Piotr **LUPA**

THE USE OF DATA FROM THE LAND AND BUILDING REGISTER AND SOIL AND AGRICULTURAL MAPS FOR QUANTIFICATION OF PROVISIONING AGROECOSYSTEM SERVICES

Piotr **Lupa**, PhD – *Adam Mickiewicz University in Poznań, Poland*

Correspondence address:
Department of Integrated Geography
Bogumiła Krygowskiego 10, 61–680 Poznań
e-mail: piotr.lupa@amu.edu.pl

WYKORZYSTANIE DANYCH Z EWIDENCJI GRUNTÓW I BUDYNKÓW ORAZ MAP GLEBOWO-ROLNICZYCH DO KWANTYFIKACJI ŚWIADCZEŃ ZAOPATRUJĄCYCH AGROEKOSYSTEMÓW

STRESZCZENIE: Kwantyfikacji świadczeń zaopatrujących związanych z wytwarzaniem biomasy użytkowej przez agroekosystemy można dokonać przy użyciu map glebowo-rolniczych (MG-R) oraz ewidencji gruntów i budynków (EGiB). Oba opracowania uwzględniają różne systemy klasyfikacji jakości gleb, stąd niezbędne jest określenie wskaźników przeliczeniowych dla uzyskania porównywalności wyników.
Celem badań było opracowanie wskaźników przeliczeniowych plonów normatywnych zbóż podstawowych i siana łąkowego, obliczonych na podstawie danych z EGiB i MG-R dla użytków rolnych gminy Krajenka. Wypracowane współczynniki dają możliwość dwukierunkowej transformacji rezultatów kwantyfikacji analizowanych świadczeń ekosystemów.

SŁOWA KLUCZOWE: zaopatrujące świadczenia ekosystemów, agroekosystem, wskaźniki, mapa glebowo-rolnicza, ewidencja gruntów i budynków

Introduction

Agricultural services fulfil a range of ecological, cultural and economic functions which are of deciding importance for the human existence. The superior role in relation to the other ones is the production of biomass, in particular, the production of plant biomass which constitutes food for people and fodder for animals[1]. In this aspect, the ability to produce usable biomass in agroecosystems, connected with the circulation of matter and the flow of energy, is the most important service from the provisioning services as it serves the satisfaction of basic biological needs of people[2]. It must be added that the provision of food and other organic material depends on the supply of supporting and regulating services, in particular those related to the pollination of cultivated plants by insects and the control of crop pest populations[3].

The level of usable biomass production in agroecosystems is determined by natural factors as well as organizational and economic ones connected, amongst other things, with the adopted cultivation system and the agricultural technology used[4]. The main natural factors that determine the size of yield include the quality of soil, relief (lay of the land), soil humidity and agroclimate, which are the basis for valuation of the agricultural production area in Poland[5].

Soil quality diversification in our country is presented in two spatial aspects. On a detailed scale, the land and building register (LBR) is usually used, which takes into account the valuation classification of agricultural land. On less detailed scales, the agricultural value of soils is reflected using soil and agricultural maps (SAM) based on division into agricultural soil suitability complexes. Both classification systems differ from each other, therefore, it is necessary to determine conversion factors between them to obtain

1 Z.M. Rosin et al., *Koncepcja świadczeń ekosystemowych i jej znaczenie w ochronie przyrody krajobrazu rolniczego*, "Chrońmy Przyrodę Ojczystą" 2011 no. 67(1), p. 3–20.

2 M. Degórski, *Wykorzystanie świadczeń ekosystemów w rozwoju regionów*, "Ekonomia i Środowisko" 2010 no. 1(37), p. 85–97; M. Degórski, *Socio-economic responses to the environment and ecosystem services in regional development*, "Geographia Polonica" 2010 no. 83(2), p. 83–95.

3 K. Norris, S.G. Potts, S.R. Mortimer, *Ecosystem services and food production*, in: R.E. Hester, R.M. Harrison (eds), *Ecosystem services, Issues in Environmental Science and Technology*, vol. 30, 2010, p. 52–69.

4 J. Kopiński, S. Krasowicz, *Regionalne zróżnicowanie warunków produkcji rolniczej w Polsce*, "Studia i Raporty IUNG-PIB" 2010 z. 22, p. 9–29.

5 T. Witek (ed.), *Waloryzacja rolniczej przestrzeni produkcyjnej Polski według gmin*, Puławy 1981; S. Krasowicz, T. Stuczyński, A. Doroszewski, *Produkcja roślinna w Polsce na tle warunków przyrodniczych i ekonomiczno-organizacyjnych*, "Studia i Raporty IUNG-PIB" 2009 z. 14, p. 27–54.

comparable results. It is of significant importance for quantification of provisioning services for agroecosystems related to the provision of usable biomass.

Due to the spatial character of ecosystem services (ES), maps and datasets are a very important source of information in research conducted in this area[6]. This is confirmed by the common use of maps in various studies devoted to the quantification of ES[7].

Aim of the study

The aim of the research was to determine conversion factors of normative yields of basic cereals and meadow hay calculated on the basis of data from LBR and SAM.

An important stage on the way to achieving this research objective is updating the normative size of the yields of cereals assigned to soil valuation classes and agricultural soil suitability complexes based on literature sources. The update of crop yield indices was necessary due to the progressive, gradual increase in the average size of the cereal yield at its very high annual fluctuations[8], which is confirmed by statistical data about varied yields of basic cereals in the years 1992–2015 (figure 1).

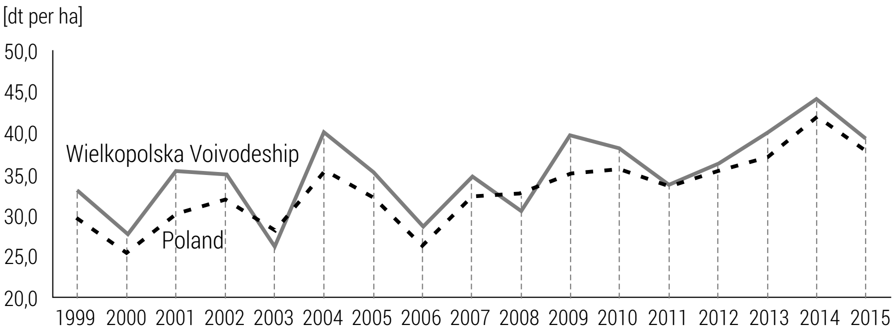

Figure 1. Variation of basic cereals' yield in years 1999–2015 in Poland and Wielkopolska Voivodeship

Source: own work based on CSO data.

6 J. Boyd, *Location, Location, Location: The Geography of Ecosystem Services*, "Resources" 2008 no. 170, p. 10–15; J. Boyd, S. Banzhaf, *What are ecosystem services? The need for standardized environmental accounting units*, "Ecological Economics" 2007 no. 63, 2007, p. 616–626.

7 According to the Web of Science database in the period 2007–2016 (as of 11/10/2016) were published 1176 English-language articles, the subject of which was associated with the use of maps in the study of ecosystem services (the search question was: *TS=[ecosystem AND services] AND TS=[map*]*).

8 J. Grabiński, G. Podolska, *Stan aktualny i perspektywy zmian w produkcji zbóż w Polsce*, "Studia i Raporty IUNG-PIB" 2009 z. 14, p. 55–70.

An additional objective of the study was to estimate potential revenues from the sale of usable biomass per hectare of production area in a given soil valuation class and agricultural soil suitability complexes.

Research area

The research included agroecosystems in the Krajenka Municipality (Złotów District) in the northern part of the Wielkopolska Voivodeship. The municipality is situated within two geographical regions – Krajenka Lakeland and Gwda River Valley.

The analyzed unit was the object of the author's research aimed at obtaining more details on the quantification of recreational and aesthetic services[9] and a determination of the influence of the scale of spatial data on the estimated size of selected ES[10].

Methods and assumptions

The research was based on simulation. It followed the assumption that provisioning services such as the production of usable plant biomass in agroecosystems may be estimated on the basis of detailed information about the yield from five basic cereal species (arable land) and meadow hay (grassland), depending on the natural production capacity of soils that belong to various valuation classes and agricultural suitability complexes.

The normative quantitative valuation method, supported by Geographic Information Systems (GIS), was used. To estimate the monetary value, the market price method was used to determine the potential revenues from the sale of usable biomass.

The spatial diversity of the biomass production level was determined by assigning the normative yield of basic cereals [t/ha/year], (i.e. wheat, rye, triticale, oats and barley) to soil valuation classes and agricultural soil suitability complexes and in the case of grasslands, the index yield of meadow hay [t/ha/year]. Elementary information about the yields of basic cereals was obtained from a research team of the Institute of Soil Science and Plant Cultivation in Puławy supervised by T. Witek[11]. Yield levels from the latest studies

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9 P. Lupa, *Ecosystems' local recreational services valuation. Krajenka municipality case study*, "Ekonomia i Środowisko" 2012 no. 2(42), p. 209–222.

10 P. Lupa, A. Mizgajski, *The influence of the data analysis scale on the estimated size of ecosystem services*, "Ekonomia i Środowisko" 2014 no. 4(51), p. 125–136.

11 T. Witek (ed.), op. cit.

on cereal productivity were the basis for proportionate adjustment of yield levels for individual classes and complexes[12]. For this purpose, an assumption was adopted on the constant difference in the size of basic yields between soil valuation classes of agricultural land and between agricultural soil suitability complexes. Apart from grain, as the main yield, the studies included data on the secondary yield in the form of straw was included (t/ha/year). The size of the secondary yield production was estimated according to a conversion factor as 0.48 of the primary yield[13]. It was the arithmetic value of the indices estimated by the cited authors. For grasslands, the size of meadow hay production was estimated by taking into account the standards defined in the thematic literature[14].

The monetary valuation of the analyzed services was performed using arithmetic means of the price of agricultural products calculated on the basis of the data published by Central Statistical Office (CSO) for the 2006–2015 decade. Based on this kind of statistical data for the country, the average prices of basic cereal grain prices – PLN 574.32 per ton, basic cereal straw – PLN 266.40 per ton, meadow hay – PLN 364.52 per ton were adopted and taken into account in the valuation of provisioning services.

The spatial data about the agricultural soil suitability complexes and soil valuation classes of arable land were obtained from the Soil and Agricultural Map of the Piła Province (1:100 000) and the Land and Building Register (1:2000–1:5000) kept by the District Centre of Geodesic and Cartographic Documentation in Złotów.

Using the updated normative values of yields concerning two soil quality classification systems, spatial data from cartographic studies and GIS tools, the contours of soil valuation classes (figure 2A) were plotted on agricultural soil suitability complexes (figure 2B) and compared. In this way, new soil contours were determined, which constitute intersections of two sets of pol-

12 T. Witek, K. Bukowski, *Produktywność gruntów ornych*, Puławy 1997; H. Terelak, S. Krasowicz, T. Stuczyński, *Środowisko glebowe polski i racjonalne użytkowanie rolniczej przestrzeni produkcyjnej,* Pamiętnik Puławski – Materiały Konferencji, z. 120, 2000, p. 455–469; S. Nawrocki, H. Terelak, *Bonitacja a wartość użytkowa gleb Polski*, in: S. Nawrocki, B. Dobrzański, S. Grundas (eds), *Bonitacja i klasyfikacja gleb Polski*, Lublin 2004, p. 7–10; S. Krasowicz, T. Stuczyński, A. Doroszewski, op. cit., p. 27–54.

13 Index was the arithmetic mean value of the ratios estimated by: D.H. McCartney et al., *Review: The composition and availability of straw and Schaff from small grain cereals for beef cattle in western Canada*, "Canadian Journal of Animal Science" 2006 no. 86(4), 10.4141/A05-092, p. 443–455; W. Denisiuk, *Słoma – potencjał masy i energii*, "Inżynieria Rolnicza" 2008 no. 2(100), p. 23–30.

14 H. Czyż, E. Niedźwiecki, M. Trzaskoś, *Charakterystyka czynników siedlisk łąkowych*, in: M. Rogalski (ed.), *Łąkarstwo*, Poznań 2004, p. 13–21; S. Bródka, A. Macias, *Kryteria i metody waloryzacji zasobów przyrodniczych*, w: S. Bródka (ed.), *Praktyczne aspekty ocen środowiska przyrodniczego*, Poznań 2010.

ygons representing the spatial distribution of complexes and classes (figure 2C). This made it possible to determine differences in normative yields and the construction of conversion factors[15].

Factors calculated in this way make it possible to convert the results of quantification of analyzed provisioning services obtained using the SAM data in a scale of 1: 100 000 into a value which would have been estimated for a given area with high probability, if the data on soil valuation classes of agricultural land from LBR had been used originally.

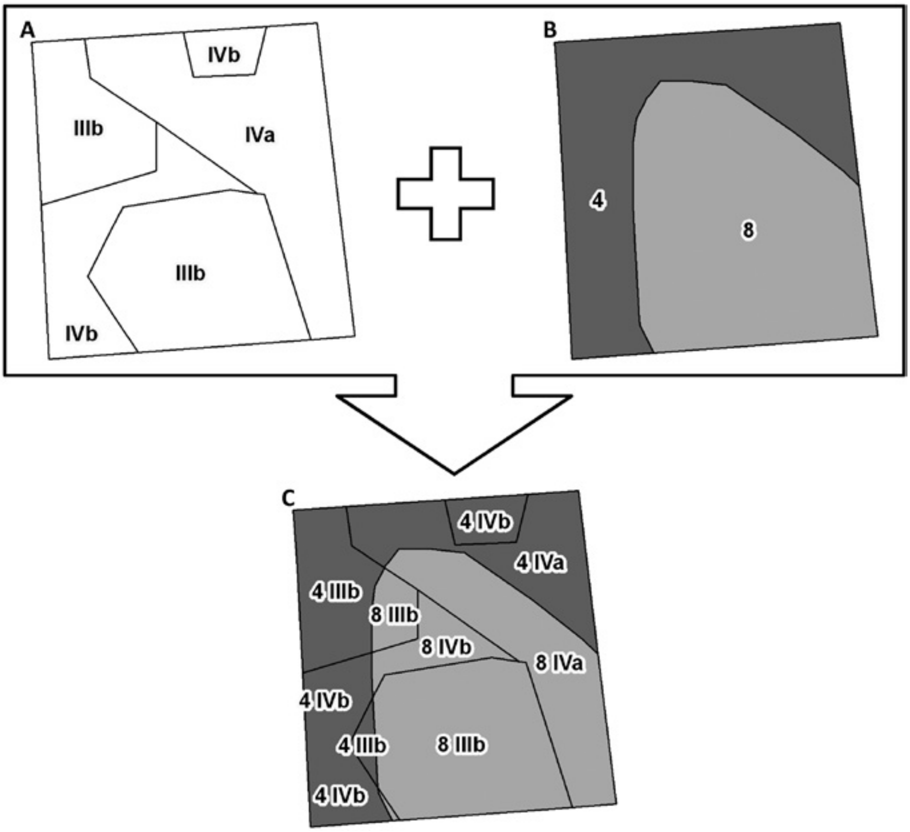

Figure 2. The scheme of determination of the new soil contours

15 The weighted average amount of yield was determined individually for each soil valuation class, based on the spatial data of soil suitability complexes. Calculated amount was compared to the normative yield assigned to a given soil valuation class (table 1 and 2).

Results

Table 1. Updated normative yields of basic cereals (grain and straw) with indices of potential revenue from the sale of usable biomass (arable land)

Classification of soil quality – arable land cereal grain		Yields of [t/ha/year]			Potential revenue from the sale of usable biomass [PLN/ha/year]		
		cereal straw	total	cereal grain	cereal straw	total	
Soil valuation classes of arable land							
I	arable soils of the best quality	5,48	2,63	8,11	3 147	701	3 848
II	arable soils of very good quality	5,08	2,44	7,52	2 918	650	3 568
IIIa	arable soils of good quality	5,01	2,40	7,41	2 877	639	3 517
IIIb	arable soils of medium-good quality	4,52	2,17	6,69	2 596	578	3 174
IVa	arable soils of medium quality, higher	3,97	1,90	5,87	2 280	506	2 786
IVb	arable soils of medium quality, lower	3,41	1,63	5,04	1 958	434	2 393
V	arable soils of poor quality	2,76	1,33	4,09	1 585	354	1 939
VI	arable soils of the poorest quality	2,08	1,00	3,08	1 195	266	1 461
Soil suitability complexes of arable land							
1	very good wheat complex	5,25	2,52	7,77	3 015	671	3 687
2	good wheat complex	4,99	2,39	7,38	2 866	637	3 503
3	poor wheat complex	4,01	1,92	5,93	2 303	511	2 815
4	very good rye complex	4,54	2,18	6,72	2 607	581	3 188
5	good rye complex	3,81	1,83	5,64	2 188	488	2 676
6	poor rye complex	2,75	1,32	4,07	1 579	352	1 931
7	very poor rye complex	2,55	1,22	3,77	1 465	325	1 790
8	good cereal-fodder complex	4,30	2,06	6,36	2 470	549	3 018
9	poor cereal-fodder complex	2,77	1,33	4,10	1 591	354	1 945
10	mountain wheat complex	4,98	2,39	7,37	2 860	637	3 497
11	mountain cereal complex	4,35	2,09	6,44	2 498	557	3 055
12	mountain oat-potatoes complex	3,06	1,47	4,53	1 757	392	2 149
13	mountain oat-fodder complex	2,05	0,99	3,04	1 177	264	1 441
14	arable land suitable for grassland	-	-	-	-	-	-

Source: own work based on literature review and CSO data.

Based on the literature data, the estimated value of provisioning services related to the production of plant biomass was assigned to soil valuation classes and agricultural soil suitability complexes (table 1 and 2).

On the best quality arable land (Class I), the total level of basic cereal production was determined at 8.1 t/ha, which is 2.6 times more than the yield value adopted for the poorest soils (Class VI). In the monetary aspect, the difference between the revenues from the sale of produce was nearly PLN 2400. For agricultural soil suitability complexes, the total cereal yield level on very good wheat complex was estimated at nearly 7.8 ha/t. It was 2 and 2.5 times higher than the potential yield obtained on very poor rye complex and mountain oat-fodder complex. The discrepancy between the potential revenue was nearly PLN 1900 in the first case and PLN 2200 in the second case (table 1).

Depending on the quality of soil of grasslands, the normative yield of the meadow hay was specified at 5 t/ha in Class I up to 1.5 t/ha in Class VI. The difference in the estimated revenues from the sale of such biomass reached nearly PLN 1300. The span of the meadow hay yield per hectare of grassland between the extreme complexes was nearly 3 t, while the difference between revenues was PLN 1050 (table 2).

Table 2. Normative yields of meadow hay with indices of potential revenue from the sale of usable biomass (grasslands)

Classification of soil quality – grasslands		Yields of meadow hay [t/ha/year]	Potential revenue from the sale of usable biomass [PLN/ha/year]
Soil-valuation classes of grasslands			
I	grasslands soils of the best quality	5,0	1823
II	grasslands soils of very good quality	4,0	1458
III	grasslands soils of good quality	3,0	1094
IV	grasslands soils of medium quality	2,0	729
V	grasslands soils of poor quality	1,7	620
VI	grasslands soils of the poorest quality	1,5	547
Soil suitability complexes of grasslands			
1z	very good and good grasslands	4,5	1640
2z	moderate grasslands	2,5	911
3z	poor and very poor grasslands	1,6	583

Source: own work based on literature review and CSO data.

Table 3. Conversion factors of provisioning services value related to production of usable plant biomass in agroecosystems

Classification of soil quality – arable land and grasslands		Conversion factor of total yield (for provisioning agroecosystem services)
Soil suitability complexes of arable land *		
2	good wheat complex	0,763
4	very good rye complex	0,822
5	good rye complex	0,843
6	poor rye complex	1,040
7	very poor rye complex	0,991
8	good cereal-fodder complex	0,904
9	poor cereal-fodder complex	1,003
Soil suitability complexes of grasslands *		
2z	moderate grasslands	0,753
3z	poor and very poor grasslands	1,032
Soil valuation classes of arable land **		
IIIa	arable soils of good quality	0,880
IIIb	arable soils of medium-good quality	0,980
IVa	arable soils of medium quality, higher	1,078
IVb	arable soils of medium quality, lower	1,150
V	arable soils of poor quality	1,220
VI	arable soils of the poorest quality	1,450
Soil-valuation classes of grasslands **		
III	grasslands soils of good quality	0,833
IV	grasslands soils of medium quality	1,248
V	grasslands soils of poor quality	1,468
VI	grasslands soils of the poorest quality	1,626

The use of a factor makes it possible to convert the quantification results for provisioning services connected with the annual production of usable biomass in agroecosystems expressed in tons of biomass per surfaces occupied by:
* a given agricultural soil suitability complex into the size of usable biomass production, which would be estimated for a given surface if data about soil valuation classes from LBR were used; ** a given soil valuation class into the size of usable biomass production which would be estimated for a given surface if data about agricultural soil suitability complexes from SAM in a scale of 1:100 000 were used.

The factors developed on the basis of data obtained for agricultural land in the Krajenka municipality where no soils from complexes 1, 3, 10–14 and 1z and from the valuation classes of soils and grasslands I-II were classified.

In the case of soil valuation classes of arable land, the highest value of the conversion factor was estimated for the poorest arable soils (1.450) and the lowest for good arable soils (0.880). In the case of agricultural soil suitability complexes of arable land, the highest value of the conversion factor was estimated for the poor rye complex (1.040) and the lowest for the good wheat complex (0.763), (table 3).

While transforming the results of quantification from values obtained on the basis of SAM in a scale of 1:100 000 (complexes) into values which would be estimated for the same surface using data from the LBR (classes), reducing coefficients apply more often (<0). This shows that higher quantification results are obtained on the basis of data from SAM than those which were calculated for a given area using LBR data, which was confirmed in previous studies[16].

Conclusions

To quantify provisioning services of agroecosystems related to the production of usable plant biomass, it is recommended that first LBR data should be used, as it is updated on a regular basis by district centres of geodesic and cartographic documentation. Moreover, it is characterized by a higher degree of detail of its contents measured by the average size of the demarcated soil contours, which was 1.45 ha for the analyzed area and which was 64 times smaller than the value from SAM demarcations in a scale of 1:100 000. A drawback of using LBR data is the difficulty in obtaining them for larger areas, e.g. from the entire country or individual regions and the necessity of incurring high costs to gain access to such data.

While using SAM, one should consider the use of conversion factors. They make it possible to obtain similar quantification results for provisioning services using data with a considerably smaller degree of details from SAM in a scale of 1:100 000.

The updated normative yield values, together with indices of the sale of biomass, can be used for the assessment of the agroecosystem potential to provide provisioning services.

Quantification models of agroecosystem services, based on the normative basic cereal yield values are characterized by high sensitivity due to observed considerable fluctuations of the average yield in Poland and in individual regions.

Further research should be aimed at providing missing conversion factors and their testing on other research areas.

16 P. Lupa, A. Mizgajski, op. cit., p. 125–136.

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