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THE INFLUENCE OF THE DATA ANALYSIS SCALE ON THE ESTIMATED SIZE OF ECOSYSTEM SERVICES

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WPŁYW SKALI OPRACOWANIA DANYCH NA SZACOWANĄ WIELKOŚĆ ŚWIADCZEŃ EKOSYSTEMÓW

STRESZCZENIE: Określanie wielkości świadczeń ekosystemów (ES) odbywa się często na podstawie wtórnych źródeł informacji, dlatego istotne jest rozpoznanie wpływu stopnia generalizacji danych źródłowych na dokonywane szacunki.
Celem badań było określenie wpływu stopnia generalizacji danych wejściowych na szacowane wielkości wybranych ES na terenie gminy Krajenka. Kwantyfikacji poddano lokalne walory rekreacyjne i estetyczne środowiska przyrodniczego, należące do grupy świadczeń kulturowych oraz produkcję płodów rolnych w agroekosystemach jako przykład świadczeń zaopatrujących.
W pracy wykorzystano zestaw opracowań kartograficznych i baz danych przestrzennych różniących się poziomem szczegółowości treści. Przy testowaniu hipotez badawczych wykorzystano techniki geoinformacyjne (GIS) i statystyczne, a wśród nich test ANOVA rang Kruskalla-Wallisa i test U Manna-Whitneya. Wykazano istotny statystycznie wpływ stopnia generalizacji danych wejściowych na wyniki kwantyfikacji świadczeń estetycznych oraz świadczeń zaopatrujących związanych z produkcją płodów rolnych.

SŁOWA KLUCZOWE: kwantyfikacja świadczeń ekosystemów, generalizacja kartograficzna, gmina Krajenka

Introduction

The methodological concept of the ES research is aimed at enriching argumentation in favour of moderate use of natural environment resources[1]. A vast majority of research in this area is based on information from secondary sources including cartographic studies. It raises the problem of defining the degree of detail of the input data on the results obtained, especially as regards economic valuation[2]. According to R. Costanza 2012[3], a key challenge in the ES valuation involves the imperfection of the information that one has access to and determination of the influence on the degree of detail of the information about processes in ecosystems.

The research included provisioning services connected with biomass production in ecosystems and cultural services in open areas connected with conditions for rest and relaxation (recreational services) and with experiencing the beauty of nature (aesthetic services).

The analysis was performed for the Krajenka Commune situated in the north part of the Wielkopolska region. It is an area of high natural value connected with the occurrence of forest complexes and natural bodies of water with small pressure of economic activities. According to the ecological and landscape classification prepared for the purposes of the ES assessment in Poland[4], the area of research is situated in the lake district zone characterised by an above-average level of the supply of regulating and cultural services, which is connected with considerable biodiversity and recreational attractiveness of this area.

The aim of the research was to define the effect of the spatial data scale on the results of estimating the size of selected ecosystem services. It was verified whether statistically significant differences occurred between the ES quantification results obtained using the same research method but assigned to spatial data sets from cartographic studies with varying degrees of detail.

[1] A. Mizgajski, *Problemy percepcji idei zrównoważonego rozwoju w naukach przyrodniczych*, in: A. Graczyk (ed.), „Prace Naukowe Akademii Ekonomicznej. Zrównoważony rozwój w teorii ekonomii i w praktyce" z. 1190, Wrocław 2007, p. 171-180; A. Mizgajski, Świadczenia *ekosystemów jako rozwijające się pole badawcze i aplikacyjne*, „Ekonomia i Środowisko" 2010 no. 1(37), p. 10-19.

[2] R.S. de Groot et al., *Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation*, in: P. Kumar (ed.), *Chapter 1: The Economics of Ecosystems and Biodiversity*, London 2010, www.teebweb.org [27-09-2014]; F. Müller, L. Willemen, R.S. de Groot, *Ecosystem services at the landscape scale: the need for integrative approaches*, "Landscape Online" 2011, p. 1-11.

[3] R. Costanza, *Ecosystem functions and services*, „Ekonomia i Środowisko" 2012 no. 2(42), p. 8-17.

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

Research methods and assumptions

Quantification of provisioning services

The spatial differentiation of the biomass production level was defined by assigning the normative yields of basic cereals, including wheat, rye, triticale, oats and barley to the soil quality class and to complexes of agricultural suitability[5]. Yield sizes were updated to include data from more recent studies on cereal yields (cf. A. Macias 1996[6], H. Terelak et al. 2000[7], S. Krasowicz et al. 2009[8]). Apart from grain, as the main yield, the studies included data on the secondary yield in the form of straw was included. The size of the secondary yield production was estimated according to a conversion factor as 0.48 of the primary yield[9]. For grassland, the size of the meadow hay production was estimated, taking into account indices from the literature[10]. The monetary valuation of services connected with grain and straw production for basic cereals and the production of meadow hay were performed using arithmetic means of the price of agricultural products calculated on the basis of the data published by BDL GUS (Local Data Bank, Central Statistical Office) for the 2003-2012 decade.

Spatial data about complexes of agricultural suitability of soil and quality classes of arable land meadows came from agricultural soil maps at a scale of 1:5 000 and 1:100 000 and Land and Building Registers at a scale of 1:2 000 – 1:5 000.

Quantification of cultural services

To estimate the size of cultural services, the scored classification was used, which was based on the results of surveys conducted in randomly selected groups of Krajenka Commune inhabitants. The recreational attractiveness index for the land cover (WAR) and the landscape aesthetic attractiveness index (WAE) were

[5] T. Witek (ed.), *Waloryzacja rolniczej przestrzeni produkcyjnej Polski według gmin*, Puławy 1981.
[6] A. Macias, *Przyrodnicze uwarunkowania rozwoju lokalnego*, in: J.J. Parysek (ed.), *Rozwój lokalny i lokalna gospodarka przestrzenna*, Poznań 1996, p. 67-97.
[7] H. Terelak, S. Krasowicz, T. Stuczyński, *Środowisko glebowe polski i racjonalne użytkowanie rolniczej przestrzeni produkcyjnej*, „Pamiętnik Puławski-Materiały Konferencji" 2000 v. 120, p. 455-469.
[8] 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.
[9] Wskaźnik stanowił średnią arytmetyczną wartość wskaźników oszacowanych przez: D.H. McCartney, H.C. Block, P.L. Dubeski, A.J. Ohama, *Review: The composition and availability of straw and Schaff from smallgrain cereals for beef cattle in western Canada*, „Canadian Journal of Animal Science" 2006 no. 86(4), p. 443-455; W. Denisiuk, *Słoma – potencjał masy i energii*, „Inżynieria Rolnicza" 2008 no. 2(100), p. 23-30.
[10] H. Czyż, E. Niedźwiecki, M. Trzaskoś, *Charakterystyka czynników siedlisk łąkowych*, in: M. Rogalski (ed.), Łąkarstwo, Poznań 2004, p. 13-21; p. Bródka, A. Macias, *Kryteria i metody waloryzacji zasobów przyrodniczych*, in: S. Bródka (ed.), *Praktyczne aspekty ocen środowiska przyrodniczego*, Poznań 2010.

constructed. The construction of indices based on the percentage shares of respondents' answers (Rs), which assigned recreational and aesthetic attractiveness ranks to the individual types of the land cover, the land cover structure and the relief (equation 1).

$$WAR/WAE_{LULC/M/R} = Rs_a + Rs_b/2 \quad (1)$$

Explanation:
Rs_a – the (%) share of responses assigning the highest rank of recreational/aesthetic attractiveness to a given feature.
Rs_b – the (%) share of responses assigning the medium rank of recreational/aesthetic attractiveness to a given feature. explanation

The indices can be interpreted as a reflection of the social value of cultural services assigned by the commune inhabitants to a given type of land cover or relief (lie-of-the-land). They assume values from the range of 0 – 100 points, taking into account the fact that it is very unlikely to obtain extreme values for a research group consisting of a large number of respondents. The subjectivity of the individual assessment of the ES value was limited owing to the inclusion of information from a large group of randomly selected respondents characterised by diverse socioeconomic features and preferences as regards the perception of physiognomic features of the natural environment and rest in open areas. The representativeness of the results is limited to the area inhabited by the population, from which the research group was selected and to populations similar to the research group[11].

The assessment of the influence of the data analysis scale on the estimated size of services

The influence of the scale of the spatial data used on the estimated size of selected ES was tested by means of an experiment involving a comparison of the estimated ES values in areas randomly selected for analysis in the research area. They consisted of circular areas randomly covering fragments of the Krajenka Commune. The surface area of each testing ground was 3.14 ha (r=100 m). 365 research areas were selected for provisioning services and 332 areas were selected for cultural services.

[11] The description of the pilot studies and main surveys, including the structure of the questionnaire, the adopted methodological assumptions and description of respondents are presented in more detail in the following publications: P. Lupa, *Wartość rekreacyjna zbiorników wodnych w koncepcji świadczeń ekosystemów*, in: T. Wiskulski, M. Pilarski (eds.), *Współczesne zagadnienia, problemy i wyzwania w badaniach geograficznych*, v. 1, Gdańsk 2013, p. 41-54; P. Lupa, *Ecosystems' local recreational services valuation. Krajenka municipality case study*, „Ekonomia i Środowisko" 2012 no. 2(42), p. 209-222.

Non-parametric tests were used in the statistical analysis of significance of differences in the estimated ES: the Kruskal–Wallis one-way analysis of variance and the Mann–Whitney U-test[12]. This allowed to verify two research hypotheses:

- H_0: no significant differences in the value of services between individual data accuracy groups (zero hypothesis),
- H_1: a significant difference between at least two data accuracy groups (alternative hypothesis).

The α=0.05 statistical significance level was adopted, which means that the probability of committing an error during the verification of hypotheses was not higher than 5%. When the probability of error was higher than the α level, it was concluded that there were no grounds for rejecting the zero hypothesis. Likewise, when the value was lower than the adopted statistical level α, it was concluded that there were grounds for rejecting the zero hypothesis and the alternative hypothesis was adopted.

Research results

Provisioning services

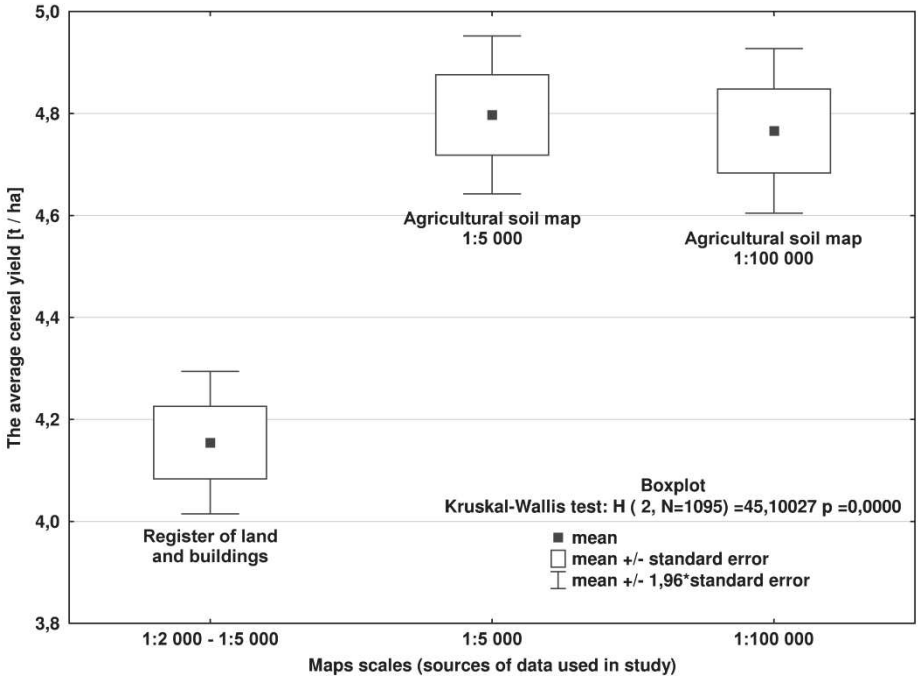
Estimated values of provisional services were assigned to individual soil fertility (quality) classes in agricultural ecosystems. The total crop production level was determined as 2.7 times higher on top-quality arable lands than on the least fertile lands. The differences between the best and poorest grassland complexes as regards provisioning services were 3.3 times higher, i.e. greater than for arable land.

The estimation of biomass production based on spatial structure of soil quality, which has been calculated at the varied detail of spatial data. It amounted to 4.15 t/ha/year (1,894 PLN/ha/year), when data from Land and Building Registers were used, while for data from agricultural soil maps, these values ranged from 4.77–4.80 t/ha/year (PLN 2,173–2,187 ha/year). The results obtained were 7 – 8% lower than average values calculated for agricultural ecosystems in the entire commune, which indicates a good representativeness level of the research sample.

Using the Kruskal–Wallis one-way analysis of variance, it was found that the difference between results obtained from data from various sources were statistically significant. The degree of generalisation of agricultural soil maps did not influence the result, which confirms the high quality of the generalisation procedure of these maps (Figure 1).

[12] A. Stanisz, *Przystępny kurs statystyki w oparciu o program STATISTICA PL na przykładach z medycyny*, Kraków 1998; A. Stanisz, *Podstawy statystyki dla prowadzących badania naukowe. Odcinek 6: ABC weryfikacji hipotez*, 2000, www.mp.pl [20-09-2014].

Figure 1
Graphic interpretation of statistical differences of biomass productivity levels depending on data sources used in study (maps scales)



Source: own study.

Cultural services

According to the survey results, forest and woodlots are the most highly valued areas for rest and recreation as well as surface waters in the research areas, for which the WAR index exceeds 70 points per maximum of 100 points (see equation 1). These values are twice as high as in developed areas, which are considered to be the least attractive (Table 1). The intermediate level of attractiveness was assigned to arable lands and grasslands.

The value of the average weighted index of recreational attractiveness of the land cover WAR for measurement areas calculated on the basis of data from Land and Building Registers was 61.78 points and it was almost identical with values obtained from data from the other sources. The spread of the results was only 0.92 points[13]. Thus, in this case, the degree of detail of individual input data did

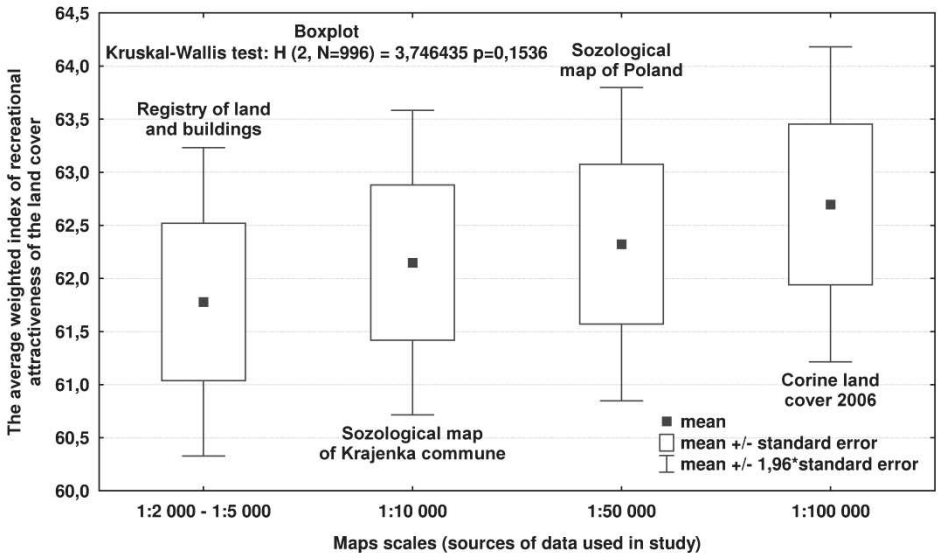
[13] The results of calculations for testing areas were by 0,5-1,6% higher than values of the index calculated for the entire commune, which indicates a very good degree of representativeness of the research sample.

Table 1
Valuation of recreational services in Krajenka Commune

No.	Basic types of land use / land cover (LULC)	Level of recreational attractiveness [% of answers, n=198]			WAR
		low	average	high	
1.	Forests and woodlots	6	35	59	76,3
2.	Surface waters	9	36	55	73,2
3.	Urban green	24	46	30	52,8
4.	Farmlands (arable lands)	28	49	23	47,5
5.	Meadows (grasslands)	22	64	14	45,7
6.	Built-up areas	35	56	9	37,1

Source: own study.

Figure 2
Graphic interpretation of statistical differences of WAR values depending on data sources used in study (maps scales)

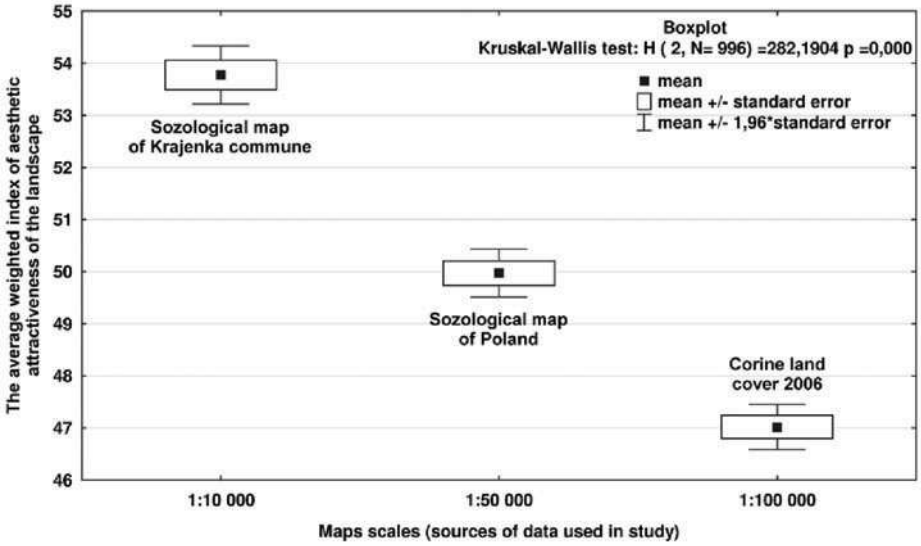


Source: own study.

not influence the quantification result. Despite a trend visible in the graphic representation (Figure 2), the differences turn out to be statistically insignificant.

As regards the landscape aesthetic attractiveness index WAE calculated for measurement areas, it was found that there was a statistically significant relationship between the degree of generalisation of the spatial data and the size of

Figure 3
Graphic interpretation of statistical differences of WAE values depending on data sources used in study (maps scales)



Source: own study.

the average weighted index (Figure 3). The level of this index grows together with a growing degree of detail of the spatial data source.

The index had the lowest value (47.02 points) when data from the Corine land cover 2006 database where used and its value was the highest (53.77 points) when data from the Sozological map of Krajenka Commune were used. It should be noticed that the results of research obtained for the testing areas differed only by 0.1–0.4% from the values calculated for the entire commune.

An additional study was performed as regards aesthetic services, which specifically considered the influence of the degree of detail on three measures of aesthetic value: land cover type (LULC), land cover structure (M) and relief (R).

Forests and surface waters were characterised by the highest value of aesthetic services among the tested land cover types, measured by the value of the WAE_{LULC} index. Considering the forest division according to the share of deciduous and coniferous trees, mixed forests were regarded as the most interesting, as followed by deciduous forests and coniferous forests. A significantly lower value of aesthetic services was estimated for dispersed habitation areas, next for meadows and farmlands. WAE_{LULC} adopted values ranging from 45.2 points for dense developments to 74.9 points for mixed forests (Table 2).

Depending on the degree of detail of the input data used, the value of the average weighted land cover attractiveness index WAE_{LULC} within the measurement areas was estimated at a level ranging from 58.86 to 59.67 points. Such low dif-

Table 2
Results of aesthetic services valuation (WAE_{LULC}, WAE_M, WAE_R values)

No.	Landscape features	Level of aesthetic attractiveness [% of answers, n=187]			Indicator
		low	average	high	
Land use / land cover types (LULC)					WAE_{LULC}
1.	Mixed forests	56	37	6	74,9
2.	Deciduous forests	53	39	7	73,0
3.	Surface waters	54	35	11	71,4
4.	Coniferous forests	45	44	11	67,1
5.	Dispersed habitation areas	25	52	22	51,3
6.	Meadows (grasslands)	19	61	20	49,7
7.	Farmlands	24	49	27	48,7
8.	Densely built-up areas	20	50	30	45,2
Land cover structure					WAE_M
9.	Areas with a mosaic land cover structure	45	42	13	66,3
10.	Areas with monotonous land cover structure	8	58	34	37,2
Relief					WAE_R
11.	Areas with diverse relief (river valleys, hills, etc.)	57	31	12	72,2
12.	Areas with monotonous relief (flat areas)	14	55	31	41,4

Source: own study.

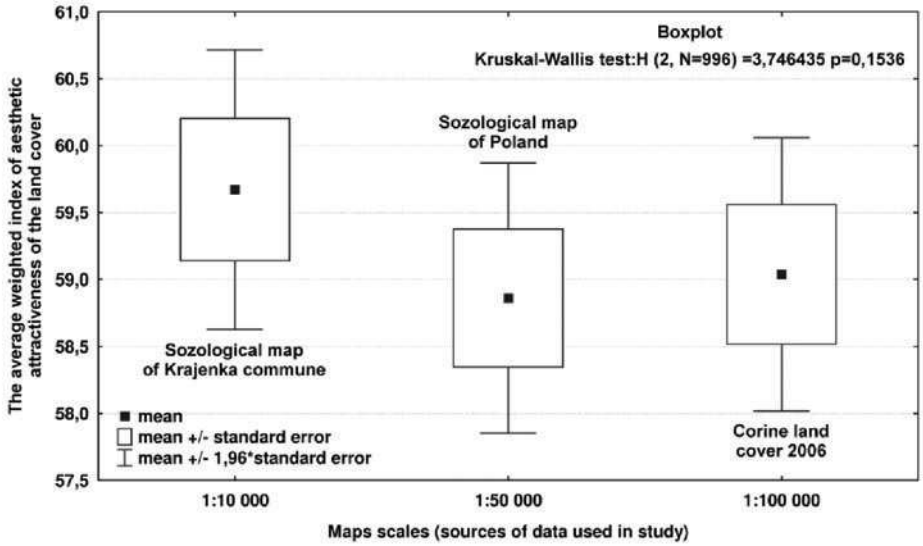
ferentiation in the value of this index shows that there is no significant influence of the type of the spatial data used. This conclusion is confirmed by the results of the Kruskal–Wallis one-way analysis of variance.

Areas with a mosaic land cover structure were characterised by high aesthetic attractiveness in the commune (WAE_M = 66.3), (Table 2), while areas with monotonous land cover diversity were the least interesting (WAE_M = 37.2). Considering three different sources of spatial data used during the quantification, the average weighted index of aesthetic attractiveness of the land cover structure assumed values ranging from 40.34 to 57.91 points for the measurement areas[14].

The conducted statistical analysis confirmed the occurrence of significant differences between values WAE_M calculated using input data with a different degree of generalisation (Figure 5). The research proved that the estimated level of the value resulting from the land cover structure decreases together with an increase in the degree of the input data generalization used for quantification.

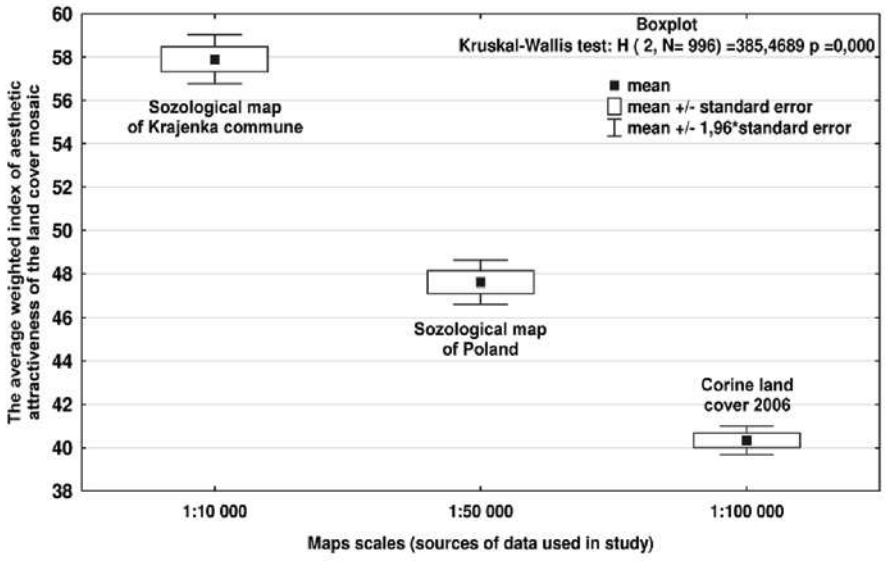
[14] The results of calculations for testing areas were by 0,4-1,7% lower than values of the index calculated for the entire commune, which indicates a very good degree of representativeness of the research sample.

Figure 4
Graphic interpretation of statistical differences of WAE_{LULC} values (land cover types) depending on data sources used in study



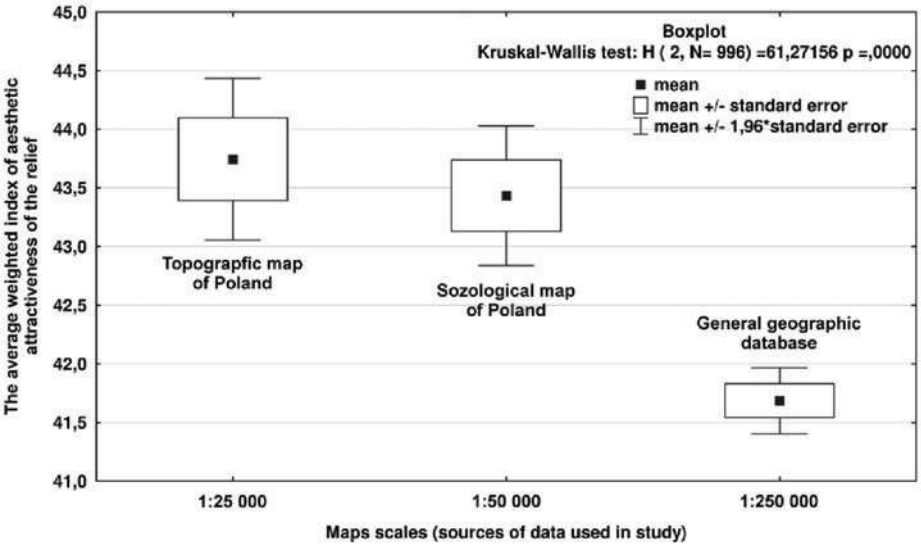
Source: own study.

Figure 5
Graphic interpretation of statistical differences of WAE_M values (land cover structure) depending on data sources used in study (maps scales)



Source: own study.

Figure 6
Graphic interpretation of statistical differences of WAE_R values (relief) depending on data sources used in study



Source: own study.

In the respondents' opinion, areas with diverse relief (borderline areas of river valleys and lake troughs, hilly areas with considerable height difference and high and varied slope) were by far more visually attractive than vast flat areas with monotonous lie-of-the-land and small height difference (e.g. outwash plains, strips of flat ground moraine). The WAER value was estimated at levels ranging from nearly 41.5 points for areas with monotonous lie-of-the-land to 72.2 points for areas with diverse relief. The average weighted index of the aesthetic attractiveness of the relief for the areas under analysis (WAE_R) assumed values ranging from 41.69 to 43.75 points, depending on the source of spatial data from which information about the elevation diversity of the area is obtained. These values differed only by 0.2–0.6% from the values of the index calculated for the entire commune, which confirms the representativeness of the tested sample.

Statistical analysis confirmed the existence of significant differences between WAE_R values calculated in accordance with the General geographic database at a scale of 1:250 000 (Figure 6), and a lack of such differences between the levels of such an index calculated from a topographic map at a scale of 1:25 000 and the thematic map at a scale of 1:50 000. The obtained result can be considered as approximate to the young glacial lowlands. Obviously the more intense relief needs for a more detailed scale of spatial data.

Conclusions

The results obtained can be assigned to the trend of methodological studies related to ES quantification. In the literature devoted to this area, a relationship is noticed between the obtained results of quantification and the degree of generalisation of the input data and the spatial scale at which a given service is considered (cf. K. M. Konarska et al. 2002[15], M. Kandziora et al. 2002[16], L. Hein et al. 2006[17], B. Marion-Lopez et al. 2009[18], Y. Zhang et al. 2013[19]). Against this background, this study analyses a specific set of ecosystem services on a local scale. The results obtained did not confirm previous findings (K. M. Konarska, op. cit.), which showed that an increase in the degree of detail of spatial data led to an increase of the size of the estimated services by several times. For provisioning services, results with the opposite trend were obtained as data with a higher degree of detail from cadastral maps resulted in a nearly 20% decrease in the estimated values of services than those obtained from less detailed agricultural soil maps. The results presented also make it possible to conclude that correctly generalised maps prepared on the same basis of empirical research do not cause differences in the values of the calculated provisioning services.

The results obtained for cultural services also show a diversified situation. The estimated level of recreational services did not show statistically significant different conditions by the degree of detail of the spatial data. Significant differences occurred, on the other hand, for aesthetic services, for which the calculated values were higher for more detailed sources of spatial data.

In general, it can be concluded that the diversity of the size of the spatial data should be considered critically in the light of the assessment of the source data used. It is of lesser importance for comparative studies when homogeneous databases are used. Assuming a similar systematic error, registered differences are not encumbered with this error. Particular care must be exercised while interpreting the absolute values and while comparing the results obtained on the basis of data from various sources.

[15] K. M. Konarska, P. C. Sutton, M. Castellon, *Evaluating scale dependence of ecosystem service valuation: a comparison of NOAA-AVHRR and Landsat TM datasets*, "Ecological Economics" 2002 no. 41, p. 491-507.
[16] 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.
[17] 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.
[18] B. Martin-Lopez, E. Gómez-Baggethun, P.L. Lomas, C. Montes, *Effects of spatial and temporal scales on cultural services valuation*, "Journal of Environmental Management" 2009 no. 90, p. 1050-1059.
[19] Y. Zhang, C. Holzapfel, X. Yuan, *Scale-dependent ekosystem services*, in: S. Wratten, H. Sandhu, R. Cullen, R. Costanza (eds.), *Ecosystem services in agricultural and urban landscapes*, 2013, p. 107-121.