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LAND COVER AND ECOSYSTEM SERVICES CHANGES IN AGRICULTURAL LANDSCAPES OF THE DĘBNICA RIVER CATCHMENT (WEST POMERANIA, POLAND)

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ZMIANY W POKRYCIU TERENU I USŁUGACH EKOSYSTEMOWYCH W KRAJOBRAZACH ROLNICZYCH ZLEWNI DĘBNICY (POMORZE ZACHODNIE, POLSKA)

STRESZCZENIE: Porównano usługi ekosystemowe tych samych krajobrazów rolniczych z okresu centralnie planowanej gospodarki upaństwowionej i gospodarki rynkowej. Określono je na podstawie bioróżnorodności krajobrazowej wynikającej z użytkowania i pokrycia terenu. Bioróżnorodność została określona na podstawie kompleksów roślinności rzeczywistej zdelimitowanych metodą symfitosocjologiczną, drogą kartowania terenowego. Kompleksy pozwoliły ocenić usługi z poziomu typów klasowych w hierarchicznej klasyfikacji CICES v4.3.

SŁOWA KLUCZOWE: krajobrazy rolnicze, bioróżnorodność, usługi ekosystemowe, pokrycie terenu, metoda symfitosocjologiczna, kompleks roślinności

Introduction

In 2014, the assessment of ecosystems and their services in the member states of the European Union will be completed. It is one of activities (Action 5) within the framework of the EU Biodiversity Strategy to 2020 (J. Maes et al.[1]). General tools were proposed, including Common International Classification of Ecosystem Services (R. Haines-Young and M. Potschin[2]), which make it possible to aggregate the obtained results on a Pan-European scale. To prepare this assessment, the data on geodiversity and biodiversity of geoecosystems and their functions are required. In 2011-2014, geodiversity and biodiversity of geoecosystems of the Dębnica River catchment and a reaction of geoecosystems to anthropopressure were studied. Some changes in land cover were found (J. Borysiak et al.[3]), which correspond to the general trend for Poland stated by D. Łowicki and A. Mizgajski[4]. These changes, visible also in agriculture (R. Kulikowski[5]), forestry and unused lands result, among others, from the political system transformation initiated in Poland on the end of 80. in 20th century. This paper presents some results from the study of the Dębnica River basin related to land cover, ecosystem biodiversity and ecosystem services. The application of the concept of real vegetation complex for the determination of changes in agricultural space will be shown and, based on this, also changes in the catalog of ecosystem services prepared according to the CICES v4.3 classification, currently tested in Europe.

Data and methods

Study area

The land cover of four agricultural landscapes of the Dębnica River drainage basin was diagnosed. This basin is a part of the first order drainage basin of

[1] J. Maes, A. Teller, M. Erhard et al., *Mapping and assessment of ecosystems and their services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020*, Luxembourg 2013.
[2] R. Haines-Young, M. Potschin, *Common international classification of ecosystem services (CICES): Consultation on version 4. Raport to the Europaean Environment Agency*, www.cices.eu [20-09-2013].
[3] J. Borysiak, M. Mazurek, Z. Zwoliński, *Concept of sustainable management involves landscape geodiversity of hydrogeomorphological units: the Dębnica River, Poland*, The 8th IAG/AIG International Conference on Geomorphology and Sustainability, Paris, France, August 27-31, 2013.
[4] D. Łowicki, A. Mizgajski, *Typology of physical-geographical regions in Poland in line with land-cover structure and its changes in the years 1990-2006*, „Geographia Polonica" 2003 no. 86, p. 255-266.
[5] R. Kulikowski, *Produkcja i towarowość rolnictwa w Polsce. Przemiany i zróżnicowania przestrzenne po II wojnie światowej*, „Prace Geograficzne Instytutu Geografii i Przestrzennego Zagospodarowania PAN" 2013 no. 241, p. 131.

Parsęta River. An analysis involved such spatial fragments for which land cover on the topographic map 1:10000 in 1980 was different than in 2014. The use of time criterion allowed to analyze land cover in two completely different periods of economic development of Poland, i.e., nationalized, centrally planned economy (1980) and market economy (2014). The modern pattern of Holocene and post-glacial landforms of the Dębnica River catchment is mainly shaped by typical lowland morphogenetic processes like: chemical denudation (which predominates over mechanical), erosion and accumulation produced by the runoff, incision in the upper reaches of rivers, alluvial sedimentation into floodplain terraces, bank erosion in the lower reaches of rivers, and degradation and aggradation caused by anthropopression (Z. Zwoliński et al.[6]). An effect of these processes is a high geodiversity (A. Kostrzewski et al.[7]) and, as a consequence, high biodiversity. In the areas with such features, a high differentiation of ecosystem services is expected.

The studied landscape units are situated in the villages of: Kołacz (WGS: N53°46'59.96" / E16°10'57.35"), Liniec (N53°45'19.81" / E16°18'19.9"), Łeknica (N53°46'11.75" / E16°17'9.04") and Uradz (N53°40'45.32" / E16°18'41.21"), and covered the area of: 159, 155, 111 and 80 hectares, respectively. According to J. Kondracki[8], they belong to the subprovince of South Baltic Lake District and a mesoregion of the Drawskie Lake District. They are situated in the marginal zone of the Pomeranian phase of Vistulian (Weichselian) glaciation (A. Karczewski[9]). The moraine plateau areas in the vicinity of Liniec and Łeknica sites are composed of glacial till, while in the Uradz site – of glacial gravel and silty sands or glacial gravel and silty sands lying on glacial till (W. Popielski[10]). In the Kołacz site, sands and gravels of kettle depressions, glacial gravel and silty sands, glacial till and fens prevail. The valleys of rivers in the Liniec site are covered by sands and slope deposits, while the valleys of rivers and depressions in Łeknica and Uradz sites – by humus sands and peats. Glacial till is strongly sandy, decalcified and weathered, with a high content of Scandinavian erratics in the upper parts of bedrock (W. Popielski[11]). The north-west area in the Uradz site is the valley of Dębnica River, a watercourse fed by groundwater, rain and snow (I. Dynowska[12]).

[6] Z. Zwoliński, A. Kostrzewski, A. Stach, *Tło geograficzne współczesnej ewolucji rzeźby młodoglacjalnej*, in: L. Starkel, A. Kostrzewski, A. Kotarba, K. Krzemień (eds.), *Współczesne przemiany rzeźby Polski*, Kraków, 2008, p. 271-276.
[7] A. Kostrzewski, R. Kolander, J. Szpikowski, *Zintegrowany monitoring środowiska przyrodniczego*, in: *Raport o stanie środowiska przyrodniczego w województwie zachodniopomorskim 2006-2007*, „Biblioteka Monitoringu Środowiska" 2008, p. 198-222.
[8] J. Kondracki, *Geografia regionalna Polski*, Warszawa 1998, p. 440.
[9] A. Karczewski, *Morfogeneza strefy marginalnej fazy pomorskiej na obszarze lobu Parsęty w vistulianie (Pomorze Środkowe)*, Poznań 1989, p. 48.
[10] W. Popielski, *Szczegółowa mapa geologiczna Polski 1:50 000, arkusz 159-Barwice (N-33-81-D)*, Kielce 2001.
[11] W. Popielski, *Objaśnienia do Szczegółowej mapy geologicznej Polski 1:50 000. Arkusz Barwice (159)*, Warszawa 2005.
[12] I. Dynowska, *Typy reżimów rzecznych w Polsce*, „Zeszyty Naukowe Uniwersytetu Jagiellońskiego, Prace Geograficzne" 1971 no. 28, p. 155.

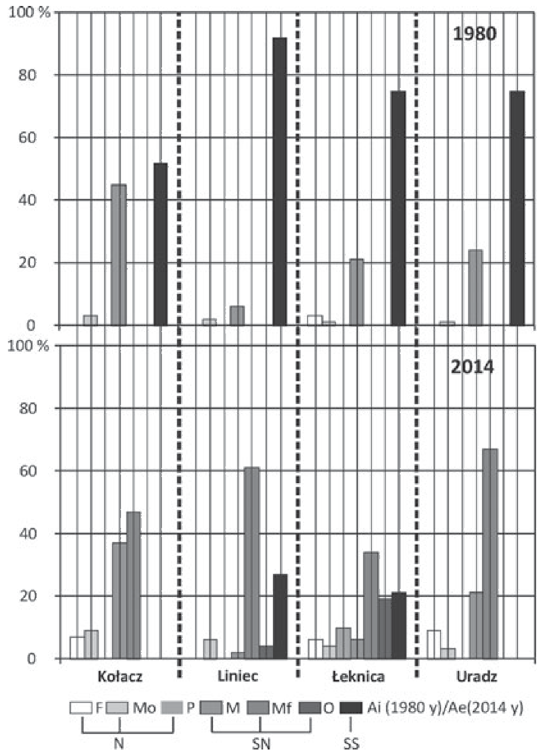
According to the climate regionalization by A. Woś[13], the studied landscape units are located in the Central Pomeranian Region.

Field mapping

In 2014, in the first stage of the site, the phytocoenotic diversity of landscape units of sites Kołacz, Liniec, Łeknica and Uradz was diagnosed by mapping in the field. Plant associations were identified following syntaxonomical survey of A. Brzeg and M. Wojterska[14], and W. Matuszkiewicz[15]. The result of diagnosis was used to make symphytosociological *relevés* in the real vegetation complexes according to the method of R. Tüxen[16]. These complexes were homogenous regarding one (areally dominant) potential natural vegetation and, also, the same (areally dominant) way of land use and land cover. Potential natural vegetation was determined according to R. Tüxen (after A. Richling and J. Solon[17]). The complex position in the hierarchical structure of landscape was given by J. M. Matuszkiewicz[18] – it is a geosystem of the next higher rank than ecosystem, the type of biocoenosis. To each plant association of the complex, syngenesis according to the classification of J. B. Faliński[19] was assigned. Also, symphytosociological *relevés* made in the villages of Pustkowie (N53°45'33.67"/E16°30'12.6") and Przybkowo (N53°43'45.26"/E16°30'34.09") were used for the result interpretation. Ecosystem services were assigned to the delimited types of the real vegetation complex, following the classification CICES v4.3. Each service from the class type level was credited with one score.

[13] A. Woś, *Zarys stosunków klimatycznych w rejonie górnego odcinka zlewni Parsęty*, in: A. Kostrzewski (ed.), *Zintegrowany monitoring środowiska przyrodniczego. Stacja Bazowa Storkowo*, „Biblioteka Monitoringu Środowiska", Warszawa 1994, p. 79-96.
[14] A. Brzeg, M. Wojterska, *Zespoły roślinne Wielkopolski, ich stan poznania i zagrożenie*, in: M. Wojterska (ed.), *Szata roślinna Wielkopolski i Pojezierza Południowopomorskiego*, Poznań 2001, p. 39-110.
[15] W. Matuszkiewicz, *Przewodnik do oznaczania zbiorowisk roślinnych Polski*, Warszawa 2011, p. 536.
[16] R. Tüxen, *Zür Homogenität von Sigmassoziationen, ihrer syntaxonomischen Ordnung und ihrer Verwendung in der Vegetations Kartierung*, „Doc. Phytosoc., N.S." 1977 no. 1, p. 321-327.
[17] A. Richling, J. Solon, *Ekologia krajobrazu*, Warszawa 2011, p. 464.
[18] J. M. Matuszkiewicz, *Landscape phytocomplexe and vegetation landscape real and typological landscape units of vegetation*, „Doc. Phytosoc. N. S." 1979 no. 4, p. 663-672.
[19] J. B. Faliński, *Zbiorowiska autogeniczne i antropogeniczne. Próba określenia i klasyfikacji*, „Ekologia Polska B" 1969 no. 15, p. 173-182.

Figure 1
Structural changes in agricultural landscapes in the Dębnica River catchment (West Pomerania, Poland)



1980, 2014 – case study years; vegetation complex type in analyzed sites: Ae – arable land in extensive cultivation, Ai – arable land probably in intensive cultivation, F – forest, M – meadow, Mf – mowed fallow, Mo – mosaic of natural phytocoenoses (forest, shrub, tall herb fringe), O – orchard in sod, P – pond; syngenesis of vegetation complex: N – natural, SN – seminatural, SS – synanthropic segetal;

locality of sites (name of village): K – Kołacz, L – Liniec, Ł – Łeknica, U – Uradz;

Source: own elaboration.

Results

Land cover changes

In the analyzed agricultural landscapes, substantial changes in land cover in relation to 1980 were observed (Figure 1). In Kołacz site, arable land disappeared. It was replaced by mowed fallow land (47%) and in considerable part (5%) – forest biotopes. Also, the area of meadows and pastures decreased from 47% to 37%, while 10% of the transformed area is occupied by the tall herb fringe-shrub-forest complex. In Liniec site, the area of arable land decreased by

65%, mainly in favour of mowed fallow land. The contribution of meadows decreased from 6% to 2%, and they were replaced by the mosaic of forest and shrub patches, and tall herb fringe communities. In Łeknica site, a pond of 11 hectares was constructed at the cost of the half of meadow area, 21% of meadows was replaced either by tall herb fringe-shrub-forest formation or forest, and 25% of arable land was transformed into a fruit orchard in sod. In Uradz site, arable land also disappeared; 89% of its area changed into mowed fallow land. However, in the valley of the Dębnica River almost the whole complex of meadows (89%) survived. Along with the changes in land cover, an intensity of the synanthropization process decreased in all analyzed landscapes. It was assumed that in 1980, when arable land was managed by the state farms, an intensive farming was practiced.

Agrochemical treatments were used that suppressed the growth of weeds. It is presumed that at that time, only synanthropic vegetation of herbicidal fallow occurred. In 2014, mostly, semi-natural vegetation of mowed fallow land was found, as well as fruit orchards in sod, with the mowed strips between the rows of trees and with no traces of herbicides within the tree and shrub rows. In the large areas of former meadows and pastures, the secondary biocoenotic succession took place. It resulted in the replacement of semi-natural vegetation by natural vegetation. In the remaining arable land, abundance of weeds and very well developed phytocoenoses of segetal synanthropic associations were found, what proves extensive farming.

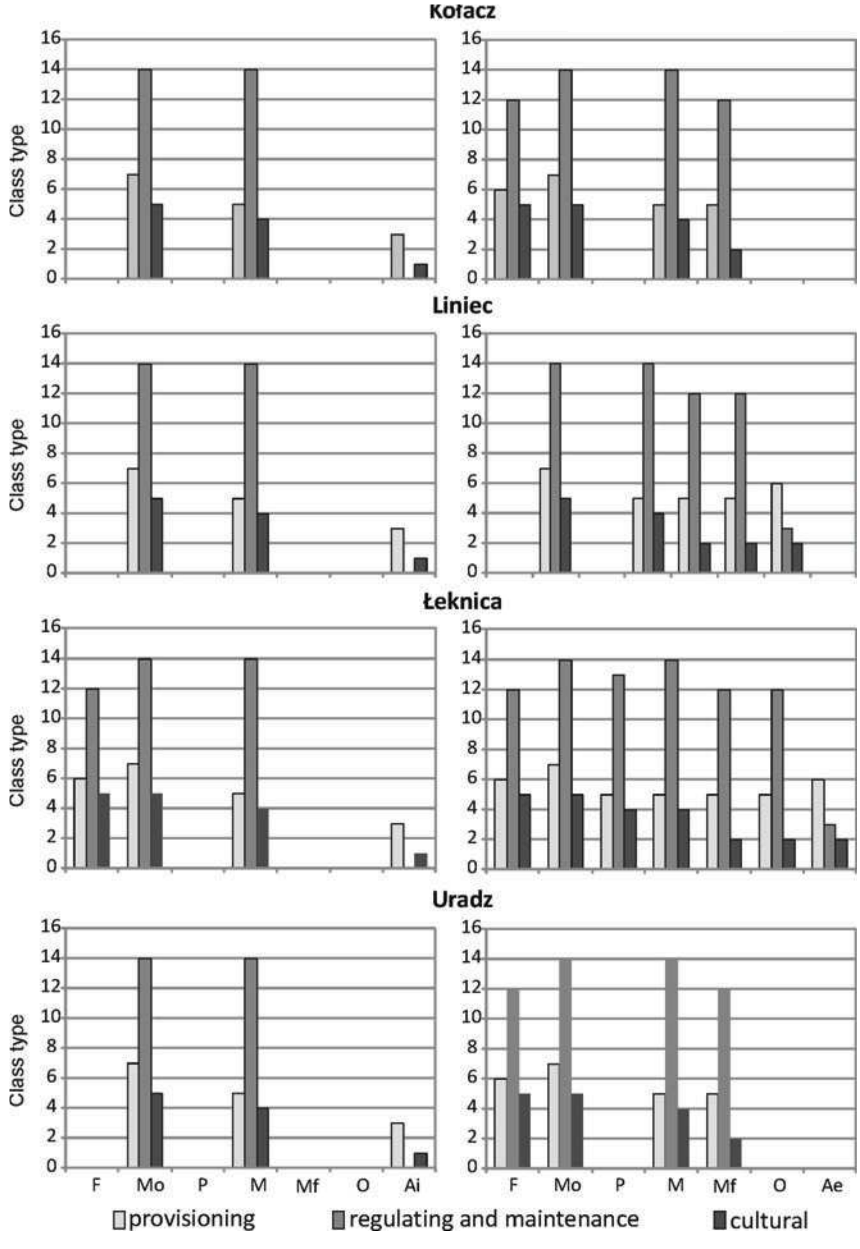
To show the renaturalization degree of the analyzed agricultural landscapes, the phytocoenotic structure and syngenesis of new substitute complexes of real vegetation were presented (Table 1). The four new complexes – water and rush vegetation of the constructed pond (P), forest (F) and tall herb fringe-shrub-forest (Mo), were documented. Also, the *relevés* taken in the preserved meadow complexes (M) were included. Next column shows the segetal complex of extensively used arable land, while the last column – the same type of arable land complex (Ae) traditionally cultivated for over 65 years (personal information from a farmer). The phytocoenotic structure of the Łeknica complex (Ae) compared to this type of complex from Pustkowie (Ae) may be an evidence for extensive farming in Łeknica. Table does not include new complexes of mowed fallow land and fruit orchards. Vegetation of such units has undetermined phytocoenotic relationships and consists mainly of native species from *Molinio-Arrhenatheretea* and *Artemisietea*. Mowing, and sometimes also grazing (e.g. goat herds in Liniec site), justifies classification of this vegetation to the semi-natural type.

Ecosystem services changes

Table 2 presents comparison of ecosystem services for the seven types of real vegetation complexes that, in 2014, occupied the land of the four studied landscape sites. The last column in the table shows services related to the complex type connected with the intensively cultivated arable land replaced by new types. In 2011-2014, this type was observed only in the area of large-scale agricultural

Figure 2

Changes in ecosystem services of agricultural landscapes in the Dębnica River catchment (West Pomerania, Poland)



1980, 2014 – case study years; vegetation complex type in analyzed sites: Ae – arable land in extensive cultivation, Ai – arable land probably in intensive cultivation, F – forest, M – meadow, Mf – mowed fallow, Mo – mosaic of natural phytocoenoses (forest, shrub, tall herb fringe), O – orchard in sod, P – pond; syngenesis of vegetation complex: N – natural, SN – seminatural, SS – synanthropic segetal; locality of complex, name of village: K – Kołacz, L – Liniec, Ł – Łeknica, U – Uradz

Source: own elaboration.

Table 1

Phytocoenotic structure of vegetation complexes in changed agricultural landscapes (the Dębnica river catchment, West Pomerania, Poland)

Specification		Investigated sites							
		Łeknica	Kołacz	Uradz	Uradz	Kołacz	Uradz	Łeknica	Pust-kowie
Vegetation complex		P	F		Mo	M		Ae	
Area of sigmassociation (ha)		0,2	0,8	1,1	0,7	0,5	0,5	0,9	0,8
Share of natural phytocoenoses (% N)		100	98	100	100	10	25	-	-
Share of seminatural phytocoenoses (% SN)		-	2	-	-	90	75	-	-
Share of segetal (weet) phytocoenoses (% SS)		-	-	-	-	-	-	95	95
Share of ruderal phytocoenoses (% SR)		-	-	-	-	-	-	5	5
Number of associations	Syn	10	8	5	12	10	12	4	6
Associations									
Salicetum auritae Jonas 1935 em. Oberd. 1964	N	2 0	.	.	.	.	.	.	.
Glycerietum maximae (Allorge 1922) Hueck 1931	N	2 /	.	.	.	.	.	.	.
Phragmitetum communis (W. Koch 1926) Schmale 1939	N	1 /	.	.	.	.	.	.	.
Caricetum elatae W. Koch 1926	N	2 .	.	.	.	+ .	.	.	.
Caricetum paniculatae Wangerin 1916 ex v. Rochow 1951	N	1 .	.	.	.	+ .	1 .	.	.
Hottonietum palustris R. Tx. 1937 ex Pfeiffer 1941	N	1 .	.	.	.	.	.	.	.
Junco-Molinietum (R. Tx. 1937) Preising in R. Tx. et Preising 1951 em. Pass. 1964	N	1 .	.	.	.	.	.	.	.
Lemnetum minoris Soó 1927	N	1 .	.	.	.	.	.	.	.
Potametum natantis Soó 1927 ex Podbielkowski et Tomaszewicz 1978	N	1 .	.	.	.	.	.	.	.
Sagittario-Sparganietum emersi R. Tx. 1953	N	1 .	.	.	.	.	.	.	.
Calamagrostio arundinaceae-Quercetum petraeae (Hart. 1934) Scam. et Pass. 1959	N	.	5 0	.	.	.	.	.	.
Agrostio-Populetum tremulae Pass. in Pass. et Hofm. 1968	N	.	1 .	.	.	.	.	.	.
Armerio elongatae-Festucetum ovinae R. Knapp 1944 ex Celiński 1953	SN	.	+ .	.	.	.	.	.	.
Calamagrostietum epigeios Juraszek 1928	N	.	+ .	.	.	.	.	.	.
Euonymo-Prunetum spinosae (Hueck 1931) Pass. in Pass. et Hofmann 1968	N	.	+ .	.	.	.	.	.	.
Sieglingio-Agrostietum capillaris Balc. et Brzeg 1978	SN	.	+ .	.	.	.	.	.	.
Rubetum idaei Malinowski et Dziubałtowski 1914 em. Oberd. 1973	N	.	+ .	+ .	.	.	.	.	.
Torilidetum japonicae Lohmeyer in Oberd. et al. 1979 ex Görs et Th. Müller 1969	N	.	+ .	+ .	.	.	.	.	.
Deschampsio flexuosae-Fagetum Schroder 1938	N	.	.	5 0	.	.	.	.	.
Stellario-Carpinetum Oberd. 1957	N	.	.	1 /	.	.	.	.	.
Agrimonio-Vicietum cassubicae Pass. 1967 nom. invers.	N	.	.	+ .	.	.	.	.	.

Fraxino-Alnetum W. Mat. 1952	N	.	.	.	5 0	.	.	.	.
Aegopodio-Sambucetum Doing 1962 em. Wojt. 1990	N	.	.	.	2 .	.	.	.	.
Carici elongatae-Alnetum W. Koch 1926 ex R. Tx. 1931	N	.	.	.	1 0	.	.	.	.
Cardamino-Chrysosplenietum alternifolii Maas 1959	N	.	.	.	+ .	.	.	.	.
Euonymo-Coryletum Pass. in Pass. et Hofmann 1968	N	.	.	.	+ .	.	.	.	.
Prunello vulgaris-Plantaginetum brachystachyae Faliński 1961 ex 1963	SN	.	.	.	+ .	.	.	.	.
Stachyo sylvaticae-Impatientetum noli-tangere (Pass. 1967) Hilbig 1972	N	.	.	.	+ .	.	.	.	.
Urtico-Calystegietum Görs et Th. Müller 1969	N	.	.	.	+ .	.	.	.	.
Epilobio hirsuti-Convolvuletum Hilbig, Heinrich et Niemann 1972	N	.	.	.	+ .	+ .	.	.	.
Eupatorietum cannabini R. Tx. 1937	N	.	.	.	+ .	.	+ .	.	.
Filipendulo-Geranietum palustris (Scherrer 1923) W. Koch 1926	N	.	.	.	+ .	.	2 0	.	.
Scirpetum silvatici Ralski 1931	N	.	.	.	+ .	2 0	2 0	.	.
Angelico-Cirsietum oleracei R. Tx. 1937 em. 1947	SN	.	.	.	.	5 0	4 0	.	.
Stellario palustris-Deschampsietum cespitosae Freitag 1957	SN	.	.	.	.	2 0	2 0	.	.
Caricetum acutiformis Eggler 1933	N	.	.	.	.	1 .	+ .	.	.
Lysimachio vulgaris-Filipenduletum Bal.-Tulačkova 1978	N	.	.	.	.	+ .	1 .	.	.
Phalaridetum arundinaceae Libbert 1931	N	.	.	.	.	+ .	1 /	.	.
Potentilletum anserinae Rapaics 1927 em. Pass. 1964	SN	.	.	.	.	+ .	+ .	.	.
Caricetum gracilis Almquist 1929	N	.	.	.	.	.	1 .	.	.
Peucedano-Calamagrostietum canescentis Weber 1978	N	.	.	.	.	.	1 /	.	.
Digitarietum ischaemi R. Tx. et Preising in R. Tx. 1950 ex R. Tx. 1954	SS	.	.	.	.	.	.	2 0	4 0
Setario-Lycopsietum arvensis Pass. 1959	SS	.	.	.	.	.	.	3 0	2 0
Convolvulo arvensis-Agropyretum repentis Felfoldy (1942) 1943	SR	.	.	.	.	.	.	2 /	2 /
Papaveretum argemones Kruseman et Vlieger 1939	SS	.	.	.	.	.	.	2 0	1 .
Echinochloo-Setarietum pumilae Felfoldy 1942 corr. Mucina 1993	SS	.	.	.	.	.	.	.	2 0
Scleranthо-Arnoseridetum minimae R. Tx. 1937	SS	.	.	.	.	.	.	.	1 .

Vegetation complex: Ae – arable land in extensive cultivation, F – forest, M – meadow, Mo – mosaic of natural phytocoenoses (forest, shrub, tall herb fringe), P – pond; Syn – syngenesis of association: N – autogenous natural, SN – anthropogenic seminatural, SS – synanthropic segetal (weed communities), SR – synanthropic ruderal; pattern of association patch in vegetation complex: 0 – over great surface, / – in long, narrow linear form, . – singular or dispersed in irregular form; quantity acc. to Braun-Blanquet scale: + – one patch of phytocoenose or a few ones; 1 – <5%, 2 – 5-25%, 3 – 25-50%, 4 – 50-75%, 5 – 75-100%

Table 2
Ecosystem services of vegetation complex types (Dębnica River catchment)

Provisioning	Nutrition	Biomass	Cultivated crops	*Land ecosystems:* cereals – buckwheat, mustard, rye	0	0	0	0	0	0	1	1
				Land ecosystems: fruits – apple, black and red currant, pear, plum	0	0	0	0	0	1	0	0
			Reared animals and their outputs	*Land ecosystems:* insects – bees (honey)	1	1	1	1	1	1	1	1
				Land ecosystems: mammals – goads (meat, milk, cheese)	0	0	0	0	1	0	0	0
			Wild plants and their outputs	*Land ecosystems*: blackberry, elderberry, hawthorn, hazel, raspberry, rose, sorrel, mushrooms	1	1	0	0	0	0	0	0
			Wild animals and their outputs	*Land ecosystems*: molluscs – pomatia; game – boar, deer, fallow deer, hare, mallard, pheasant, red deer	1	1	1	1	1	1	1	0
				Freshwater ecosystem: fish – crucian carp, eel, pike, roach, ruffe, tench	0	0	1	0	0	0	0	0
	Materials	Biomass	Fibres and other materials from plants and animals for direct use or processing	*Land ecosystems*: resin, wood	1	1	0	0	0	0	0	0
			Materials from plants, algae and animals for agricultural use	*Land ecosystems:* green fodder – clover; grasslands – hay for fodder	0	0	0	1	1	1	0	0
				Land ecosystems: arable lands – straw (bedding for cattle)	0	0	0	0	0	0	1	1
			Genetic materials from all biota	*Land and freshwater ecosystems*: medicinal herbs	1	1	1	1	1	1	1	0
		Water	Surface water for non-drinking purposes	*Freshwater ecosystems*: irrigation, livestock consumption	0	1	1	1	0	0	0	0
	Energy	Biomass -based energy sources	Plant-based resources	*Land ecosystems*: firewood for energy production	1	1	0	0	0	0	0	0
				Land ecosystems: straw for energy production	0	0	0	0	0	0	1	0
				Total for provisioning section	6	7	5	5	5	5	6	3

Regulating and maintenance	Mediation of waste, toxic and other nuisances	Media-tion by ecosys-tems	Filtration/sequestration/storage /accumulation by ecosystems	*Land and freshwater ecosystems*: bio-physicochemical filtration/sequestration/storage/accumulation of pollutants in soil/bottom sediments	1	1	1	1	1	1	0	0
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	*Land ecosystems*: erosion and denudation protection	1	1	0	1	1	1	0	0
			Buffering and attenuation of mass flows	*Freshwater ecosystems*: transport and storage of sediment by watercourses, storage of sediments by ponds	0	1	1	1	0	0	0	0
		Liquid flows	Hydrological cycle and water flow maintenance	*Land and freshwater ecosystems*: capacity of maintaining baseline flows for water supply and discharge – river channel and pond retention, soil retention	1	1	1	1	1	1	0	0
			Flood protection	*Land and freshwater ecosystems*: flood protection by vegetation cover and landscape retention	1	1	1	1	1	1	0	0
		Gaseous /air flows	Ventilation and transpiration	*Land and freshwater ecosystems*: change in temperature and humidity	1	1	1	1	1	1	0	0
	Maintenance of physical, chemical, biological conditions	Lifecycle main-tenance, habitat and gene - pool protec-tion	Pollination and seed dispersal	*Land and freshwater ecosystems*: pollination, seed bank, seed dispersal	1	1	1	1	1	1	1	0
			Maintaining nursery populations and habitats	*Land and freshwater ecosystems*: astatic ponds, balks, roadside shrubs and trees, heaps of erratic stones, network of watercourses	1	1	1	1	1	1	0	0
		Pest and disease control	Pest control	*Land ecosystems*: extensive agriculture, multifunctional forest, feeding grounds for birds	1	1	1	1	1	1	1	0
		Soil forma-tion and compo-sition	Weathering processes	*Land ecosystems*: maintenance of bio-geochemical conditions of soils including fertility, improvement of nutrient storage and soil structure, slowing down the processes of physical and chemical weathering (overgrowing of arable lands and grasslands – secondary biocenotic succession)	1	1	1	1	1	1	0	0

			Decomposition and fixing processes	*Land ecosystems*: Maintenance of bio-geochemical conditions of soils including fertility, improvement of nutrient storage and soil structure, slowing down the processes of physical and chemical weathering (overgrowing of arable lands and grasslands – secondary biocenotic succession)	1	1	1	1	1	1	0	0
		Water cond-itions	Chemical condition of freshwaters	*Freshwater ecosystems*: maintenance of chemical composition of freshwater column and sediment to ensure favourable living conditions – overgrowing of arable lands and grasslands (secondary biocenotic succession) in the catchments of watercourses and ponds	0	1	1	1	0	0	0	0
		Atmo-spheric compo-sition and climate regu-lation	Global climate regulation by reduction of greenhouse gas concentrations	*Land and freshwater ecosystems*: Global climate regulation by greenhouse gas sequestration by ecosystems and their biota	1	1	1	1	1	1	1	0
			Micro and regional climate regulation	*Land and freshwater ecosystems*: Modifying of topo-, micro- and regional climate patterns caused biocenotic secondary succession	1	1	1	1	1	1	0	0
	Total for regulating and maintenance section				12	14	13	14	12	12	3	0
Cultural	Physical and intellectual interactions with biota, ecosystems and landscapes	Physical and expe-riential inter-actions	Experiential use of plants, animals and landscapes in different environmental settings	*Land and freshwater ecosystems*: Experiential use of traditional agricultural landscapes rich in natural biocenotic structures, bird watching	1	1	1	1	1	1	1	0
			Physical use of landscapes in different environmental settings	*Land and freshwater ecosystems*: angling, boating, hiking, hunting, jogging, walking	1	1	1	1	1	1	0	0
		Intellec-tual and repre-senta-tive inter-actions	Scientific	*Land and freshwater ecosystems:* Regional Directorate for Environmental Protection in Szczecin – master plan for PLH390039 Czaplinek Lakes; A. Mickiewicz University in Poznań – Changes of ecosystem services in landscapes modified by man, geoecosystems and economic studies	1	1	1	1	1	1	1	1
			Educational	*Land and freshwater ecosystems*: Połczyn Forest District: educational activities; thematic village	1	1	0	0	0	0	0	0

			Aesthetic	*Land and freshwater ecosystems:* harmonious natural and seminatural landscapes, advanced regenerative processes of natural vegetation	1	1	1	1	1	1	1	0
	Spiritual, symbolic and other interactions with biota, ecosystems, landscapes	Other cultural outputs	Existence	*Land and freshwater ecosystems*: enjoyment provided by wildlife	1	1	1	1	0	0	0	0
			Bequest	*Land and freshwater ecosystems*: willingness to preserve plants, animals, ecoystems, landscapes for the experience and use of future generations	1	1	1	1	0	0	0	0
	Total for cultural section				5	5	4	4	2	2	3	1
Total number of scores					24	27	23	24	20	20	12	4

Ae – arable land in extensive cultivation, Ai – arable land in intensive cultivation, F – forest, M – meadow, Mf – mowed fallow (former arable land), Mo – mosaic of natural phytocoenoses (of forest, shrub, tall herb fringe patch), O – orchard in turf, P – pond; syngenesis of vegetation complex: N – autogenous natural, SN – anthropogenic seminatural, SS – anthropogenic synanthropic segetal (weed plant communities) cooperatives, as, for instance, in the village of Przybkowo. The total number of scores for ecosystem services of all types of complexes (Table 2) from the section 'provisioning' is similar and stays within the range 5-7. The total sum within each type comprises the same or completely different services from the class type level. Similar situation concerns more less evened score for the services from the 'regulating and maintenance' section (12-14 scores). An exception is a low score for the segetal vegetation complex connected with arable land (Ae and Ai). In the section 'cultural', the number of scores for the mowed fallow land complex (Mf) and fruit orchards in sod (O) is equal, but much lower than for the forest, mosaic and pond-related complexes (F, Mo, P and M).

Appropriately to the character of changes in land cover, also ecosystem services changed in all tested landscape units (Figure 2). In each one, the general number of services in all sections increased. In Łeknica site, it is an increase of 84%, in Liniec site – 79%, while in Kołacz and Uradz sites – 72%. The highest increase (86% and 92%) was noted in the section 'regulating and maintenance', which results from the very high decrease in the synanthropization level.

Concluding remarks

In the preparation of the list of ecosystem services and, earlier, in the assessment of landscape biodiversity, the concept of real vegetation complex was used. Previously, J. Solon[20] indicated the possibility of using such spatial unit of biosphere organisation in studies of the relationship between land cover and biodiversity, as well as an analysis of landscape changes in time. Delimitation of complexes based on field mapping, made it possible to provide ecosystem services from the class type level, while the presented catalog of services reflects the real state and can be the source of reliable information for the determination of environmental management directions.

The presented changes that took place in 1980-2014 are largely an effect of transition from nationalized, centrally planned economy (1989) to market economy and, also, the realization of agri-environmental schemes. According to A. Sadłowski[21], the period of industrial intensification of farming was finished in 1989. The cause of changes in land cover was a low economic effectiveness of cultivating the land of a low agricultural usefulness. After 1989, sandy, highly skeletal, of poor fertility and with low underground water table arable land has been covered by spontaneously developed vegetation due to the lack of ploughing. Nowadays, this vegetation is mainly mowed and has been largely included in the agri-environmental schemes (personal information from its users). Complex-

[20] J. Solon, *Ocena różnorodności krajobrazu na podstawie analizy struktury przestrzennej roślinności*, „Prace Geograficzne Instytutu Geografii i Przestrzennego Zagospodarowania PAN" 2002 no. 185, p. 232.

[21] A. Sadłowski, *Płatności obszarowe jako instrument polityki ochrony środowiska*, "Journal of Agribusiness and Rural Development" 2011 no. 4(22), p. 145-151.

es of segetal synanthropic vegetation, connected with intensively cultivated arable land, were replaced by multifunctional mosaic of agricultural landscape. Spontaneous reafforestation took place on the poorest, sandy fallow land and on permanent grasslands with long-stagnant water. The disappearance of open landscapes of fallow land and permanent grasslands due to giving up cultivation and regeneration of natural forest vegetation was many times reported (e.g. M. Hunziker[22], B. Barabasz-Krasny[23], K. Falińska[24], M. Gellrich et al.[25], J. M. Matuszkiewicz et al.[26]). Apart from reafforestation, also a homogenization of landscape with the contribution of natural and semi-natural complexes took place. It is the reverse process to the anthropogenic fragmentation of space (J. Solon[27]). Such situation is connected with the decrease in synanthropization level and increase in natural biodiversity. It was proved, for instance, as the result of investigation of spontaneous succession on the abandoned field in Białowieża (W. Adamowski and A. Bomanowska[28]), as well as on the post-agricultural land in the Wielkopolski National Park (S. Balcerkiewicz and G. Pawlak[29]). During 36 years in Białowieża and 25 years in the Wielkopolski NP, the majority of anthropophytes subsided and was replaced by native species, while weed plant communities was replaced by juvenile forest phytocoenoses. K. Hedlund et al.[30] documented an increase in biodiversity during the early secondary succession on the former arable land, based on the studies in five European countries.

An increase from 72 to 84% in ecosystem services at the class type level took place, depending on the section. Present-day, the transformed agricultural landscapes have two basic functions: one of them – food production, is continued. The other is protection of environment and it is strongly connected with the increase in biodiversity. This increase results from elimination of agroecosystems with

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[22] M. Hunziker, *The spontaneous reafforestration in abandoned agricultural lands: perception and aesthetic assessment by locals and tourists*, "Landscape and Urban Planning" 1995 no. 31, s. 399-410.

[23] B. Barabasz-Krasny, *Sukcesja roślinności na łąkach, pastwiskach i nieużytkach porolnych Pogórza Przemyskiego*, "Fragm. Flor. Geobot. Polonica, Suppl." 2002 no. 4, p. 3-81.

[24] K. Falińska, *Alternative pathways of succession: species turnover patterns in meadows abandoned for 30 years*, "Phytocoenosis 15 (N. S.), Archiv. Geobot." 2003 no. 9, p. 104.

[25] M. Gellrich, P. Baur, B. Koch, N. E. Zimmermann, *Agricultural land abandonment and natural forest re-growth in the Swiss mountains: A spatially explicit economic analysis*, "Agriculture, Ecosystems and Environment" 2007 no. 118, p. 93-108.

[26] J. M. Matuszkiewicz, A. Kowalska, J. Solon, *Long-term evolution models of post-agricultural forests*, „Prace Geograficzne Instytutu Geografii i Zagospodarowania Przestrzennego PAN" 2013 no. 240, p. 312.

[27] J. Solon, *Ocena różnorodności krajobrazu ...*, op. cit.

[28] W. Adamowski, A. Bomanowska, *Forest return on an abandoned field secondary succession under monitored conditions*, "Folia Biologica et Oecologica" 2010 no. 7, p. 49-73.

[29] S. Balcerkiewicz, G. Pawlak, *Antropofity na tle dynamiki roślinności – studium na podstawie długoterminowego eksperymentu na powierzchni stałej*, "Acta Botanica Silesiaca" 2011 no. 6, s. 63-80.

[30] K. Hedlund, I. Santa Regina, W. H. Van der Putten et al., *Plant species diversity, plant biomass and responses of the soil community on abandoned land across Europe: idiosyncracy or above-belowground time lags*, "Oikos" 2003 no. 10, p. 45-58.

synanthropic vegetation. The dependence of ecosystem services on the biodiversity state is widely stressed (J. Borysiak[31], J. Maes et al.[32]). W. Dembek[33] reported that in the past decade, realization of common agricultural policy in the European Union was of essential significance for the improvement of environmental conditions of rural areas. The aim of this policy is implementation of multifunctional agriculture. An instrument, which will allow to keep both the new and preserved natural and semi-natural complexes of real vegetation and their ecosystem services, are the agri-environmental and climate schemes, realized since 2014 (Project[34]). It implies a remuneration system for farmers for providing noncommercial environmental services. The role of a farmer as a provider of public goods was clearly emphasized in the EU Biodiversity Strategy to 2020[35].

[31] J. Borysiak, *Ecosystem services of extensive wet grasslands. Wielkopolska Region (Poland) case study*, „Ekonomia i Środowisko" 2012 no. 42, p. 136-152.
[32] J. Maes, A. Teller, M. Erhard et al., *Mapping and assessment of ecosystems and their services …* op. cit.
[33] W. Dembek, *Problemy ochrony polskiej przyrody w kontekście wspólnej polityki rolnej*, „Woda-Środowisko-Obszary Wiejskie" 2012 no. 12(4), p. 109-121.
[34] *Projekt Programu Rozwoju Obszarów Wiejskich na lata 2014-2020 (PROW 2014-2020)*, www.minrol.gov.pl [20-09-2014].
[35] *The EU Biodiversity Strategy to 2020*, Luxembourg: Publications Office of the European Union, 2011, www.ec.europa.eu [20-09-2014].