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ECOSYSTEM SERVICES HOT SPOT MAPPING: PROTECTED AREAS IN THE LOWER SILESIA PROVINCE

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ANALIZA ZRÓŻNICOWANIA PRZESTRZENNEGO WYBRANYCH USŁUG EKOSYSTEMÓW NA TLE OBSZARÓW CHRONIONYCH W WOJEWÓDZTWIE DOLNOŚLĄSKIM

STRESZCZENIE: Niezbędna jest poprawa wiedzy na temat ekosystemów i oferowanych przez nie usług w krajach należących do Unii Europejskiej, aby osiągnąć główne cele zapisane w Strategii ochrony różnorodności biologicznej do 2020 roku. Z tego powodu państwa członkowskie, we współpracy z Komisją Europejską, są zobowiązane zidentyfikować i ocenić stan ekosystemów i ich usług. Istnieją różne podejścia do mapowania usług ekosystemów, z których jednym jest analiza hot spot. Jest ona dobrym narzędziem do identyfikacji obszarów, które nie są chronione, lecz są ekologicznie cenne i dostarczają wielu usług ekosystemów. W badaniu przeprowadzono analizę czterech potencjałów usług ekosystemów: globalnej regulacji klimatu, kontroli erozji, moderacji ekstremalnych zjawisk i dostarczania wody pitnej. Większość z punktów hot spot dla wybranych usług ekosystemów województwa dolnośląskiego była zlokalizowana w obrębie obszarów chronionych, zwłaszcza tych objętych ochroną w formie Natura 2000.

SŁOWA KLUCZOWE: usługi ekosystemów, kartowanie za pomocą narzędzi GIS, wojewodztwo dolnośląskie

Introduction

The concept of ecosystem service has recently gained a lot of academic attention[1]. There have been many research initiatives concerning the classification[2], mapping[3] and valuation of ecosystem services[4]. The Millennium Ecosystem Assessment (MEA) was the first and the biggest research project concerning this topic. MA (2005) provided the most commonly recognized definition of ecosystem services, which is *benefits that human obtain from nature*, and categorization of services into: supporting, regulating, provisioning and cultural[5]. Although this division and distinction between ecosystem functions, services and products are still under discussion[6], it is commonly understood that in order to include ecosystem services into decision making processes the systematization is necessary. The ecosystem service concept provides new approach to translate the importance of natural capital and its contribution to improving human well-being into economic value. This very anthropogenic perspective may be implemented into environmental policy documents and spatial planning[7]. Ecosystem services has already been included in the European Union Biodiversity Strategy to 2020, the main aim of which is to maintain and restore ecosystems and their services[8]. In order to achieve this it is necessary to improve knowledge on ecosystems and services they deliver in countries belonging to the European Union[9]. Therefore, Member States, in cooperation with the European Commission, are obliged to identify and assess the state of ecosystems and their services and measure the economic value of these services[10]. Under the action 5 of the Biodiversity Strategy each country should map ecosystem services by 2014. In order to facilitate this process European Commission has run several projects among which MAES[11] (Mapping and Assessment of Ecosystems and their Services) presents availabili-

[1] R. Costanza, I. Kubiszewski, *The authorship structure of "ecosystem services" as a transdisciplinary field of scholarship*, "Ecosystem Services" 2012 no. 1, p. 16-25.
[2] R. S. de Groot et al., *A typology for the classification, description and valuation of ecosystem functions, goods and services,* "Ecological Economics" 2002 no. 41(3), p. 393-408.
[3] B. Burkhard et al., *Mapping and modelling ecosystem services for science, policy and practice*. "Ecosystem Services" 2013 no. 4, p. 1-3.
[4] J. P. Schägner et al., *Mapping ecosystem services' values: Current practice and future prospects.* "Ecosystem Services" 2013 no. 4, p. 33-46.
[5] *MEA, Millennium Ecosystem Assessment, Ecosystems and Human Well- Being: Synthesis*, Washington DC 2005.
[6] K. J. Wallace, *Classification of ecosystem services: Problems and solutions*, "Biological Conservation" 2007 no. 139, p. 235-246.
[7] B. Raszka, M. Hełdak, *Świadczenia ekosystemów w polityce przestrzennej gmin powiatu wrocławskiego*, Wrocław 2013.
[8] *The EU Biodiversity Strategy to 2020*, Luxemburg 2011.
[9] R. Brouwer et al., *A synthesis of approaches to assess and value ecosystem services in the EU in the context of TEEB Final Report* 2013.
[10] *The EU Biodiversity Strategy to 2020*, Luxemburg 2011.
[11] J. Maes et al., *Mapping ecosystem services for policy support and decision making in the European Union,* "Ecosystem Services" 2012 no. 1(1), p. 31-39.

ty of data necessary to set indicators on national level. MAES is based in the Common Classification of Ecosystem Services (CICES v4.3).

Even before the European Union's initiatives, mapping ecosystem services has been a topic of academic research in Europe[12] and outside Europe[13]. In Poland the case study mapping attempts have mostly been done for small-scale, detailed unit areas. That is why we decided to conduct a study for the whole Lower Silesia province which is struggling in achieving balance between nature conservation and socio-economic development. Even though there are publications on spatial distribution on natural resources and the state of the environment[14], these studies have seldom presented distribution of ecosystem services[15].

The aim of the paper is to contrast existing protected areas which are environmentally valuable according to traditional preservation rules with the areas where provision of the selected ecosystem services is the greatest according to the current research standards on ecosystem service hotspot mapping. In order to achieve that we developed the comprehensive method for mapping ecosystem services which could be applied in the national ecosystem assessment process. We selected four ecosystem services, each of which is spatially presented and evaluated using appropriate indicators. The services we consider are global climate regulation, moderation of extreme events, erosion control, and fresh water provision. According to the Common International Classification of Ecosystem Services vol. 4.3 these ES could be divided into two section: provisioning and regulating. Fresh water provision belongs to ecosystem service class ground water for drinking, whereas the rest of selected ES belong to the following classes: global climate regulation by reduction of greenhouse gas concentrations, flood protection, and mass stabilization and control of erosion rates. The choice of ecosystem services is governed by literature overview and the possibility for them to be quantified. The research results show spatial distribution and overlaid of individual ecosystem service, on the basis of which the aggregated ecosystem service map is produced. The Lower Silesia region is the study area selected for this research as it is faced with common for the whole country spatial problems such as excessing soil sealing, poor water relations balance and expansion of built-up areas. On the other hand, Lower Silesia is the region characterized by one of the best environmental conditions and a lot of Nature 2000 areas in Poland.

[12] L. C. Braat, *ECOSER 4th Volume: Special issue on mapping and modelling ecosystem services*, "Ecosystem Services" 2013 no. 4.
[13] M. Petter et al., *A methodology to map ecosystem functions to support ecosystem*, "Ecology and Society" 2013 no. 18(1).
[14] Chief Inspectorate for Environmental Protection, *Report on the state of the environment in Poland 2008*, Warsaw 2010.
[15] A. Mizgajski, M. Stępniewska, *Ecosystem services assessment for Poland – challenges and possible solutions,* "Economics and Environment" 2012 no. 2 (42), p. 54-73.

Study area

The case study region Lower Silesia province (LSp) is one of the main 16 administrative divisions (viovodships) in Poland. It is located in the southwest part of the country (Figure 1). The total population of the region is almost three millions. The biggest urban centre and the capital of a province is the city of Wroclaw. Wroclaw metropolitan area has got around 1 million inhabitants what makes it the fifth biggest city in Poland. Constantly expanding suburbanization processes impose greater impact on the protected environmentally valuable areas located in human settlement proximity.

The Lower Silesia region has got one of the best environmental conditions in the country. The growing season here is the longest in Poland (above 220 days) and winters are much milder. There is a temperate climate with an average annual temperature of 7,7°C and an average annual precipitation of 595 mm. The region is very diverse in landscape forms. The east and northern parts of the province is covered with lowlands whereas in south-west there are Sudeten Foreland and part of the Sudetes mountain range. The Odra River is a main supplier of fresh waters for the region. At the same the river basin is at high risk of flooding. The greatest of flood happened in 1997 when almost half of the province was affected. The region is covered with relatively good quality soils in Poland. The ration of good quality soils to rather bed soils is positive. Because of its unique environmental resources there are several forms of protection introduced to the region (two national parks, 12 landscape parks and 20 protected landscape areas), which covers less than 20 percent of the province. However, the region is dense with forests (around 30 percent of the area) and agricultural lands (50 percent of the area).

The Lower Silesia attracts a lot of tourists every year. Most of the tourist influx is directed to the city of Wroclaw, but still many people visit less built-up areas. Most attractive natural place are Sudetes Mountains and Sudeten Foreland.

Materials and methods

There are different approaches to map ecosystem services. In MAES second technical report[16] three main approaches were presented:

- Ecosystem services mapping using available indicators,
- Ecosystem services mapping linking different indicators with land use data,
- Model-based approaches to map ecosystem services.

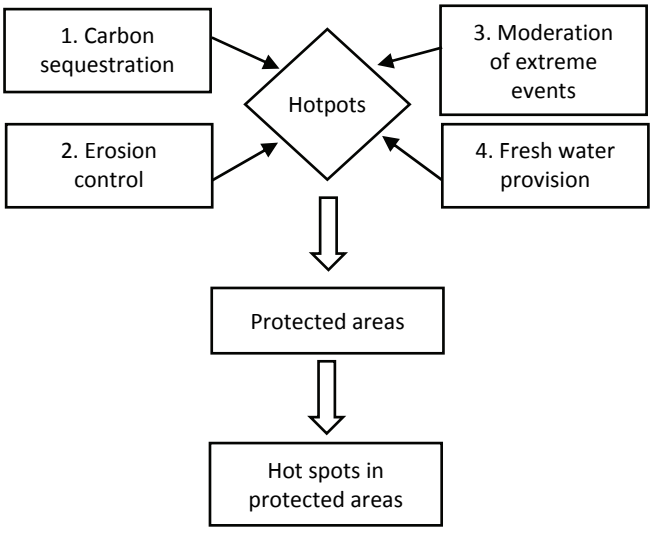
The first approach is perceived as the simplest way to map ecosystem services since it requires the usage of available indicators and presenting their values

[16] MAES, *Mapping and assessment of ecosystems and their services. Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020*, European Commission, 2nd technical report – Final, February 2014.

Figure 1
The Lower Silesia province and its location in Poland

Source: own elaboration.

Figure 2
Method for estimating ecosystem service potential in protected areas



Source: own elaboration.

spatially. Second approach combines indicators with land use data and the last one encompasses modelling biophysical processes instead. The hotspot mapping for Lower Silesia province involved first two ways to visualize ecosystem service potential and capacity. First of all, the hotspot of global climate regulation and erosion control were identified. Then the moderation of extreme events – flood protection was added and the last ES fresh water provision was mapped using 0-1 when underground water springs were identified (Figure 2).

The quality of the ES maps increase with the use of primary data and representative sampling rather than secondary data taken from look-up tables, expert knowledge and casual relationships[17]. However, the hotspot analysis was carried out using secondary data sources for the case study area being the Lower Silesia province. Types of data source consisted of biophysical, topographical, hydrological, and land-cover data available at different resolutions. Although 100 m resolution Corine Land Cover (CLC) raster data served as a basis, the erosion control map's one kilometre resolution was finally adapted. Maps were produced using ArcGIS 10 software and were not verified in the field due to the fact that was not the aim of the research.

The analysis of the spatial distribution of ecosystem services was conducted on the basis of land cover classes distinguished in the Corine Land Cover. Then, the areas with the highest total value of ecosystem service level indicators were compared with valuable natural areas in the Lower Silesia which are subject to various forms of protection. On the basis of that the areas have been identified where a high level of services provided ecosystems overlap with areas designated as environmentally valuable.

Climate regulation service is defined as the influence of ecosystems on climate[18]. In this study we assumed that carbon stock potential was based on the relationships between land use and carbon stock. There are different approaches to map global climate regulation, most often applied are carbon storage layer[19], mean f-evapotranspiration value and mean emissivity index[20] or carbon sequestration[21]. For the purpose of this study erosion control is defined as contrary to soil erosion. PESERA – The Pan-European Soil Erosion Risk Assessment – is the map produced by the Joint Research Centre under European Commission. It is a

[17] M. J. Martínez-Harms, P. Balvanera, *Methods for mapping ecosystem service supply: a review*, "International Journal of Biodiversity Science, Ecosystem Services & Management" 2012 no. 8(1-2), p. 17-25.

[18] L.C. Braat, R. de Groot, *The ecosystem services agenda: bridging the worlds of natural science and economics, conservation and development, and public and private policy*, "Ecosystem Services" 2012 no. 1(1), p. 4-15.

[19] H.K. Gibbs, *Major world ecosystem complexes ranked by carbon in live vegetation: an updated database using the GLC2000 land cover product.* Oak Ridge (TN), Oak 2006.

[20] N. Schwarz, A. Bauer, D. Haase, *Assessing climate impacts of planning policies. An estimation for the urban region of Leipzig (Germany),* "Environmental Impact Assessment Review" 2011 no. 31(2), p. 97-111.

[21] G.E. Ausseil et al., *Assessment of multiple ecosystem services in New Zealand at the catchment scale*, "Environmental Modelling & Software" 2013 no. 43, p. 37-48.

model that quantifies soil erosion by water and assess its risk across Europe[22]. PESERA may replace such methods as Universal Soil Loss Equation (USLE) which is very often use for mapping that ES. Moderation of extreme events type of ecosystem service is mapped by presenting areas of potential flood prevention characteristics – wetlands. Flood protection was chosen considering the yearly flooding in the region due to its topographic and hydrological conditions. The Lower Silesia Province experienced catastrophic flooding in 1997. Fresh water provision ecosystem service for the purpose of this study is limited to underground fresh water sources. This ES is diversely defined in the literature. One may find that clean water provision is measured by nitrate leaching[23].

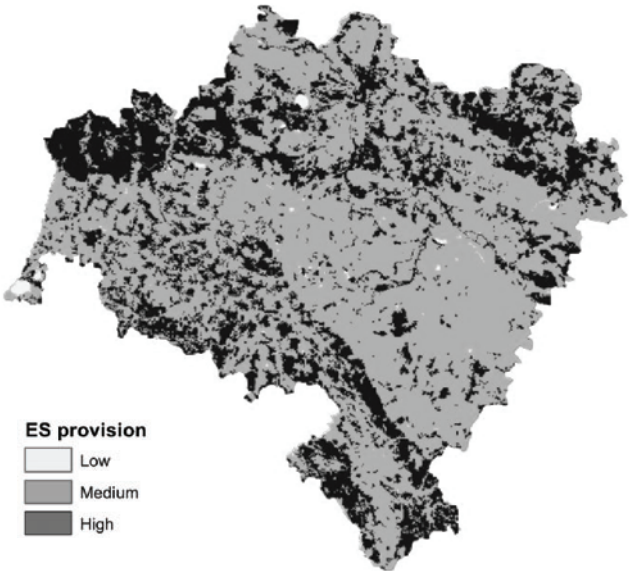
Results

The hot spot analysis of global climate regulation proves considerable ecosystem service potential for the region (Figure 3). All the high values for this ES provision constitute hot spot, the greatest number of which are located in the north-west part of the province, within Nature 2000 site of Bory Dolnośląskie. It is scientifically suggested that forests and peatlands are carbon sinks[24] which is also proven by the results for the first out of four ES potential. Moreover, high carbon stock potential is correlated with the erosion control ecosystem service and therefore most of the hot spot of climate regulation are overlaid by erosion control ES potential (Figure 4). However, erosion control is influenced by such factors as topography, land use and other. The results of hot spot analysis shows that the highest provision of this ES is located in the southern parts of the province as well as in the south-west, middle-east parts.

The hot spots of moderation of extreme events ecosystem service potential aare mainly located in the north part of the province whereas the hot spots for the fresh water provision occur in the south, mountain areas (Figure 5). This may be explained by the topography of the region which is flat in northern side. There are a lot of wetland which retain water in dry seasons and accumulate the excess during wet season. Wetlands located in the closest proximity of the rivers play the greatest role in flood prevention. Apart from wetlands, flood plains protect the built-up areas from the natural catastrophes. The analysis of the land use, however, reveals the housing development increasing at that sites which hinders the ecosystem services and the benefits they bring to human well-being. In this research we considered provision of fresh water as ecosystem service only from the underground water sources, though it is acknowledged surface resources also play important role.

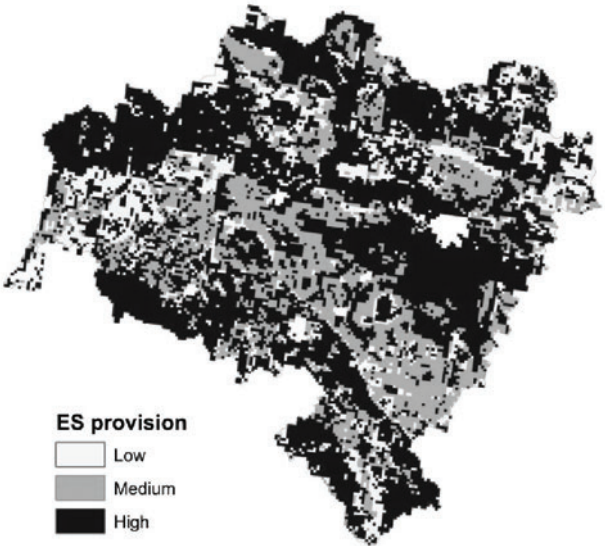
[22] www.eusoils.jrc.ec.europa.eu [01-09-2014].
[23] G.E. Ausseil et al., op. cit., p. 37-48.
[24] UK National Ecosystem Assessment, *The UK National ecosystem assessment: synthesis of the key findings*, Cambridge 2011.

Figure 3
Hot spots of global climate regulation ecosystem service potential



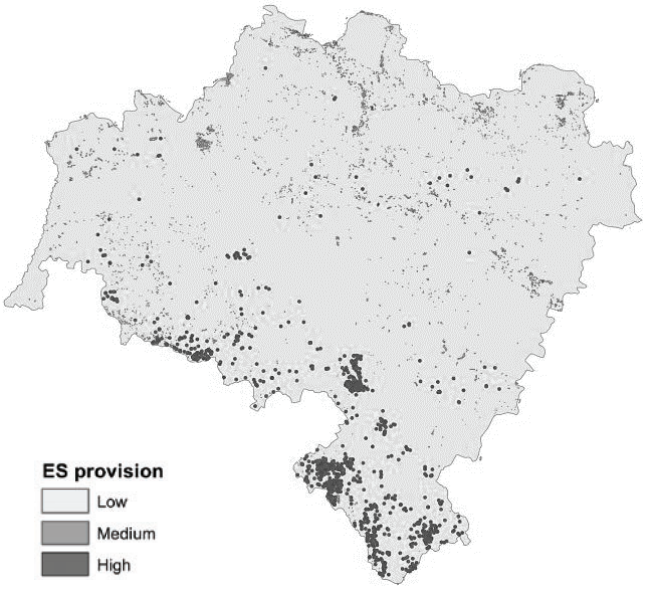
Source: own elaboration.

Figure 4
Hot spots of erosion control ecosystem service potential



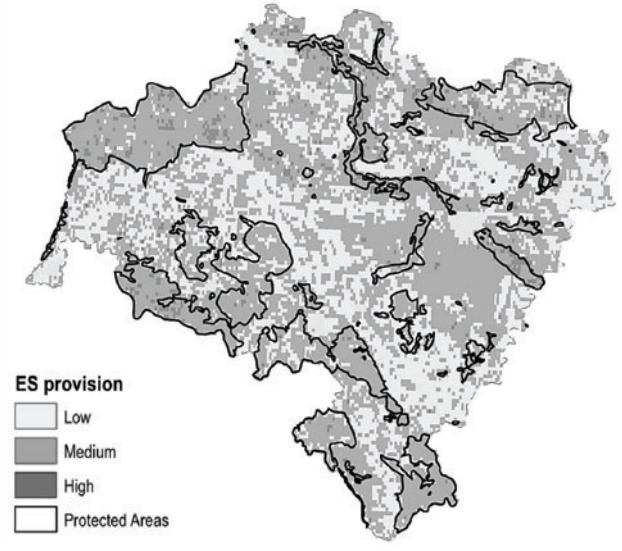
Source: own elaboration.

Figure 5
Hot spots of moderation of extreme events and fresh water provision ecosystem service potential



Source: own elaboration.

Figure 6
Hot spots of the selected ecosystem services potential and boarders of the protected areas in Lower Silesia province



Source: own elaboration.

Figure 6 presents hot spots of the selected ecosystem services potential and boarders of the protected areas (Nature 2000, national, landscape and preservation parks). Out of 17681 polygons 712 are classified as hot spots. The analysis shows that only about 12 percent of hot spots is located within national, landscape and reservation parks whereas Nature 2000 sites host about 60 percent of all the hot spots. The greatest amount of hot spots outside protected areas occur in the central north and north-east side of the Lower Silesia Province. These are also topographically the lowest parts of the region. Then cold spots are concerned, about 30 percent of them is situated within boarders of protected areas. Although cold spots are usually agricultural lands and mountain areas, places proving medium amount and quality of the selected ecosystem services are often of the same use.

Conclusions

The hot spot analysis over the one kilometre resolution data enable us to identify hot spots of ecosystem services potential that are not protected. Ecosystem service hot spot is a good tool for spatial analyses which brings new perspective to the ecosystem service mapping. Mapping ecosystem services gives also a broader perspective for protected areas' management. If ecosystem services are overlapping on a given area there is a high probability of ES trade-offs[25]. The range of ES hotspot may vary according to spatial resolution, scale and types of ecosystem services[26].

According to Seppelt et al. (2011) the use of secondary data for ecosystem service mapping and no results validation are more common in the research papers concerning that topic than the use of primary data and results being validated. It is, however, without a doubt that the reliable and comprehensive ecosystem service assessments requires biophysical measurement, modelling and monitoring of ecosystem functions[27]. Although such assessment may be time-consuming and cost-generating, it seems to be necessary in order to achieve reliable and satisfactory for decision making. Nevertheless, ecosystem service mapping still faces a lot of challenges and one of the most important of them is to set standards on the level of detail and resolution that is acceptable for comprehensive and not misleading maps[28] for all the stakeholders.

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[25] B. Locatelli, P. Imbach, S. Wunder, Synergies and trade-offs between ecosystem services in Costa Rica, "Environmental Conservation" 2013 no. 41(01), p. 27-36.

[26] M. Kandziora, B. Burkhard, F. Müller, *Mapping provisioning ecosystem services at the local scale using data of varying spatial and temporal resolution*, "Ecosystem Services" 2013 no. 4, p. 47-59.

[27] R. Seppelt et al., *A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead*, "Journal of Applied Ecology" 2011 no. 48(3), p. 630-636.

[28] J. Hauck et al., *Maps have an air of authority. Potential benefits and challenges of ecosystem service maps at different levels of decision making*, "Ecosystem Services" 2013 no. 4, p. 25-32.