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RELATION BETWEEN CHARACTERISTICS OF NATURAL ENVIRONMENT AND ECOSYSTEM SERVICES OFFERED, THEIR INDICES AND MEASURES (CASE STUDY OF THREE COMMUNES OF PODLASKIE VOIVODSHIP)

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SPECYFIKA ŚRODOWISKA PRZYRODNICZEGO A ZESTAW USŁUG EKOSYSTEMOWYCH, ICH WSKAŹNIKÓW I MIAR (NA PRZYKŁADZIE TRZECH GMIN WOJEWÓDZTWA PODLASKIEGO)

STRESZCZENIE: Określono zależności między przykładowymi usługami ekosystemowymi i dobrami naturalnymi trzech gmin województwa podlaskiego: Giby, Nowinka, Suwałki. Celem analizy jest powiązanie wybranych elementów środowiska przyrodniczego gmin z usługami dostarczonymi przez ekosystemy. Spośród trzech gmin – Giby wyróżniają się przewagą lasów, Nowinka jezior, Suwałki – użytków rolnych. Z wymienionych różnic wynikają najbardziej typowe dla każdej z gmin usługi ekosystemowe; dla Gib – zaopatrzeniowe uzyskane z ekosystemów leśnych; dla Suwałk – zaopatrzeniowe dostarczane z produkcji rolnej; dla Nowinki – kulturowe dostarczane z ekosystemów wodnych.

SŁOWA KLUCZOWE: usługi ekosystemowe, struktura użytkowania ziemi, typy siedliskowe lasu, ekosystemy wodne, grunty orne

Introduction

An awareness of the benefits that humans obtain from the natural environment lies at the basis of the developing concept of ecosystem services (ES). Ecosystem services are broadly defined as the set of ecosystem products (e.g. timber, forest fruit, game) and functions (e.g. purification of water and air, production of oxygen, places for recreation) that society takes advantage of¹).

The present paper aims to link selected ecosystem services related to differential natural conditions, and particularly structure of land use, in three communes of the Podlaskie voivodship in Poland, namely Giby, Nowinka and Suwałki.

It is assumed that differences in the prevalence of particular land use patterns result in a multiplicity of services provided by ecosystems. The paper presents examples of ecosystem services that are secondary to the dominant pattern of land use in a specific commune. For the commune of Giby, these are provisioning services delivered by forest ecosystems, which occupy approx. 75% of the commune's area. For the commune of Nowinka, characterised by the highest percentage of lakes (approx. 15%), we chose to describe cultural services associated with recreation and ecotourism. The commune of Suwałki is characterised by a predominance of agricultural land use (arable land accounts for approx. 54%), which favours provisioning services related to food production.

Theoretical basis of investigations

The concept of ecosystem services (ES) is currently very popular and much researched. According to the simplest and most popular conceptualisation, there are four categories of ecosystem services: (1) provisioning services, including food and water; (2) regulating services, such as flood and drought control, preventing land degradation or disease control; (3) supporting services, including soil formation and biogenic cycling; and (4) cultural services, i.e. recreational, spiritual, religious and other intangible values². According to the classification developed by I. Green et al.³, only two categories (provisioning and cultural services) comprise products and structures that are directly advantageous to human society, while the remaining two (regulating and supporting services) provide a structural and functional framework that influences the overall integrity of a landscape system and its capacity to produce specific services.

¹ R. Costanza et al., *The value of the world's ecosystem services and natural capital*, "Nature" 1997 no. 387; J. Solon, *Koncepcja „Ecosystem Services” i jej zastosowania w badaniach ekologiczno-krajobrazowych*, „Problemy Ekologii Krajobrazu” 2008 no. 21, p. 25-44.

² MEA, *Millennium Ecosystem Assessment Synthesis Report*, 2005, www.maweb.org [02-06-2006].

³ I.M. Green, C. Folke, R.K. Turner, I. Bateman, *Primary and secondary values of wetland ecosystems*, "Environmental and Resource Economics" 1994 no. 4, p. 55-74.

The growing awareness of benefits that ecosystems provide to society makes it worthwhile to disseminate and develop the ES conception⁴. Papers on ES are proliferating, especially in the United States, but also in European countries, including Poland⁵. They represent diverse theoretical and practical value⁶. A common goal in many of these papers is, above all, the assessment of the effect of human activity on the supply of ecosystem services. The ecosystem services debate often revolves around planning protective measures in areas of natural value⁷.

Importantly, the literature on ecosystem services provides a disorderly network of concepts and a similarly disorderly array of methods, leading to devaluation of its fundamental term. Assessments of ecosystem services account for most scientific literature in nature conservation, environmental economics and ecology^{8,9,10}. The natural environment supplies humans with raw materials, finished products, energy and services. Some authors also perceive, analyse, classify and assess ecosystem services from two vantage points: biological-ecological and socioeconomic¹¹. A. Mizgajski and M. Stępniewska¹² refer to ecosystem services as environmental services and define them as all benefits obtained by humans from ecosystem metabolism.

The present paper analyses two categories of ecosystem services: provisioning and cultural ones. Provisioning services refer to products obtained from ecosystems (such as food, fuel, fiber, genetic resources, biochemical substances, natural pharmaceuticals, water resources and natural raw materials used by art and culture, such as wood for ornaments or sculptures)¹³. Cultural services comprise intangible benefits derived from ecosystems (such as cognitive, recreational, reflective values, aesthetic experiences and spiritual enrichment).

⁴ J.A. Foley et al., *Global Consequences of Land Use*, "Science" 2005 no. 309, p. 570-574.

⁵ E. Roo-Zielińska, B. Grabińska, *Ecosystem services – classification and different approaches at various levels of biosphere organisation – a literature review*, "Geographia Polonica" 2012 no. 85, v. 2, p. 65-81.

⁶ M. Degórski, *Wykorzystanie świadczeń ekosystemów w rozwoju regionów*, „Ekonomia i Środowisko” 2010 no. 1(37), p. 85-97.

⁷ B. Ego, *Integrating ecosystem services into conservation assessments: A review*, "Ecological Economics" 2007 no. 63, p. 714-721.

⁸ K.E. Limburg et al., *Special issue: The dynamics and value of ecosystem services. Integrating economic and ecological perspectives complex systems and valuation*, "Ecological Economics" 2002 no. 41, p. 409-420.

⁹ R Costanza, *Ecosystem services. Multiple classification system are needed*, "Biological Conservation" 2008 no. 141, p. 350-352.

¹⁰ Z.M. Rosin et al., *Koncepcja świadczeń ekosystemowych i jej znaczenie w ochronie przyrody polskiego krajobrazu rolniczego*, „Chrońmy Przyrodę Ojczyzną” 2011 no. 67(1), p. 3-20.

¹¹ B. Poskrobko, *Usługi środowiska jako kategoria ekonomii zrównoważonego rozwoju*, „Ekonomia i Środowisko” 2010 no. 1(37), p. 21-30.

¹² A. Mizgajski, M. Stępniewska, *Koncepcja świadczeń ekosystemów a wdrażanie zrównoważonego rozwoju*, in: D. Kiełczewski, B. Dobrzańska (eds.), *Ekologiczne problemy zrównoważonego rozwoju*, Białystok 2009, p. 12-13.

¹³ A. Becla, S.Czaja, A. Zielińska, *Pozaeconomiczne użytki środowiska przyrodniczego a usługi ekosystemów w świetle współczesnego rachunku ekonomicznego*, „Ekonomia i Środowisko” 2013 no. 2(45), p. 10-22.

Becla et al. (2013) emphasise that “a characteristic feature of cultural services is that they can be reused and the manner of using them depends considerably on the preferences of particular social groups”. The identification and classification of services precedes their quantification, which involves the description of services in natural units compatible with those occurring in the natural environment.

Source of data

The initial stage of our research was analysis of a variety of planning documents, such as Studies of Determinants and Directions of Land-Use Planning (SUiKZP), statistical data about the Podlaskie voivodship and Suwałki district, data from the Regional Directorate of State Forests in Białystok, Environmental Protection Programmes for the Suwałki district, Environmental Protection Plans for the communes, data from Commune Offices, Local Development Programmes for the communes and the relevant Commune Development Strategies. Additionally, on the basis of a very detailed review of literature and on-line data, “services for” and “services from” land use in the three communes were identified.

The next stage involved the compilation of a possibly complete list of provisioning and cultural services. List of provisioning ecosystem services from forest ecosystems for the Giby and from agroecosystems for the Suwałki commune as well as list of cultural services supplied by aquatic ecosystems for the Nowinka commune had been elaborated. Apart from the category of a service, it details the index/measure, result of measurement, source of data and the service provider.

General characteristics of the three test communes

The choice of test communes was based on two fundamental criteria: (1) the degree of anthropogenic transformation (assessed tentatively on the basis of the proportion of forested area, population density and the presence or absence of industry) and (2) landscape diversity. Three communes in the Podlasie voivodship, namely Giby, Nowinka and Suwałki, were selected for the study involving the identification, valuation and assessment of ecosystem services.

Natural values

The commune of Giby is located in the north-eastern part of the Podlasie voivodship. It occupies a total area of nearly 324 km², which accounts for approximately 36% of the area of the Sejny district. The land use includes forests, agricultural land, rivers, lakes and wetlands. In its southern reach extends the picturesque Puszcza Augustowska (Augustów Primeval Forest). A portion of the area of

the commune belongs to Wigry National Park. The rivers Czarna Hańcza and Marycha flow through the commune. The Forest Districts Pomorze and Głęboki Bród, whose ranges partly overlap with the Giby commune, mainly support coniferous forest habitats with a dominance of pine. The mean age of forest stands in the commune is 67 years, and average stock exceeds 300 m³/ha.

The commune of Nowinka is situated in the central part of the Suwałki-Augustów Lakeland, in the southern mesoregion shaped as an outwash plain by the waters of a melting ice sheet about 17-18 thousands years ago. The commune lies in the northern part of the Podlasie voivodship and in the northern part of the Augustów district. It occupies an area of 204 km², of which forests and lakes account for 60%. The Nowinka commune abounds in stagnant bodies of water, especially in the north-east. In the north, the commune extends over a part of Lake Długie Wigierskie. The dense forest complexes of Puszcza Augustowska are partially legally protected as a nature reserve ("Lake Kalejty") and as areas belonging to Wigry National Park. Of the wide gamut of landscape and natural attractions of the commune, it is Puszcza Augustowska that merits a special mention as one of the largest forest complexes in Poland. Wigry National Park, established in 1989, whose southern range lies in the Nowinka commune, is a landscape pearl of the Suwałki region, with its impressive faunal and floral richness comprising more than 100 species of rare plants (including 50 protected species), 80 species of birds, more than 30 species of fish and more than 40 species of mammals.

The commune of Suwałki is one of 9 municipal communes in the Suwałki district. It occupies an area of approx. 264 km² representing a young glacial landscape, mostly a hilly and outwash plain lakeland landscape. The commune focuses on agriculture and forest management, as reflected in its land use structure, where agricultural land and forested areas predominate. Agriculture plays a major role in the commune's economy. Due to the characteristic landscape of the Suwałki region, agriculture thrives on the plains. Land dedicated to agricultural production accounts for more than half of the commune's total area (54.5%), with individual farmers managing approx. 84% of the agricultural land. The predominance of agriculture in the commune is attested by its 1366 individual farms, of which 932 concentrate solely on farming, 60 are exclusively involved in non-agricultural activity, 155 have a mixed agricultural and non-agricultural profile and 219 are not active in the agricultural and non-agricultural sector. An individual farm in the commune covers on average an area of 15.3 ha.

The natural values of the Suwałki commune comprise above all its natural resources, i.e. areas supporting the development of tourism, such as forests, numerous lakes, the varied post-glacial landscape and natural resources found in Wigry National Park. The Suwałki commune is characterised by a high contribution of lakes (almost 11%) to land use structure. Water tourism is possible on seven lakes (Wigry, Pierty, Leszczewek, Mulaczysko, Omułowek, Czarne k. Bryzga and Czarne k. Gawrychrudy), occupying a total area of 2420 ha, which corresponds to as much as 88.5% of the total surface area of lakes in Wigry National Park. Making the commune even more attractive are its many historical buildings, including a real pearl in the form of a former Camaldolese monastic complex

in Wigry, in a picturesque location on a hill overlooking Lake Wigry, one of the largest lakes in Poland.

The area of the Suwałki commune belongs to the Suwałki Forest District, with a predominance of coniferous forest habitats with pine as the dominant species.

Land use structure

The three communes differ in area and population density. The Giby commune occupies the largest area of the three, and Nowinka the smallest. These two communes have a similar population. The commune of Suwałki has the highest population density per km² (Table 1).

In the communes of Giby and Nowinka, the largest part of the area is occupied by forest ecosystems (approx. 75 and approx. 61%, respectively). The commune of Suwałki has the lowest forest cover (approx. 29%). The largest proportion of the area there is occupied by arable land (approx. 54%). The lowest proportion of arable land is found in Nowinka (approx. 11%), which also has a relatively large share of lakes (approx. 15 %) (Figure 1).

Table 1
Area and population of test communes

Characteristics	Unit	Commune		
		Giby	Nowinka	Suwałki
Area	[km ²]	324	204	264
Population	[thousand]	3	2,7	6,6
Population density	[population/km ²]	9	14	24,3

Source: Database – Commune, Institute of Tourism, 1998-2010.

Importantly, meadow and pasture ecosystems occupy similar portions of the total area in the communes of Nowinka and Suwałki (approx. 11%), while their proportion in Giby is by far the smallest.

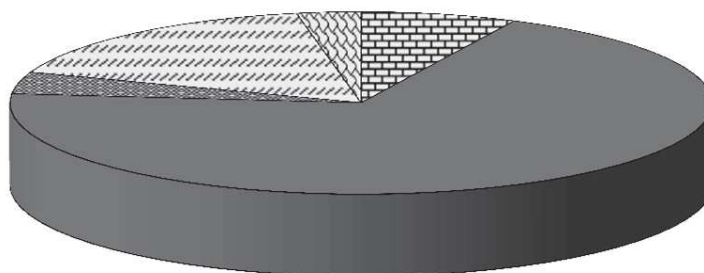
Provisioning and cultural ecosystem services, their measures and indices, for the three test communes

A sample provisioning service from forest ecosystems in the Giby commune

The Giby commune has the highest afforestation index of the three test communes (see Figure 1). Consequently, most of its provisioning services derive from forest ecosystems. The dominant forest habitat in the commune is the coniferous forest, mostly mixed mesic forests (occupying approx. 77% of forested land),

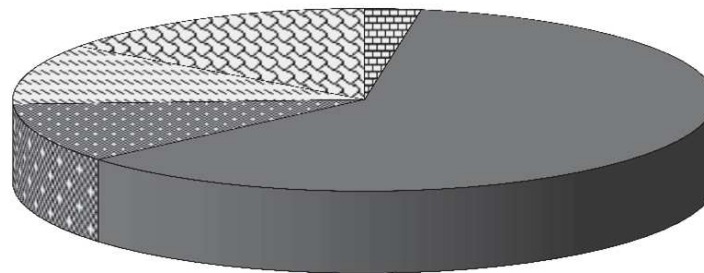
Figure 1
Land use structure of three test communes

Giby



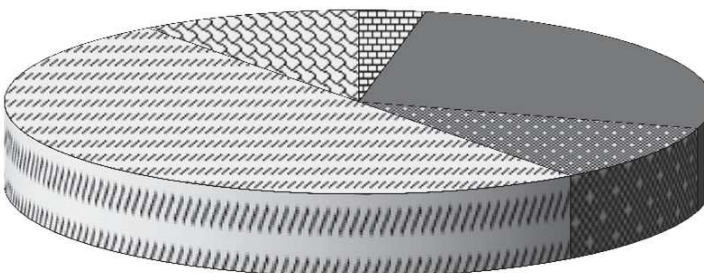
built-up-area forest meadows and pastures arable land and orchards lakes

Nowinka



built-up area forest meadows and pastures arable land and orchards lakes

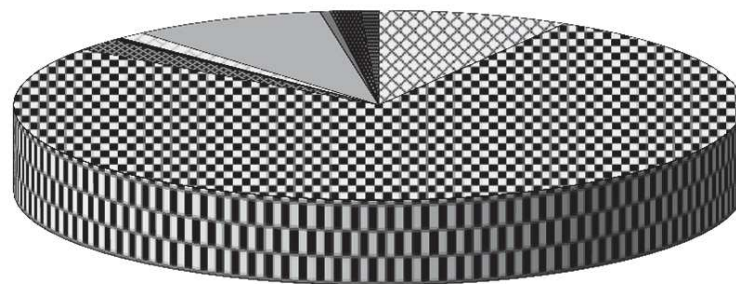
Suwałki



built-up area forest meadows and pastures arable land and orchards lakes

Source: own elaboration.

Figure 2
Shares (%) of forest habitat types in the Giby commune



▣ fresh coniferous forest	▣ fresh mixed coniferous forest	▣ swamp coniferous forest
■ moist coniferous forest	□ fresh forest	▣ fresh mixed forest
■ moist forest	▣ swamp mixed forest	▣ alder forest

Source: own elaboration.

with fresh coniferous forests and mixed fresh broad-leaved forests each contributing approx. 9% (Figure 2). Consequently, forest ecosystems provide most of the commune's ES. The services comprise broadly defined forest products, including wood and other wood products, products of the forest floor and the population of game species. Examples of these services are given in Table 2. Narrowly defined services provided by forest ecosystems in the Giby commune comprise large- and middle-sized timber, whose indices are: average volume of a forest stand, i.e. mean wood stock per unit of forest area (m^3/ha), and the measure of the service is mean annual timber logging (m^3/ha) – Table 2.

Other ES derived directly from forests in the Giby commune include the production of seeds, production of seedlings of main forest tree species, supply of Christmas trees for sale, supply of cones providing the best genetic material for afforestation. The forests of the Giby commune¹⁴ supply seeds from seed-producing stands excluded from cutting and from managed seed-producing stands. Seed-producing stands supply approx. 123 kg seeds a year (Table 2). Directly related to the production of seeds is the production of cones. The gathering of cones of the Giby commune mainly supplies cones of pine and spruce (between 1300 kg and 1500 kg annually), reflecting the forest stand dominance pattern. Of note, the prevailing species in the forest stands of the Giby commune is pine, which reflects the fact that the largest proportion of forested areas in the commune is occupied by coniferous stands (see Figure 2). Spruce makes a much smaller contribution, while the admixtures of oak, maple, sycamore, elm, ash, birch and black alder account for only 1-2%.

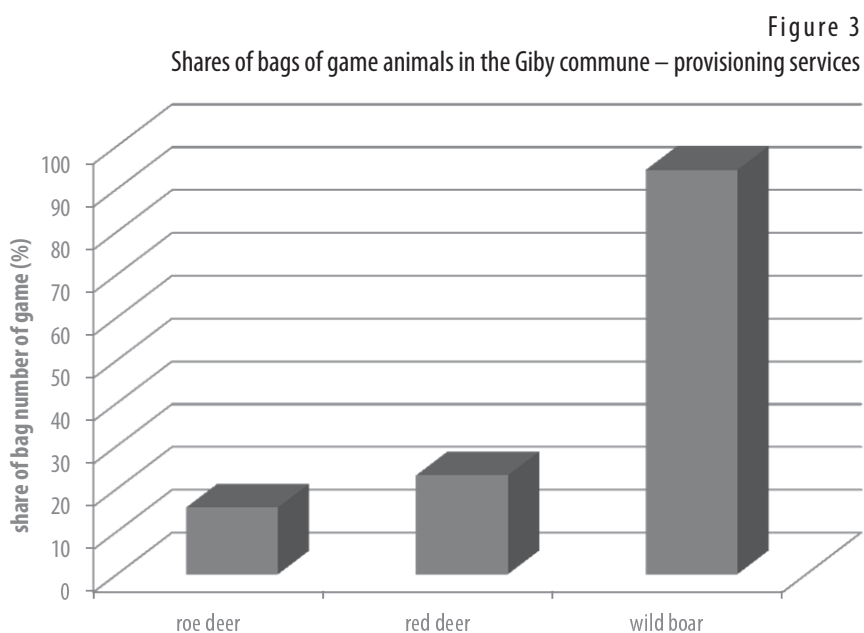
¹⁴ www.gleboki-brod.bialystok.lasy.gov.pl [20-09-2014]; www.pomorze.bialystok.lasy.gov.pl [20-09-2014].

Table 2
An example of provisioning ecosystem services from forest ecosystems in the Giby commune

Services	Index/Measure	Measurment results*
narrowly defined		
Large- and middle-sized timber	average stocks of wood per forest area [m ³ /ha]	627.00
	timber logging, average per year [m ³ /ha]	9.81
Christmas trees	trees sold, average per year	216,00
Cones of coniferous trees	gathering of cones, average per year [kg]	2912.00
Tree seedlings of the main forest tree species	average production per year [thous. pieces]	1782.50
Forest-tree seeds of high genetic value	seed production, average per year [kg]	123.00

* Monitoring of Forest Condition in Forest Districts

Source: own elaboration.



Source: own elaboration.

The production of seedlings of forest trees and shrubs is a very significant ecosystem service. In the Giby commune, this type of service yields an average of 1,782,500 seedlings a year (Table 2), mainly of pine, spruce, oak and (smaller quantities) of linden, maple and black alder.

Forest ecosystems also play a significant role in the supply of game and game meat. A sample narrowly defined ecosystem service obtained from the forest is the population of game species, measured as the bag of individuals hunted. The main game species hunted are roe deer, red deer and wild boar. According to an inventory of March 2012, the roe deer was the most abundant game species and

the stock of red deer was a little less abundant, while the population of the wild boar was the least abundant. In the bag, the highest count was that of wild boars, and the lowest, of roe deer (Figure 3).

A sample cultural service from aquatic ecosystems in the Nowinka commune

The pattern of human use of natural conditions in the Nowinka commune serves as an example of cultural services derived from aquatic ecosystems. The reason, among others, is that lakes have a high contribution among land use forms (approx. 15%) in the commune (see Figure 1). The cultural service broadly defined as recreational and ecotouristic value is associated with the particular value represented by surface water bodies (lakes and rivers) in the commune. Situated in Puszcza Augustowska, the commune of Nowinka includes 9 large lakes and 6 rivers. They are attractive above all to anglers and lovers of water sports such as sailing, canoeing and iceboating. The indices corresponding to the cultural services obtained from the lake ecosystems in the Nowinka commune comprise the number of lakes, the area of a lake, lake depth and lake quality class (Table 3). The quality assessment of the lakes was based on a set of several indices of water quality¹⁵. The nine lakes listed are classified as quality class I or II. The cleanest lakes are Busznica and Długie (Kalejty), classified as quality class I. The lakes differ widely in size, from approx. 17 ha to more than 2000 ha. The largest lake (Wigry) is an exceptional tourist attraction, being known all over Poland and attracting swarms of tourists for years. Lake Wigry is both the largest and the deepest of the nine lakes (Table 3).

For water courses, the relevant indices that should be considered with regard to potential services comprise the number of rivers, the length of a river, the width of the river channel and quality class. Table 4 presents the water quality status¹⁶ of the six rivers of the Nowinka commune which are a source of recreational and ecotouristic services. The rivers are quality class I to III. Only the rivulet of Jałówka has quality class I. It empties into the Rospuda near a site called "Święte Miejsce", frequented by land excursions and cruises¹⁷.

Angling opportunities can serve as an example of a valuable service offered by the commune. It can be measured in terms of the number of spots available for angling or the number of licence-days issued to anglers (Table 5). Canoeing tours are a major and popular tourist attraction in the commune. Among the most beautiful canoeing routes in Poland is that on the rivers Rospuda, Blizna and Szczeberka.

¹⁵ An assessment system developed by the Institute of Environmental Protection. The classification accounted for physicochemical and biological indices, and the final score was assigned to a specific class (I, II, III or out of classification). Report of the Voivodship Environmental Protection Inspectorate in Suwałki, 2008.

¹⁶ Overall assessment of water quality – based on an Ordinance of the Minister of Environment of 9 Nov 2011 as part of water monitoring effort in the years 2010-2013.

¹⁷ www.suwalszczyzna.net [20-09-2014].

Table 3
Selected indices of cultural services and measurement results as exemplified by lakes
in the Nowinka commune

Measurements results			
Lakes			
name	water quality class*	surface [ha]	depth of lake [m]
Blizno	II	238.50	28.80
Blizienko	II	38.80	16.80
Busznica	I	49.40	48.00
Długie (Kalejty)	I	159.70	12.00
Jałowo	II	17.50	11.90
Krusznik	II	26.80	18.00
Mulaczysko	II	18.30	20.50
Tobołowo	II	87.00	9.50
Wigry	II	2118.30	73.00

* Water quality was assessed as part of the Water Quality Assessment Monitoring Program in the years 2010-2012

Source: own elaboration.

Table 4
River quality class in the Nowinka commune - a sample index and measurements of cultural services

Rivers	
name	water quality class*
Blizna	II
Dłużanka	II
Jałówka	I
Olszanka	III
Rospuda	III
Szczeberka	III

* Water quality was assessed as part of the Water Quality Assessment Monitoring Program in the years 2010-2012

Source: own elaboration.

A sample provisioning service from an agroecosystem in the Suwałki commune

The commune Suwałki was included in the study to exemplify provisioning services provided by agroecosystems as arable land occupies an exceptionally high percentage of the area of the commune (see Figure 1). The rural profile of the commune is evidenced by the dominant role played by agriculture in the

Table 5
An example of cultural services from aquatic ecosystems in the Nowinka commune

Services			Index/Measure
broadly defined	narrowly defined	detailed specification	
Recreational and ecotouristic value	surface water	lakes	(a) number of lakes, (b) surface area of lakes [ha], (c) depth [m], (d) water quality class
		rivers	(a) number of rivers, (b) river length [km], (c) river channel width [m]
			angling (a) number of sites adapted for fishing, (b) number of fishing licence-days issued; sailing (a) number of watercourses, (b) number of domestic and international canoeing routes (c) number of cruises

Source: own elaboration.

Table 6
Sample provisioning services in the Suwałki commune

A. Service and index

Service		Index/measure
narrowly defined	detailed specification	
Agricultural plant products	grains, potatoes, industrial crops	(a) tonnes/ha. (b) crop area/ha
Livestock count	cattle, cows, swine, sows, sheep, horses, hens	stocking density (heads of livestock/100 ha of agricultural land)

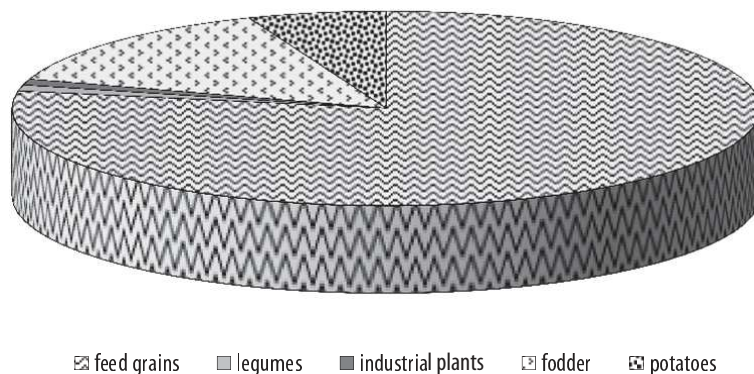
B. Measurement results of stocking density

Livestock count	Measurement result
Total cattle	39.00
Cows	18.30
Total swine	119.00
Total sheep	0.10
Horses	4.80
Hens	1003.00

Source: Local Development Program of the Suwałki commune for the years 2004-2013.

commune's economy. Agricultural production space accounts for more than half of the commune's area (approx. 54.0%). Plant products and the population of breeding animals are examples of narrowly defined ecosystem services provided by agriculture in the Suwałki commune (Table 6AB).

Figure 4
Cropping patterns on arable land in the Suwałki commune



Source: own elaboration.

The indices and measures of agricultural ecosystem services associated with plant production comprise yield per hectare or crop area (ha) – Table 6A.

The crop structure in individual farms demonstrates a dominance of cereals, which occupy nearly 80% of the crop area, while forage plants account for approx. 14%, and potatoes approx. 6% (Figure 4)¹⁸.

The agriculture of the commune of Suwałki is also characterised by a large diversity of animal breeding, with swine and cattle breeding as the predominant types. The index for this service is the head count of livestock /100 ha agricultural land. Of note is also a high proportion of poultry in animal breeding production (Table 6B). Poultry breeding has a long tradition in the Suwałki commune. Several poultry farms are in operation now, with the largest one (40,000 broiler chickens) in Zielone Kamedulskie¹⁹. The agricultural profile of the commune is also owed to its 1,366 individual farms, the number possibly representing an index of the broadly defined category of provisioning services referred to as food production.

Conclusions

The preliminary results of desk studies and correlating the sample services to the diverse environmental conditions permit the following conclusions:

1. The three test communes, manifesting an agriculture- and forest-oriented functional profile and possessing exceptional environmental values on the country scale, represent qualitatively similar natural values.

¹⁸ Program rozwoju lokalnego gminy Suwałki na lata 2004-2013, Suwałki 2004.

¹⁹ Studium uwarunkowań i kierunków zagospodarowania przestrzennego Gminy Suwałki, tekst ujednolicony, Suwałki 2012.

2. The accumulation of natural resources in the communes provides for diverse benefits in the form of ecosystem services associated with rural and wooded areas and exceptional aquatic resources.
3. A comparison of land use patterns in the three communes revealed a predominance of forests in the Giby commune, arable land in the Suwałki commune and the highest percentage of lakes in the Nowinka commune. This provides grounds for expecting that the services offered by nature in the Giby commune will be classified as provisioning services derived from forest ecosystems, while those from Nowinka will predominantly represent cultural services associated with recreation and ecotourism and Suwałki will generally provide provisioning services from agricultural produce.

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