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THE USE OF INTEGRATED ENVIRONMENTAL PROGRAMME FOR ECOSYSTEM SERVICES ASSESSMENT

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WYKORZYSTANIE PROGRAMU ZINTEGROWANEGO MONITORINGU ŚRODOWISKA PRZYRODNICZEGO DO OCENY USŁUG GEOEKOSYSTEMOWYCH

STRESZCZENIE: W artykule przedstawiono koncepcję zastosowania Zintegrowanego Monitoringu Środowiska Przyrodniczego (ZMŚP) do realizacji zadań w zakresie usług geoekosystemów. Program ZMŚP stwarza możliwości oparcia ocen usług regulacyjnych na danych pomiarowych realizowanych w różnych typach krajobrazów Polski, reprezentatywnych dla struktury krajobrazowej kraju. Pomiary realizowane przez Stacje Bazowe ZMŚP pozwalają ocenić na przykład usługi regulacyjne lasów w zakresie remediacji toksyn i innych uciążliwości, regulacji procesów glebotwórczych i jakości gleby, regulacji klimatu przez sekwestrację węgla, a także usługi ekosystemów wodnych związane z regulacją cyklu hydrologicznego, regulacją jakości wody oraz regulacją transportu materii. Realizacja programu badawczo-pomiarowego ZMŚP poszerzona jest o programy specjalistyczne, specyficzne dla poszczególnych Stacji Bazowych. Stwarza to możliwość oceny usług geoekosystemów z uwzględnieniem specyfiki środowiska przyrodniczego zlewni badawczych oraz specjalizacji zespołów badawczych.

SŁOWA KLUCZOWE: Zintegrowany Monitoring Środowiska Przyrodniczego, usługi regulacyjne, wzmacnianie lub konkurowanie, beneficjenci

Introduction

Scientists and practitioners have a lot of experience in the assessment of the majority provisioning and cultural services like timber, food and recreation services[1], however regulating services are more difficult to estimate and thus still pose serious challenges.[2] Much of the conceptualisation around regulation ecosystem services is not supported by observation data and the links to ecological processes are poorly defined. Applications to new situations are often largely qualitative, based on expert judgement or assumptions,[3] and lack supporting evidence from field measurements. In this context, long-term monitoring data relating to complex functioning of ecosystems seem to be very useful. Taking this into account, the article presents a concept of the use of the Integrated Environmental Monitoring Programme (IEMP) for the identification and assessment of services for various types of Poland's landscapes.

The Integrated Environmental Monitoring Programme (IEMP) functions within the State Environmental Monitoring Programme since 1994. Its task, as opposed to specialist monitoring, involves long-term research, both abiotic and biotic of elements of the natural environment, based on planned and organized stationary tests.

The aim of the IEMP is to provide data for defining the current environmental status and, based on multi-year observation cycles, to present short- and long-term environmental changes in the conditions of climate changes and growing human impact on the environment. The results obtained from the conducted observations are the basis for preparing short- and long-term forecasts of the development of the natural environment and presenting the directions for threats and methods for preventing them. The Integrated Environmental Monitoring Programme, as opposed to sector-related monitoring provides comprehensive information, not only within selected measurement programmes, but mostly about cause and effect relationships and results of their impact on the geographical environment.

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[1] M. Hernández-Morcillo, T. Plieninger, C. Bieling, *An empirical review of cultural ecosystem service indicators*, "Ecological Indicators" 2013 no. 29, p. 434-444; 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; A.I. Milcu, J. Hanspach, D. Abson, J. Fischer, *Cultural ecosystem services. A literature review and prospects for future research*, "Ecology and Society" 2013 no. 18, v. 3, p. 47-59; M. Pérez-Soba et al., *Study on the role of agriculture as provisioning ecosystem service*, Interim report to the Institute for Environment and Sustainability (JRC/IES), Alterra Wageningen UR, Copenhagen 2012.

[2] P. Kumar, M. Verma, M.D. Wood, D. Negandhi, *Guidance manual for the valuation of regulating services*, Nairobi 2010.

[3] L. Jones et al., *A review and application of the evidence for nitrogen impacts on ecosystem services*, "Ecosystem Services" 2014 no. 4, p. 76-88.

The IEMP is a scientific and research programme and it is used for recognizing the functioning of geoecosystems, their protection and preservation of Poland's landscape structure. In terms of the methodology, the IEMP is based on the concept of system functioning[4], implements the assumptions of preserving geodiversity and biodiversity of the whole country. The basic object of IEMP research is the river or lake catchment area within which test research areas are located which are representative for the landscape under analysis.

A broad range of complementary stationary research is conducted according to standardised methods at 11 IEMP Base Stations in the entire country and at the Polar Base Station in Spitsbergen as a reference station for the assessment of the condition of the natural environment in Poland. The location of IEMP Base Station in Poland takes into account the diversity of landscapes-ecological zones[5] and mesoregions by dominant forms of land cover[6] (Figure 1, Table 1).

Figure 1
The location of Integrated Environmental Monitoring Programme Base Stations in landscape-ecological zones

Source: own study based on the Land Cover Structure according to landscape-ecological zones; M. Stępniewska, A. Mizgajski, op. cit.

[4] A. Kostrzewski, *Geoekosystem obszarów nizinnych. Koncepcja metodologiczna,* „Zeszyty Naukowe Polskiej Akademii Nauk, Człowiek i Środowisko Komitet Naukowy przy Prezydium PAN" 1993 no. 6, p. 11-17.

[5] A. Mizgajski, M. Stępniewska*, Ecosystem services assessment for Poland – challenges and possible solutions*, "Ekonomia i Środowisko" 2012 no. 2(42), p. 54-73.

[6] D. Łowicki, A. Mizgajski, *Typology of physical-geographical regions in Poland in line with land-cover structure and its changes in the years 1990-2006*, "Geographia Polonica" 2013 no. 86(3), p. 255-266.

Table 1
Physicogeographical characteristics of representative catchment areas of the Integrated Environmental Monitoring Programme

IEMP Base Station	Catchment research	Area [km^2]	Landscape-ecological zone4	Catchment/ Basin	Physical-geographic macro-region[8]	Dominant forms of land cover in mesoregion[9]
Wolin	Gardno Lake	2,6	Baltic Sea	Baltic Sea	Szczecin Coastland	Distinctly forested and averagely artificial
Storkowo	Parsęta	74,0	Lakelands	Parsęta	Westpomeranian Lakeland	Diversified
Puszcza Borecka	Łękuk Lake	13,3	Lakelands	Węgorapa/ Pregoła	Masurian Lakeland	Diversified
Wigry	Czarna Hańcza	7,4	Lakelands	Niemen	Lithuanian Lakeland	Distinctly agricultural
Koniczynka	Struga Toruńska	35,2	Lakelands	Wisła	Chelmno-Dobrzyn Lakeland	Distinctly agricultural
Różany Strumień	Różany Stream	10,1	Lakelands	Warta/ Odra	Poznań Lakeland	Diversified
Kampinos	Olszowiecki Channel	20,2	Lowlands	Łasica/ Wisła	Central Mazovia Lowland	Distinctly artificial and averagely forested
Święty Krzyż	I rank catchment	1,3	Uplands	Kamienna/ Wisła	Kielce-Sandomierz Upland	Distinctly agricultural and averagely artificial
Roztocze	Świerszcz	46,5	Uplands	Wieprz/ Wisła	Roztocze	Distinctly forested
Szymbark	Bystrzanka	13,0	Medium-high Mountains	Ropa/ Wisła	Central Beskydy Mountains/Central Beskydy Foothills	Distinctly agricultural and averagely artificial
Karkonosze	Wrzosówka	93,2	Medium-high Mountains	Kamienna/ Odra	Giant Mountains	Distinctly forested

Source: own study based on the Integrated Environmental Monitoring Programme.

As regards the organization of the measurement system, research methods and substantive studies, the IEMP refers to the European Integrated Monitoring Programme[9]. The research and measurement scope of the IEMP includes the fol-

[7] A. Kondracki, *Geografia regionalna Polski*, Warszawa 2000, p. 441.
[8] D. Łowicki, A. Mizgajski, op. cit.
[9] A. Kostrzewski, J. Tylkowski, *Conditions of geo-ecosystems of Poland in 2012 – Implementation of the Integrated Environmental Monitoring Programme;* S. Kleemola, M. Forsius (eds.), *23rd Annual Report Convention on Long-range Transboundary Air Pollution International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems*, Finnish Environment Institute 2014, p. 45-51.

lowing programmes: meteorology, air pollution, chemistry of precipitation, chemistry of throughfall and stemflow, chemistry of soil solutions, groundwater, surface water, soils, structure and dynamics of the vegetation and invasive alien species, damage to trees and stands of trees, epiphytes, heavy metals and sulphur in lichens, land cover and the use of land, hydrobiology of rivers – macrophytes and hydromorphological assessment of river beds, ecosystem services.

The use of the Integrated Environmental Monitoring Programme for valuation of ecosystem services

Table 2 presents parameters from the measurement programme implemented by IEMP Base Stations which may support the quantification of selected regulating services listed in the CICES classification[10]. The measurement of the load of pollutants reaching the ground with the throughflow and stemflow as compared to loads of these pollutants brought to the ground with precipitation in an open area informs about regulating services in forests in the area of remediation of toxics and other nuisances. Forest services pertaining to the regulation of soil-forming processes and soil quality may be characterised owing to the measurement of the organic matter reaching the forest floor and the biogenic loads it contains. The carbon content in the organic precipitation, on the other hand, is an indicator of services related to global climate regulation by carbon sequestration.

The degree of defoliation is an indicator of the forest condition useful for the end user for the determination of the representativeness of results obtained at IEMP Base Stations as compared to the level of environmental pollution. This parameter is measured on monitored surfaces in the basic IEMP programme and its value can be compared by the end user with the degree of defoliation in the area under analysis owing to data from the state forest monitoring.

Further measurement parameters allow for characterising regulating services of river ecosystems related to the regulation of sediment transport. The IEMP programme also includes the measurement of a range of parameters used to define the quantitative and qualitative status of aquatic ecosystems. These include physicochemical properties of waters, characteristic flows in rivers, the status of groundwater, indices of changes in retention in a hydrological year in relation to the energy of the lay-of-the-land and the structure of the land use. Transformation of these parameters into useful indices of services in the area of regulation of the hydrological cycle and regulation of water quality requires the assessment of their influence on the degree of meeting the needs of aquatic habitats and water-dependent habitats. The seasonal water regime and water quality determine the possibility of the fulfilment of various functions of these habitats and, as a result, of providing ecosystem services, e.g. maintaining habitats plant and animal

[10] *Common international classification of ecosystem services (CICES) v. 4.3 (update January 2013)*, www.cices.eu [24-07-2014].

Table 2

Parameters of the IEMP measurement programme useful for the assessment of ecosystem services

CICES Division	CICES Group	CICES Class	Indicators of ecosystem services
Mediation of toxics and other nuisances	Mediation by ecosystems	Filtration/ sequestration/ storage/ accumulation by ecosystems	• **Remediation of pollutants reaching the forest floor with throughfall and stemfall**: Pollutant loads reaching the ground with throughfall and stemfall, mg/m2: Basic programme: S-SO4, SO4, N-NO3, NO3, NH4, N-NH4, Cl, Na, K, Mg, Ca; Extended programme: Cd, Cu, Pb, Mn, Fe, Zn, Ni, As, Cr, Al. • **Remediation of pollutants reaching the forest floor with organic precipitation:** Loads of elements reaching the forest floor with organic precipitation, kg of dry matter/ha/year Extended programme: total S, Ca, Mg, Na, K, Mn, Zn, B, Cu, Mo, Pb, Cd. • **Background: pollutant loads reaching the ground with precipitation in an open area** Loads of pollutants brought to the ground with precipitation, kg/km2: Basic programme: S-SO4, SO4, N-NO3, NO3, N-NH4, NH4, Cl, Na, K, Mg, Ca; Extended programme: Cd, Cu, Pb, Mn, Fe, Zn, Ni, As, Cr, Al.
Maintenance of physical, chemical, biological conditions	Soil formation and composition	Decomposition and fixing processes	• **Maintenance of biogeochemical conditions of soils by decomposition of dead organic material, nitrification, denitrification and other biogeochemical processes:** – Organic matter reaching the forest floor, g/m2 – Basic programme – Loads of elements reaching the forest floor with organic precipitation, kg of dry matter/ha/year Extended programme: organic C, total N, total P
	Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	• **Global climate regulation by carbon sequestration:** – Organic C load reaching the forest floor with organic precipitation, kg of dry matter/ha/year – Extended programme
Mediation of flows	Mass flows	Buffering and attenuation of mass flows	• **Transport of sediment by rivers:** Load of dissolved substances carried with river runoff, kg/ha/year: Basic programme: S-SO4, N-NO3, HCO3, total P, total Al, N-NH4, Cl, Na, K, Mg, Ca; Extended programme: Cd, Cu, Pb, Mn, Zn, Ni, As, Fe, Cr.

Source: own study based on the: A. Kostrzewski, R. Kruszyk, R. Kolander, *Zintegrowany monitoring środowiska przyrodniczego. Zasady organizacji, system pomiarowy, wybrane metody badań 2006*, www.staff.amu.edu.pl [23-07-2014].

nursery and reproduction, flood and drought protection, maintaining baseline flows for water supply[11].

The implementation of the IEMP measurement programme is extended by specialist programmes specific for individual stations. It makes it possible to assess ecosystem services taking into account the specificity of the natural environment of the investigated catchment areas and specialization of research teams (e.g. research of lateral erosion in river beds, research of soil erosion, landslides, drainage catchment areas, cliff abrasion).

The assessment of trade-offs and synergies between the ecosystem services is a promising research area. This type of analyses should provide grounds for answering a question of practical relevance: in which landscape structures of Poland can the bundle of ecosystem services be increased? [12]

IEMP Base Stations situated in areas of high natural value are attractive for analysing trade-offs and synergies between regulating and cultural services. A broad range of regulating services are accompanied by a low degree of anthropogenic transformation there. At the same time, the aforementioned areas are attractive places of rest and relaxation providing a range of cultural services, e.g. entertainment, heritage or educational values. The intensity of use of cultural benefits influences the structure and level of regulating services. In addition, these areas are the place of residence for the local community which obtains food and materials for their own needs there (provisioning services)[13].

IEMP base stations with research catchment areas transformed by human activity connected with agriculture are promising areas for research on trade-offs and synergies between provisioning, regulating and cultural services. In addition to food, fuel and fiber, agricultural areas can provide another ecosystem services, e.g. regulation of water quality, biocontrol services, climate stabilization, providing natural habitats for conservation and recreation, aesthetic and cultural amenities such as beautiful farmscapes. Various agricultural management practices have differing effects, sometimes in opposition and at other times synergistic for providing these regulating and cultural services[14].

The IEMP potential for the assessment of ecosystem services is also connected with the identification of spatial *distribution* of *ecosystem service beneficiaries (ESBs).* Different stakeholders often attach a different value to ecosystem services, depending on their cultural background and the impact of the service on their well-being. *Depending on the* ecosystem service under analysis*, ESBs* can occur at a local, regional, national and even global level. For example the value of the supply of tourism and recreational activities at a given location does not

[11] E. Maltby et al., *Freshwaters – Openwaters, Wetlands and Floodplains*, in: *The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment,* Cambridge 2011.
[12] A. Ruijs et al., *Trade-off analysis of ecosystem services in Eastern Europe*, "Ecosystem services" 2013 no. 4, p. 82-94.
[13] I. Palomo et al., *National Parks, buffer zones and surrounding lands: Mapping ecosystem service flows*, "Ecosystem Services" 2013 no. 4, p. 104-116.
[14] G.P. Robertson et al., *Farming for ecosystem services. An ecological approach to production agriculture*, "BioScience" 2014.

necessarily accrue only to the local community. It is a frequent situation that external visitors are the main beneficiaries of such services. On the other hand, the benefits from clean water supply, waste treatment or moderation of extreme events (e.g. flood) generally directly accrue to the welfare of local communities[15]. Consideration of *beneficiaries* for various types of Polish landscape enhances the applicability of ecosystem services assessment to support decision making, as different stakeholders' interests often result in different visions on the management of the area. The formulation of management plans that are acceptable to all stakeholders requires the balancing of these different interests[16].

Conclusions

The Integrated Environmental Monitoring Programme implemented for 20 years is a good source of quantitative data pertaining to the functioning of the natural environment of catchment areas under investigation which are representative for landscape-ecological zones in Poland.

The verified IEMP database containing 1 million records is a reliable basis for identifying and valuating ecosystem services, especially as regards the assessment of regulating services. Within the framework of the IEMP, a specialist ecosystem services programme will be implemented in the years 2015-2017, which is aimed, amongst other things, at developing methodological and application principles of the assessment of ecosystem services in Poland.

However, parameters of the measurement programme implemented by IEMP Base Stations will be useful indicators of ecosystem services only if they are adapted to the indices of benefits supplied to human societies. Operationalization of measurement parameters as proposed by the European Environment Agency[17], would be a good platform that would make it possible to standardize the methodology for the whole country and to ensure comparability of results with other countries.

[15] R. S. de Groot et al., *Global estimates of the value of ecosystems and their services in monetary units*, "Ecosystem Services" 2012 no. 1, p. 50-61.
[16] L. Hein, K. van Koppen, R. S. de Groot, E.C. van Ierland, *Spatial scales, stakeholders and the valuation of ecosystem services*, "Ecological Economics" 2006 no. 57, p. 209-228.
[17] European Environment Agency, op. cit.