(c) > -\mu = \frac{d-n}{r}$, then $c^*(t) \equiv 0$ and the conversion does not take place. However, if $C'(c) < -\mu = \frac{d-n}{r}$, then $c^*(t) \equiv c_1$. Of course, if $n < d$, the slope of H will be negative and $c^*(t) \equiv 0$. Similarly, the process of restoring the area to its natural state can be described.

In the light of the model, the conversion process is economically justified when the shadow price of the ecosystem is negative, i.e., capitalized rent value to developed land (for agricultural, residential and other purposes) exceeds the capitalized value of the unit of ecosystem services. Conversely, if the shadow price of the ecosystem is positive, it is advisable to restore the areas previously developed to their original state (if possible). Despite the continual lack of valuation of ecosystem services, this criterion allows for a preliminary economic assessment of land cover changes. The authors are aware that this is rather broad simplification.

Let us observe that the model presents an anthropocentric point of view. The value of nature (as well as the right of ecosystems to exist) depends on the flows of benefits it provides for human society. Ecosystems "pay" for their existence. The authors are aware of the fact that such a presentation of the problem may be controversial. However, these issues are far beyond the scope of this study.

3. The use of spatial data in the assessment of changes in natural capital resources

The European Environment Agency undertakes attempts to assess changes in natural capital resources using spatial data (including, among others Corine Land Cover – CLC data). As noted, in the last 5-10 years loss of soil function took place due to the increase of urbanization and land degradation; Nearly a third of Europe's landscape is characterized by high fragmentation (30% of EU territory), which affects the state of ecosystems, their ability to provide services, and the provision of safe habitats for species (EEA, 2015a: 59).

Between 2000 and 2006 a growth in the share of artificial areas was observed, mainly stemming from the demand for housing, services and recreation (EEA, 2013). The result is a disturbance of natural cycles and a reduction of the range of services provided by the soil, particularly important in the face of mitigating climate change and adapting to its consequences. Soil functions, such as the supply of food and raw materials, the production of biomass and biofuels, the storage of carbon dioxide, the maintenance of biodiversity, the filtering of water, and its role in the biogeochemical cycle are under increasing pressure (EEA, 2015b).

Attempts taken to create land cover accounts are based on the CLC classification (EEA, 2006). Since the coverage of the site may be altered or degraded but also reconstructed, this process is very similar to the transformation of capital resources in the economy. It can therefore be described in terms of flows between different types of land cover.

Apart from the quantitative approach (the size of area of the given type), the quality of natural capital is also relevant. It depends on the stage of fragmentation of natural areas which is caused mainly by the development of transport infrastructure and the urban sprawl. Fragmentation poses a threat to biodiversity (population separation and loss of habitats) and negatively affects ecosystem services (EEA, 2011a). It is estimated that the extent of the fragmentation of natural areas in Europe is very diverse, but the most fragmented are the Benelux countries, Germany, France, and Central Europe.

The green infrastructure concept which is also based on the CLC (EEA, 2011b) is now being developed. Overall, it is estimated that 27% of the EU-27 area may be designated as green infrastructure of C type (conservation), 17% is green infrastructure of R type (in need of restoration), and 56% cannot be included into green infrastructure because of their bad condition (EEA, 2014, p. 12). Green infrastructure can be analyzed at the level of the selected area (landscapes) or at the local level (e.g. urban). Various tools for assessing green infrastructure with the use of CLC data as well as Urban Atlas data are proposed. Part of these tools, such as the Integrated Valuation of Environmental Sciences and Tradeoffs (InVEST) or the Guide to Valuing Green Infrastructure by Center for Neighborhood Technology (CNT), allow for the assessment of the change of value of the green infrastructure (*Green Infrastructure – Valuation Tools Assessment*, 2013).

The use of spatial data for describing changes in natural capital resources, although apart from economic aspects, seems currently to be the best approach to assessing natural capital and using this concept in decision-making processes.

4. Preliminary assessment of changes in land cover in Poland in 2000-2012

The availability of spatial data enables to conduct a preliminary assessment of changes in natural capital resources in Poland in two time periods: 2000-2006 and 2006-2012. The Corine Land Cover[7] data for Poland has been developed at level 4 of the regional scale, which corresponds to a map on a scale of 1:50 000.

[7] In Poland Corine Land Cover 2012 project was conducted by the Institute of Geodesy and Cartography and financed by the European Union. The results of the project were obtained from the website of the Chief Inspectorate for Environmental Protection

The basic methodological problem is the division of particular forms of land cover regarding the category of natural capital. For the purposes of this paper, the division into three classes is proposed: class 1 represents anthropogenic areas, class 2 semianthropogenic, and class 3 natural[8]. Table 1 shows the changes in land cover in 2000, 2006 and 2012 according to land cover classes.

Table 1. Surface and percentage share of classes in 2000, 2006 and 2012

Cl.	2000			2006			2012		
	Number of objects	Surface, ha	%	Number of objects	Surface, ha	%	Number of objects	Surface, ha	%
1	11268	1018687,50	3,24	13763	1241519	3,94	21320	1752542,2	5,55
2	85729	20196688,70	64,17	81660	19713945	62,54	74577	18760008,4	59,43
3	45985	10256230,80	32,59	47767	10566246	33,52	53009	11053512	35,02

Source: Author's own elaboration

Between 2000 and 2012 a marked increase in the share of anthropogenic areas can be seen - from 3.24% to 5.55% in 2012, with major changes taking place in 2006-2012. The share of natural areas has also increased slightly from 32.6% to 35.02% in 2012. The share of semianthropogenic areas (mainly agricultural areas, orchards and pastures) decreased from 64% in 2000 to 59,4% in 2012.

The valuation of ecosystem services is an essential problem in the economic assessment of changes in ecosystems. A significant number of the valuation methods, as well as the local nature of most of the valuations, impede the use of the results from secondary sources.

R. Costanza et al. (2014) assessed the changes in the global value of ecosystem services between 1997 and 2011. Basic benefit transfer was used, i.e., assuming constant value of ecosystem services per hectare of the specified types of ecosystems. It was estimated that the global annual value of ecosystem services decreased by $ 4.3 trillion (using 1997 values) or $ 20.2 trillion (using 2011 values).

De Groot et al. (2012) conducted an overview of the existing valuation results (over 320 publications) for the 10 major biomes: open ocean, coral reefs, coastal systems, coastal wetlands, inland wetlands, lakes, tropical forests, temperate forests, woodlands and grasslands. The results are presented in Table 2.

[8] It was assumed that the green areas (141 of the LCL classification) would belong to the semianthropogenic instead of anthropogenic areas.

Table 2. Valuation of ecosystem services for individual biomes (international dollars / ha / year, 2007 prices)

Biom	Mean	Median	Minimum	Maximum
Open oceans	491	135	85	1 664
Coral reefs	352 915	197 900	36 794	2 129 122
Coastal systems	28 917	26 760	26 167	42 063
Coastal wetlands	193 845	12 163	300	887 828
Inland wetlands	25 682	16 534	3 018	104 924
Rivers and lakes	4 267	3 938	1 446	7 757
Tropical forest	5 264	2 355	1 581	20 851
Temperate forest	3 013	1 127	278	16 406
Woodlands	1 588	1 522	1 373	2 188
Grasslands	2 871	2 698	124	5930

Source: De Groot et al., 2012.

It is important to note that for most biomes less than half of the services provided by ecosystems has been taken into account. Thus, the presented values are clearly underestimated.

Furthermore, several attempts have been made to model and evaluate different scenarios of land use changes taking into account ecosystem services at the country level (Bateman et al., 2013), and at regional scale (Nelson et al., 2009; Goldstein et al., 2012) from an economic perspective. These models require the involvement of specialists from a number of fields (forecasting carbon stocks, water quality, biodiversity status, agricultural crops, etc.). Hence, running similar analyses lies beyond the scope of this paper.

In the context of this study, what is crucial is the value of the benefits provided by biomes in Poland, i.e. coastal ecosystems, wetlands, lakes, temperate forests, woodlands and grasslands (see Table 2). According to Central Statistical Office of Poland[9], the prices of arable land and meadows in 2006-2012 were as follows (Table 3).

Table 3. Average prices of arable land and meadows in private turnover, PLN/ha

2006	2007	2008	2009	2010	2011	2012	**Mean value, PLN**	**Mean value, Int. dolar**
Arable land								
9260	12134	15388	17042	18037	20004	25442	**16758**	**9840**
Meadows								
6069	8088	10882	12022	12952	14152	17166	**11618**	**6822**

Source: Central Statistical Office of Poland

[9] http://stat.gov.pl/en/

The available data allow for classification of land cover changes for the period of 2006-2012 according to the following key (see Table 4). We assume that the "price" of the ecosystem is equal to the present value of provided benefits, i.e.:

$$NPV = \frac{Annual\ value\ of\ benefits}{r}$$

Let us assume that $r = 3\%$. In the case of arable land (category 21) and pastures (category 23), the average price from 2006-2012 was converted into international dollars[10].

The results of spatial analyses are presented in Table 5. Similarly, it is possible to calculate the "financial result" of land cover changes in Poland. We calculate net unit value as the difference between the values in 2006 and 2012 and multiply it by the size of the changed area. Summing up the obtained values, we will receive the value of the total net change in land cover. For the values of ecosystem services vary considerably, the calculations were made separately for median, minimum and maximum values of ecosystem services. The value of the median seems to be the best approximation of the annual value of ecosystem services in Poland.

In the years 2006-2012 changes in land cover reached 266391 hectares of Polish land. The share of areas for which values are inaccessible accounts for about 6.7% of the total changed area in 2006-2012, thus, in the preliminary assessment of all changes, they may as well be omitted.

According to calculations from Table 5, the overall economic balance of changes in land cover in Poland is positive regardless of the accepted values of ecosystem services. For the median it is about $ 1.6 billion and is lower than the corresponding result for the median. The obtained results indicate the increase of natural capital resources in Poland in the period 2006-2012. It is noteworthy that the largest changes occurred in the coverage of forests (code 31) and woodlands (code 32). However, these changes cancel each other out on a national scale.

[10] 1 int. dolar = 1,703 PLN. Source: IMF , World Economic Outlook Database (Implied PPP conversion rate for 2007).

Table 4. Monetary values of land covers (values in int.$, 2007 price levels)

GIS code	Biom	CLC type	NPV, r=3%			
11	Anthropogenic areas	1.1.1 Continuous urban fabric 1.1.2 Discontinuous urban fabric 1.2.1 Industrial or commercial units 1.2.2 Road and rail networks and associated land 1.2.3 Port areas 1.2.4 Airports 1.3.1 Mineral extraction sites; 1.3.2 Dump sites 1.3.3 Construction sites 1.4.2 Sport and leisure facilities 1.4.1 Green urban areas	n/a	n/a	n/a	n/a
21	Arable land	2.1.1 Non-irrigated arable land 2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation	9840	9840	9840	9840
22	Orchards	2.2.2 Fruit trees and berry plantations 2.4.2 Complex cultivation patterns	n/a	n/a	n/a	n/a
23	Meadows and pastures	2.3.1 Pastures	6822	6822	6822	6822
			Mean	**Median**	**Min.**	**Max.**
31	Temperate forest	3.1.1 Broad-leaved forest 3.1.2 Coniferous forest 3.1.3 Mixed forest	100433	37567	9267	546867
32	Woodlands	3.2.4 Transitional woodland-shrub	52933	50733	45767	72933
33	Grasslands	3.2.1 Natural grasslands 3.2.2 Moors and heathland 3.3.3 Sparsely vegetated areas	95700	89933	4133	197667
41	Inland wetlands	4.1.1 Inland marshes 4.1.2 Peat bogs	856067	551133	100600	3497467
51	Lakes	5.1.1 Water courses 5.1.2 Water bodies	142233	131267	48200	258567
52	Coastal ecosystems	5.2.1 Coastal lagoons	963900	892000	872233	1402100
53	Sea and ocean	5.2.3 Sea and ocean	16367	4500	2833	55467

Source: Author's own elaboration

Table 5. Total net values of land cover change in 2006-2012 (values in int.$, 2007 prices)

2006	2012	Area, ha	Total net value_mean	Total net value_median	Total net value_min	Total net value_max
11	21	147,9	N/A			
	22	69,0				
	23	239,5				
	32	1161,4				
	51	431,2				
	53	19,3				
21	22	4862,6				
	23	870,6	-2 627 358	-2 627 358	-2 627 358	-2 627 358
	31	285,4	25 854 824	7 913 158	-163 532	153 265 028
	32	21174,8	912 484 044	865 899 566	760 745 695	1 335 979 295
	51	1209,4	160 111 204	146 849 328	46 391 167	300 801 246
22	11	1965,3	N/A			
	21	1296,8				
	23	30,2				
	32	49,7				
	51	18,0				
23	11	7299,0				
	21	2695,5	8 135 144	8 135 144	8 135 144	8 135 144
	22	274,9	N/A			
	31	58,0	5 429 762	1 783 316	141 818	31 324 480
	32	14503,0	668 749 811	636 843 116	564 821 005	958 810 669
	51	841,2	113 912 991	104 687 966	34 808 780	211 777 670
31	11	5228,6	N/A			
	21	56,3	-5 098 241	-1 560 374	32 246	-30 221 903
	23	91,1	-8 527 542	-2 800 732	-222 729	-49 195 677
	32	95074,5	-4 516 040 646	1 251 751 392	3 470 220 707	-45 059 056 996
	33	75,4	-357 037	3 950 261	-387 286	-26 342 116
	41	63,6	48 049 063	32 656 504	5 807 660	187 622 003
	51	147,4	6 160 323	13 809 146	5 737 796	-42 488 545
32	11	2028,3				
	21	1172,2	-50 512 541	-47 933 756	-42 112 735	-73 956 043
	22	17,7	N/A			
	23	413,9	-19 086 995	-18 176 336	-16 120 731	-27 365 712
	31	99174,6	4 710 794 466	-1 305 733 051	-3 619 873 642	47 002 224 511
	51	77,1	6 887 907	6 211 766	187 663	14 318 362
33	11	15,9	N/A			
	23	18,4	-1 636 250	-1 530 079	49 505	-3 513 470
	32	3052,1	-130 528 232	-119 641 469	127 070 227	-380 697 933
	51	39,0	1 813 146	1 610 568	1 717 059	2 372 952
41	11	30,0	N/A			
	51	22,3	-15 943 579	-9 377 764	-1 170 361	-72 341 269
51	11	34,7	N/A			
	32	17,7	-1 584 389	-1 428 859	-43 167	-3 293 576
	41	38,1	27 184 490	15 989 492	1 995 516	123 344 987
Total Net Value			**1 943 624 365**	**1 587 280 947**	**1 345 140 447**	**4 558 875 748**

Source: Author's own elaboration.

In view of the model described in chapter 1, changes taking place between various types of land cover may be evaluated according to the total net value sign. It is economically unreasonable to convert arable land into farm meadows and pastures. If we assume a minimum value of the ecosystem services of forests (int.$ 9267 per year), it is also economically unreasonable to resign from growing crops to afforestation. Adopting median values (int.$ 37,567) leads to the opposite conclusion. This clearly indicates the need for analysis taking into account local conditions, and thus allowing for more accurate valuation. On the whole, accepting the median value of ecosystem services, it is economically justified to restore the agricultural areas to its natural state. Let us note, however, that during the period 2006-2012 there was an increase in the prices of agricultural land in Poland. If this tendency persists, in the future it may affect the economic account of changes in land cover.

5. Conclusions

As obvious enough, the authors of the paper are aware that the results are preliminary and subject to a large error. The results obtained show that restoring natural ecosystems at the expense of agricultural crops brings net benefits for the society. Changes between different types of biomes also take place, however local case studies are needed to formulate specific conclusions.

Future research may be developed in several directions. Firstly, it is possible to estimate the value of ecosystem services in Poland more accurately using ESVD data and the meta-regression model (De Groot, 2012: 56). However, this requires gathering relevant spatial data.

Secondly, it may be of particular interest to apply this approach at local, especially urban, scale. Land use change analysis within the city requires very detailed data. In further research, the authors plan to use Urban Atlas data to study land cover changes and estimate their value in the largest cities in Poland. From the sustainable development point of view, it is particularly important to estimate the net value of changes of green and semianthropogenic areas into anthropogenic ones (e.g. for housing purposes). Values attributed to built-up and invested areas may be based on data from local real estate markets in the given cities.

Thirdly, from a theoretical point of view, it is necessary to develop an economic model of land use change taking into account the qualitative parameters of a given area, e.g. green infrastructure indicators or degree of fragmentation, which surely determine the range of available ecosystem services. Of course, practical applications of such model will still be limited due to data availability, however it could lead to better understanding of trade-offs resulting from ecosystem conversion and development processes.

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Zmiany w zasobach kapitału naturalnego Polski – ujęcie przestrzenno-ekonomiczne

Streszczenie

Ocena zmian w zasobach kapitału naturalnego spowodowanych przekształcaniem ekosystemów jest kluczowe dla rozwoju społeczno-gospodarczego. Świadczenie ekosystemów mają duży wpływ na jakość życia oraz dobrobyt społeczny. Ekosystemy są koncepcją przestrzenną, więc naturalnym podejściem jest użycie GIS do oceny zmian w pokryciu terenu. Podstawowy ekonomiczny model zmian w użytkowaniu ziemi pozwala na sformułowanie kryteriów racjonalności ekonomicznej w zarządzaniu kapitałem naturalnym. Celem pracy jest wstępne zastosowanie kryteriów wynikających z ekonomicznego modelu użytkowania gruntów w celu oceny zmian pokrycia terenu w Polsce w latach 2000-2012.

***Słowa kluczowe**:* gospodarka gruntami, świadczenia ekosystemów, kapitał naturalny, Corine Land Cover, zrównoważony rozwój, dynamiczna optymalizacja.

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