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Afforestations structure in the context of requirements for biogeochemical barriers in an agricultural catchment

Introduction

Among many significant environmental problems related to agricultural production, the matter of the first importance is the decrease in water quality. European Community policy has been concerned with this issue for over twenty years. But whilst the initial directives concerned themselves mainly with water for human consumption, more recent directives, such as those on nitrates from agricultural sources (Directive 91/676/EEC) have placed increased emphasis on the environmental effects of excess nitrogen, in particular eutrophication. In the context of agriculture there are two main objectives of the Nitrate Directive: to reduce water pollution caused by nitrates from agricultural sources and to prevent further pollution of this kind. In order to achieve the objectives, the member states have to identify waters affected by, and those subject to pollution, and designate these areas as Vulnerable Zones. In these areas, as well as promoting crop rotations, soil winter cover or limitations per crop, the Nitrate Directive implements the use of non-fertilised grass strips and hedges along watercourses and ditches to serve as buffer zones (Duer, 2003; Report COM(2002)407).

The importance of permanently vegetated land strips in controlling diffuse pollution from agricultural sources has been proved in many studies, most of them concerned with the efficiency of riparian plant buffer zones (Haycock et al.,1977). In addition to these, much has been published on shelterbelts and grasslands functioning as biogeochemical barriers reducing pollutants in ground water in upper parts of drainage areas (Bartoszewicz, 1994b, 2000, 2001; Prusinkiewicz et al., 1996; Ryszkowski et al., 1989, 1996; Szpakowska et al., 1994). Although a great deal has been published on this matter there is still some uncertainty about barrier size requirements for site-specific locations and a need for accepted methods for biogeochemical barrier design. As T.A. Dillaha and S.P. Inamdar pointed out (1997, after Castelle et al., 1994) buffers that are undersized place aquatic resources at risk. On the other hand, buffers that are larger than necessary needlessly deny landowners the use of a portion of their land.

The difficulties with establishing rules for designing biogeochemical barriers are related to the complexity of landscape processes, which require evaluations based on different scale analysis of all landscape components. When considering practical aspects of the issue, local scale analyses are of critical importance. As the evaluation of biogeochemical barrier requirements is a very complex task, there is a need for a method for practical use in landscape planning. A way for it would be an estimation of the spatial structure of afforestations in subcatchments where surface and groundwater are highly polluted from agricultural sources, which suggests high barriers requirements. The obtained values, of the indexes proposed, can be compared to those in similar landscape types in order to evaluate afforestations requirements there.

The aim of this study is to attempt to evaluate the structure of agricultural landscape afforestations and answering the question: what are the main spatial characteristics of such insufficient structure in two subcatchments located in two different agricultural landscape types?

Methods

Descriptions of natural conditions of Wyskoć Canal catchment and delimitation of its subcatchments have been prepared using cartographic materials and papers available. Two subcatchments representing different types of landscape but with similar agricultural impact and under high threat from diffuse pollution (Bartoszewicz, 1994a; Styczeń, 2002; RZWG, 2003) have been chosen as study objects.

MapInfo Professional 5.0 has been used to measure area of different land uses, the length of the Mórka Lake shore and the length of ditches, as well as the width, length and area of different forms of afforestations. GIS measurements have been taken from topographical maps and aerial photographs. Information about continuity of tree lines used in this work comes from a database completed during inventory work carried out in the area.

Different forms of afforestations have been distinguished according to their shape. Afforestations with a width to length proportion over 2:5 have been described as tree patches (Szyszkiewicz-Golis, 2001). Those with a proportion of less than 2:5 have been described as tree belts whereas those consisting of one or two rows of trees and (or) shrubs are described as tree lines.

The tree line area has been calculated by multiplying the average width by the total length of all sections covered by trees (continuity). In order to obtain average line width, 30 randomly chosen tree lines located along ditches and 30 located along roads have been measured on aerial photographs. In both cases the average results of measurements were 11 m. In order to demonstrate the level of requirement for biogeochemical barriers (BB), the index has been calculated for both subcatchments:

$$\frac{BB}{TA} = \frac{\text{biogeochemical barriers area}}{\text{total area of subcatchment}} =$$

$$= \frac{\text{woodlands} + \text{afforestations} + \text{meadows} + \text{wetlands} + \text{small waterponds}}{\text{total area of subcatchment}}$$

In addition the participation of the total area of afforestations in total arable fields area has been calculated:

$$\frac{AA}{AF} = \frac{\text{afforestations area}}{\text{arable fields area}}$$

As well as this the percentage of the Mórka Lake shore and the length of ditches protected by trees were calculated.

Location and descriptions of researched areas

The Wyskoć Canal catchment is a subcatchment of the Kościan Obra Canal drainage basin located in the central part of the Great Poland Region. According to Kondracki (1998) this terrain is situated in the following classification units: subprovince of Southern Baltic Lakeland (315), macroregion of Leszczyńskie Lakeland (315.8) and two mesoregions: Kościan Plain (315.83) and Krzywiń Lakeland (315.82). The area is in the Kościan, Czempiń, Krzywiń, Śrem, Dolsk and Gostyń districts.

The Wyskoć Canal catchment is of elongated shape and covers an area of above 17,000 hectares (170 km^2). It can be divided into two parts of different types of landscapes. The western part of the basin area, called "Turew region" is located in the Kościan Plain and represents its typical landscape with slightly undulating ground moraine and some drainage valleys. The elevation of the rolling plain ranges from 85 to 90 m above sea level and drainage valleys range from 75 to 77 m above sea level. The depth of the ground water table ranges from 0.5 to 3.5 m below the surface. In the valleys, organic deposits predominate (Marcinek, 1996) whereas the ground moraine surface consist of light textured soil Hapludalfs and Udipsamments (Bartoszewicz, 2000). The land here is mostly cultivated with no large water bodies or woodlands. The most interesting features of the landscape are the surroundings of Turew village, where historic tree belts are preserved. These were introduced in the early 19th century by General Dezydery Chłapowski. Because of these afforestations the whole area of "Turew region" is protected by law as a landscape park dedicated to the memory of General Chłapowski. In the NW of this region, the first of chosen areas, the Witkówka subcatchment, is located.

In contrast, the landscape of the eastern part of the catchment ("Dolsk region"), which is situated in the Krzywiń Lakeland, appears much more varied. Characteristic relief features of this area are numerous lakes and ground elevations ranging even from 77.5 to 149 m above sea level near Ostrowieczno village (Kaniecki, 2001). Many types, subtypes and classes of soils are distributed depending on relief differentiation, substrate and moisture. The coexistence of hills, lakes and woodlands results in very diverse and contrasting landscape, where agriculture is still the main man activity, what is especially truth of the western part of "Dolsk region", where the second area for studies, the Mórka Lake subcatchment, has been selected (Fig. 1).

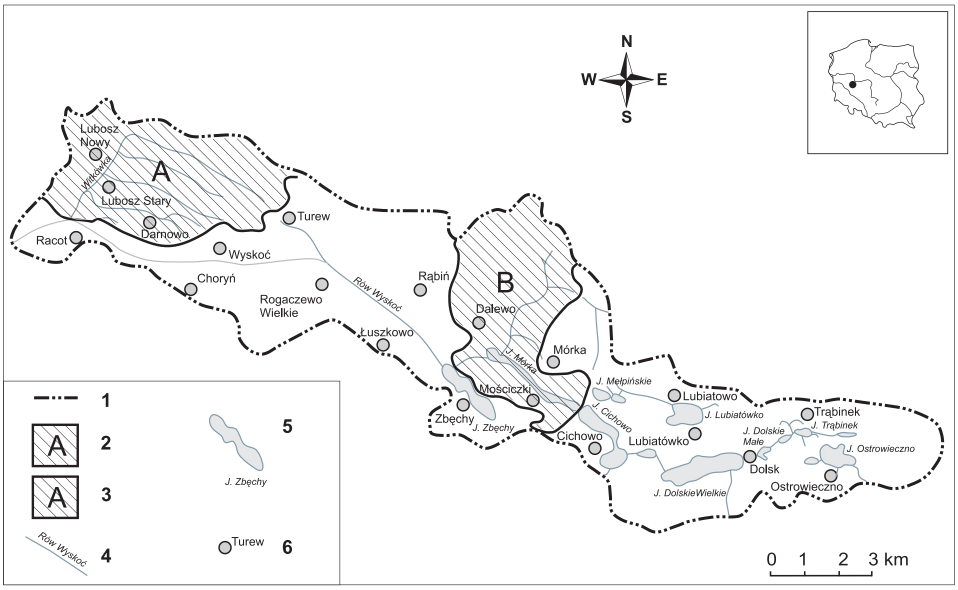

Fig. 1. Localization of Witkówka and Mórka Lake subcatchments in Wyskoć Canal catchment area: 1 – Wyskoć Canal catchment border; 2 – Witkówka subcatchment; 3 – Mórka Lake subcatchment; 4 – water courses; 5 – lakes; 6 – settlements

Ryc. 1. Położenie zlewni cząstkowych Witkówki i jeziora Mórka w dorzeczu kanału Wyskoć: 1 – dział wodny zlewni kanału Wyskoć; 2 – zlewnia Witkówki; 3 – zlewnia jez. Mórka; 4 – cieki; 5 – jeziora; 6 – osady

Results and discussion

As assessment of the data collected by monitoring (Styczeń, 2002; RZGW, 2003) and others studies (Bartoszewicz, 1994a) proved, diffuse pollution from agriculture resulted in poor surface and ground water quality in the two subcatchements studied. The Witkówka catchment, in the "Turew region" landscape, is 2,710 ha in size, and the Mórka Lake catchment situated in "Dolsk region" is 2,045 ha. Land use analyses show a high percentage of arable fields in both areas (Table 1). It is much higher than the average for the whole Wyskoć Canal catchment, which is estimated as 59.7% (Styczeń, 2002).

A small percentage of land use types functioning as biogeochemical barriers such as woodlands, grasslands, wet areas and small water bodies and afforestations (Bartoszewicz, 1994b, 2000, 2001; Prusinkiewicz et al., 1996; Ryszkowski et al., 1989, 1996; Szpakowska et al., 1994) results in a low index of biogeochemical barrier. The low values in both subcatchments, suggests high requirements for such barriers (Table 2).

The need for afforestations can be evaluated by comparing values of the index of afforestations share in arable fields. In both researched catchments the values are very low compared to the index calculated for the village Turew surroundings. On the basis of estimations for the model agricultural landscape, the recommended value of this index in lowland agricultural landscape in Poland ranges approximately from 2.2% to 4% (Bałazy, 1990). It has been suggested that in the landscapes of varied relief the value should be higher.

Table 1. Land use structure in Witkówka and Lake Mórka catchments
Tabela 1. Struktura użytkowania ziemi w zlewniach Witkówki i jeziora Mórka

Catchment	Witkówka		Mórka Lake	
	[ha]	[%]	[ha]	[%]
Total area	2,710.0	100.00	2,045.0	100.00
Arable fields	1,995.8	73.65	1,436.0	70.22
Woodlands	412.3	15.21	163.0	7.97
Meadows	172.6	6.36	229.0	11.20
Afforestations	36.6	1.35	34.5	1.68
Orchards	0.8	0.03	4.2	0.21
Water bodies (small bodies + lakes)	0.7+ 0.0	0.03	2.2+91.3	4.57
Wetlands	0.0	0.00	40.5	1.98
Wastelands	0.6	0.02	4.9	0.24
Urban areas	90.6	3.34	39.3	1.93

Table 2. Share of biogeochemical barrier area in total areas of subcatchments
Tabela 2. Udział barier geochemicznych w ogólnym obszarze zlewni

Subcatchment	$\frac{BB}{TA}$	Share of BB in TA [%]	$\frac{AA}{AF}$	Share of AA in AF [%]
Witkówka	0.230	23.0	0.018	1.8
Mórka Lake	0.229	22.9	0.024	2.4

The situation appears more unfavourable in the Mórka Lake catchment, where specific geological and hydrological conditions determine higher requirements for biogeochemical barriers. The surface elevations results in easier and faster nutrient flow in ground waters and a higher erosion rate. In this context, the Mórka Lake exposure to non-point pollution emissions is a matter for consideration. The lake is of very elongated shape (over 4 km in length), with an area of 91.3 ha (own measurements) so the shore line is relatively long (about 10 km). In addition to this it is quite shallow – the average depth is 4.5 m (Styczeń, 2002). Analysis of the level of protection of the shore by biogeochemical barriers shows that less than a half of it is well protected by a buffer strip consisting of wide (>100 m) tree and meadow cover. Almost 44% of the shore line is protected from the fields only by a riparian tree belt with an average width of 15 m. Basnyat et al. (2000) proposed that to assimilate or detain more than 90% of the nitrate passing through the forested buffer, a buffer width of 16 to 104 m must be maintained. This depends on soil permeability, soil moisture, depth to water table, slope, and vegetation type and cover. Considering the steep slopes there, the 15 m belt seems to be insufficient to protect the shore. Besides this, over 1 km of the shore is not protected by any barrier (Table 3).

Ditches as very important nutrient flow routes, contribute significantly to total nutrients input to the main watercourses and lakes. Studies carried out in the "Turew region" show that when protected by wide strips of meadows or trees, the water quality improved (Falkowski et al. 1990). According to Antonov (1987) 12.5 m wide deciduous shelterbelts reduced 20–30% of pollution in the case of shelterbelts alone and by over 50% in the case of shelterbelts with an embanked ditch. It can be presumed that one or

Table 3. Protection of the Mórka Lake shore
Tabela 3. Ochrona brzegów jeziora Mórka

State of barriers	Length of riparian line	
	[km]	[%]
No biogeochemical barriers	1.072	10.63
A belt of trees or shrubs (15m)	4.458	44.19
A wide barrier of meadow and woodland (< 100m)	4.559	44.18

Table 4. Protection of ditches by tree biogeochemical barriers in studied subcatchments
Tabela 4. Ochrona cieków przez drzewiaste bariery geochemiczne w badanych zlewniach cząstkowych

	Witkówka subcatchment		Mórka Lake subcatchment	
	[km]	[%]	[km]	[%]
Total length of ditches with tree BB	13.1	25.0	6.6	20.0
Total length of ditches with tree belts or woodlots	0.0	0.0	2.8	8.5
Total length of ditches with tree or shrub lines	13.1	25.0	3.8	11.5

Table 5. Continuities of tree and shrub lines along ditches
Tabela 5. Kontynuacja liniowych zadrzewień i zakrzewień wzdłuż cieków

Continuity [%]	Total length of tree and shrub lines in subcatchments			
	[km]		[%] In relation to total ditches length	
	Witkówka	Mórka Lake	Witkówka	Mórka Lake
up to 25	1.9435	0.372	3.7	1.1
26–50	0.807	0.000	1.6	0.0
51–75	4.312	1.716	8.1	5.2
76–100	6.017	1.717	11.6	5.2

two rows of trees (of average width 11 m) can change the nutrient content as well. In the researched areas only 20–25% of the total length is protected by tree barriers (Table 4).

Only 8.5% of the total length of the Mórka Lake catchment is efficiently protected by a riparian buffer in the form of tree belts and woodlots. The continuity of such tree lines is a very important structural characteristic, which determines its barrier efficiency (Table 5).

The analyses show, that not even half of the total length of tree lines along ditches in both areas are of high continuity (over 75%) thus providing some degree of protection to the ditches.

Final remarks

The value of biogeochemical barriers index for both catchments is 0.23, what seems to be not efficient for both types of agricultural landscape in the Great Poland region. Due to different landscape relief, the higher value of afforestations index, obtained in the Mórka Lake catchments (0.024), does not imply lower barrier requirements than in the Witkówka catchment (0.018). There is a need to consider spatial arrangement of potential barriers as well as to test this method of estimations in higher number of catchments in order to find the recommended values for certain types of areas. To improve water quality it is necessary to widen existing ones and introduce new barriers in both subcatchments, especially along the ditches and the Mórka Lake shore.

Acknowledgements

I thank Peter Scarlett from Centre for Ecology & Hydrology, Natural Environment Research Council, Dorset, UK, who corrected the English version of this paper.

Struktura zadrzewień w kontekście zapotrzebowania na bariery biogeochemiczne w zlewni o charakterze rolniczym

Streszczenie

Zagadnienie ograniczania zanieczyszczeń obszarowych na terenach rolniczych znalazło swoje odbicie w prawie UE (Dyrektywa 91/676/EWG), gdzie wskazuje się m.in. na potrzebę wprowadzania pasów zadrzewień chroniących wodę. Określenie zapotrzebowania na zadrzewienia w skali lokalnej jest zadaniem bardzo skomplikowanym metodycznie. Ażeby ułatwić wprowadzanie zadrzewień ochronnych, konieczne jest wypracowanie norm dla różnych typów krajobrazu.

Zlewnia rowu Wyskoć (ok. 17 000 ha) reprezentuje dwa typy krajobrazu rolniczego: o dużym zróżnicowaniu hipsometrycznym w części wschodniej oraz dość monotonny krajobraz nizinny w części zachodniej. Na tle całego regionu charakteryzuje się ona większym procentowym udziałem gruntów ornych oraz wyższym zużyciem nawozów sztucznych (Styczeń, 2002). W dwóch charakterystycznych dla tych typów krajobrazu zlewniach cząstkowych (ryc. 1), gdzie analizy wód wykazują największe stężenia zanieczyszczeń pochodzenia rolniczego (Bartoszewicz, 1994a; Styczeń, 2002; RZGW, 2003), podjęto próbę oceny wybranych cech przestrzennych struktury zadrzewień, decydujących o niskim stopniu spełniania funkcji barier biogeochemicznych. Na podstawie pomiarów użytkowania ziemi w zlewniach Witkówki i jeziora Mórka (tab. 1) obliczono wskaźnik udziału powierzchni potencjalnych barier biogeochemicznych i wskaźnik nasycenia zadrzewieniami gruntów ornych (tab. 2). Na tym tle oceniono wybrane cechy przestrzenne struktury zadrzewień, decydujące o ich funkcji ochronnej: średnią szerokość, długość, stopień pokrycia linii brzegowej jeziora Mórka (tab. 3), obecność zadrzewień wzdłuż rowów (tab. 4) oraz ich kompletność (tab. 5). Uzyskane wartości mogą być wykorzystane do porównań i szacowania zapotrzebowania na zadrzewienia w innych zlewniach, przy uwzględnieniu specyfiki warunków fizjograficznych oraz przestrzennego rozmieszczenia (rozdrobnienia) potencjalnych barier.

References

Antonov V.I., 1987, Water pollution control by shelterbelts, Lesnoi Zhurnal 3, s. 17–21 [in Russian].

Bałazy S., 1990, Zasady ograniczania rozprzestrzeniania się zanieczyszczeń obszarowych, Zakład Badań Środowiska Rolniczego i Leśnego PAN, Poznań, maszynopis.

Bartoszewicz A., 1994a, Azotany w wodach studni wiejskich oraz w wodach gruntowych i powierzchniowych terenów użytkowanych rolniczo, [w:] Sekcja Toksykologii i Ochrony Środowiska Polskiego Towarzystwa Toksykologicznego, Azotany/Azotyny zagrożenie dla środowiska, materiały konferencyjne, s. 15–17.

Bartoszewicz A., 1994b, Skład chemiczny wód powierzchniowych zlewni intensywnie użytkowanych rolniczo w warunkach glebowo-klimatycznych Równiny Kościańskiej, Roczniki Akademii Rolniczej w Poznaniu, Rozprawy Naukowe 5, Poznań.

Bartoszewicz A., 2000, Effect of the change of soil utilization on the concentration of nitrogen mineral forms in soil and ground waters, Polish Journal of Soil Science XXXIII, 2, s. 13–20.

Bartoszewicz A., 2001, Zmiany zawartości rozpuszczalnych w wodzie form niektórych składników mineralnych w glebie płowej pod kilkuletnim zadrzewieniem śródpolnym, Zeszyty Problemowe Postępów Nauk Rolniczych, 478, s. 405–411.

Basnyat P., Teeter L., Lockaby B.G., Flynn K.M., 2000, Land Use Characteristics and water Quality: A Methodology for Valuing of forested Buffers, Environmental Management 26, 2, s. 153–161.

Dillaha T.A., Inamdar S.P., 1996, Buffer Zones as Sediment Traps or Sources, [in:] N. Haycock, T. Burt, K. Goulding, G. Pinay (eds.) Buffer Zones: Their Processes and Potential in Water Protection., Quest Environmental, Harpenden, UK, s. 33–42.

Duer I., 2003, The implementation of the Nitrates Directive in Poland: Code of Good Agricultural Practice, Institute of Soil Science and Plant Cultivation, Puławy, www.Agronavigator.cz/nitrat/content/ref/duer-en.doc

Fałkowski M., Kozłowski S., Kukułka I., 1990, Wpływ biologicznej zabudowy brzegów na chemizm wód powierzchniowych okolic Turwi, [w:] L. Ryszkowski L., J. Marcinek, A. Kędziora (red.), Obieg wody i bariery biogeochemiczne w krajobrazie rolniczym, Wyd. Nauk. UAM, Poznań, s. 159–166.

Haycock N., Burt T., Goulding K., Pinay G., 1996, Buffer Zones: Their Processes and Potential in Water Protection, Quest Environmental, Harpenden, UK.

Kaniecki A., 2001, Komentarz do mapy hydrograficznej w skali 1:50 000, Arkusz M-33-11-A, Gostyń, Uniwersytet im. A. Mickiewicza, Poznań.

Kondracki J., 1998, Geografia regionalna Polski, Wydawnictwo naukowe PWN, Warszawa.

Marcinek J., Komisarek J., 1990, Gleby Środkowej Wielkopolski, [w:] L. Ryszkowski L., J. Marcinek, A. Kędziora (red.), Obieg wody i bariery biogeochemiczne w krajobrazie rolniczym, Wyd. Nauk. UAM, Poznań, s. 21–35.

Prusinkiewicz Z., Pokojska U., Józefkowicz-Kotlarz J., Kwiatkowska A., 1996, Studies on the Functioning of Biogeochemical Barriers, [in:] L. Ryszkowski, N.R. Frencz, A. Kędziora (eds.), Dynamics of an Agricultural Landscape, Pan. Wyd. Roln. i Leśne, Poznań, s. 110–119.

Regionalny Zarząd Gospodarki Wodnej w Poznaniu, 2003, Wykaz wód powierzchniowych i podziemnych wrażliwych na zanieczyszczenia związkami azotu ze źródeł rolniczych oraz obszarów szczególnie narażonych, Synteza, Poznań, maszynopis powielony.

Report COM, 2002, Directive 91/676/EEC on nitrates from agricultural sources, Eutrophication and health, 407, www. Europa.eu.int/comm/environment/water-nitrates/

Ryszkowski L., Bartoszewicz A., 1989, Impact of agricultural landscape structure on cycling of inorganic nutrients, [in:] M. Clarholm, L. Bergstrom (eds.), Ecology of Arable Land, Kluwer Academic Publishers, s. 241–246.

Ryszkowski L., Bartoszewicz A., Kędziora A., 1996, The Potential of Mid-Field Forests as Buffer Zones, [in:] N. Haycock, T. Burt, K. Goulding, G. Pinay, Buffer Zones: Their Processes and Potential in Water Protection. The Proceedings of the International Conference on Buffer Zones, Quest Environmental, Harpenden, UK, s. 171–191.

Styczeń L., 2002, Stan czystości wód w zlewni Kościańskiego Kanału Obry, Wojewódzki Inspektorat Ochrony Środowiska w Poznaniu, Delegatura w Lesznie.

Szpakowska B., Życińska-Bałoniak I., 1994, The Role of Biogeochemichal Barriers In Water Migration of Humic Substances, Polish Journal of Environmental Studies 3, 2, s. 35–41.

Szyszkiewicz-Golis, 2001, Zmiany użytkowania ziemi a struktura krajobrazu rolniczego Wielkopolski na przykładzie zachodniej części zlewni rowu Wyskoć, [w:] K. German, J. Balon (red.), Przemiany środowiska przyrodniczego Polski a jego funkcjonowanie, Problemy Ekologii Krajobrazu 10, Instytut Geografii i Gospodarki Przestrzennej Uniwersytetu Jagiellońskiego, Kraków, s. 92–99.