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EVALUATION OF THE LAND USE STRUCTURE IN THE WARMIAN-MASURIAN VOIVODESHIP (POLAND) BASED ON VARIOUS CLASSIFICATION METHODS – CHANGES IN 2002–2012

Magdalena Jastrzębska, Marta K. Kostrzewska

Department of Agroecosystems
University of Warmia and Mazury in Olsztyn

Key words: agricultural landscape, municipalities, land use trends, ecosystem evaluation, cluster analysis.

Abstract

The article evaluates the land use structure in municipalities of the Warmian-Masurian voivodeship (Poland) in 2002–2012. The dynamics of changes in land use and the correlations between the components of the agricultural environment and land use structure were determined. The trends in land use and agricultural land management were identified, and agricultural and forest ecosystems were evaluated. Clusters of municipalities characterized by similar habitat conditions and land use were identified. The land use structure in the analyzed region was highly stable, and it was strongly correlated with the natural environment. A minor decrease in the percentage share of arable land, grassland and orchards was noted, and it was accompanied by an increase in forest cover in all municipalities. The forest cover in Warmia and Mazury exceeds the level planned for 2020. The applied classification methods produce highly similar results, and they point to clear regional variations in the natural and agricultural environment. The northern part of the region comprises mostly agricultural land, and it ranks lower with regard to its ecological importance. Agricultural acreage is also the predominant type of land use in the south-western part of the region despite poor quality soils. The southern and south-eastern parts of the region are also characterized by low quality soils, they feature a higher share of forests and grasslands which increase their ecological significance and raise their recreational appeal.

OCENA ZAGOSPODAROWANIA ZIEMI W WOJEWÓDZTWIE WARMIŃSKO-MAZURSKIM (POLSKA) ZA POMOCĄ RÓŻNYCH METOD KLASYFIKACJI – ZMIANY W LATACH 2002–2012

Magdalena Jastrzębska, Marta K. Kostrzewska

Katedra Agroekosystemów
Uniwersytet Warmińsko-Mazurski w Olsztynie

Słowa kluczowe: krajobraz rolniczy, gminy, kierunki użytkowania ziemi, waloryzacja ekologiczna ekosystemów, analiza skupień.

Address: Magdalena Jastrzębska, University of Warmia and Mazury in Olsztyn, pl. Łódzki 3, 10-718 Olsztyn, Poland, phone: +48 (89) 523 48 29; e-mail: jama@uwm.edu.pl

Abstrakt

W artykule przedstawiono ocenę zagospodarowania ziemi w gminach województwa warmińsko-mazurskiego w latach 2002–2012. Oceniono dynamikę zmian w sposobach wykorzystania przestrzeni i zależności między elementami środowiska rolniczego a strukturą jego użytkowania, określono kierunki użytkowania ziemi i zagospodarowania użytków rolnych, dokonano przyrodniczej waloryzacji ekosystemów rolno-leśnych. Wyodrębniono skupienia gmin o podobnych warunkach siedliskowych i sposobach użytkowania gruntów. Struktura użytkowania ziemi w województwie wykazywała dużą stabilność i silną zależność od warunków przyrodniczych. Generalnie w regionie udział gruntów ornych, użytków zielonych i sadów nieznacznie się zmniejszył, ale we wszystkich gminach wzrosła lesistość. Aktualna lesistość województwa przekracza poziom zakładany na rok 2020. Zastosowane metody klasyfikacji wykazują dość dużą zbieżność i wskazują na wyraźne regionalne zróżnicowanie przyrodniczo-rolnicze. W pasie północnym województwa, przestrzeni o gorszych walorach ekologicznych, ale większej przydatności do celów rolniczych, dominuje takie właśnie zagospodarowanie. W części południowo-zachodniej podobnie dominuje użytkowanie rolnicze, mimo gorszej jakości gleb. Część południowa i południowo-wschodna, odznaczająca się również słabszymi glebami, jest silniej zalesiona i zadarniona, co podwyższa jej wycenę ekologiczną i staje się atutem rekreacyjnym.

Introduction

The agricultural landscape is a mosaic of agricultural land, forests and rural settlements. Meadows and pastures are also important elements of the agrarian environment, whereas orchards play a minor role in this system (STANIAK 2009). It is generally believed that agriculture and forestry are the key branches of the economy which are responsible for landscape protection and management. Rational spatial management policies should be based on quantitative evaluations of landscape quality and the condition of natural resources (KUNDROTAS 2002, KRASOWICZ et al. 2011). Land use structure should be synchronized with the natural and economic environment, subject to the sustenance and cultural needs of the local community (KUNDROTAS 2002, KOZOVÁ and FINKA 2010, SIUTA 2012). Changes in land use are inevitable and necessitated by urban development and the construction of transport networks (KRASOWICZ et al. 2011), but excessive anthropogenization leads to direct or indirect deformations of the natural landscape (*Planning of forestation*... 2002, SIUTA 2012). The loss of vast stretches of agricultural land and forests has a particularly devastating effect on ecosystem balance (VERBURG et al. 2009). For this reason, the course and dynamics of changes in land use should be monitored on a regular basis (ZANCHI et al. 2007, KRASOWICZ et al. 2011).

Land use analyses are one of the main tools supporting evaluations of the agricultural landscape (HARKOT et al. 2011). Poland has a well-established record of research into agricultural land use and changes in the agrarian environments, as demonstrated by numerous publications that discuss the issue on a regional and national basis. Land use analyses are conducted with the involvement of various mathematical methods, including multidimen-

sional statistical analyses (BAŃSKI 1997, KUŚ et al. 2002, KOSTRZEWSKA et al. 2004, 2006, ZARÓD 2009, JASKULSKI and JASKULSKA 2011).

The Warmian-Masurian voivodeship is characterized by significant landscape diversity owing to the wealth of its natural resources as well as its turbulent political and economic history. This article makes a reference to earlier studies of land use in different municipalities of the region (WANIC et al. 2002, KOSTRZEWSKA et al. 2004). The last analysis was performed 10 years ago, and this research attempts to analyze the changes that have taken place in the past decade, including Poland's accession to the European Union. The main objectives of the research were: to evaluate the changes in land use structure in the Warmian-Masurian voivodeship (Poland) in 2002–2012, and to compare land use evaluation methods used in the study.

Materials and Methods

This evaluation is based on habitat indicators developed by the Institute of Soil Science and Plant Cultivation (IUNG) (*Waloryzacja rolniczej przestrzeni*... 1981) as well and land use data covering the municipalities of the Warmian-Masurian voivodeship.

The abovementioned habitat indicators were developed on the basis of the assessment of the most important effects of habitat factors on the potential crops productivity. The analysis was performed for all municipalities in Poland. The point method was used by cited Authors in the assessment. The details of the method are included in Table 1.

Table 1

Evaluation of agricultural production area quality developed by the Institute of Soil Science and Plant Cultivation (IUNG) (*Waloryzacja rolniczej przestrzeni*... 1981)

Valuation index	Basis of evaluation	Range of points
Soil quality and agricultural suitability	Polish system of soil quality evaluation (classes and complexes of agrarian suitability of the soil)	18–95
Agroclimate	effect of climatic factors on crops yields increase	1–15
Land relief (lay of the land)	the share of particular types of relief (favourable and unfavourable for farming) within the agricultural land	0–5
Water relations	the share of particular categories of soil moisture (favourable and unfavourable for farming) within the agricultural land	0.5–5
Index of agricultural production area quality	total score of four indicators	19.5–120

The main body of data (for the analyzed municipalities, as at 1 January 2012) was provided by the Regional Center for Geodetic and Cartographic Documentation, courtesy of the Department of Rural and Agricultural Development of the Marshal's Office of the Warmian-Masurian voivodeship in Olsztyn. The remaining information was obtained from regional statistical publications (Basic information... 2003, Statistical Yearbook... 2003). In our analysis, rural and urban municipalities with the same name were classified as single units, and the area occupied by different types of land was summed up (a total of 101 municipalities were evaluated). The diversity in the land use structure in 2002 and 2012 was expressed with basic statistical data.

In the studied period, the dynamics of changes in land use in the analyzed municipalities was expressed by the redistribution coefficient (RC; after BAŃSKI 1997, modified), calculated based on five types of land (arable land, permanent grassland, orchards, forests, other):

$$RC = \sum_{j=1}^{m} r_j \cdot 200^{-1}$$

where:
m – number of land types,
j – 1, 2, ..., m,
$r_j = |W_j(t_1) - W_j(t_0)|$,
W_j – share of the jth type of land in the municipality's area,
t_1 – final year (2012),
t_0 – starting year (2002).

The coefficient takes on values in the range of 0–1 (where values closer to 0 represent a more stable land use structure).

The strength of correlations (dependencies) between the elements of agriculturally productive area (quality and agricultural suitability of soils, agroclimate, land relief, water relations) and the predominant types of land was determined with the use of correlation coefficients.

The natural and agricultural diversity of the local landscape was evaluated with the involvement of three methods:

1. Land use trends in the studied municipalities were determined by the successive quotients method based on the ratio of agricultural land (R) to forests (F). Seven main land use trends were identified based on the six major quotients (KULIKOWSKI 1969). Land use categories were named in line with the nomenclature proposed by PAWŁOWSKI et al. (1992) and MAGIERA-BRAŚ (1992): R6 – predominantly agricultural; R5F1 – agricultural function with a share of forests; R4F2 – agricultural function with forests; R3F3 – mixed agricultural

and forestry production; R2F4 – forests with agricultural land; R1F5 – forests with a share of agricultural land; F6 – predominantly forests. Agricultural land use trends were identified based on the ratio of arable land to permanent grassland, and the following nomenclature was used: A6 – arable land, A5G1 – arable land with a share of grasslands, A4G2 – arable land with grasslands, A3G3 – mixed arable lands and grasslands, A2G4 – grasslands with arable land.

2. A random sampling method proposed by HERNIK (2001) was used to perform an ecological evaluation of land in the analyzed municipalities. In this method land use types (= ecosystems) are evaluated in view of their ecological attributes: water retention, degree of land erosion, sanitary and hygiene standards, health benefits and esthetic value. The details of the assessment are included in Table 2. For each municipality the average value of the index for evaluating agricultural and forest ecosystems was calculated according to the following formula:

$$\mathrm{AEEI} = \left[\sum_{j=1}^{m} \mathrm{EEI_j} \cdot A_j\right] \cdot \left[\sum_{j=1}^{m} A_j\right]^{-1}$$

where:
AEEI – average ecosystem evaluation index,
m – number of land types,
j – 1, 2, ..., m,
$\mathrm{EEI_j}$ – ecosystem evaluation index of the jth type of land (meadows, pastures, orchards, arable land, forests),
A_j – area of the jth type of land.

Table 2
Ecological evaluation of selected land use types using the random sampling method (HERNIK 2001)

Ecological attributes	Land use types				
	meadows	pastures	orchards	arable land	forests
Water retention	2	2	2	1	3
Degree of land erosion	2	2	2	1	3
Sanitary and hygiene standards	2	2	1	0	3
Health benefits	1	1	1	0	3
Esthetic value	2	1	1	1	3
Ecosystem evaluation index	1.8	1.6	1.4	0.6	3.0

0 – lack of positive impact on the environment, neutral impact; 3 – highly positive impact on the environment

3. Habitat indicators and elements of the land use structure (a total of 10 variables, evaluation of soil, agroclimate, land of relief and water relations, index of agricultural production area quality, share of farmland, arable land, perranent grassland, orchards and forests) were used to perform a *k*-means cluster analysis of the examined municipalities (FILIPIAK and WILKOS 1998). Six clusters of municipalities with similar characteristics were identified.

Results

Although the Warmian-Masurian voivodeship is generally recognized as an agricultural region, the local conditions are less than ideal for agricultural production (evaluation index of 66.2 points). On average, agricultural land has a 53.0% share of the local land use structure, and this parameter remained fairly stable in the past decade (Table 3). Similarly to the data recorded ten years ago, agricultural land accounts for more than 50% of total area in 70 municipalities. The number of municipalities where agricultural land has more than a 70% share in the local land use structure has decreased from 24 in 2002 to 19 in 2012. The median value of this parameter is higher than the weighted average for the region, but it is lower than that noted ten years ago. The past decade witnessed an insignificant drop in the share of arable land, grassland and orchards in the region, whereas an increase was noted in total forest cover. The above trend was observed in the vast majority of the analyzed municipalities. The median values illustrating the share of arable land, grassland and orchards decreased, and they were generally lower than the respective weighted averages for the region. The average share of forests increased, and

Table 3

Land use structure in the Warmian-Masurian voivodeship – statistical data

Category	Year	Municipalities			Region Average
		median	range of variation	coefficient of variation	
Agricultural land [%]	2002	58.0	11.5–83.4	28.7	53.9
	2012	56.7	11.1–83.6	28.9	53.0
Arable land [%]	2002	38.7	5.2–71.5	36.4	37.3
	2012	37.7	5.0–66.0	36.1	36.6
Permanent grassland [%]	2002	16.7	5.4–32.1	34.5	16.4
	2012	16.2	5.3–38.0	35.5	16.3
Orchards [%]	2002	0.12	0.01–1.11	97.6	0.16
	2012	0.09	0.00–0.74	102.0	0.11
Forests [%]	2002	24.5	0.1–74.1	52.0	29.6
	2012	27.5	0.3–74.8	48.3	32.5

this trend was illustrated by a higher median value (which, however, remained below the average). In the group of 101 analyzed municipalities, relative agricultural area increased in only 17 administrative units, and the above changes were not accompanied by a simultaneous drop in forest cover. The arable acreage increased in 30 municipalities, and the said expansion was achieved by expanding agricultural area in five municipalities, whereas in 17 municipalities, it was accomplished by reducing the share of meadows, pastures and orchards. In 23 municipalities, arable land accounted for minimum 50% of the total area (down from 24 in 2002). The share of grasslands increased in only 28 municipalities, and in 17 administrative units, this increase took place at the expense of arable land or orchards. Relative orchard area increased in only one municipality (Dobre Miasto). This form of land use is still marked by the highest degree of spatial variation. The range of forest cover variation remained fairly wide and has not significantly changed, but the median value is higher than that noted ten years ago.

Spatial distribution of forest cover changes in 2002–2012 is presented in Figure 1. In the past decade, forest cover increased in all municipalities but two (Markusy, Iłowo-Osada), where an insignificant decrease was noted. In most municipalities, forest cover increase reached up to 5%. A rise of over 5% was observed in the municipalities of Pieniężno, Srokowo, Płoskinia, Lidzbark

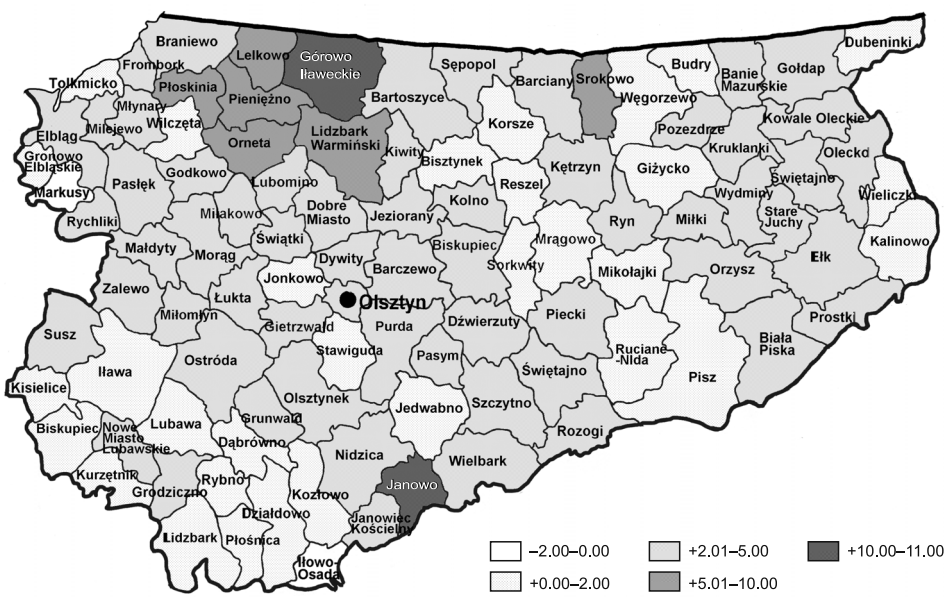

Fig. 1. Changes in share of forests in the municipalities of the Warmian-Masurian voivodeship in 2002–2012 [%]

Warmiński, Lelkowo and Orneta, and in the area of Górowo Iławeckie and Janowo it even exceeded the 10% level. With the exception of Janowo, these municipalities are located in the north-west part of Poland, where the share of forests in total lands amounts to between 20 and 40%. Currently, only in two municipalities (Gronowo Elbląskie and Markusy) forest cover is less than 10%. Although, in comparison to the situation in 2002, the number of municipalities with over 50% forest cover increased by only one unit, it is worth noting that the number of municipalities where the forest share is less than 20% decreased from 36 to 27. This decline indicates a positive change in municipalities with relatively low forest cover. Furthermore, in 31 municipalities, forests had a 33–34% share of the local land use structure, which exceeds the level planned by the National Afforestation Program (ŁONKIEWICZ 1995).

Low values of the redistribution coefficient point to a relatively stable land use structure in the past decade, although local variations were noted (Table 4). The most radical changes were observed in the municipality of Gronowo Elbląskie where around 20% of the area covered by arable land was transformed to grassland. Ruciane-Nida, the municipality with the highest forest cover (more than 70%), was characterized by the greatest structural stability.

The coefficients of correlation shown in Table 5 indicate that land-use planning decisions were made based on soil conditions, followed by the local hydrological regime.The share of forests in the municipalities' total area showed a strong negative correlation with the soil quality. The above mathematical relationship shows that the majority of forest land spreads over notably poorer grounds. Additionally, these areas are unsuitable for agriculture management due to inadequate water conditions, as evidenced by a negative correlation between forest cover and the relevant valuation index. Hunger for land, well-known in history, always pushed forest ecosystems to lands marked with the worst conditions. In the analyzed period, the strong positive correlation between soil quality and agricultural suitability, water relations and the share of agricultural and arable land, and the negative correlation between soil quality and agricultural suitability, water relations and forest cover were weakened. The above implies that contrary to the common practice of the 1980s and the 1990s (WANIC et al. 2002), afforestation programs no longer involve only soils of the poorest quality. The positive correlations between the share of grasslands and the quality of agriculturally productive area (all components, excluding agroclimate) and between the share of orchards vs. agroclimate and soil quality were strengthened.

Land use trends in the analyzed municipalities in 2012 are presented graphically in Figure 2. Agriculture was the predominant form of land use in 74 out of 101 municipalities (down from 77 municipalities in 2002). Five

Table 4
Dynamics of changes in the land use structure of the Warmian-Masurian voivodeship in 2002–2012 expressed by the redistribution coefficient (RC)

RC (intervals)	Municipalities
≤0.010	Ruciane-Nida (0.007), Lubawa (0.010)
0.011–0.020	Działdowo (0.015), Iłowo-Osada (0.016), Kurzętnik (0.016), Kalinowo (0.017), Iława (0.017), Lidzbark (0.017), Budry (0.018), Biskupiec (0.019), Dąbrówno (0.019), Dubeninki (0.019), Jonkowo (0.019), Sorkwity (0.019), Stawiguda (0.019), Olsztynek (0.020)
0.021–0.030	Janowiec Kościelny (0.021), Mrągowo (0.021), Tolkmicko (0.021), Rybno (0.022), Jedwabno (0.023), Kolno (0.,023), Reszel (0.023), Gołdap (0.024), Mikołajki (0.024), Nidzica (0.024), Ostróda (0.024), Piecki (0.024), Płośnica (0.024), Pozezdrze (0.024), Stare Juchy (0.024), Biskupiec (0.025), Kiwity (0.025), Pasym (0.025), Pisz (0.025), Barciany (0.026), Dźwierzuty (0.026), Nowe Miasto Lubawskie (0.026), Susz (0.026), Barczewo (0.027), Ełk (0,027), Gietrzwałd (0,027), Miłakowo (0,027), Purda (0,027), Miłki (0.028), Prostki (0.028), Grodziczno (0.029), Olecko (0.029), Małdyty (0.030), Miłomłyn (0.030), Pasłęk (0.030), Zalewo (0.030)
0.031–0.040	Biała Piska (0.031), Korsze (0.031), Kozłowo (0.031), Świętajno k. Szczytna (0.031), Wydminy (0.031), Szczytno (0.032), Dywity (0.033), Łukta (0.034), Ryn (0.034), Grunwald (0.035), Kruklanki (0.035), Świętajno (0.035), Frombork (0.036), Świątki (0.037), Wielbark (0.038), Kowale Oleckie (0.039), Młynary (0.039), Bisztynek (0.040)
0.041–0.050	Jeziorany (0.041), Wieliczki (0.043), Wilczęta (0.043), Olsztyn (0.044), Banie Mazurskie (0.045), Lubomino (0.046), Dobre Miasto (0.047), Morąg (0.047), Kętrzyn (0.048)
0.051–0.060	Godkowo (0.051), Lelkowo (0.051), Milejewo (0.052), Płoskinia (0.052), Giżycko (0.054), Rozogi (0.055), Węgorzewo (0.057), Lidzbark Warmiński (0.059), Elbląg (0.060), Kisielice (0.060), Orneta (0.060)
0.061–0.070	Braniewo (0.061), Bartoszyce (0.062), Srokowo (0.063), Pieniężno (0.066), Sępopol (0.066)
0.071–0.080	Rychliki (0.074)
0.081–0.090	Orzysz (0.087)
0.091–0.100	Markusy (0.094)
0.101–0.110	Górowo Iławeckie (0.106)
0.111–0.120	Janowo (0.112)
>0.121	Gronowo Elbląskie (0.220)
0.020	For the voivodeship

municipalities were classified as predominantly agricultural (R6), three of which (Elbląg, Gronowo Elbląskie and Markusy) are characterized by fertile soils of Żuławy Wiślane (Vistula delta) region. Ruciane-Nida was listed in the F6 category on account of its high forest cover and very few changes in the local land use structure. In comparison with 2002, changes in land use trends were noted in 14 municipalities: the significance of forest management increased in 12 municipalities, whereas only two municipalities (Elbląg, Lidzbark) placed greater emphasis on agricultural production (Table 6). In 89 municipalities,

Table 5

Coefficients of linear correlation between the percentage share of main land use categories and the valuation index of the analyzed area

Valuation index	Year	Percentage share in land use structure				
		agricultural land	arable land	grassland	orchards	forests
Soil quality and agricultural suitability	2002	0.569***	0.522***	0.287**	0.187**	–0.657***
	2012	0.559***	0.488***	0.359***	0.205**	–0.637***
Agroclimate	2002	0.083	0.166	-0.186	0.150	–0.104
	2012	0.069	0.142	-0.154	0.262**	–0.092
Land relief	2002	-0.013	-0.019	0.013	-0.054	0.114
	2012	0.002	-0.056	0.138	-0.034	0.105
Water relations	2002	0.403***	0.308**	0.357***	0.150	–0.464***
	2012	0.391***	0.272**	0.418***	0.152	–0.443***
Index of agricultural production area quality	2002	0.538***	0.499***	0.256**	0.212*	–0.624***
	2012	0.527***	0.462***	0.335**	0.228*	–0.606***

* – significant at $p = 0.05$; ** – significant at $p = 0.01$; *** – significant at $p = 0.001$

Table 6

Changes in the land use structure of the Warmian-Masurian voivodeship in 2002–2012

Municipality	Land use trend	
	2002	2012
Lidzbark	R3F3	R4F2
Elbląg	R5F1	R6
Młynary, Kowale Oleckie, Dobre Miasto, Rozogi	R4F2	R3F3
Braniewo, Lelkowo, Pieniężno, Prostki, Srokowo, Wilczęta	R5F1	R4F2
Lubawa, Świątki	R6	R5F1
Other municipalities	no change	

the predominant part of agriculturally productive area constitutes arable land (Figure 3). Grasslands with arable land (A2G4) were observed in only one municipality (Wielbark), whereas 11 municipalities were characterized by a mixed profile of arable lands and grasslands (A3G3). In 2002–2012, changes in agricultural land use (Table 7) were observed in 14 municipalities, and they involved an increase in arable area (eight municipalities) or the expansion of meadows and pastures (six municipalities). The most significant changes were observed in the municipality of Gronowo Elbląskie where the land use profile moved down two categories.

The ecological evaluation index for the region reached 1.72 (marking an increase in the past decade), and it was characterized by considerable spatial variation in the range of 1.08–2.77 across the studied municipalities (Figure 4). The lower limit of that range was significantly raised, and a minor increase was

Table 7

Changes in agricultural land management in the Warmian-Masurian voivodeship in 2002–2012

Municipality	Agricultural land use trend	
	2002	2012
Rozogi	A2G4	A3G3
Wilczęta	A3G3	A4G2
Dywity, Giżycko, Małdyty, Milejewo, Olecko, Zalewo	A4G2	A5G1
Banie Mazurskie, Markusy	A4G2	A3G3
Elbląg, Olsztyn	A5G1	A4G2
Gronowo Elbląskie	A6	A4G2
Kisielice	A6	A5G1
Other municipalities	no change	

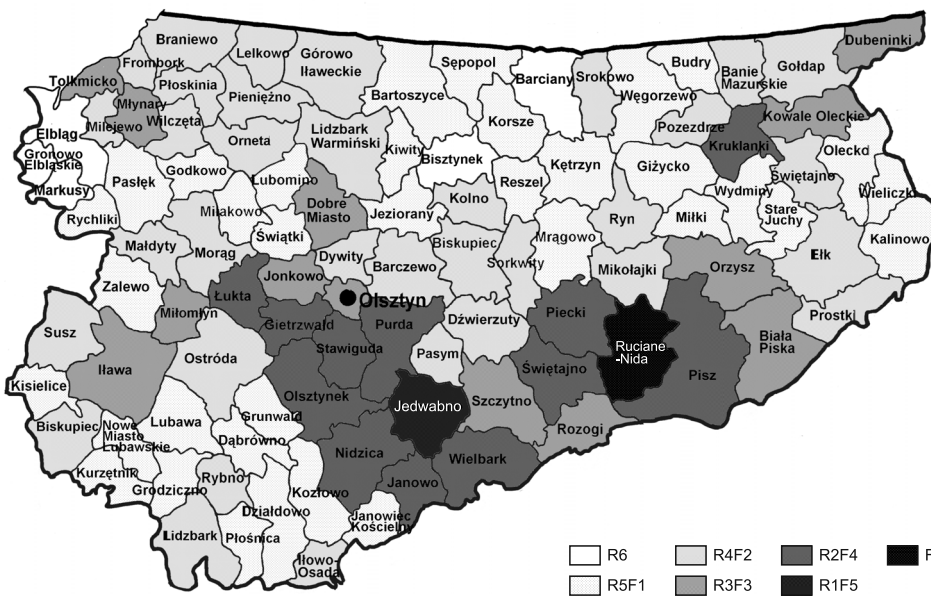

Fig. 2. Land use trends in the municipalities of the Warmian-Masurian voivodeship determined by the successive quotients method

also observed in the upper limit. Similarly to 2002, Ruciane-Nida and Jedwabno, municipalities with the highest forest cover, ranked highest with regard to ecological attributes (water retention, degree of land erosion, sanitary and hygiene standards, health benefits, esthetic value). The lowest value of the ecological evaluation index was noted in Lubawa. Gronowo Elbląskie

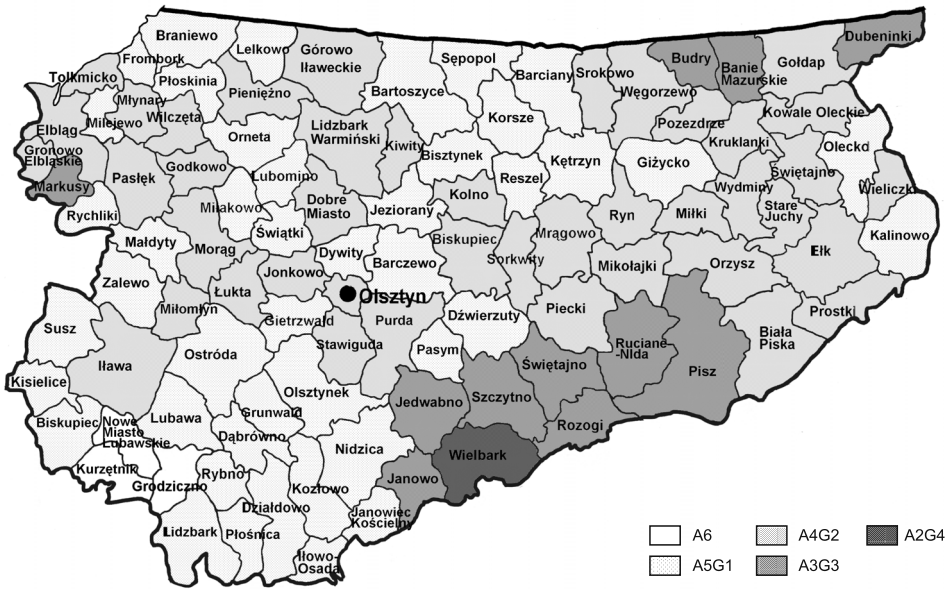

Fig. 3. Agricultural land management trends in the municipalities of the Warmian-Masurian voivodeship determined by the successive quotients method

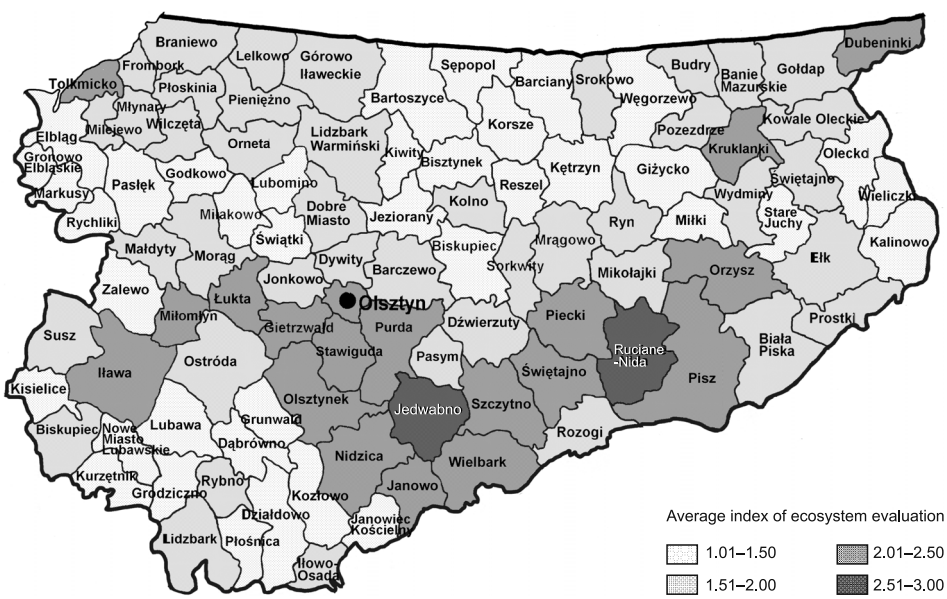

Fig. 4. Evaluation of agricultural and forest ecosystems in the municipalities of the Warmian--Masurian voivodeship

(which ranked last in 2002) moved up one category following the conversion of vast areas into grassland. The value of the ecological evaluation index exceeded 2.0 in 21 municipalities, most of which are situated in the central-southern part of the region.

In the past decade, the value of the ecological evaluation index decreased in only three municipalities, and it remained constant in six administrative units (Table 8). An increase was observed in the majority of the analyzed municipalities, and the most positive changes were reported in the Żuławy region (Elbląg and Gronowo Elbląskie).

Table 8

Changes in the value of the ecological evaluation index in the Warmian-Masurian voivodeship in 2002–2012

Change	Municipality
–	Giżycko, Iłowo-Osada, Milejewo
0	Bisztynek, Kozłowo, Płośnica, Rozogi, Tolkmicko, Wilczęta
+	Other municipalities
++	Braniewo, Frombork, Górowo Iławeckie, Lidzbark Warmiński, Markusy, Morąg, Olsztyn, Orneta, Pieniężno, Rychliki
+++	Elbląg, Gronowo Elbląskie
+	For the region (1.72)

– decrease in the range of 0.01–0.10; 0 – decrease or increase in the range of 0.00–0.01; + – increase in the range of 0.01–0.10; ++ – increase in the range of 0.10–0.20; +++ – increase in the range of 0.20–0.50

Similarly to the evaluation performed in 2002, the clustering analysis supported the identification of six groups (clusters) characterized by similar habitats and land use patterns (Table 9, Figure 5). Significant variations were not observed in the composition or the attributes of the studied clusters. Only four municipalities (Iłowo-Osada, Rybno, Węgorzewo, Zalewo) were moved to different groups. Clusters I and II cover a total of 31 municipalities characterized by the least supportive agricultural environment (low value of the index evaluating the agricultural production area and its constituent elements), most of which are situated in the southern and north-eastern parts of the region. Clusters I and II were identified in view of their land use structure, in particular the ratio of relative agricultural acreage to forest cover. Cluster I groups municipalities with a higher share of agricultural land (47.4%) and lower forest cover (38.6%), whereas cluster II characterizes administrative units with a relatively lower contribution of agricultural land (average of 28.5%) and extensive forest cover. In comparison with the analysis performed in 2002, cluster I decreased by two municipalities (Rybno and Iłowo-Osada), whereas cluster II remained unchanged.

Table 9

Values of variables in clusters of municipalities in the Warmian-Masurian voivodeship

Specification	Cluster (number of municipalities)					
	I (13)	II (18)	III (19)	IV (22)	V (15)	VI (14)
Soil evaluation	44.5	41.5	60.1	52.3	45.9	62.7
Agroclimate evaluation	7.3	8.0	8.7	8.1	7.8	8.5
Evaluation of land relief	3.2	3.6	3.5	3.1	3.3	3.8
Evaluation of water relations	2.9	3.0	4.0	3.4	2.9	4.1
Index of agricultural production area quality	57.9	56.2	76.2	66.9	59.9	79.0
Farmland [%]	47.4	28.5	61.4	53.9	68.9	74.8
Arable land [%]	30.5	17.4	43.0	35.7	55.2	53.2
Permanent grassland [%]	16.8	11.0	18.3	18.1	13.5	21.5
Orchards [%]	0.1	0.1	0.1	0.1	0.2	0.1
Forests [%]	38.6	53.5	24.5	29.0	20.4	14.3

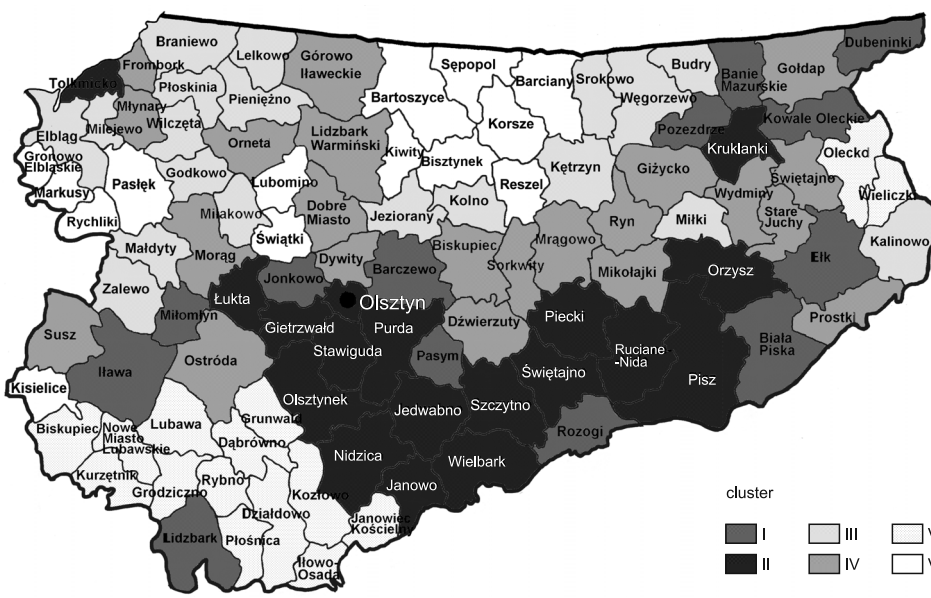

Fig. 5. Classification of municipalities in the Warmian-Masurian voivodeship into groups based on cluster analysis

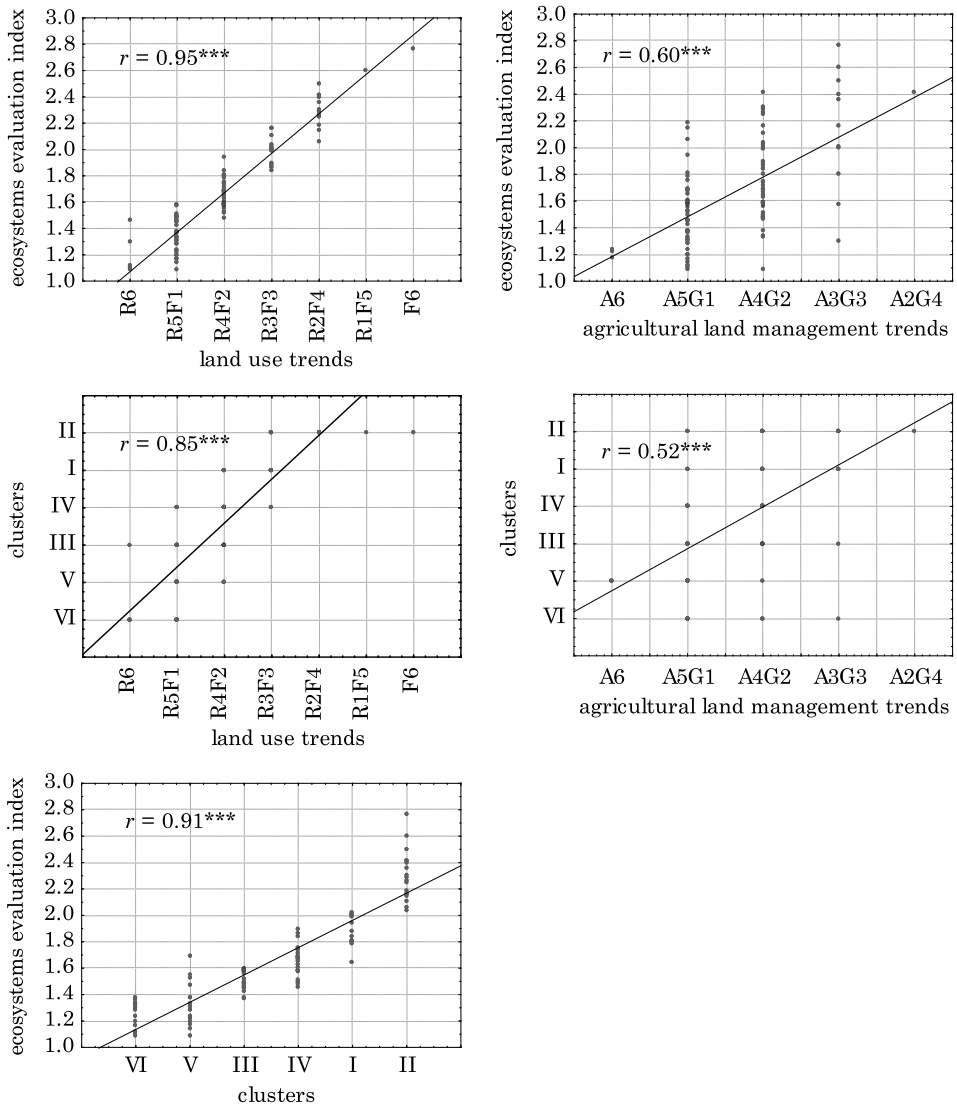

Fig. 6. Binary relationship between the methods used for classification of municipalities (r – coefficient of linear correlation; *** – r significant at $p = 0.001$)

Clusters III and VI are also characterized by similar habitats, and they bring together municipalities (19 and 14, respectively) with the most fertile soils, most supportive agroclimate and water relations. Clusters III and VI cover mostly administrative units in the central-northern and north-western parts of the region. Their distinctive feature is forest cover which is nearly

twice lower in cluster VI than in cluster III. Forest cover is negatively correlated with the area of land used for agricultural production. In cluster VI, agricultural land has the highest share of the local land use structure, and this group of municipalities is also characterized by the greatest contribution of grassland. In comparison with the previous evaluation (2002), cluster III was expanded by two municipalities (Węgorzewo and Zalewo), whereas no changes were reported in the structure of cluster VI.

Cluster IV comprises 22 municipalities, and it has lost two units on behalf of cluster III since the previous analysis. Cluster IV is largest in terms of both the number of municipalities and their combined area (24% of the region). Its municipalities are characterized by less than ideal farming conditions and land use patterns which are similar to the regional average.

Cluster V groups 15 municipalities (increase of two units at the expense of cluster I since 2002), situated mostly in the south-western part of the region (only two municipalities, Olecko and Wieliczki, are found in the eastern part). The municipalities are characterized by poor soils and relatively unfavorable farming conditions. Despite the above, agricultural production is the predominant type of land management, and cluster V is characterized by the highest average percentage of arable land in the local land use structure.

Despite procedural variations and differences in the pursued objectives, the analyzed methods for evaluating the land use structure delivered similar results (Figure 6). Municipalities were most effectively classified into the relevant categories by the highest averages method, followed by the ecological evaluation method and cluster analysis.

Discussion

Land use planning is a complex and long-term process (VERBURG et al. 2013, MEIYAPPAN et al. 2014). Land use and cover change have been identified as one of the prime determinants of global change with major impacts on ecosystems, global biogeochemistry and climate change (VERBURG et al. 2009). However, regardless of its global, regional or national significance, land management must begin at the local level (MEIYAPPAN et al. 2014). On the national and European scale,the Warmian-Masurian voivodeship stands out for its biodiversity and richness of the natural environment which include: varied topography, numerous lakes, and dense forest complexes (PZPWWM 2015). Half of the province are the areas covered by the legal protection of wildlife, including these of international rank (Natura 2000, CORRINE programme). The whole voivodship is located within the functional area of the Green Lungs of Poland. Warmia and Mazury region was included in the Baltic

Landscape project (SVENSSON 2014). For all the abovementioned reasons, rational land management of this area, preventing the loss of its natural values, seems to be worthy of not only regional, but also wider international interest.

In a classical study of land management practices in areas with undulating topography, NIEWIADOMSKI and KRZYMUSKI (1965) advocated the development of meadows in valleys with a slope of less than 2% and forests in areas with slope gradients higher than 35%, regardless of soil class. In the above publication, the proposed forest cover for lakelands was 24–27%. In 2002–2012, closer correlations were noted between the percentage share of grassland and land relief, and an increase in forest cover was observed in all municipalities of the Warmian-Masurian voivodeship. The threshold proposed by the above authors was exceeded in 58% of the analyzed municipalities. While the earlier afforestation land supply was mainly due to the crisis of agriculture in Poland (WANIC et al. 2002, KOSTRZEWSKA et al. 2004), currently the rise in forest cover also results from the implementation of the National Afforestation Program (ŁONKIEWICZ 1995) and the National Afforestation Policy (1997) which made afforestation a permanent element of Poland's spatial, ecological and economic policies. The aim of those policies is to increase Poland's forest cover to 30% in 2020 and 33% after 2050. Efforts will also be made to rearrange the boundaries between arable land and forests in order to bring greater cohesion to the local landscape, agricultural functions and forest management practices. According to the latest version (KALISZEWSKI et al. 2009) of the National Afforestation Program (ŁONKIEWICZ 1995), the goal of increasing Poland's forest cover to 30% is unlikely to be met by 2020 at the current rate of afforestation. The most realistic figure is 29.1–29.2%. The drop in the national afforestation rate after 2006 could be attributed to Poland's accession to the European Union and the greater popularity of agricultural subsidies over afforestation premiums. A reverse trend was observed in Warmia and Mazury where the area afforested in 2001–2008 exceeded the planned values (121%). According to the National Afforestation Program (ŁONKIEWICZ 1995), forest cover in the region should reach 31.4% in 2020, but the above level has already been exceeded (32.5%). The Warmian-Masurian voivodeship is particularly suited for afforestation programs. According to SIUTA and ŻUKOWSKI (2002), forest coverage in the region can be increased to 38% by planting forests on soils of the lowest quality class (VIz, VI and V). In a different study, SIUTA (2012) argued that the national forest cover can reach 45% with regional averages in the range of 30–60%. According to the cited author, Poland has a vast potential for increasing its forest coverage. Part of the fallow farmland has already been overgrown with trees and shrubs, but the above is not reflected by geodetic or statistical data.

According to URBAN (2009), the availability of direct agricultural subsidies after Poland's accession to the European Union has led to changes in land use structure, and it increased the share of meadows and pastures in total land area. The results of our evaluation did not confirm the above trend, and the relative area of arable land and grassland in the Warmian-Masurian voivodeship decreased in 2012. BAŃSKI (1997) observed that arable land has the highest share of the local land use structure in regions characterized by high quality soils. In Warmia and Mazury, the percentage of arable land was highly correlated with soil quality and the index of agricultural production area. It should, however, be noted that the above correlation was somewhat weakened in the past decade. According to BAŃSKI (1997), the percentage of grassland is higher in areas characterized by low quality of agricultural production area, namely regions with poor soils, unfavorable water relations and a shorter growing season. In the Warmian-Masurian voivodeship, the share of grassland was highly correlated with the quality of agricultural production area, and this relationship was further strengthened in the past decade.

Agriculture and forestry are the predominant types of land use in Europe. The key trends in European land use patterns include a decrease in agricultural areas, an increase in forest cover and the expansion of highly urbanized areas (EU-LUPA 2013). *t* the global scale, Europe is an anomalous continent in terms of forest trends. While the global forests shrink, the European forests expand (FRA 2010).Currently in Europe (without the Russian Federation), the average forest cover is estimated at 32,2%, and in the European Union (27, without Croatia) – at 37.6% (State of Europe's forests 2011). According to ZANCHI et al (2007), in Europe a general increase of forest area is reported, but trends differ between regions and can be due to different processes.

A few words should be said about the methodological aspects of the study. In this evaluation, we relied on several simple procedures that can be performed with a standard spreadsheet as well as on a more complex k-means cluster analysis. Changes in land use structure in vast and spatially differentiated areas are often illustrated with the use of maps, in particular color maps (WANIC et al. 2002). They can also be expressed by the redistribution coefficient. According to BAŃSKI (1997), even low values of the redistribution coefficient, which result from a short experimental period (as in this study), emphasize the variability of changes in land use structure and support an objective evaluation of their stable or variable character.

The choice of method for evaluating the diversity of the natural and agricultural environment should be determined by the aim of the classification process. According to BAŃSKI (1997), the successive quotients method fulfills two seemingly conflicting objectives: it provides detailed information about the

land use structure of a vast number of territorial units, while at the same time, the identified land use trends are sufficiently generalized to support graphic presentation and analysis. The cited author also observed that this objective method has been long used in agricultural geography, therefore, it enables a comparison of various research results. The random sampling method proposed by HERNIK (2001) was used to rank productive land (forests, meadows, pastures, orchards and arable land) in view of their ecological attributes: water retention, degree of land erosion, sanitary and hygiene standards, health benefits and esthetic value. The algorithm was developed based on published data and the author's observations. Forests were found to be the most "ecologically valuable" sites, whereas arable acreage scored the lowest number of points. The value of the average ecosystem evaluation index, a respective weighted average, was determined in the range of 0.6 to 3.0. The higher its value, the greater the ecosystem's impact on the local environment. Multidimensional analyses are increasingly used to classify agricultural sites (KUŚ et al. 2002, KOSTRZEWSKA et al. 2004, 2006, ZARÓD 2009, JASKULSKI and JASKULSKA 2011). The k-means cluster analysis identifies homogenous groups with similar characteristics, it reduces large groups of objects to several key categories for further analyses, and it supports comparisons of multi-attribute objects (ZARÓD 2009). In this method, homogenous regions can be identified without significant loss of information about individual municipalities.

Many authors point to the need for research on land management in terms of spatial and temporal variability (BAŃSKI 1997, CARRANZA et al. 2007, VERBURG et al. 2013, MEIYAPPAN et al. 2014). Landscape planning at the level of municipalities should follow the national planning policy, and, after Poland's accession to the European Union, requirements defined by relevant European directives and agreements (PZPWWM 2015). However, all rules implemented in landscape planning and management are expected to be based on the knowledge oflandscape ecology. The former faulty land management, mainly deforestation, is recognized as one of the causes of the steppization observed in central Poland, as well as in other countries of Central and Eastern Europe (PORĘBSKA and SADOWSKI 2007). The presented analysis of changes in land use in the municipalitiesgives the opportunity to predictthe trends for the years to come, including the possibility of changes in the function of agricultural land and forest.

The issue of land use and management is undertaken by specialists in many disciplines (BAŃSKI 1997), using more and more modern research methods (CARRANZA et al. 2007, MEIYAPPAN et al. 2014). In this context, the finding that despite procedural variations and differences in the pursued objectives the analyzed methods for evaluating the land use structure delivered similar results, is particularly significant.

Conclusions

The land use structure in the Warmian-Masurian voivodeship, largely determined by local natural conditions, was highly stable in the past decade (2002–2012). A minor decrease in the percentage share of arable land, grassland and orchards was noted, and it was accompanied by an increase in forest cover in all municipalities. The forest cover in Warmia and Mazury exceeds the level planned for 2020 by the National Afforestation Program (ŁONKIEWICZ 1995). Despite procedural variations and differences in the pursued objectives, the analyzed methods for evaluating the land use structure delivered similar results, and they point to clear regional variations in the natural and agricultural environment. The northern part of the region comprises mostly agricultural land, and it ranks lower with regard to its ecological importance. Agricultural acreage is also the predominant type of land use in the southwestern part of the region despite poor quality soils. The southern and south-eastern parts of the region are also characterized by low quality soils, they feature a higher share of forests and grasslands which increase their ecological significance and raise their recreational appeal.

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